ENGLISH SUMMARY

The present report from the Chairmen of the Danish Council of Environmental Economics contains the three chapters:

- Traffic Noise, chapter 1
- Environmental Taxes and Research Subsidies in Climate Policy, chapter II
- Tax structure and climate targets, chapter III

Chapter 1: Traffic Noise

Most people are exposed to traffic noise in their everyday lives, either at home, at work, or outside on the street or in recreational areas. Noise can disturb sleep and conversation and cause annoyance and stress. Research in the area suggests that long term exposure to noise related stress can lead to hypertension and heart disease. Traffic noise is a standard environmental externality, as the individual driver has no incentive to reduce his own noise emission. As a result, the amount of traffic noise is greater than what would be economically efficient. In Denmark road noise alone affects approximately 30 percent of all homes.[1] In densely populated areas, the share of homes exposed to traffic noise is even higher.

In order to determine the size and nature of the cost associated with traffic noise in Denmark, two valuation studies have been carried out in the Report. The first analysis is concerned with the cost associated with the health effects of traffic noise and is based on the existing epidemiological literature describing the dose-response relationship between exposure to traffic noise and disease. The second is a hedonic analysis of the cost associated with annoyance from traffic noise. Both analyses show that the cost of traffic noise increases more than proportionally with the amount of traffic noise, i.e., the marginal increase in noise is more costly when the level of traffic noise is high at the outset.

1) e.g. houses impacted by more than 58 dB (Lden).

Furthermore, the cost associated with traffic noise differs markedly between houses and apartments.

Health cost of road noise

The first analysis quantifies the health costs of traffic noise. It is based on two meta-analyses of the dose-response relationships between traffic noise and hypertension and ischemic heart disease respectively, see Babisch (2006) and Babisch & van Kamp (2009). The dose-response function for ischemic heart disease suggested that an increased risk of getting the disease can be attributed to living in a home with noise above 60 dB (Lden). For hypertension, the increased risk is already present from 50 dB.

However, the epidemiological surveys that the meta-analyses are based on have a potential problem with selection bias that leads to endogeneity. This can mean that the observed relationship in theory could be due to other factors such as, e.g., a lack of healthy life style. If this is the case, the surveys show a too high or even spurious connection between the exposure to traffic noise and heart disease. As the size of the problem with selection bias is unknown, the meta-analyses are treated as the best available data. These dose-response functions are coupled with a national survey of the number of homes affected by more than 55 dB (Lden) of road noise (Tetraplan (2009)). This gives the proportion of cases of the two diseases that can be attributed to traffic noise, and the result shows that one percent of all cases of ischemic heart disease and six percent of all cases of hypertension could possibly be attributed to traffic noise (central estimate).[2]

2) The confidence interval of the results is between zero and 2 percent for ischemic heart disease and between zero and thirteen percent for hypertension.

Table A *Total health cost of road noise, mil. DKK per year, 2010 prices*

	Low est.	Central est.	High est.
Premature death due to ischemic heart disease	0	330	650
Premature death due to hypertension	0	210	410
Treatment cost	0	80	160
Total	0	620	1.230

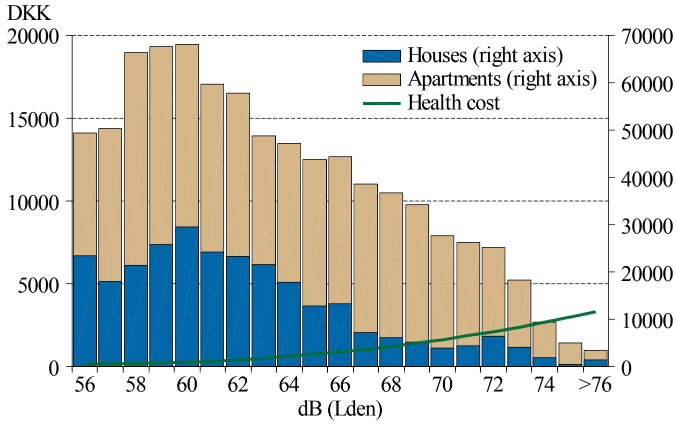
Source: Own calculations, 3 percent discount rate, value of lost life years (VLY) 700,000 DKK per year.

This fraction of cases of heart disease attributable to road noise leads to 50 premature deaths due to hypertension and 70 due to ischemic heart disease every year. The central estimate of the total health cost of traffic noise is estimated to be 620 mil. DKK per year (see table 1). This can be divided into treatment costs and costs of premature death from ischemic heart disease and hypertension.[3]

The average health cost is increasing with the level of road noise, see figure A. Every year, 700 DKK can be attributed to a home with a noise level at 65 dB compared to a home with the background road noise level. In the areas with high road noise levels, most homes are apartments rather than houses. Therefore, the average attributable health cost is higher for apartments compared to houses.

