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Towards Green Growth in Denmark: Improving Energy and Climate Change Policies

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ABSTRACT/RÉSUMÉ

Towards green growth in Denmark: improving energy and climate change policies

Denmark's green growth strategy focuses on moving the energy system away from fossil fuels and investing in green technologies, while limiting greenhouse gas (GHG) emissions. On the whole, current policies should allow Denmark to reach near-term climate change targets, but may not be sufficient to achieve its most ambitious targets. The challenge is to achieve objectives in a cost-effective manner and to ensure that these ambitions contribute as much as possible to global GHG emissions mitigation and to stronger and greener growth in Denmark. Better exploiting interactions with EU and international policies, finding the appropriate way to support green technologies and reducing GHG emissions in sectors not covered by the EU emission trading scheme are key issues which need to be addressed to meet this challenge.

This Working Paper relates to the 2012 *OECD Economic Survey of Denmark* (www.oecd.org/eco/surveys/denmark).

JEL classification: Q48 ; Q54 ; Q58
Keywords: Denmark; climate change; greenhouse gases emissions; climate change mitigation policy; energy security; carbon tax; renewable energy; green technologies.

Vers une croissance verte au Danemark : améliorer les politiques énergétiques et climatiques

La stratégie de croissance verte du Danemark vise pour l'essentiel à supprimer les combustibles fossiles du système énergétique et à investir dans les technologies vertes, tout en limitant les émissions de gaz à effet de serre (GES). Dans l'ensemble, les mesures en cours devraient permettre au Danemark d'atteindre les objectifs d'atténuation du changement climatique à court terme mais peut-être pas de réaliser ses objectifs les plus ambitieux. Toute la difficulté sera de les atteindre de manière économiquement efficiente et de veiller à ce que ces ambitions contribuent au mieux à l'atténuation des émissions de GES dans le monde ainsi qu'à une croissance plus forte et plus verte au niveau national. Pour faire face à ce défi, le Danemark devra mieux exploiter les interactions avec les politiques mises en œuvre dans le cadre de l'UE et à l'échelle internationale, trouver le meilleur moyen de soutenir les technologies vertes et réduire les émissions de GES dans les secteurs qui ne relèvent pas du système communautaire d'échange de quotas d'émissions.

Ce Document de travail se rapporte à *l'Étude économique de l'OCDE du Danemark*, 2012 (www.oecd.org/eco/etudes/danemark).

Classification JEL : Q48 ; Q54 ; Q58
Mots clés: Danemark ; changement climatique ; émissions de gaz à effet de serre ; politiques d'atténuation du changement climatique ; taxe carbone ; énergie renouvelable ; technologies vertes.

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TOWARDS GREEN GROWTH IN DENMARK: IMPROVING ENERGY AND CLIMATE CHANGE POLICIES

By Stéphanie Jamet[1]

Green growth ranks high on Denmark's policy agenda. The country has taken measures and developed plans to reduce the use of fossil fuels and limit greenhouse gas (GHG) emissions, as well as other forms of pollution, while investing in green technologies as a potential new source of growth. The target of eliminating fossil fuels without the use of nuclear energy by 2050 stands out. In many respects, this strategy is visionary. However, it also illustrates the difficulties to achieve various green growth objectives when uncertainties and irreversibilities surround technological choices even as international policies and actions are evolving.

As in many other countries, energy policy in Denmark was dominated historically by concerns about the security of energy supply rather than climate change. After the first oil crisis in 1973, energy policy aimed at making the energy system less dependent on imported oil. Since the mid-1980s, most energy policies focussed on reducing the dependence on foreign suppliers and on improving supply security by increasing energy efficiency. Governments have also introduced actions and plans to shift away from energy sources that are likely to become scarce, and to move towards renewables. More recently, an agreement to have 50% of electricity consumption coming from wind power by 2020 was reached between the main parties with a majority at the Parliament.

These various policies have led to considerable energy efficiency gains and a more diversified energy supply based, in addition to oil, on coal, natural gas and renewables. The utilisation of oil and gas resources from the North Sea and, more recently, the expansion of wind power have turned the country into a net energy exporter. These policies have also helped lower GHG emissions. Denmark took measures to reduce CO_2 emissions during the 1990s, ratified the Kyoto protocol and participates in EU climate policies. More recently, the new government has announced a target to reduce GHG emissions by 40% in 2020 from the 1990 base, which is, with Norway, the largest reduction pledged by a developed country.

Denmark thus pursues a mix of energy and climate change policies and stands out by the ambition of its objectives. The challenge is to achieve these objectives in a cost-effective manner and to ensure that these ambitions contribute as much as possible to global GHG emissions mitigation and to stronger and greener growth in Denmark.

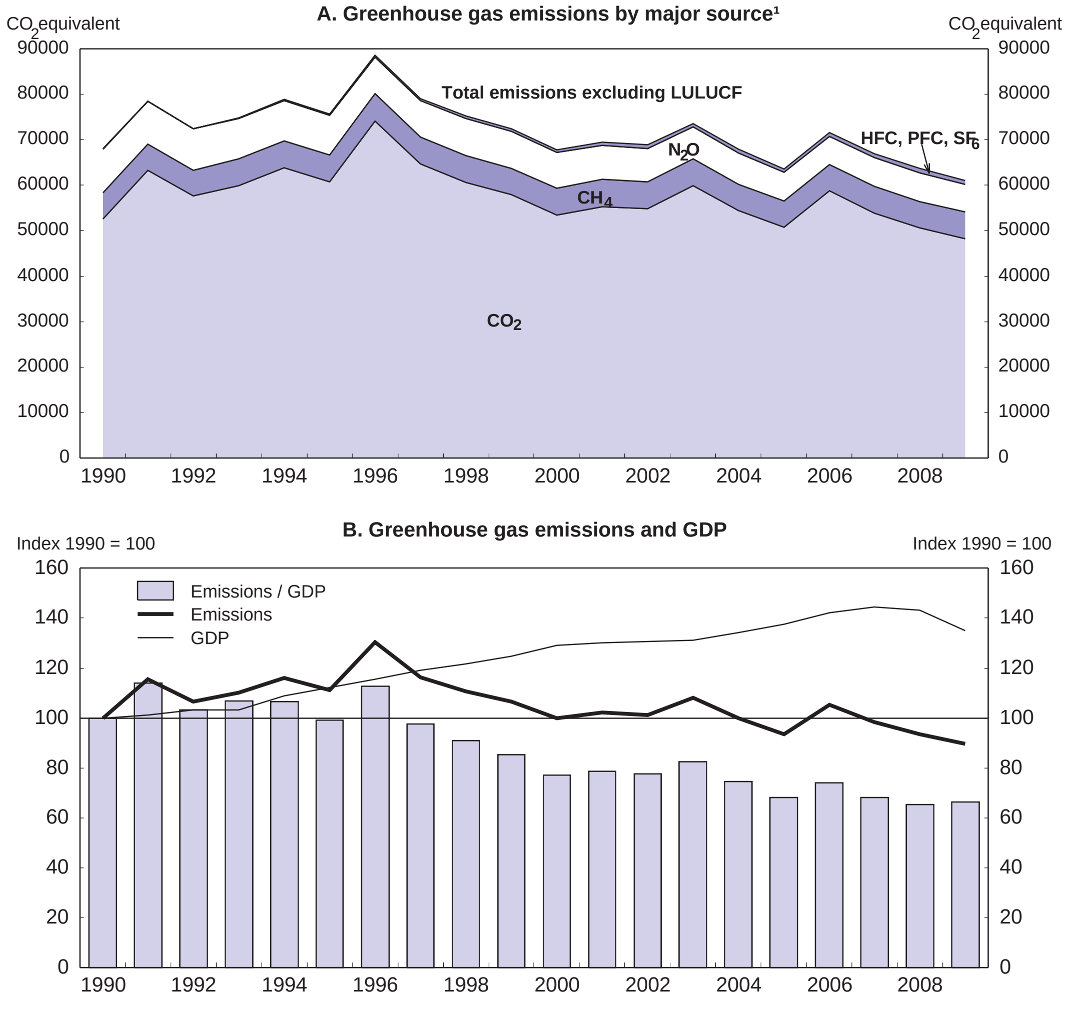
This paper assesses Danish energy and climate policies and discusses how they could be improved to ensure that objectives are met at least cost. It first depicts the evolution of GHG emissions and the energy mix since 1990. It then puts energy and climate policies and targets into perspective and sets out the main challenges. The final section assesses how policies could be shaped to enhance the efficiency of these targets and minimise their costs.

1. Stéphanie Jamet is from the Economics Department of the OECD. This paper is a slightly updated version of a chapter from the *OECD Economic Survey of Denmark* published in January 2012 under the authority of the Economic and Development Review Committee (EDRC). It has benefited from background research by Jean-Marc Burniaux. The author would like to thank Nils-Axel Braathen, Balázs Egert, Andrew Dean, Jorgen Elmeskov, Robert Ford, Jens Hoj, Vincent Koen, Alain de Serres and Jacob Vastrup for valuable comments on earlier drafts. Special thanks go to Lutécia Daniel for technical assistance and to Nadine Dufour and Pascal Halim for technical preparation.

Past energy and GHG emission trends

Danish GHG emissions (excluding emissions from Land Use, Land Use Change and Forestry – LULUCF) peaked in 1996 and have steadily declined thereafter, to just above 60 million tonnes in 2009, *i.e.* 10% below their 1990 levels (Figure 1, Panel A). This GHG emission reduction is relatively high as emissions increased OECD-wide over the same period. Nevertheless, Denmark's GHG emissions per capita were 22% above the EU average in 2009, though in line with the OECD average (Table 1, Panel B). Danish emissions fluctuate around their downward trend, reflecting trade in electricity with Nordic neighbours.[2] CO_2 amounts to around 80% of these emissions, a proportion that has remained stable over time. GHG emissions have been increasingly decoupled from GDP since the early 1990s (Figure 1, Panel B).

