International Energy Agency

Energy Policies of IEA Countries

Denmark

2011 Review

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Denmark

Denmark is a leader among OECD member countries in terms of its well-designed policies for renewable energy, energy efficiency and climate change. The country is a forthright voice in international fora for climate policy and a strong advocate of tougher climate-change mitigation measures. A long history of consensus-based policy making and political stability has been leveraged to develop Denmark's far-reaching and comprehensive energy policies, and also allowed a clear long-term vision to emerge.

Denmark's long-term energy goal is to become completely independent of fossil fuels use by 2050. In 2011, the government published the Energy Strategy 2050, a detailed and ambitious policy document that sets out a series of new energy-policy initiatives. The strategy aims to transform Denmark into a low-carbon society with a stable and affordable energy supply.

The first phase of the strategy focuses on a series of short-term initiatives that significantly reduce dependence on fossil fuels by strengthening and expanding existing policies in energy efficiency and renewable energy. The second and third phases will involve development and implementation of long-term energy solutions including building a green transport sector and promotion of smart grids.

This review analyses the energy-policy challenges facing Denmark as it develops and implements the ambitious policies outlined in the Energy Strategy 2050, and provides critiques and recommendations for further policy improvements in particular sectors. The intent of the review is to assist Danish policy makers as they move towards a sustainable, low-carbon energy future.

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Belgium
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Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency

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1. EXECUTIVE SUMMARY AND KEY RECOMMENDATIONS

EXECUTIVE SUMMARY

Denmark is a leader among OECD member countries in terms of renewable energy, energy efficiency and climate change policies. Since 1990, Denmark has decoupled economic growth and energy consumption while at the same time reducing greenhouse gas emissions. The country is an outspoken voice in international forums for climate policy and is a strong advocate of tougher mitigation measures. It has a long history of consensus-based policy making and political stability and has been able to utilise this to develop its own far-reaching and comprehensive energy policies.

A high level of political consensus has allowed a clear long-term vision to emerge, generally unimpeded by short-term political changes and changes of government. Implementation is vested in strong, well-resourced institutions with clearly defined responsibilities and obligations. Energy policy making is overseen by the Ministry of Climate, Energy and Building, which also maintains a strong international presence, and implemented by the Danish Energy Agency. It is indicative of the inclusive and open debate conducted by the government on energy policy that there is broad support among all stakeholders for the government's long-term vision.

Denmark's long-term energy goal is to become independent of fossil fuel use by 2050. In 2011, the government published *Energy Strategy 2050*, a detailed and ambitious policy document, which contains a series of new energy policy initiatives, the purpose of which is to build on existing policies and transform Denmark into a low-carbon society with a stable and affordable energy supply. The implementation in Danish legislation of the new energy policy initiatives outlined in *Energy Strategy 2050* is to be negotiated in Parliament. The government is working towards broad agreement behind the Strategy's long-term goal and initiatives up to 2020.

LONG-TERM STRATEGY

Energy Strategy 2050 is the outcome of a long and stable process and is a continuation of previous policies which commenced in the 1980s and existing uniquely-Danish energy agreements. In 2007, the government stated in its policy platform that Denmark should be a low-carbon society with a visionary energy and climate policy. The government elaborated a long-term vision for a Denmark no longer relying on fossil fuels. An independent Commission on Climate Change Policy was established the task of which is to investigate how this vision could be achieved and to identify the long-term climate and energy policies that will be needed to achieve independence from fossil fuels.

The Climate Commission published its findings in September 2010. It made 40 specific recommendations to the government on how the process to convert the present energy

system to one independent of fossil fuels can be initiated.[1] *Energy Strategy 2050* builds on the work of the Climate Commission and outlines the energy policy instruments that will transform Denmark to a fossil fuel-free economy.

The Strategy conveys an understanding of what is implied by independence of fossil fuels and sets out transparent principles for the transition. This clarity is important for stakeholders and ensures that there is the broadest possible understanding of the government's goals. The Strategy is pragmatic and incorporates the flexibility to respond to changing technologies over time. It highlights the need for targeted measures and interventions.