3) The social cost of premature death is calculated using the value of a life year lost of 700,000 DKK per year, a discount rate of 3 percent, 10 years of lost life per person and 10 years latency between the illness and the premature death.

Figure A *Average health cost and number of homes by noise level*



Average health cost in DKK per home per year compared to a home at 50 dB (Lden). Distribution of houses and apartments. Shows road noise above 55 dB (Lden) only.

Source: Own calculations.

Annoyance cost of road noise

The second analysis is based on the hedonic method estimates the annoyance cost of traffic noise that can be attributed to homes with traffic noise levels above 55 dB (Lden). The data for the analysis consist of 100,000 house sales between 2000 and 2008 in the Greater Copenhagen Area. The data set includes information about each home's characteristics, e.g., size and type of house and sale prices. This is combined with the noise level from train, airport and road traffic calculated for each house. For the demand analysis, the socio-economic characteristics of the current household are also used.[4] The analysis is carried out in two stages: In the first stage, the effect of traffic noise on the house price is estimated for each noise source. These marginal price effects are then used in the second stage to estimate the demand for relative quiet dependent on the price for relative quiet and socio-economic characteristics of the household.

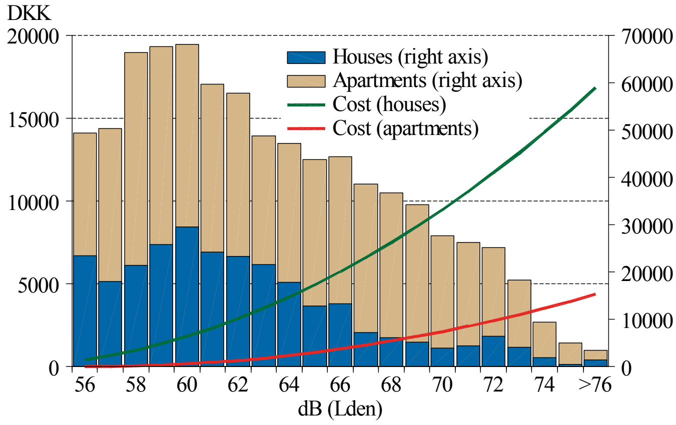
4) The data were obtained from Statistics Denmark and the Ministry of Environment.

The first stage is carried out for 9 different submarkets of Greater Copenhagen, which are then combined into one demand analysis in the second stage.

The results of the first stage show significant effects from road noise in all submarkets, with a greater negative effect on the prices for houses compared to apartments. For train noise, significant effects were also found in all the relevant submarkets, but due to fewer observations of train noise, there was greater variation in the results between markets. It was difficult to find significant effects from airport noise, which was probably due to the use of a fixed effects model.

The demand analysis of road noise is only carried out for houses and apartment separately, since the demand for each type of home was distinct from the other. Preliminary results for the demand for train noise did not show promise and the analysis was dropped. The demand analysis shows that the marginal willingness to pay is much higher for people living in houses compared to people living in apartments, see figure B. The marginal willingness to pay is increasing with the noise level for both types of homes. For houses, households are prepared to pay 5,000 DKK per year for a reduction in road noise levels from 65 dB to 55 dB. For apartments, the willingness to pay is 850 DKK per year for the same reduction. The total annoyance cost is estimated to be 1.5 billion DKK per year.

Figure B *Annoyance cost and number of homes by noise level*



Annoyance cost in DKK per home per year compared to a home at 55 dB (Lden). Distribution of houses and apartments. Shows road noise above 55 dB (Lden) only.

Source: Own calculations.

Total cost of road noise

Based on the combined costs per household of the annoyance and health effects associated with traffic noise, an estimate of the total cost of traffic noise in Denmark can be found. It is estimated that the detrimental effects of traffic noise cost approximately 2.1 billion DKK each year for homes exposed to more than 55 dB. The costs associated with annoyance account for roughly two thirds of the total cost and the health effects account for one third. The costs are mainly born by those households exposed to the highest levels of traffic noise.

The gains from reducing traffic noise across the country to below the Danish official threshold level of 58 dB would amount to 1.8 billion DKK each year. Reducing traffic noise for those households exposed to traffic noise above 68 dB to a level below 68 dB would result in a welfare gain equivalent to 4000 million DKK each year. A reduction of noise emissions by 1 dB would amount to 170 million DKK a year in welfare gains.

Regulation of traffic noise emissions is necessary to ensure that the right balance exists between the welfare costs incurred through traffic noise and the welfare gains to be had from transportation. Traffic noise is on the political agenda both in the EU and in Denmark. The current political goals and policies take, as their point of departure, the number of homes affected by traffic noise as defined by the official threshold levels. In Denmark, the costs of traffic noise have, until now, been related to the dB level of traffic noise using the "Noise Burden Number" (StøjBelastningsTallet). The two analyses in the Report have estimated the benefits of noise reduction for different noise levels directly, so the "Noise Burden Number" is no longer needed in order to determine the value of a change in noise exposure.