Figure 1. Evolution of greenhouse gas emissions in Denmark



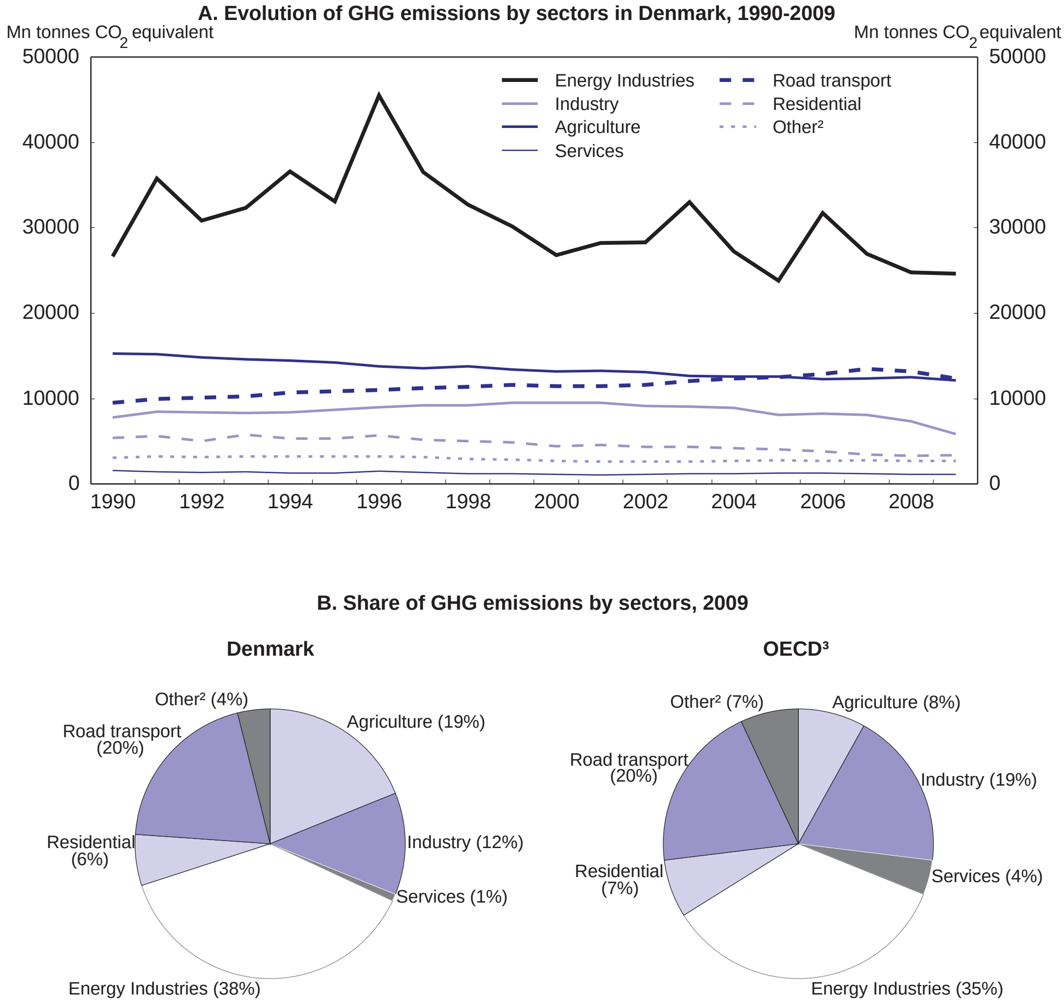
1. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (HFC, PFC, SF_6). In CO_2 equivalent excluding net CO_2, CH_4 and N_2O from LULUCF.

Source: UNFCCC and OECD, Analytical Database.

2. For instance in the recent period, peaks correspond to high wind power in Denmark combined with low rainfalls in Nordic countries that restrict their supply of hydroelectric power.

The fall in GHG emissions has mainly come from energy industries, agriculture and the residential sector, while emissions from transport have continued to increase steadily (Figure 2). Compared to other OECD countries, emissions from agriculture are high – with a share of 19% compared with 8% for the EU average in 2009, mainly coming from the livestock. The proportion of GHG emissions generated by the energy sector is close to the OECD average.

Figure 2. Sectoral contributions to greenhouse gas emissions[1]



1. Total CO_2 equivalent emissions without land use, land-use change and forestry.
2. Includes waste, other transport, solvent and other product use and other not elsewhere specified.
3. The OECD aggregate is an unweighted average and excludes Chile, Israel, Korea and Mexico.

Source: United Nations Framework Convention on Climate Change Database.

GHG emissions per capita coming from the energy sector (including electricity generation and transport) were below the OECD average in 2009, but higher than in Sweden and France for instance (Table 1, Panel B). This reflects high GDP per capita coupled with a relatively high emission intensity of energy. In contrast, Denmark belongs to the group of countries that use energy most efficiently but this is not enough to put the country in the low-emission group.

Table 1. Decomposition of energy GHG emissions[1]

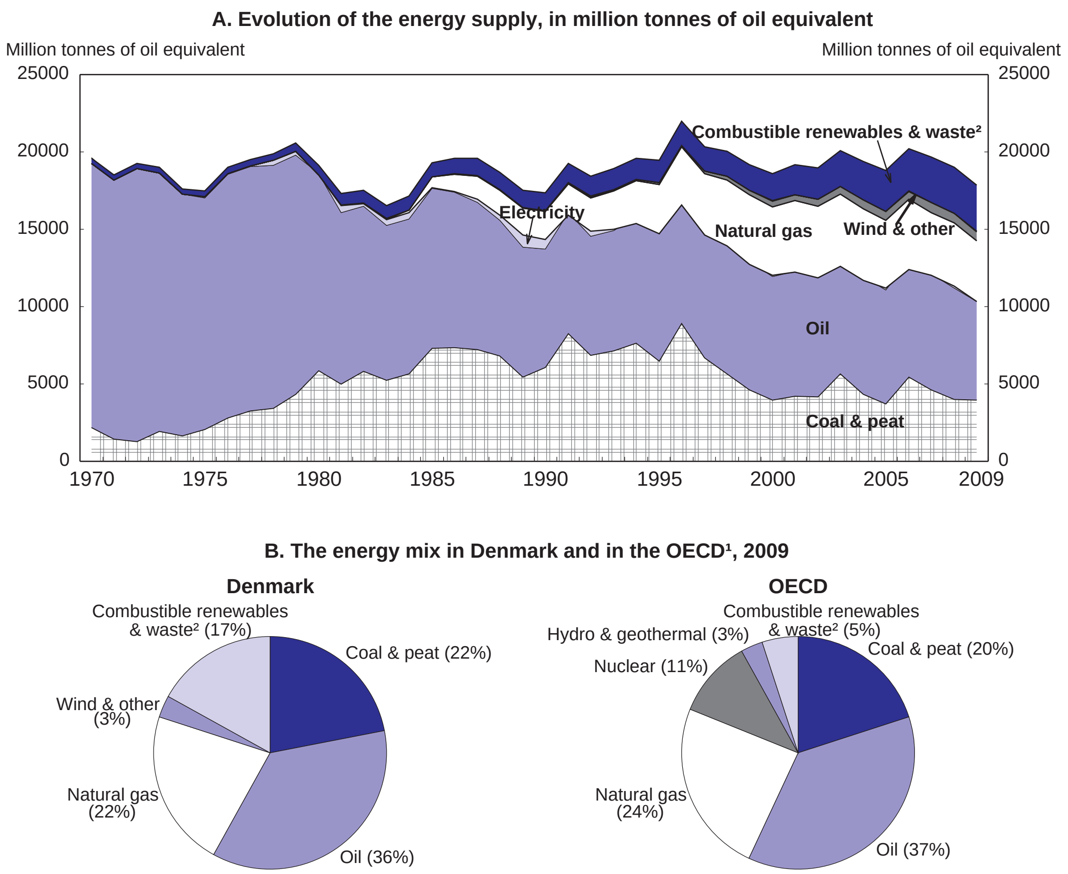
Country/ region (%)	GHG emissions/capita[2]	A=B*C*D Energy GHG emissions/capita[2]	B GDP per capita[3]	C Energy GHG emissions/energy[4] use	D Energy use/GDP[5]
Panel A: Emissions 1990					
USA	24.6	21.1	31.8	2.8	0.24
UK	13.6	10.6	23.7	3.0	0.15
Germany	15.7	12.8	25.9	2.9	0.17
France	9.7	6.6	24.3	1.7	0.16
Italy	9.2	7.4	23.8	2.9	0.11
Denmark	**13.5**	**10.3**	**25.4**	**3.1**	**0.13**
Sweden	8.5	6.2	24.6	1.1	0.22
Norway	11.7	7.0	32.1	1.4	0.15
OECD	13.1	10.7	22.6	2.5	0.19
EU-27	11.8	9.1	18.3	2.6	0.19
Panel B: Emissions 2009					
Country/ region (%)	GHG emissions/capita[2]	A=B*C*D Energy GHG emissions/capita[2]	B GDP per capita[3]	C Energy GHG emissions/energy[4] use	D Energy use/GDP[5]
USA	21.5	18.7	41.1	2.7	0.17
UK	9.2	7.8	32.0	2.5	0.10
Germany	11.2	9.3	32.2	2.4	0.12
France	8.1	5.7	29.4	1.4	0.14
Italy	8.2	6.8	26.5	2.5	0.10
Denmark	**11.3**	**8.9**	**32.0**	**2.7**	**0.11**
Sweden	6.5	4.8	32.2	1.0	0.15
Norway	10.6	8.1	47.1	1.4	0.12
OECD	11.4	9.6	29.4	2.2	0.15
EU-27	9.2	7.3	27.1	2.2	0.12
Panel C: Average annual growth in emissions 1990-2009					
Country/ region (%)	GHG emissions/capita	A$\simeq$B+C+D Energy GHG emissions/capita	B GDP per capita	C Energy GHG emissions/energy use	D Energy use/GDP
USA	-0.7	-0.6	1.4	-0.2	-1.8
UK	-2.0	-1.6	1.6	-1.0	-2.1
Germany	-1.8	-1.7	1.2	-1.0	-1.8
France	-0.9	-0.8	1.0	-1.0	-0.7
Italy	-0.6	-0.4	0.6	-0.8	-0.5
Denmark	**-0.9**	**-0.8**	**1.2**	**-0.7**	**-0.9**
Sweden	-1.4	-1.3	1.4	-0.5	-2.0
Norway	-0.5	0.8	2.0	0.0	-1.2
OECD	-0.7	-0.6	1.4	-0.7	-1.2
EU-27	-1.3	-1.2	2.1	-0.9	-2.4

1. Energy GHG emissions/head = (GDP/head) * (Energy GHG emissions /energy) * (energy/GDP). In recent years, GHG emissions have been strongly affected by the global economic and financial crisis.
2. In tonnes of CO_2eq per head.
3. In thousand US$ using PPP exchange rates for the year 2005.
4. For total final energy consumption in ktoe/billion PPP US$ for the year 2005.
5. For total final energy consumption in Mt CO_2eq/ktoe. In Ktoe/billion PPP US$ for the year 2005.

Source: OECD calculations and UNFCCC.

Energy-related GHG emissions per capita declined more in Denmark over 1990-2009 than OECD-wide (Table 1, Panel C). Nevertheless, several countries (Germany, United Kingdom, Sweden) reduced their emissions per capita more than Denmark. This mostly reflects limited gains in energy efficiency, stemming from the fact that Denmark already used energy relatively efficiently in 1990 (Table 1, Panel A). The drop in the emission intensity of energy in Denmark was in line with countries that also started from high levels in 1990 (United Kingdom and Germany). Hence, even though the emission intensity of energy in Denmark has dropped, it remains relatively high, reflecting the evolution of the energy mix. Since the early 1990s, the share of coal and oil in total energy consumption has tended to decline, and that of natural gas and renewables to rise but since 2000, the fall in the use of coal has stopped (Figure 3, Panel A). This energy mix, which relies mostly on fossil fuels (80% of total primary energy demand), generates fairly high GHG emissions (Figure 3, Panel B). Countries with a lower proportion of fossil fuels in their energy mix generally use nuclear power and/or hydro. Denmark has decided that nuclear energy is not an option and hydropower cannot be developed because of the country's geography.