Regulation of traffic noise

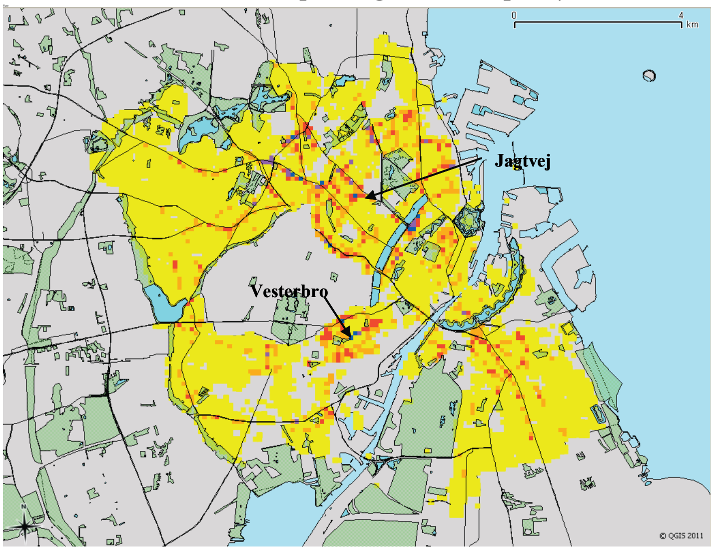
Reducing the overall amount of traffic would reduce traffic noise. It is unlikely, however, that such a reduction in the amount of traffic would be economically sound as the opportunity costs would be high due to the relationship between the number of vehicles and total noise emissions. A 10 percent reduction in the amount of traffic generates a noise reduction of only 0.5 dB, which is barely perceptible to the human ear. Reducing noise levels by 3 dB requires total traffic to be reduced by 50 percent. However, traffic planning that concentrates traffic on fewer roads can lead to welfare gains. This is due to the fact that an additional car has very little effect on the noise level when there are many cars to begin with. In contrast, removing a car, when there are only a few cars to begin with, can have a large effect on overall noise emissions from the road in question.

Concentrating traffic on fewer roads can have side effects in terms of, e.g., increased congestion and risk of accidents. For this reason it is important to take into consideration all the external effects associated with transportation when addressing the appropriate policies for noise reduction.

Exposure to traffic noise can be alleviated at the source and at the receiver. In addition, it is possible to affect the diffusion of noise through technical means. The costs and effects of different policy tools vary and many different aspects are important in determining which measure is most cost-effective. The most cost-effective measure must be decided upon in each case with careful consideration of the specific conditions in the area in question.

Reducing noise emissions at the source can be done through standards for vehicle noise emissions, e.g. lowering engine noise or requiring noise reducing tires. Alternatively the use of noise reducing asphalt can limit the amount of noise emitted from each passing vehicle. Noise barriers can reduce the diffusion of noise from the road, as can reductions in driving speeds. Finally, residential soundproofing can reduce the noise experienced inside a home. The gains to be had from each of these measures depend on the initial level of noise, the population density in the area and the type of residence. On the basis of the analyses carried out in the Report, it is possible to construct a "benefit map" showing where the potential welfare gains are largest for a given reduction in noise levels, see figure C. The map is based on the number of dwellings and should be amended to take into account those affected by noise outside their homes, e.g. in public parks.

Figure C *Yearly benefits from a 1 dB reduction in road noise in Copenhagen Municipality*



The map shows the benefits from a 1 dB reduction in road noise levels in Copenhagen Municipality compared to the noise level in 2006. Benefits are calculated as the sum of the willingness to pay for changing the noise level for all homes within a 100x100 meter grid.
Yellow: <15,000 DKK per year.
Orange: 15,000 – 25,000 DKK per year.
Red: 25,000 – 35,000 DKK per year.
Purple: 35,000 – 45,000 DKK per year.
Dark Blue: >45,000 DKK per year.

Source: Own calculations.

Traffic has a number of other negative externalities such as air pollution, congestion, accidents and CO_2 emissions. A combined road pricing scheme taking all of these external effects of traffic into account could be a good idea if it is designed correctly. It is important to include traffic noise in such a road pricing scheme, as aiming at congestion can have unfavourable side effects on noise exposure. A congestion charge can displace traffic into residential areas where the cost of increased noise is high.

The nature of the relationship between traffic volumes and noise emissions implies that concentrating traffic can reduce the overall cost of traffic noise. Noise emissions will only increase very slightly when traffic is concentrated in streets with heavy traffic, whereas noise can be reduced significantly by lessening the volume of traffic in less busy areas. Therefore, it is possible that concentrating traffic in certain areas can reduce the overall cost of traffic noise even though it makes some people worse off. Those exposed to more noise in the process should be compensated accordingly so that no-one is made worse off by the measure.