Figure 3. The energy mix[1]

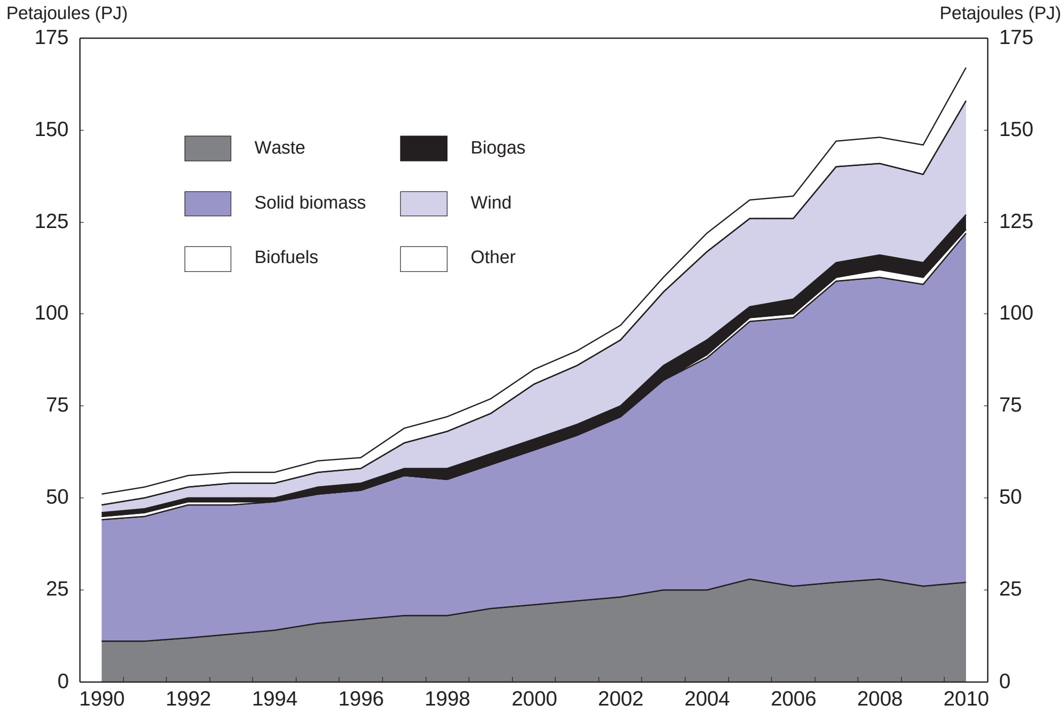


1. As a share of total primary energy supply (TPES).
2. Includes non-renewable municipal waste, industrial waste, electricity trade and other sources of primary energy.

Source: IEA (2011), Energy Balances of OECD Countries.

Renewables have been developed vigorously and their share in energy supply amounted to almost 20% in 2008 versus an OECD average of 7%. Among renewables, most of the increase came from the use of solid biomass for heating and wind power for electricity generation. Wind accounted for 3% of the energy supply in Denmark in 2009 while its contribution was close to 0% OECD-wide. In contrast, the use of biofuels and biogas remains marginal (Figure 4).

Figure 4.The take-off of renewables[1]



1. In gross energy consumption. Corrected for electricity trading. Historical figures are climate adjusted.

Source: Danish Energy Outlook (2011).

In sum, total GHG emissions in Denmark have declined more than the OECD average (and roughly in line with other EU countries) since 1990, but in per capita terms they remain just at the OECD average. This is because: *i)* its energy mix implies higher emissions per energy unit; and *ii)* GHG emissions from agriculture are high. Going forward, the potential for reducing GHG emissions in Denmark relies mostly on changing the energy mix away from carbon-rich fossil fuels and reducing non-CO_2 emissions from agriculture.

Danish climate change and energy policies in perspective

Main targets and current policies

Denmark has long considered policies to reduce GHG emissions as part of a set of broader objectives and has been a pioneer in climate change mitigation policies. In 1992, Denmark was one of the first countries, just after Sweden, to introduce carbon taxation, with a carbon tax on some energy uses by households and space heating in industry, which has since been increased and extended to other industrial processes (OECD, 2007a). The tax rate differed across users and sectors, with households paying most (Table 2). Much lower rates applied to energy-intensive industries on the ground of competitiveness concerns. In addition, these industries benefited from tax rebates in the context of voluntary agreements with the authorities for implementing energy-saving measures. The revenues of the carbon tax were earmarked to subsidise environmental innovation. CO_2 is also indirectly taxed through energy taxes that have been increased, and in effective terms Denmark now has the highest taxation of energy among EU countries (Figure 5).

Table 2. Carbon tax rates

Euros/tonnes of CO_2 equivalent, nominal

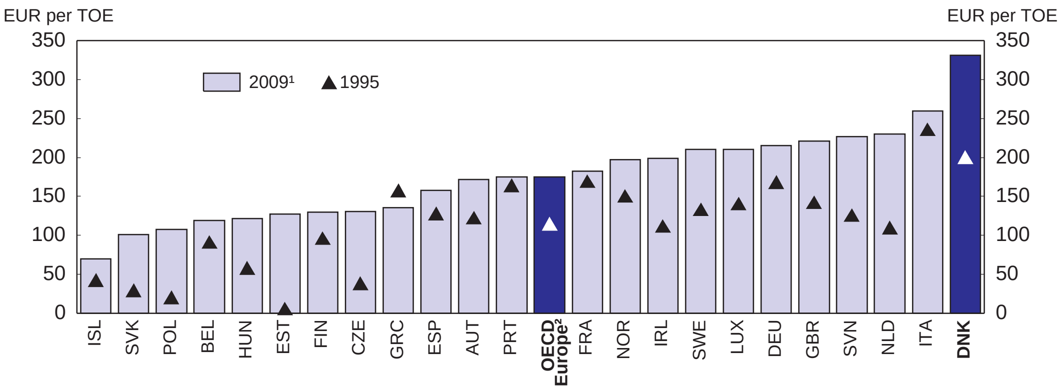
	1996	2000-04	2005	2008	2011
Denmark					
Households (basic rate)	13.4	13.4	12.1	20	21.3
Industry					
Heating (basic rate)	13.4	13.4	12.1	20	21.3
Light processes:					
Without voluntary agreement	6.7	12.1	12.1	20	21.3
With voluntary agreement	6.7	9.1	9.1	20	21.3
Energy-intensive processes					
Without voluntary agreement	0.7	3.4	3.4	20	21.3
With voluntary agreement	0.4	0.4	0.4	20	21.3
Sweden					
General carbon tax rate	40.0	69.3	98.7	108.9	114.0

Source: OECD (2007a), Danish Ministry of Taxation, and Swedish Ministry of Finance.

In addition, during the 1990s, Denmark implemented an extensive set of command-and-control and subsidy instruments in order to boost the production of renewable energy and increase energy efficiency. In particular, support to wind technology has taken the form of a feed-in tariff that guarantees a price to producers to cover their costs and hence involves a supplement to the market price.

Figure 5. Effective taxes on energy

EUR per tonnes of oil equivalent (TOE), base year 2000



1. The last available year is 2008 for Hungary, Portugal and Norway and 2006 for Iceland.
2. The OECD Europe aggregate is a simple average and does not include Switzerland and Turkey.

Source: European Commission (2011), Taxation Trends in the European Union: Data for the EU Member States, Iceland and Norway.

Over the past decade, Denmark has had the goal of meeting the emission reduction targets under the Kyoto Protocol and the EU Burden Sharing Agreement in a cost-effective way (Ministry of Climate and Energy, 2009; Box 1). It set itself an ambitious target of cutting emissions by 21% over 2008-12 relative to base-year levels – one of the steepest reductions among EU countries which called for new measures.[3] These included:

- The introduction of a cap-and-trade system. Denmark introduced it for electricity generation in 2001, with a free allocation of permits based on firms' past emissions and provisions for banking. The system was extended in 2003 and replaced in 2005 by the EU emission trading scheme (ETS).

Box 1. Main climate change mitigation and energy targets

Near-term targets

Under the EU burden sharing agreement of the Kyoto Protocol, Denmark should reduce GHG emissions by 21% below 1990 levels for the average level of GHG emissions over 2008-12.

Under the 2008 Agreement on Danish Energy Policy, the share of renewables in gross energy supply should be raised to 20% by 2011.

Targets for 2020 and 2050

EU targets for 2020

As an EU member, Denmark has to contribute to the achievement of EU targets, which are:

- A 20% reduction in GHG emissions relative to 2005 levels. This reduction can be scaled up to as much as 30% should there be a new global climate change agreement with other developed countries making comparable efforts.
- A 20% share of EU energy consumption from renewables.
- A 10% share for renewables in the transport sector.
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Richer EU countries are expected to contribute more than poorer ones. For Denmark, the specific targets are:

- A decrease in emissions of sectors outside the EU ETS by 20% between 2005 and 2020, which is the steepest reduction for Member States.
- An increase in the share of energy supply from renewables from 17% in 2005 to 30% in 2020.

National targets

The new government has reaffirmed Denmark's target to become "independent from fossil fuel" in 2050, which means that the share of energy from renewables would have to reach 100%. In addition, the new government has announced four sub-targets:

- By 2020, 50% of electricity would come from wind.
- A 40% cut in GHG emissions is to be achieved mainly domestically by 2020 relative to 1990 levels.
- The use of coal for power generation and of oil boilers for residential heating would be phased out by 2030.
- Electricity and heating supply would be fully covered by renewable energy by 2035.

3. The reference year is 1990 for CO_2, methane and nitrous oxide and either 1990 or 1995 for industrial GHG. According to Denmark's 2003 Climate Strategy, the target would have been exceeded by 20 to 25 thousand tonnes of CO_2eq. annually over 2008-12 in the absence of additional measures.

- A harmonisation and increase in the carbon tax rate. Differences in rates across industries were reduced in 2005 and abolished in 2008 (Table 1). The rate was raised to €20 per tonne of CO_2 in 2008, which was the expected carbon price in the EU ETS. It is, however, much below the statutory rate in Sweden, which exceeded €100 in 2008. Since then, the carbon tax rate has been lifted by 1.8% per year. The coverage has been reviewed after the introduction of the EU ETS but some sectors are still taxed twice. This is the case for producers of district heating that are covered by the carbon tax regardless of whether they are inside or outside the EU ETS.

- The use of the flexible mechanisms considered in the Kyoto Protocol: Joint Implementation (JI) and Clean Development Mechanism (CDM).

- The cost of developing the capacity of electricity production from wind turbines is gradually passed on to all domestic consumers of electricity through a "public service obligation", which is paid by electricity consumers and finances the supplement to the electricity market price guaranteed to electricity producers. Other renewables also benefit from the system, but to a lesser extent than wind.

- To ensure some uniformity of abatement efforts between ETS and non ETS sectors as well as to identify additional cost-effective measures to meet the EU Burden-Sharing target, a benchmark of €16 (DKK 120) per tonne of CO_2eq. was set as a basis for implementing domestic measures outside the sectors covered by the EU ETS. This benchmark can be adjusted over time.

In 2007, Denmark also set itself an objective of independence from fossil fuels by 2050. The new government has reiterated this target, by stating that 100% of energy should come from renewables by 2050 and adding some sub-targets (Box 1). In particular, it has announced a new target to cut GHG emissions by 40% by 2020 relative to 1990 levels, with at least a large portion of this reduction to be achieved domestically. This target comes on top of Denmark's commitment to reducing GHG emissions in sectors outside the EU ETS by 20% in 2020 relative to their 2005 levels as part of the 2008 EU climate and energy package.

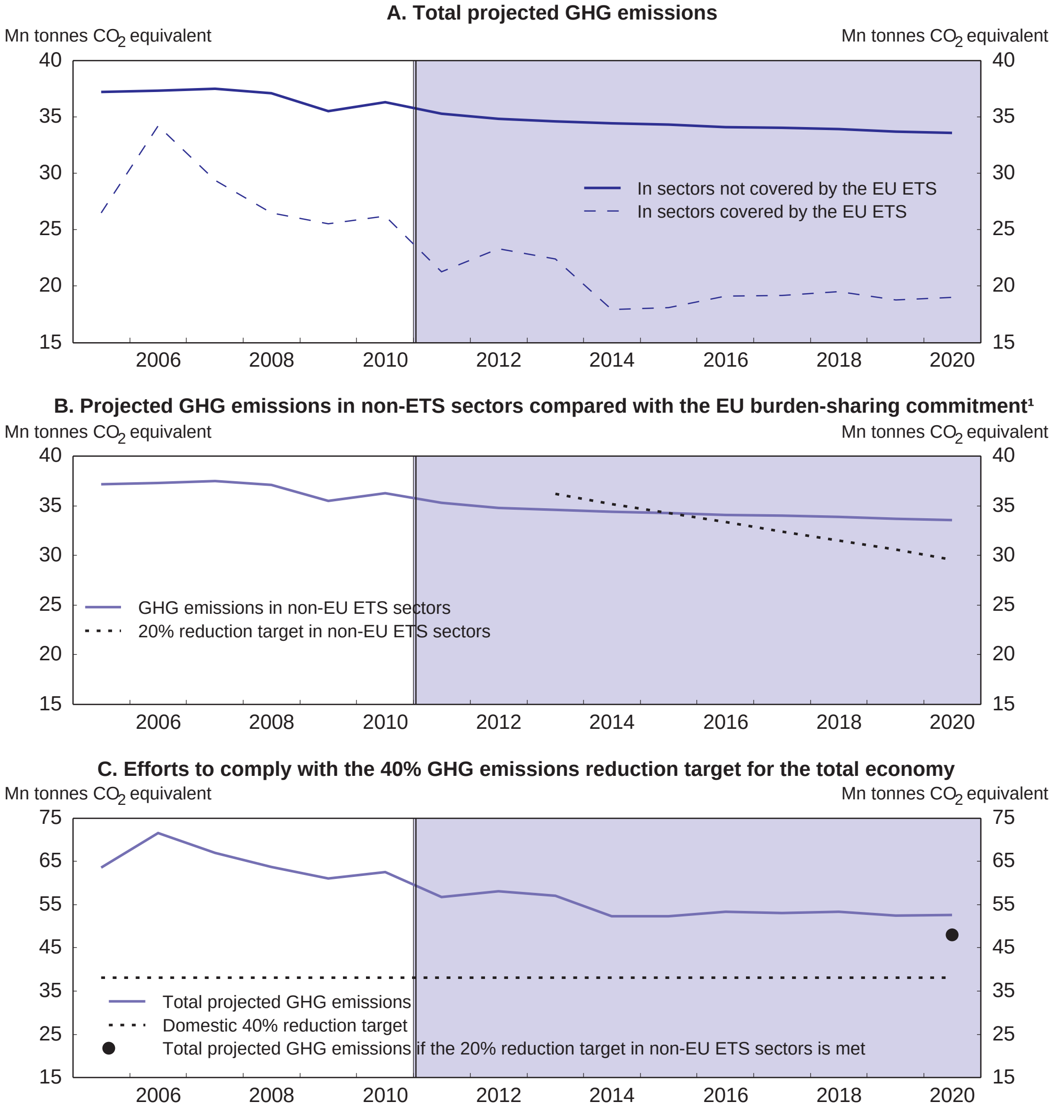
Efforts required to comply with targets

The Danish Energy Agency has carried out projections through 2025 that give some information on the size of the efforts that will be required to achieve the Kyoto targets and 2020 targets (Danish Energy Agency, 2011). These projections are very sensitive to assumptions regarding policies and future economic growth, fuel prices, technology and the carbon price. Concerning policies, the projection only includes measures already adopted by end-2010, *i.e.* an increase in energy saving as part of the 2008 Energy Agreement, the 2009 tax reform that raised some energy taxes and some measures in the transport sector, and the EU ETS. Projections of fossil fuel and EU ETS allowances are based on the IEA's *World Energy Outlook* 2010 and growth projections are from the Ministry of Finance. As illustrated by the large and unexpected fall in energy consumption in 2008-09 due to the recession, such assumptions are fragile.

Bearing that caveat in mind, the projections suggest that Denmark can meet its Kyoto target. The latter caps Danish GHG emissions at an annual 54.8 million tonnes of CO_2eq. on average during 2008-12, as against a recorded 62.1 million in 2008-09. The gap between the two would be filled through the use of credits from forest carbon sinks and flexible mechanisms (CDM and JI) combined with a continued decline of GHG emissions in non EU ETS sectors that can however be difficult to achieve if the economy grows faster than expected.

The 2020 GHG emission targets are very ambitious (a 20% cut relative to 2005 levels in non-EU ETS sectors and a 40% cut relative to 1990 levels in all sectors) and would require significant new measures unless they are achieved by financing GHG emission cuts outside Denmark. Up to now, GHG emissions have been mainly reduced in sectors covered by the EU ETS while they have barely declined in sectors outside the EU ETS (Figure 6, Panel A). This partly reflects difficulties to cut GHG emissions in the transport sector. The Danish Energy Agency projections show that emissions in non-EU ETS sectors would exceed the level implied by the 20% reduction target significantly (Figure 6, Panel B). The newly-introduced 40% reduction target covering all sectors introduces even stronger constraints. Indeed, under the Danish Energy Agency scenario, even if the 2020 20% reduction target in non-EU ETS sectors were achieved, GHG emissions in all sectors would be 10% above the level implied by the 40% reduction target (Figure 6, Panel C).

Figure 6. Projected greenhouse gas emissions compared to targets under an unchanged policy scenario[1]



1. The projection includes the effects of measures already adopted, *i.e.* the 2008 Energy Agreement, the 2009 tax reform and the review of the latter in 2010, and the EU ETS.

Source: Danish Energy Outlook (2011).

Reaching targets for the development of renewable energy will also be challenging. In the Danish Energy Agency scenario, the share of renewables in total energy consumption would reach 28%, just below the 30% target to which Denmark has committed itself at the EU level. The corresponding share for the transport sector would be only 6%, well below the 10% EU target. In 2009, around 19% of domestic electricity came from wind power. Under the Danish Energy Agency scenario, the share of electricity from wind would rise slightly above 30% by 2020, hence also well below the new target to have 50% of electricity coming from wind by 2020. This scenario assumes an expansion of offshore wind turbines as already contracted and the replacement of onshore wind turbines by more efficient ones. The expansion of onshore wind turbines is uncertain as capacity constraints are already almost fully exploited. Hence, it is very likely that the capacity will have to be mainly extended offshore to meet the 50% target, which is likely to remain more costly than onshore technologies for quite some time (Table 3).

Table 3. Cost projections for renewable electricity generation

	Investment cost USD/kW		Operation and maintenance cost USD/kW/yr	
	2010	**2050**	**2010**	**2050**
Biomass steam turbine	2 500	1 950	111	90
Geothermal	2 400-5 500	2 150-3 600	220	136
Large Hydro	2 000	2 000	40	40
Small hydro	3 000	3 000	60	60
Solar PV	3 500-5 600	1 000-1 600	50	13
Solar CSP	4 500-7 000	1 950-3 000	30	15
Ocean	3 000-5 000	2 000-2 450	120	66
Wind onshore	1 450-2 200	1 200-1 600	51	39
Wind offshore	3 000-3 700	2 100-2 600	96	68

Note: Estimates of costs and efficiencies in 2050 are inevitably subject to great uncertainty. These data refer to plants in the US.

Source: IEA (2010), Energy Technology Perspectives.

On the whole, although government projections suggest that Denmark is on course to meet its commitments, additional efforts are required to ensure their fulfilment. One of the major challenges will be to bring down emissions in the non-ETS sectors, more than 70% of which are accounted for by emissions from agriculture and transport. Marginal abatement costs are expected to be high in a number of activities outside the EU ETS (Ministry of Climate and Energy, 2009). Another challenge will be to expand wind power capacity at least cost.

There are some risks for a small country to adopt very ambitious targets, mainly in terms of overall cost (Box 2). The bulk of the GHG emission cuts could be achieved at a lower cost by financing emissions reductions outside Denmark. There are also potential gains from having ambitious targets as green growth may create new opportunities and could help boost potential growth in Denmark. However, identifying these new growth opportunities *ex ante* is difficult and depends *inter alia* on the choices other countries will make.

Box 2. The pros and cons of ambitious domestic energy and climate targets

There are pros and cons for adopting stringent targets. The advantages include the following:

- The announcements by successive governments regarding energy and climate change mitigation targets demonstrate their strong commitment to act, and send credible signals that fossil fuel and GHG emissions will be taxed in the future. This removes part of the uncertainty surrounding the international framework and hence encourages investment. So does having targets extending beyond the EU horizon.
- At the international level, strong actions by some countries, even if they contribute only modestly to world GHG emissions, may reinforce the credibility of mitigation policies and encourage others to act likewise.
- Greening growth will require expanding some of the existing technologies and finding new ones. There is also growing demand from consumers and investors for more environmentally-friendly products. Hence, there are opportunities for new markets and industries and some potential gains for being a leader in this area (OECD, 2011a). Such a strategy would also attract skilled workers. Being a leader in the area of "clean" technologies may boost productivity growth, which has been weak in Denmark over the past 15 years.

The main drawbacks of adopting ambitious energy and climate targets pertain to their potential costs:

- In a small country that has already cut its GHG emissions significantly, low-cost abatement opportunities are expected to be rare and overall marginal abatement costs to be high. Hence, reaching ambitious targets can be very costly. As climate is a global good, where GHG emissions are cut does not affect the overall outcome, hence, GHG emissions should be reduced where it is cheapest.
- The irreversibility of the Danish strategy is also part of the cost (IEA, 2007a). There is a strong irreversibility associated with the wind technology as the turbine cost typically represent about 75% of the total cost, with infrastructure, grid connection and foundations accounting for the rest. Furthermore, as the best spots have been sought out first, they tend to be occupied by rather old and inefficient technologies that need to be replaced, generating some additional dismantling costs. If new less costly technologies appear or if some existing technologies become less costly, these investments would be lost. For instance, the full availability of the carbon capture and storage technology at a competitive price would make the target to move away from fossil fuel much less relevant.
- Having a large share of electricity coming from wind generates costs beyond investment and maintenance. One particular issue concerning wind technology is that output varies with wind and hence, wind plants do not operate at full power all the time. Higher penetration of this technology requires increasing the flexibility of wind power systems with smart grids, including interconnection and storage. Similarly, the penetration of electric cars would require the development of public and private recharging infrastructure.
- Furthermore, ambitious domestic policies to reduce emissions in sectors already covered by the EU ETS will not lead to lower GHG emissions at the EU level as long as the EU cap is fixed (see below).