In general, residential soundproofing will reduce the cost of traffic noise. The homeowner will experience an increase in the value of his home reflecting the reduced health and annoyance effects associated with traffic noise exposure after soundproofing. This implies that it will be in the homeowner's own interest to soundproof his home if the private gains exceed the costs. However, it is possible that the entire cost of traffic noise has not been capitalised into house prices, e.g. because homeowners are unaware of the detrimental health effects. In this case, it may be the case, that social benefits from noise abatement exceed the private benefits. In such cases a subsidy corresponding to the difference between the social and private benefits may be in order. Such a subsidy should be available to all households regardless of their noise exposure, as long as the social gains from noise abatement exceed the private gains.

When transportation infrastructure is expanded or the traffic volume changes unexpectedly, e.g., due to traffic planning, the homeowners affected should be compensated for the losses they incur as a result. This will ensure that the activity does not make anyone worse off. It is important that such a change in the noise exposure of the households be unanticipated so that it is not already incorporated into the house price at the time of purchase.

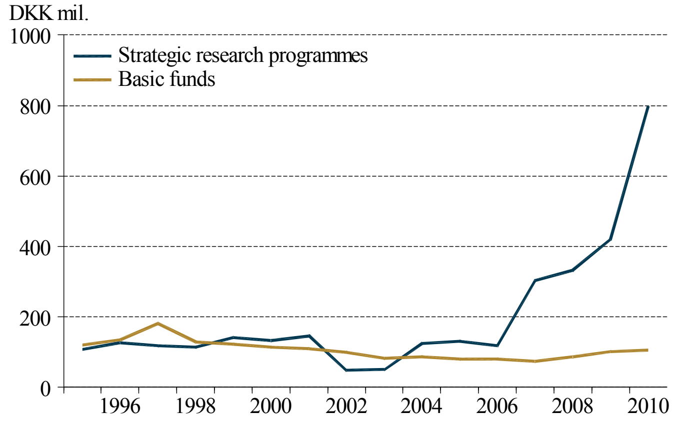
The policy measures for noise abatement currently in use in Denmark are generally in tune with the recommendations made here. Further efforts should concentrate on traffic planning and standards concerning noise emissions for vehicles.

Chapter II: Environmental Taxes and Research Subsidies in Climate Policy

Like the rest of the world, Denmark faces major challenges in dealing with climate change and becoming less dependent on fossil fuels. The chapter on *Environmental Taxes and Research Subsidies in Climate Policy* addresses the use of and interaction between environmental and research policy instruments for achieving these objectives.

During the late 2000s the share of government R&D expenditure earmarked for energy research rose markedly in Denmark. The increase was primarily in additions to strategic energy research programmes that support research carried out in specific strategic areas. In contrast, funding for more basic energy research performed by universities and other research institutions did not increase correspondingly. Consequently, the share of public energy R&D expenditure allocated to energy research programmes has increased from around 50 percent in the period prior to the mid-00s to around 90 percent in 2010, cf. figure D.

Figure D *Government expenditure for energy research, fixed prices*

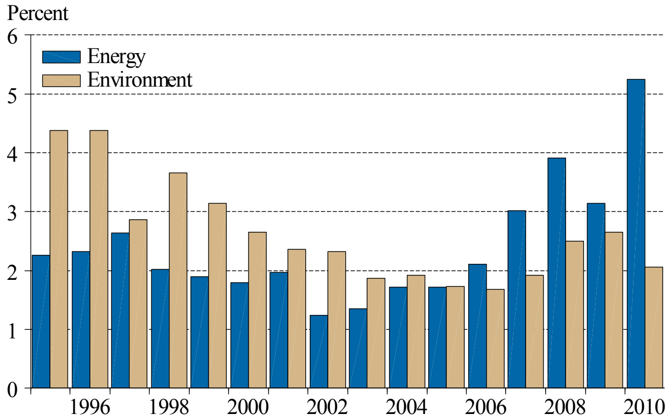


Source: Ministry of Finance, *Research Database*.

In addition to increasing funding, the overall focus of Danish energy programmes has been, to a larger degree, directed towards research with a more immediate commercial potential. Hence, a larger part of the funds allocated to Danish energy research programmes is being used for demonstration and market maturation of already developed technology, rather than more fundamental research. As a result, public funds for energy research are, to a larger degree, given to research performed in the private sector. This development indicates that the increase in public expenditure on energy research seems to be motivated by business support objectives.

In contrast, the share of public R&D funds earmarked for environmental non-energy related research has been gradually reduced since the mid 1990s. Despite an increase over the last couple of years, the proportion of environmental research in public R&D expenditure remains below its mid-90s level, cf. figure E.

Figure E *Share of government appropriations for energy and environmental research*



Source: OECD, *Main Science and Technology Indicators 2009*, Statistics Denmark, and own calculations.