Proposed policies towards a future without fossil fuels

The new government has confirmed the long-term vision of relieving Denmark completely of its dependence on fossil fuels, indicating how this target will be achieved in *Our Future Energy* (Danish Government, 2011a). This document follows up on the *Energy Strategy 2050* developed by the previous government (Danish Government, 2011b), which built on the analysis of the Commission on Climate Change Policy discussing out how to achieve independence from fossil fuels . The challenge is a formidable one, as 80% of primary energy consumption now comes from fossil fuels. The definition of independence used by the Commission is that "no fossil energy is used/consumed in Denmark, and the average annual domestic production of electricity based on renewables must at least equal Danish consumption" (Danish Commission on Climate Change Policy, 2010). Under this definition, Denmark can continue to trade electricity with countries where it is based on fossil fuels provided this is offset by exports of renewable energy, but cannot continue to consume oil in the transport sector and to compensate for this by exporting electricity based on renewables. The definition of independence used in *Our Future Energy* is that the energy and transport network should rely solely on renewables. This definition is more ambitious than the one used by the Commission on Climate Change Policy.

The Commission offered 40 specific recommendations, involving a massive conversion to electricity from offshore wind turbines, complemented by biomass as a backup for wind turbines as well as for part of the transport sector that can hardly rely on electricity. Nuclear power was rejected by the Danish Parliament in 1985 and is not considered as a cost-effective option for this transition. In terms of market-based instruments, the Commission recommended to have an energy tax (expressed in DKK per energy unit) applied uniformly to all fossil fuel uses and gradually increasing over time. It also recommended equalising the domestic carbon tax to the carbon price on the EU ETS market so as to approximate a cost-effective allocation of emission abatements across ETS and non ETS sectors.

The Commission concluded that the aggregate economic cost of achieving full fossil fuel independence is very low – only a 0.5% of GDP by 2050, with GDP projected to more than double over that period. This stems from a number of factors including that: *i)* fossil fuel prices are projected to increase substantially in the business-as-usual scenario, which makes the reduction of their use profitable in any event; *ii)* the conversion of the energy system is gradual and takes place over a long horizon; and *iii)* reducing fossil fuel use would cut GHG emissions and hence, limit the number of allowances to be bought by Denmark. However, the Commission recognises that many uncertainties surround these estimates.

The conversion of the Danish energy system, as proposed in *Our Future Energy* (and in line with *Energy Strategy 2050*), is meant to follow the process proposed by the Commission. This would involve:

- Far-reaching improvements in energy efficiency, notably via the replacement of combustion by electric motors.

- Almost complete electrification of the energy system (heating, industry and transport).

- Increasing the share of wind power electricity, first by replacing existing onshore wind turbines, then by expanding offshore ones; increasing utilisation of biomass for combined heat and power plants and of biofuels for very energy-intensive transport modes such as aircraft or heavy lorries.

- Developing electricity storage and integrating the Danish electricity grid more into the European grid to address the volatility of electricity coming from wind power.

To this end, the main proposed measures are:

- Greater support for renewables but structured differently (*inter alia*, by removing existing subsidies on onshore wind turbines and introducing new subsidies for biogas); calls for tender for expanding the capacity of offshore wind turbines; price deregulation for heating.

- Removal of the restrictions that hinder increased use of energy based on biomass.

- Additional standards to raise the energy efficiency of consumption and buildings. For instance, it is proposed to expand saving obligations to all companies while targeting them to building renovation and conversion, coupled with a tightening of energy standards for buildings.

- Increasing the electricity price paid by consumers. The expansion of renewables up to 2020 will be financed through the "public service obligation". In addition, a new public service obligation will be introduced for gas consumers in order to finance the cost of converting the grid from natural gas to biogas.

- The introduction of a new "security-of-supply" tax on all fuels for space heating (coal, oil, gas and biomass), in order to provide an incentive for additional energy efficiency improvements and to provide revenues to the government (see below).

- At an international level, actions to promote the phasing-out of fossil-fuel subsidies, at the EU level, pushing the EU to raise the 2020 reduction target from 20% to 30% (compared with 1990 levels).

- As these new taxes and subsidies will increase the complexity of the Danish energy tax system, a re-examination of the current system of energy taxes and subsidies is proposed.

The transition to fossil fuel independence is thus meant to be primarily financed by energy consumers, with tax revenue losses resulting from lower fossil fuel consumption being compensated by the introduction of a new security-of-supply tax on all fuels for space heating.

According to the government's estimates, measures proposed in *Our Future Energy* would ensure that the target to have 50% of electricity consumption supplied by wind in 2020 will be met and would put Denmark on track with other energy sub-targets for 2030-35. These measures would lead to a cut by 35% of GHG emissions in 2020 relative to 1990 levels and a cut by 16% relative to 2005 levels in non-ETS sectors. Hence, the measures proposed in *Our Future Energy* are not sufficient to achieve both the national and EU climate targets by 2020. The government has announced that a climate plan will be presented in 2012 to ensure the achievement of both sets of targets.

To what extent would fossil fuel independence enhance energy security?

Energy security may be defined as a low risk of disruption to energy supply, both in terms of quantity and price (Bohi and Toman, 1996).[4] Physical shortage of oil is likely to be short-lived as international prices adjust, given the fact that oil markets are fairly integrated and governments have built strategic stocks. However, natural gas shortages may last longer due to market segmentation and the relative inflexibility of gas-pipeline infrastructure. The coal market is also fragmented. Price instability remains a concern over the longer term insofar as the supply of fossil fuels becomes less and less elastic and concentrated into the hands of a small number of producing countries, hence raising the risk of large unexpected price shifts as a result, in particular, of political instability. While Denmark is among the countries that use energy most efficiently, energy security is an important issue as the share of oil and natural gas in total Danish energy consumption is large (Figure 3) and as Danish oil and gas resources in the North Sea approach exhaustion.

Policies to limit fossil fuel use and GHG mitigation policies are expected to improve long-term energy security: *i)* by reducing the energy and fossil fuel intensity in fossil fuel importing economies, hence lowering the macroeconomic cost of any future price shocks; and, *ii)* by diversifying the energy mix, hence reducing energy risk (OECD, 2009a). The latter might be partly offset, however, by additional energy-supply risk specific to some renewable, such as for instance biomass whose supply might be limited in the future at the world level, competing with the supply of food and possibly concentrated into relatively few

4. The various channels through which oil price shocks affect economies are discussed in Wurzel *et al.* (2009).

countries with high agricultural potential. Accordingly, *Our Future Energy* considers restoring the balance between fossil fuels and biomass uses by removing the current tax exemption on biomass. Policies to limit fossil fuel use will also slow the pace of depletion of oil reserves and curb the projected significant rise in the market share of the Organisation of the Petroleum Exporting Countries (OPEC) for the next three decades. The ultimate impact on energy security would however depend on OPEC's response in terms of prices and quantities.

Raising the efficiency of Danish climate and energy policies and minimising their costs

Taking better account of interactions with EU policies

The EU ETS leads to a carbon price in sectors that are covered, promoting cost-effective CO_2 abatement options. It allows emissions to be cut in countries where it is the cheapest: countries with low abatement costs reduce their emissions while those with higher abatement costs can buy permits. In addition to the EU ETS carbon price, there are several other national policies in ETS sectors that are unlikely to bring short-term global environmental benefits, due to spillover effects across EU countries. Permits not bought by Danish ETS sectors will be available for use in other EU countries. Thus, as long as the cap on emissions remains unchanged at the EU level, abatement achieved through additional overlapping instruments in one country is offset by higher emissions in other EU countries. In particular, this is the case of policies to support wind technology as the electricity sector is covered by the EU ETS. These policies have helped to cut Denmark's emissions in the EU ETS sectors (Figure 6, Panel A) but have freed room under the EU cap for increases elsewhere in the EU.

Over the longer term, however, the EU-wide cap on CO_2 emissions will be renegotiated and Denmark will be in a position to push for a more stringent one, on the grounds of its domestic efforts to reduce CO_2 emissions and of the spillovers. Countries pursuing a similar approach might push in the same direction, although others may resist. Currently, the ambition of the new government is to push for a binding EU-wide reduction target of 30% in 2020 relative to 1990. Another argument in favour of national policies on top of EU ones is that they may boost the credibility of the long-term carbon price, spurring investments in abatement technologies.

In the same vein, emission reductions achieved through the domestic carbon tax in sectors within the EU ETS will also be offset by higher emissions in other EU countries. Therefore, activities that face the EU carbon price should be exempted from the domestic carbon tax. The carbon tax is currently applied to fuels used for heat generation by combined heat-and-power plants and large district heating plants on top of the EU carbon price,[5] implying CO_2 emission cuts exceeding what is cost effective. Moreover, this double taxation makes energy from these plants more costly and hence moves energy consumption from the ETS to the non-ETS sector where coal is used, leading to more GHG emissions (Danish Economic Council, 2011). Exempting heat-and-power plants from the carbon tax while increasing taxes on coal, oil, and gas would reduce emissions in non-ETS sectors.

5. As a market-oriented activity, the increase in the carbon price resulting from the introduction of the EU ETS was passed on to electricity consumers, in addition to the Danish carbon tax. In contrast, district heating produced by combined heat and power plants is a non-profit activity where the allocation of free quotas would have resulted into a reduction in price, hence the decision to maintain the carbon tax on this sector.

It might be argued that policies to develop electricity from renewables bolster energy security in EU countries. While under such policies less fossil fuel energy would be used in Denmark, this would lead to higher CO_2 emissions in other EU countries from some other sources covered by the trading scheme. As these CO_2 emission increases imply greater use of fossil fuels among these other sources, recourse to fossil fuels, and hence energy security would be left unchanged at the EU level (Braathen, 2011).

Exploiting the opportunities to raise growth potential through green technologies

Denmark has managed to be at the frontier in the area of renewable energy technologies, notably with respect to wind, and in technologies to increase energy efficiency in the residential sector (Figure 7). This is the effect of aggressive policies in these sectors. These policies have been successful partly because they came at a time when the global demand for these technologies was rising in the absence of alternative cheaper ones. However, targeting a small range of technologies entails risks, the main one being that a new more cost-effective technology emerges. Another risk is that a different country becomes the leader and manages to exclude most competitors, all the more so as some countries support these technologies more than Denmark does. Hence, it is important to have policies that promote new green growth opportunities while limiting these risks.

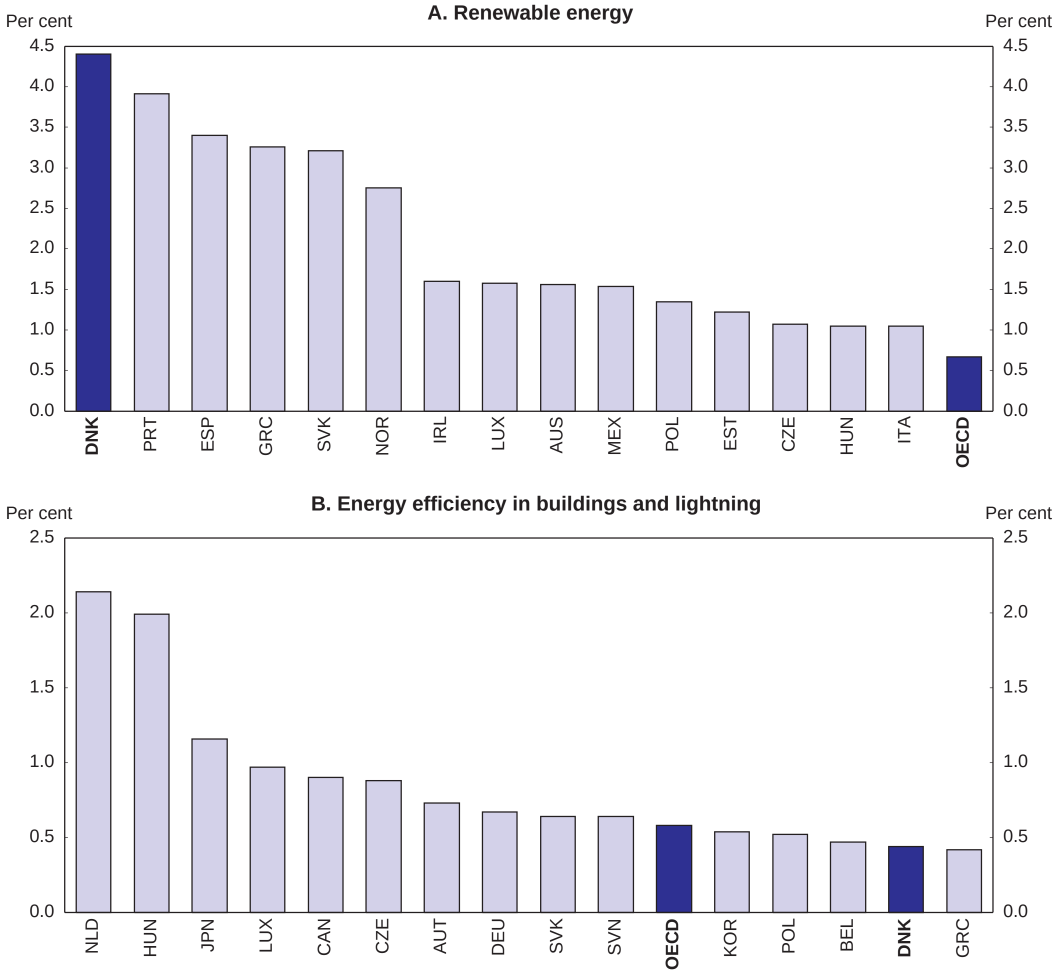
Government action is essential to foster green innovation. This is because there are several well-known market failures, the main one being that if firms and households do not have to pay for the environmental damage they inflict, there will be little incentive to invest in green innovation. Boosting green innovation requires clear and stable market signals that are well established in Denmark. However, price instruments will not be enough to deliver the necessary public investment in basic, long-term research. Recent OECD analysis shows that public research will need to cover many areas, and should increasingly be based on multi-disciplinary and interdisciplinary approaches (OECD, 2011b). It should also be neutral with respect to specific technologies, as innovations may emerge from a wide range of fields. Finally, the overall financing framework should be credible and stable to foster investment in new technologies.

The Danish government has spent more and more on energy research in recent years. This was primarily to foster the market maturation of already existing technologies, although the Energy Technology Development and Demonstration Programme supports the development of new technologies. Funding to support more basic energy research performed by universities and other research institutions did not increase. By contrast, the share of public R&D funds for environmental non-energy related research has gradually been reduced since the mid-1990s. Empirical analysis based on 2000-07 Danish firm-level data concluded that there was no economic justification for targeting government R&D expenditures on energy research performed in private firms as opposed to other environmentally-related research (Danish Economic Council, 2011). Therefore, R&D policies should leave some flexibility as regards the choice of specific technology, be harmonised across technologies and re-assessed in light of the precise market failure they try to address.

A feed-in tariff system is also in place, and it is the main policy to support electricity from renewables, with tariffs being larger for wind than for other renewable energy technologies. This system provides large subsidies to these technologies as offshore wind technologies remain very expensive compared to other options (IEA, 2010). Feed-in tariffs, as opposed to electricity certificates, allow adjusting the size of the subsidy to the technology, which can be justified by differences in cost structures and maturity of technologies. For this reason, feed-in tariffs are found to encourage innovations that are further from the market than electricity certificates (Johnstone *et al.*, 2010). However, experience has shown that once granted, support in the form of subsidies can be very difficult to withdraw even when the initial justification no longer applies and rents tend to be captured by specific industries (de Serres *et al.*, 2011). The lobbying power of these industries can be large when the national strategy is built on them. To limit this risk and to ensure that least cost options are developed, differences in subsidy between technologies should be justified by differences in cost structures and maturity of technologies. In

Figure 7. Denmark has largely contributed to the development of renewable energy technologies[1]

As a per cent of total Patent Cooperation Treaty patent applications, 2003-08



1. The figure shows the first 15 best-performing OECD countries.

Source: OECD (2011), Towards Green Growth – Monitoring Progress.

the absence of such justification, subsidies should be made more uniform across technologies. This is the case in Estonia, for instance, while in most other countries, the level of support in feed-in tariffs depends on the technology. The new government has proposed a reduction in the subsidies to future land-based windmills as their cost is expected to fall further, but subsidies to off-shore windmills will be increased. It also plans to review the energy tax and subsidy systems to raise incentives to switch from fossil fuels to electricity in non-EU-ETS sectors. The race between EU countries in terms of support to technologies through their feed-in tariffs illustrates the need for an EU policy to support renewables. A common strategy to support renewables with a view to minimise costs and risks and to limit the race between EU countries in terms of support to these technologies would help achieve the renewable target in a cost-effective manner (OECD, 2009c). However, support would have to be restricted to technologies that require it in addition to that provided by the EU ETS carbon price.

Reducing GHG emissions in sectors not covered by the EU ETS at least cost

Sectors not covered by the ETS are subject to a specific domestic target – a cut in GHG emissions by 20% in 2020 relative to 2005. As GHG emissions in these sectors are by definition not covered by a cap, any additional emission cuts in these sectors would lead to additional cuts at EU level. However, it is likely to be difficult and costly to reduce these emissions and indeed, they have barely declined in the past (see Figure 6, Panel A).

GHG emission and fossil fuel use in these sectors depend on energy and carbon taxes. These taxes tend to be high in Denmark (Table 4). They translate into an implicit tax rate per tonne of CO_2 emitted for each fuel (Figure 8). In Denmark as in other countries, there is some heterogeneity in these carbon prices while a cost-effective approach to reduce GHG emissions would require a uniform carbon price across sources.

Table 4. Carbon and total taxes on energy products in selected OECD countries

Euros, 2010

	Denmark	Finland	Iceland	Ireland	Norway	Sweden	United Kingdom
Only "carbon tax", per tonne of CO_2	~20	~30 - 50	~13	~ 15	~10 - 40	~100	~5 - 30
Heating oil, domestic use, per litre	0.33	0.087	0.02	0.04	0.17	0.41	0.0
Coal, per tonne	270.80	50.5	0.0	4.18	0.0	278.2	14.4
Natural gas, per m³	0.35	0.02	0.0	0.03	0.01	0.24	0.02
Natural gas, per MWh	31.90	2.1	0.0	2.8	0.5	21.4	1.8
Petrol, per litre	0.57	0.63	0.36	0.54	0.62	0.52	0.63
Diesel, per litre	0.43	0.36	0.32	0.45	0.47	0.41	0.63

Note: The comparison should be used with caution, see the source for more details. Whereas the first row only reflects the so-called carbon taxes, the rows below include all excise taxes levied on the energy products listed.

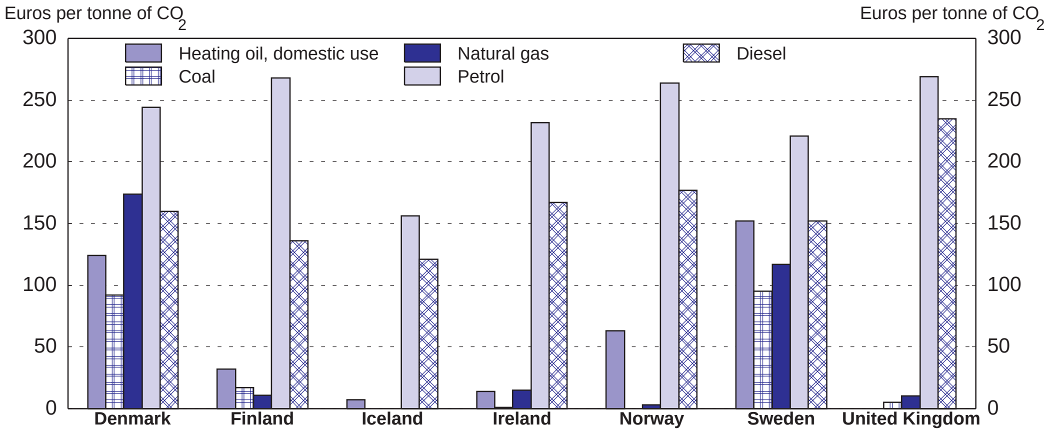
Source: Braathen, 2011.

The residential sector is an area where more emission cuts are likely to be achievable at a moderate cost (Danish Commission on Climate Change Policy, 2010). Buildings account for 40% of energy consumption in Denmark. Information problems in the residential sector lead to situations where poorly informed households and firms may act inefficiently even in the face of market incentives. For instance, landlords have better information than tenants but have little incentive to install the most energy-efficient equipment as they do not pay the energy bill (OECD, 2009a; IEA, 2007b). Well designed regulations can address these problems. Denmark has introduced a series of regulations to increase energy savings in buildings. They include stringent building codes for new buildings and regulations on energy labeling of buildings and on inspection of heating installations. There is also some support to the installation of heat pumps in areas situated outside the collective supply grid.

The Danish Commission on Climate Change Policy has concluded that, for new buildings, there is no need for further requirements beyond the already stringent existing ones. The main issues would be to implement these regulations and to monitor compliance. As there are greater opportunities to cut energy consumption in existing buildings and to exploit them at lower cost, greater incentives should be given to implement energy improvements in connection with renovation and replacement carried out for other reasons. Energy taxes contribute to these incentives as fossil fuels are still largely used for heating.

Figure 8. Implicit tax rates per tonne of CO_2 emitted in a selected number of OECD countries

Euros per tonne of CO_2, 2010



Source: Braathen, 2011.

Emissions from transport account for a very large part of non-ETS emissions and these have increased steadily. The transport sector is currently largely dependent on fossil fuels and there are no alternatives to fossil fuels that are competitive in terms of technology and price. Hence reducing GHG emissions in this sector and making it "independent from fossil fuel" is the greatest challenge among Denmark's ambitions.