Summing up, the share of government R&D expenditure earmarked for energy research has increased markedly since the mid-00s. Rather than basic funds used for more fundamental research, the additional funds have been allocated to strategic energy research programmes that, at the same time, have become more directed towards R&D with an immediate commercial potential. In comparison, the share of public R&D expenditure allocated to environmental research today is lower than 10-15 years ago, and as the following will serve to demonstrate, this development is not desirable.

Environmental and research policies should not be used with the aim of helping specific industries, but should only be used to correct market failures. With respect to climate mitigation technology there are two main market failures that may result in too few incentives to develop climate mitigation technology. The first one is the environmental market failure, i.e. consumers and producers do not fully take into account the negative environmental effects of their emissions. Therefore, without an emissions tax (or similar regulation) emissions will be higher than optimal and the incentives to invest in development of clean technology will be low. The second market failure is that private firms do not obtain the full benefit of their investments in research as other firms may benefit from the research due to knowledge spillovers. This yields a wedge between the private and the social returns to private research, and without regulation, too little private research will be carried out. First-best policies to correct for these two market failures will require two instruments: An emissions tax (or equivalent regulation) combined with subsidies to private energy research reflecting the size of the external spillovers from the particular type of private research.

In recent years the interaction between technological change, regulation and CO_2 emissions has received much attention. That higher prices of fossil fuels or regulation of emissions will lead to "induced" technological change is well documented. This means that a tax on CO_2 emissions will encourage development of sustainable energy and less carbon intensive technologies. With an optimal emissions tax consumers and producers are also provided with an incentive to adopt these new technologies. When "prices are right" the only market failure is the positive external knowledge spillovers from research, which applies to energy research as well as other types of private research. Support to private research should, therefore, correspond to the size of the positive externality from knowledge spillovers. This implies that high earmarked support for private energy research can only be justified if there are higher positive spillovers from private energy research compared to other private research.

An empirical analysis based on Danish data has been carried out to test whether there are higher spillover effects from private energy research compared to other types of private research. The analysis is carried out using an unbalanced panel containing information on research activities, use of labour, capital and value added for more than 1,000 Danish firms over the period 2000 to 2007. Spillover effects are identified using the so called direct production function approach, where a spillover knowledge pool enters directly into the firm's production function. That there are higher spillovers from private energy research as compared to other types of private research is rejected by the empirical analysis. This finding was robust to different model specifications and different specifications of the spillover mechanism between firms.

Actually, the analysis suggests that external spillover effects from energy research may even be lower than the spillover effects from other types of private research. In that case the large earmarked subsidies to energy research have led to a relatively small overall social return as compared to general research subsidies not restricted to energy research only. Thus, the results suggest that large earmarked subsidies to energy research should not be an element in a first-best policy (where CO_2 emissions are taxed optimally).

The analysis confirms that there are positive external spillover effects from private research. The results suggest that the social rate of return to investments in private research is about 28 percent. Approximately 4 percentage points of the social rate of return can be attributed to external spillovers, which is equivalent to one seventh of the overall social rate of return to research. By and large these results appear to be in line with results from previous studies, although the external return caused by spillovers seems to be relatively low compared to some of the previous studies. Thus, the analysis suggests that some general support to private research may be appropriate, but that this support should not be earmarked to energy research.

However, it should be noted that subsidizing private research may not be straightforward. When all research expenditure is subsidized (either as tax deductions or as direct subsidies) it may be difficult to define research expenditure precisely and ensure that research expenditures claimed by firms fall within the chosen definition of "research". If subsidies are given to selected individual research projects it may be difficult to identify research projects with the highest social return. There are also administrative costs that should be taken into account.

It is also worth noting that a small country like Denmark should not necessarily develop all new clean technology domestically. A tax on CO_2 emissions will also provide an incentive to import new low-carbon technology. It should not be a political objective that new environmental technologies should be produced in Denmark. Instead the objective should be to reach a given environmental target at the lowest cost. In some cases this may be achieved by importing and adapting environmentally friendly technology already available abroad. In other cases, research and technological development should take place in Denmark. A combination of a CO_2 tax and general subsidies to private research (i.e. not earmarked for energy technology) will provide the right incentives to either develop or import new technology.

For some emissions of greenhouse gasses it may be relatively difficult to put a directly targeted tax on emissions. This is, for example, the case for non-energy related emissions from agriculture. A similar problem is found with a number of environmental externalities where the marginal environmental damage varies between location or time of the emission, i.e. local air pollution, pesticides or nitrogen leaching. In these cases, it is also technically challenging to put an optimal targeted environmental tax on emissions.

When it is technically impossible to put a targeted environmental tax on emissions, incentives for firms to carry out private research to develop cleaner technologies are insufficient. In these cases it may be appropriate to earmark research subsidies, as this provides an incentive to develop cleaner technologies. However, it should be taken into account that, if there are no environmental taxes or other regulations in place to give incentives to use this new clean technology, subsidies supporting the development of cleaner technologies are not very effective. When environmental taxes are not available, other regulation must be put in place to ensure that new cleaner technologies will be used instead of the dirty technology (assuming that the costs of the cleaner technologies are reasonable compared to the environmental advantages obtained by using the cleaner technology).