Shifting from road to alternative means of transportation is one way to limit emissions. However, the Danish Commission on Climate Change Policy has concluded, based on background studies to its report, that even a doubling in public passenger transport (trains and buses) will reduce car numbers by only around 15%, which will be more than offset by the expected growth in car numbers over the next ten years. Another option to limit the use of cars is road pricing, which is not used in Denmark apart from some bridges. The new government tabled a congestion charge for Copenhagen in the Budget Bill for 2012 but the proposal has been withdrawn (see below and Box 3).

Taxes on fossil fuels provide some incentives to reduce the use of cars. In Denmark as in many other countries, diesel is taxed less than petrol (Figure 9). As the carbon content is higher for diesel than petrol, the implicit carbon price on emissions from diesel is significantly below the one on petrol. Hence, there is room to raise taxes on diesel, although this may lead to more cross-border trade. In the transport sector, there exists, on top of the carbon tax and energy taxes, some taxes on motor vehicles to be paid regularly and a one-off motor vehicle tax for new cars. These taxes depend on the fuel efficiency of the vehicle, but on the whole, they are high in Denmark, thus providing incentives to reduce the use of cars (Braathen, 2011). The motor vehicle registration tax is particularly stiff, with a basic rate of 105% on the value of the car below €10 000 and 180% above this threshold, except for electric cars, which are exempted. This tax provides a one-off incentive to purchase a less emitting car but no incentive for further abatement after the purchase (OECD, 2010a). Furthermore, the high level of the tax may discourage purchases, implying that older and less efficient cars are used. As emissions vary with motor vehicle use, it would be more cost-effective to tax motor vehicles less and fuels more as long as this adjustment does not lead to a large increase in border trade.

Box 3. Copenhagen, a green haven?

While cities account for a large share of GHG emissions because they also represent a large share of GDP and population, they are not always the most important polluters when emissions per capita are considered (Hoornweg *et al*., 2011). Copenhagen stands out as an example in this respect: in 2005, CO_2 emissions per capita in the municipality of Copenhagen were about half the average country rate. This pattern reflects cities' potential to reduce GHG emissions per capita. For instance, higher population density makes public transport more attractive, limiting the use of cars, and makes it easier and less costly to develop district heating systems (OECD, 2011c). In contrast, some GHG emissions from agriculture are difficult to reduce, explaining relatively large emissions per capita in rural areas. Suburbanisation can also contribute strongly to GHG emissions.

Copenhagen is already a low CO_2 emitting city but plans to do even more and to become the first carbon-neutral capital by 2025. Meanwhile, the city targets to cut CO_2 emissions by 20% between 2005 and 2015. Copenhagen's strategy rests on plans and policies very similar to national ones but also includes some more ambitious ones:

- 75% of the emission cut would be achieved in the energy sector by moving it away from fossil fuels. Today, most homes in Copenhagen are connected to a district heating system based on combined heat and power plants and incineration of waste, which has allowed reducing CO_2 emissions significantly but remains largely dependent on fossil fuels. Further emissions cuts would require increasing the share of renewables in electricity generation. In particular, the municipality plans to develop cogeneration from wind and biomass.
- The transport sector would account for 10% of the cut. This will be achieved by favouring walking and bicycling even more. In 2010, already 35% of all trips to work or for education in the city of Copenhagen were made by bicycle with this share rising to 50% of trips for people working and living in Copenhagen. The municipality also plans to improve the quality of public transport and to promote car-sharing. Stringent performance standards concerning CO_2 emissions from buses are being gradually introduced and the city is experimenting electric buses and municipal cars. Parking places are limited.
- 10% of the cut would also be achieved in buildings with particular efforts to increase energy efficiency in municipal buildings.
- The remaining 5% of the cut is expected to be achieved through changes in household and firm behaviour encouraged by information and education campaigns and through urban development.

By continuing on this path, the municipality expects to reduce CO_2 emissions by 45% between 2005 and 2025. Complete carbon neutrality would be achieved by investing in more windmills or by reforestation to capture more CO_2.

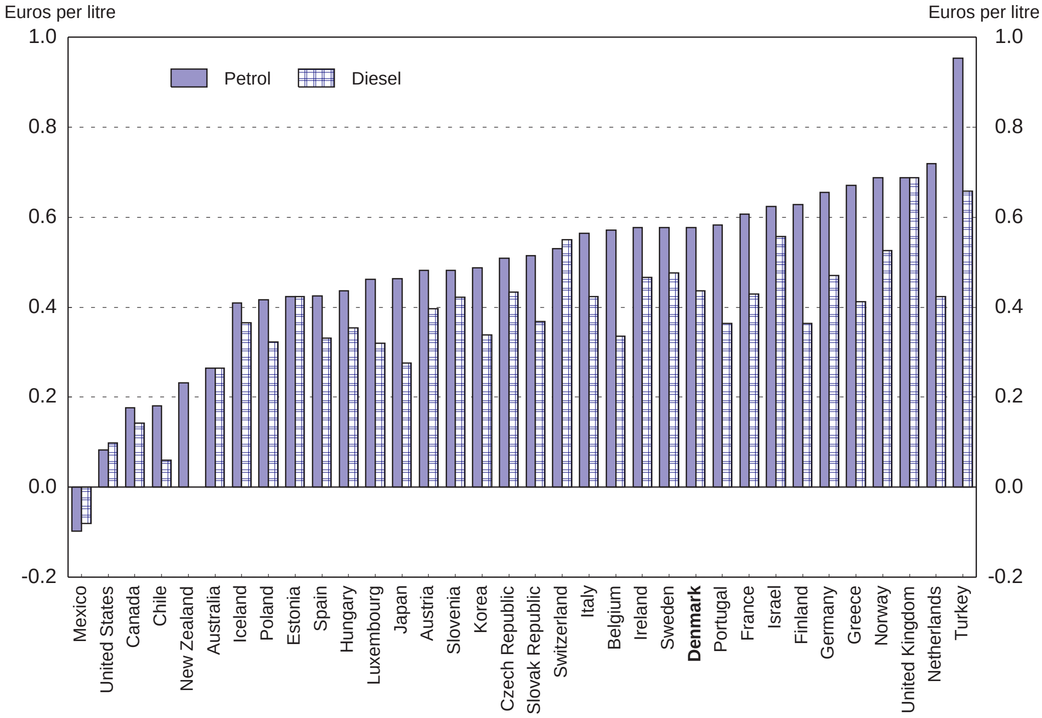
While cities have a key role to play in actions to mitigate climate change, they also need to adapt to the impacts of climate change. As a low-lying city, Copenhagen is potentially exposed to coastal flooding that will increase with climate change. The city has already undertaken a number of actions to adapt to these effects of climate change and has developed an "adaptation plan". OECD estimates suggest that, partly thanks to these actions, the city is not particularly vulnerable to sea level events (Hallegatte *et al*., 2008).

Despite these impressive achievements and objectives, Copenhagen's air quality is not among the best in selected OECD cities. Emissions of particulate matter, which have been shown to have large detrimental effects on health, were still relatively high in 2008 despite past reductions. This partly comes from pollution from diesel cars, wood stoves and other materials (OECD, 2009b). These emissions may have fallen further in the recent past with the introduction of "low emission zones"[1] and policies to limit CO_2 emissions will lead to less emissions of particular matter as a co-benefit (Bollen *et al*., 2009). Nevertheless further efforts may be required in this area.

1. Since 2006, the four largest cities in Denmark are allowed to introduce low-emission zones in which heavy vehicles have to meet some standards in terms of emissions of particulate matter.

Figure 9. Energy taxes on oil and diesel

Euros per litre, 2011

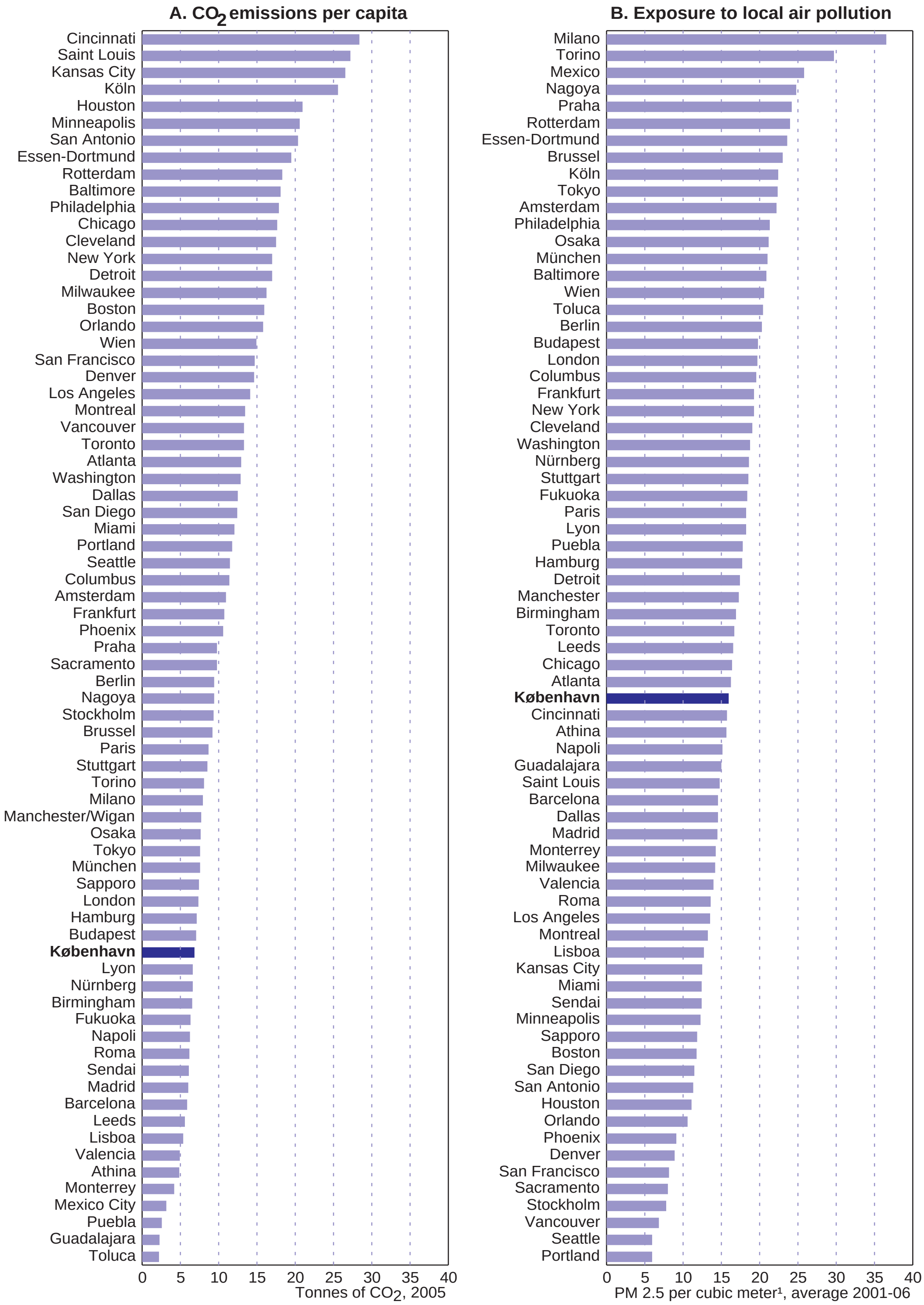


Source: OECD-EEA database on instruments used for environmental policy.