It is difficult to determine precisely the optimal level of private research subsidies that should be earmarked for research into environmental problems where it is not possible to employ a targeted tax on emissions. However, it is clearly problematic that a larger share of public research expenditure in recent years has been allocated to energy research as it is relatively simple to tax CO_2 emissions from energy use. In contrast, the share of public research expenditure going to (non-energy related) environmental research is lower today compared to 10-15 years ago, cf. figure E. This may very well be a suboptimal change in the distribution of public research expenditure between energy- and environmental research. In any case, one should only consider the possibility of large earmarked subsidies for environmentally friendly technologies when it is not technically possible to employ a targeted environmental tax on the emissions (assuming that the positive knowledge spillovers are the same for different types of private research).

In addition to environmental taxes (or equivalent regulation) and general research subsidies, in some cases, providing subsidies to production of sustainable energy using new technologies may be considered. However, such a production subsidy should always be temporary and should only be given when an unmistakably positive learning-by-doing externality can be identified. It should, however, be noted that it is often difficult to establish whether technological progress in the production of new technology derives from a learning-by-doing externality, learning-by-doing within individual firms (which is not an externality and therefore does not justify a production subsidy), investments in research or spillovers of knowledge from other firms, universities or countries. Lobbying by the supported industry may also make it difficult to phase out production subsidies, so there is a risk that the temporary production subsidy ends up becoming permanent, which may create a long-run distortion in the allocation of production factors. Altogether, there is a significant risk of regulatory failure when subsidizing the use of new technology in production and therefore subsidies should only be given with great caution.

As mentioned above, the increase in public R&D expenditure allocated to Danish energy research has primarily been directed towards R&D with an immediate commercial potential. Thus, the subsidy for energy research can largely be characterized as public aid for selected industries. A carbon tax will, in itself, also create a demand for new (cleaner) energy technologies that are close to being able to compete with conventional technologies. On the other hand, a carbon tax would probably be less effective in promoting more fundamental research. Consequently, directing public research subsidies towards a build up of general energy knowledge in the Danish society, through increased funding for more basic research, instead of focusing public R&D funds on commercializing of energy research results should be considered.

Denmark is far from the only country to have singled out clean energy technology as a potential growth area. In several other countries the share of public R&D appropriations allocated to energy research has also increased since the mid-00s. This could potentially make Danish imports of new energy technology more profitable, given that energy technology developed abroad becomes less costly. In any case, it will not be an optimal strategy to increase public expenditure on energy research simply in order to "match" the subsidy level in other countries.

In general, Danish firms seem to have succeeded in developing and exporting energy technology over the past decade. This is confirmed by a relatively large number of (renewable) energy patents in total Danish patent applications. Furthermore, an econometric analysis of patent citations, based on the OECD's citations database, confirms that Danish (renewable) energy patents receive a relatively high number of citations. This indicates that Danish energy patents are of relatively high scientific value. However, since this apparent Danish success was initiated prior to the recent increase in public energy research appropriations, it can be argued that Danish firms have been fully capable of exploiting a growing market for energy technology without being granted a significant share of the public support for R&D.

Even if selective public support for research in specific technological areas or industries contributes to a high level of exports, employment, and patents in the supported industries, one must keep in mind that without public support, labour and capital would have been used in other industries where they could potentially have generated even higher returns.

The increase in public expenditure on energy research seems to be motivated by the assumption that the market for energy technology will experience future growth. However, it can be questioned whether the government is better than the Danish firms, i.e. the actual actors in the market, at identifying future growth areas where Denmark will be able to compete successfully. Furthermore, R&D subsidies earmarked for development of technology in specific industries will always have to be given at the expense of support to other industries. One particular industry should not be favoured over another, unless there are valid arguments to do so – for example large spillover-effects from R&D. The analysis performed in the chapter does not find evidence of spillover from private Danish energy research exceeding those arising from other private research. Hence, on this account, no support for favouring energy research is found.

Chapter III: Tax structure and climate targets

The chairmen of The Economic Councils have previously recommended changing the Danish system of energy- and CO_2-taxes, since these taxes do not targeted reductions in climate gas emissions at minimum costs. First, the taxes on energy products are differentiated by energy content and usage, and not targeted at CO_2 emissions. Second, some climate gasses are not taxed at all, e.g. non-energy related emissions.

If energy taxes are to contribute to achieving the Danish CO_2-reduction target in a cost effective way, the taxation of CO_2 should be equal across all sectors, usages and fuels. This will create a uniform incentive to reduce CO_2 emissions and CO_2 reductions will take place where the costs are lowest.

Greenhouse gas emission in Denmark is divided into emissions from sectors within the Emission Trading System (the ETS sector) and from sectors outside the ETS (the non-ETS sector). Denmark is obliged by the European Union to reduce its greenhouse gas emissions from the non-ETS sector by 20 percent over the period 2005 to 2020. This chapter concerns taxation in the non-ETS sector. The analysis is based on a projection for energy consumption and emissions of greenhouse gases in Denmark from 2009 to 2025, based on the DEMS model developed by the Danish Economic Councils. Using this projection, and if the existing system of energy taxes is unchanged, Danish greenhouse gas emissions will exceed the emissions target by 6 million tonnes. Denmark is free to choose the measures to fulfil the reduction target in the non-ETS sector. The reductions can be achieved by domestic reductions and/or by purchasing foreign emission permits.

The chapter analyses various alternatives for changing the system of energy, CO_2 and transport related taxes. The purpose is to assess how Denmark can fulfil its EU greenhouse gas reduction obligations in the non-ETS sector in the most appropriate way.

A partial model is used to assess the effects of different tax changes. In this model the consumption of different types of energy depends on the prices of the specific energy type as well as on different energy usages. Thus, the tax's influence on factors other than the consumption of energy products is not considered.

A fundamental issue is whether the reduction target is to be achieved through domestic reductions or by purchasing foreign emission permits. The economically most effective method would be to apply a uniform tax on all domestic greenhouse gas emissions. The tax should equal the price of foreign emission permits. Further reductions should be achieved by purchasing foreign emission permits. This will also be beneficial for the country selling the emission permits, since this country obtains a price that is higher than the costs of reducing its own emissions.

Since there may be a political wish for some degree of domestic emission reductions, calculations are made for scenarios with no, half and full domestic reductions of the remaining emissions.

The analyses only describe changes within the existing framework of energy and CO_2 taxes. Whether specific energy taxes are more favourable than alternative public income measures is not considered. It is not likely that specific energy taxes are among the least distorting taxes. Furthermore, distributional effects between income groups from tax changes are not considered either.

Non-energy related greenhouse gas emissions from agriculture should also be taxed. Since these emissions cannot be measured directly, it is somewhat complicated to design a taxation system for these emissions. One possibility is to create a farm specific greenhouse gas account that estimates the emissions from each farm based on types of production and scientific relationships between farm processes and greenhouse gas emissions. Such a system would reduce emissions in a cost effective way, but would also demand an effort regarding registration and control. Part of such a control system already exists though, in the form of manure accounts etc. An alternative to a greenhouse gas account could be a simple tax on nitrogen input and livestock. In both cases, the tax system could be supplemented with a compensation scheme, so the farm is not burdened with unnecessary economic strain, but still has an economic incentive to reduce greenhouse gas emissions. This could be accomplished by CO_2 allowances in line with other sectors.

The calculations confirm that economic costs are minimized when imposing a uniform tax on all CO_2 emissions in the non-ETS sector and the rest of the reduction is achieved by purchasing foreign emission permits. The tax on CO_2 emissions should equal the price of foreign emission permits.

If half of the shortfall in the Danish reduction target is to be met by domestic reductions and the rest by purchasing foreign emission permits, the domestic tax on CO_2 would have to increase to 900 DKK per tonne. This is well above the assumed quota price/assumed price of foreign emission permits of 250 DKK per tonne. This will increase the efficiency loss relative to the scenario where the option for purchasing foreign emission permits is fully utilised. If the total shortfall in the Danish reduction target is to be met by domestic reductions, costs can be comprehensive. In this case the domestic tax on CO_2 would have to be around 2,100 DKK per tonne. This will create an immense imbalance between emission costs in the ETS and the non-ETS sectors. Thus, it will be costly if politicians determine that a certain amount of the reduction target should be reached by domestic reductions.

If Denmark chooses to desist from purchasing foreign emission permits, this may cause indirect and costly movements of climate gas emissions to other countries. This is due to increased import of climate gas intensive products, and increased production of climate gas extensive products in Denmark.

No matter how large the domestic reduction should be, it will always be associated with the lowest efficiency loss if greenhouse gas emissions are taxed by a uniform tax on all emissions. If some emitters are exempt from CO_2 taxes, other emitters will have to reduce their emissions further. This will imply that they will have to undertake costly reductions, which will increase the cost for society. If, for instance, the agricultural sector is exempt from greenhouse gas taxation, all other emissions of non-ETS greenhouse gas emissions must be taxed by 2,500 DKK per tonne if Denmark is to meet its reduction target through domestic reductions.

Neither consideration of Danish firms' competitive positions nor other considerations should be reasons for exempting some or all industries from greenhouse taxation. However, there can be good reasons for considering an industry's needs when the tax yield is being spent.