The development of electric car technologies is being supported through tax relief measures and subsidisation of a "test scheme". Further policies to encourage the development of electric vehicles are likely to be very costly. However, it could be argued that they could be efficient since emissions from petrol and diesel would be replaced by emissions from electricity that are capped under the EU ETS, thereby leading to an overall emission reduction.

As a large share of Denmark's expenditure is decentralised, policies at the local level to reduce GHG emissions have a key role to play. Copenhagen city aims to become carbon neutral by 2025 and has adopted a number of policies to meet this goal (Box 3). The city has already relatively low CO_2 emissions per capita (Figure 10, Panel A). Policies to further reduce these emissions in sectors not covered by the EU ETS such as the residential and transport sectors are particularly important as they will contribute to EU-wide emission cuts. Policies to reduce CO_2 emissions in the transport sector will also help lowering local air pollutant emissions, which are still relatively high (Figure 10, Panel B). The new government was planning to introduce a congestion tax, as in London and Stockholm for instance, to reduce congestion and local air pollution, but finally withdrew the proposal because of lack of support from the coalition. The effect of this type of tax on GHG and local air pollutant emissions depends on the design of the scheme. A toll ring, which was under discussion for Copenhagen, may have only limited impact as it would lead to some additional traffic to circumvent the payment zone. A system such as the one envisaged at some point in the Netherlands – which was to be GPS-based, to include both a per-kilometre price and a peak surcharge and to cover all roads – would likely cut pollutant emissions more (OECD, 2010b). Furthermore, experience from other countries shows that for this tax to bring some net benefits, road congestion needs to be severe and congestion in public transportation should be low (OECD, 2011a). While road congestion may be lower in Copenhagen than in several other large cities, it has increased substantially in recent years.

Figure 10. GHG and local air pollutant emissions in large metropolitan areas



1. Particulate matter (PM) 2.5 per cubic metric weighted by population, average over 2001-06.

Source: OECD, "Measuring the Environmental Performance of Metropolitan Areas with Geographic Information Sources", GOV/TDPC/TI(2011)5.

Reducing GHG emissions from agriculture

Agriculture accounts for approximately one-third of GHG emissions from non-ETS sectors. Non-CO_2 emissions from agriculture are not subject to any specific GHG taxation, but they have fallen significantly in recent years, partly because of limits on nitrogen emissions in a succession of action plans for the aquatic environment (Box 4).

Box 4. Aquatic environment policies in Denmark and their co-benefits in terms of GHG emission reductions from agriculture

Denmark is one of the EU countries with the largest proportion of agricultural land. In the past, too much of the low-lying land was converted into farm land subject to intensive cultivation. Excessive use of fertilisers has resulted into discharges of nitrogen and phosphorus in coastal waters and lakes, together with large emissions of nitrous oxide, which is a greenhouse gas. Since the late 1980s, policies have been implemented to reduce these discharges but also to improve the quality of underground water so that the concentration of nitrates in public water supply does not exceed safety limits. These policies have more than halved run-offs from agriculture but at a considerable cost (OECD, 2007b).

The first two plans to reduce water pollution from agriculture were launched in 1987 and 1991, with the second one setting fertiliser norms for each farm and taxing any surplus use (OECD, 2003). The Action Plan for the Aquatic Environment II was launched in 1998 with the aim of reducing nitrogen leaching by a further 37 000 tonnes by 2003, bringing the total reduction relative to the mid-1980s to close 50%. This Plan included area-related measures – subsidies to convert agricultural land into wetlands, forestry, grassland, organic farming or land set aside – and farm-related measures – including changes in feeding, reduction of the livestock density, reduction in nitrogen norms and better utilisation of nitrogen in animal manure. The cost of these measures averaged €2 per kg of nitrogen with large differences across measures suggesting that the reduction in nitrogen leaching could have been achieved at a lower cost. The cheaper measures included conversion to wetland, changes in feeding and better utilisation of nitrogen in manure management.

The Action Plan for the Aquatic Environment III launched in 2005 was closely related to the EU Water Framework Directive and set a number of objectives to be met by 2015, including:

- Halving agricultural excess phosphorus by 50% through a tax of DKK 4 per kg of mineral phosphorus and an improvement of phosphorus use based on new research.
- Reducing phosphorus discharge by creating 50 000 hectares of crop-free buffer zones along lakes and rivers that will retain phosphorus from other areas. Voluntary transfers of set-aside land together with an additional subsidy would contribute to creating these buffers. A new tax will be introduced on freshwater fish farming as it constitutes a significant source of phosphorus discharge.
- Further reducing nitrogen leaching by at least 13%, through setting aside land, better feed utilisation, implementation of the new EU agricultural reform as well as other specific measures (for instance, tightening of regulations regarding late crops, utilisation of nitrogen in livestock manure, and further conversion into wetlands).
- Reducing ammonia volatilisation from agriculture through optimisation of manure handling, a ban on surface spreading of manure and a ban on extension of livestock farms if such an extension would lead to increased ammonia discharges in natural areas vulnerable to ammonia.

In 2009, the previous government signed an Agreement on Green Growth with the Danish People’s Party that would enable Denmark to meet its obligations under the EU Water Framework Directive and the Natura 2000 Directives and facilitate the follow-up of the Action Plan for the Aquatic Environment III. As for the reduction of GHG emissions, the initiatives proposed in the Green Growth Agreement are expected to reduce emissions from agriculture by 800 000 tonnes of CO_2eq. annually. The opportunities for further emission cuts from agriculture using market-based instruments will be analysed in more detail.

Complementarities between aquatic environment and GHG mitigation policies are likely to be important, although their measurement could be improved by further modeling work. Even so, additional specific measures to curtail GHG emissions from agriculture will probably be needed for Denmark to achieve its long-term GHG emission target.

Non-CO_2 emissions from agriculture have already fallen substantially in recent years thanks to water quality policies, and will decline further as a result of complementarities induced by increased energy taxes. In addition, there are economic benefits from introducing prices on non-CO_2 emissions from agriculture, as these would promote cost-effective mitigation while restoring the current imbalance which favours relatively energy-efficient activities that emit a lot of methane and nitrous oxide. These options include reducing intensive cultivation of low-lying agricultural land, which generates large emissions of nitrous oxide, and returning these areas to nature and/or bioenergy cultivation. There are also a number of technologies in the livestock sector for reducing methane and nitrous oxide emissions from management and storage of manure. In addition, as agriculture is subsidised at the EU level, putting a price on these emissions would generate efficiency gains, hence implying both environmental and economic benefits, in addition to other co-benefits arising from lower water pollution.

As agricultural policies are largely set at the EU level, an EU-wide instrument to limit these emissions would be first best. As methane and nitrous oxide emissions from agriculture cannot be measured directly, they need to be estimated for each farm on the basis of types of livestock and quantity of nitrogen input used, which might create problems when incorporating these emissions into the EU ETS. Alternatively, a tax could be applied directly on nitrogen input and livestock in order to reduce registration and control costs (Danish Economic Council, 2011). Denmark could push at the EU level for the adoption of policies that indirectly put a price on these emissions, one imperfect option being to tax agriculture inputs.

Finding the right balance between GHG emission reductions achieved domestically and outside Denmark

Large GHG emission cuts in non-ETS sectors are expected to be difficult to achieve and costly. Model simulations show that the cost of achieving the 20% emission cut in non-EU-ETS sectors would be large if all these cuts were to be achieved domestically (Danish Economic Council, 2011). According to these estimates, assuming that all these cuts are achieved through a uniform carbon price, the price would have to be set at a very high level (of €280 per tonne of CO_2), reflecting the steep marginal abatement cost curve in the non-ETS sectors. These estimates are surrounded by large uncertainties and are highly dependent on assumptions. Nevertheless, they show that, from a cost-effectiveness perspective, most actions in non-ETS sectors should probably take place at a later stage of the transition when all cheaper options in the ETS sectors are exhausted, and that Denmark should achieve part of its target by financing emission reductions abroad by buying international permits.

The level of the domestic carbon tax partly determines the trade-off between abatements achieved domestically and those achieved abroad through the purchase of emission permits. There are a priori two options to set the domestic carbon tax in non-ETS sectors:

- The tax could be set equal to the price of buying foreign emission permits or, currently, to the CDM price. This option would minimise the cost of achieving the climate target but would imply a gap in carbon taxation between ETS and non-ETS sectors as the EU ETS carbon price is likely to be higher than the CDM price, reflecting cheaper abatement opportunities in non-Annex I countries. Furthermore, relying more on abatement abroad may be less environmentally effective given the methodological and practical weaknesses underlying a mechanism like the CDM, notably difficulties in defining an appropriate baseline and additionality problems (Wara and Victor, 2008).

- Alternatively, the carbon tax rate could be set equal to the EU ETS carbon price applying to ETS sectors, as suggested by the Danish Commission on Climate Change Policy. This option would guarantee a cost-effective allocation of abatements across sectors of the Danish economy but would imply that the low-cost mitigation options available through the Kyoto flexible mechanisms are not fully used, thereby raising the cost of reaching the target. Given the large imperfections of mechanisms such as the CDM, this option might be preferable.

Denmark's ability to achieve its most ambitious targets would ultimately depend on technological developments at the international level. It will thus be important to reassess these targets in this light, notably in the transport sector, and to adjust accordingly the share of GHG emission cuts to be achieved by financing GHG emission cuts outside Denmark. Risks concern less mature technologies but also more mature ones. One challenge with the wind technology is to cope with fluctuations in electricity production and demand. This is reflected by the introduction of negative prices in 2009 on the Nordic electricity market to allow producers to pay to deliver power in the market in case of high wind rather than to have to support the imbalance costs (Nordic Energy Regulators, 2011). This option has been used by Danish producers even as their production is highly subsidised. Another issue is to address harmful effects in terms of low-frequency noise, which has caused some backlash in public opinion, especially for onshore wind turbines, while discussions on the offset of CO_2 emission reductions achieved through these technologies at the EU level are gaining prominence in the public debate.[6] Finally, if carbon capture and storage technology were to become available at competitive prices, moving away from fossil fuels would become much less relevant.

Box 5. Climate change and energy policy recommendations

- Regularly reassess national targets in the light of international and technology developments. Adjust accordingly the share of GHG emission cuts to be achieved domestically by financing GHG emission cuts outside Denmark.
- Push for more binding caps in future EU negotiations.
- Ensure that policies towards renewable energy support least-cost abatement options and avoid supporting one technology in particular. Work at the EU level towards the introduction of a common strategy to help meet EU renewable targets at least cost.
- Rationalise the Danish energy tax system to harmonise the implicit carbon price. In particular, raise tax rates on coal and diesel to reduce the gap with the implicit carbon price on petrol.
- At the EU level, push for the adoption of a common policy to limit non-CO_2 emissions from agriculture.

6. See the recent interview of one of the wise men of the Danish Economic Council ("Vismand: Flere danske vindmøller skader klimaet", *Børsen*, 8 November 2011) as well as, "An Ill Wind Blows for Denmark's Green Energy Revolution", *The Telegraph*, 12 September 2010.

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