The sole purpose of many of the energy related taxes in Denmark is to provide a yield. Such taxes are paid by both consumers and businesses with considerable reductions for businesses. In order for such taxes to give rise to the smallest possible loss of efficiency, the taxes should be imposed where the distortion from higher taxation is lowest. This, in general, creates an argument for charging businesses lower energy taxes than households for reasons of competitiveness, but not to exempt them from energy taxes. Today businesses pay energy taxes but at the same time they can deduct an amount based on historical emission levels from their tax payments. However, it would be more efficient to compensate the businesses through lower (distorting) energy taxes than through such deductions. However, it would be more efficient to compensate the businesses through lower (distorting) energy taxes than through allowances.

Tax bases should *ceteris paribus* be as wide as possible. Given that one wants to collect revenue from energy taxation, as a basic principle, all types of energy should, therefore, be taxed in the same way. This principle influences the question of whether energy produced in the ETS-sector, such as electricity and district heating or biofuels, should be taxed.

Both energy taxes and CO_2-taxes are imposed on electricity and district heating in addition to CO_2-quota payments. These taxes are distorting since the CO_2-quotas ensure that the aggregate CO_2 emissions from the ETS-sector are reduced to the level desired by the EU. At the same time these taxes make electricity and district heating more costly which, *ceteris paribus*, moves energy consumption from the ETS-sector to the non-ETS-sector. If electricity and district heating are taxed less and coal, oil and gas are taxed more heavily, the CO_2-emissions in the non-ETS-sector will be reduced. A calculation of the CO_2 taxation that would be necessary if Denmark wanted to reduce its domestic emissions of CO_2 by another 3 million tonnes shows that the CO_2-tax "only" would have to increase to 770 DKK per tonne instead of 900 DKK, if the revenue from the CO_2 taxation was used exclusively for reducing energy taxes imposed on electricity and district heating instead of reducing all energy taxes proportionally. The selective reduction of energy taxes imposed on electricity and district heating implies a loss in welfare. This indicates that there is no economic benefit from exempting the ETS-sector from energy taxation.

Biofuels are considered CO_2-neutral and therefore do not have CO_2-taxes imposed on them. In addition they are exempted from energy taxation, which is not necessarily expedient. The principle of using wide tax bases implies that, given one wants energy taxes at all, all types of energy should be taxed including biofuels. However, taxing biofuels could lead to Denmark having to undertake new initiatives in order to fulfil its goal of 30 percent renewable energy by 2020.

At present different renewable energy sources are given different subsidies. In order to fulfil the goal of 30 percent renewable energy by 2020 it is not expedient to discriminate among renewable energy sources, since all count equally (measured per unit of energy) to meeting the renewable energy target. Therefore, replacing the existing subsidies with a uniform subsidy for all renewable energy sources should be considered. This will ensure that the most cost effective ways of producing renewable energy will be used. The subsidies for renewable energy are finances by the PSO-tariff (Public Service Obligations) imposed on consumption of electricity.

The following provides an overview of the conclusions and recommendations in the chapter.

- A uniform tax should be imposed on all emissions of greenhouse gasses in the non-ETS-sector and the tax should be equal to the price of buying foreign emissions permits

    - Non-energy related emissions from the agricultural sector should be taxed equally with all other greenhouse gas emissions from the non-ETS-sector
    - Greenhouse gas accounts for each farm can be a way of taxing greenhouse gas emis-

sions. Compensation can be given in line with other sectors

- Industries should not be exempted from taxation because of their international competitive position
- If compensation/reversal is given to the industries, it should be given through reductions in distorting taxes and not through tax free allowances

- If the uniform tax does not ensure that Denmark meets its reduction targets, these should be met by buying emission permits

    - If it is not possible to buy emission permits or there is a political wish to meet the reduction targets through domestic reductions, the reductions should be made by raising the uniform greenhouse gas on all emitters in the non-ETS-sector
    - It is preferable to tax gasoline instead of road pricing if the goal is to meet the reduction target

- If the purpose of a tax is not to regulate environmental effects but exclusively to raise revenue, it is more desirable to tax real estate or income than energy because it creates less distortions

    - Firms' use of energy should be taxed at a positive rate of taxation but less than households, given energy taxes are chosen as an option
    - Double regulation of CO_2 should be avoided. Therefore electricity and district heating produced in the ETS-sector should not be subjected to CO_2-taxation
    - Electricity and district heating should not be exempt from energy taxation, given that one wants energy taxation at all. The total taxation should not necessarily be lower than today

  - The renewable energy target should be reached by a uniform subsidy to renewable energy instead of the current support schemes for renewable energy
  - The PSO-tariff should be abolished as a tariff with the specific purpose to finance the subsidies for renewable energy

- The EU should redesign the regulation of CO_2 emissions in the ETS-sector and the non-ETS-sector such that differences in the marginal reduction costs in the two sectors will be eliminated

  - It should be possible for the member states to meet their reduction targets in the non-ETS-sector by buying quotas
  - The possibility of trading emission permits in the non-ETS-sector should be more flexible

The agricultural sector and other greenhouse gas intensive industries should be included in the ETS-sector

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