The Strategy identifies a series of government actions within a framework of three well-defined tracks or layered phases of progress.

Each of these tracks takes into account variations in operational life, decision-making processes, technological maturity and prices across the energy system. The three phases also take into consideration the time within which actions and initiatives can be implemented: those that can be achieved before 2020, those that can be achieved in the medium term and, finally, longer-term concepts. Actions in each track fall under a number of clearly defined headings: energy efficiency, heating and electricity production, transport, and the transition to an intelligent European energy system.

The first phase of the Strategy focuses on a series of initiatives that begin, in the short term, to significantly reduce the country's dependence on fossil fuels by concentrating on strengthening and expanding existing policies in energy efficiency and renewable energy, and by determining actions in key sectors up to 2020. These actions contribute towards meeting the long-term target of independence of fossil fuels and ensure that Denmark will meet its short- and medium-term international obligations.

The Strategy builds on the financial analysis carried out by the Climate Commission and acknowledges that the transition to fossil fuel independence will not be without costs. It will require investment, which in the long term may result in lower fuel costs but which in the short term will often be more expensive than currently available fossil-fuel alternatives. In the transport sector, the Strategy acknowledges that Denmark is dependent on international technological developments and therefore has to temper its ambitions at least in the medium term.

The Strategy presents Danish energy consumers with a robust set of measures to take the country to the end of the first phase of a radical transformation and the IEA commends Denmark for the depth and clarity of its vision. Nevertheless, there remains scope for strengthening the overall package.

ROOM FOR IMPROVEMENT

Monitoring and maintaining momentum will present a huge challenge for the government once the Strategy is transposed into law. Consideration should be given to the establishment of a mechanism to review, evaluate and monitor implementation of all phases of the Strategy and ensure the cost-effective delivery of outcomes. This evaluation process should also include publication of regular performance reports.

1. *Green Energy; The road to a Danish energy system without fossil fuels*, Danish Commission on Climate Change Policy, September 2010.

The shift away from fossil fuels, largely coal, in the power sector, and the expansion of renewable energy capacity will bring with it some medium-term risks to energy security. More thought needs to be given to the use of natural gas and its place in the future electricity supply mix. Implementation of the Strategy will oblige the government to conduct a number of detailed studies, among these an analysis of gas infrastructure regulation to ensure its optimal use, and another study on the greater use of biomass for energy-related purposes. The use of natural gas as a flexible source of electricity supply in the medium term should be included as an important part of the analysis.

These activities should be co-ordinated with the emphasis of securing medium-term energy supply and smoothing the path to a low-carbon power sector.

Conversely, the issue of integrating increasing amounts of variable renewable electricity produced from wind energy into the electricity system will be a major challenge. In this regard, the government and the Danish transmission system operator, Energinet.dk, has already undertaken extensive analysis and large investments have been made in transmission infrastructure and international connections. The IEA own analysis suggests that penetration of variable renewable energy in Danish gross electricity demand could increase to more than 60% and still be balanced by existing flexible resources.[2]

Nevertheless, even if the total amount of future variable renewable energy is lower than technically possible, a significant transformation of the electricity transmission system will be required. Investment in the electricity infrastructure should remain a priority. Regional interconnections will need to be further strengthened and the preparation of a strategy for the promotion of smart grids, including extensive use of electric vehicles, heat pumps and advanced metering technology, should be accelerated. A thorough review of renewable energy tendering procedures should also be undertaken to ensure that consumers are getting the most efficient electricity generation mix within the new policy framework and that the costs of capacity investments are fairly distributed.

SUSTAINABLE ENERGY POLICIES

In the climate change sector, Denmark has played an influential role in a number of international negotiations, most notably in the European Union but also within the context of United Nations Climate Change Conferences. Denmark has adopted one of the most stringent greenhouse gas emissions reduction target (21% reduction from the base-year level) of all Annex I countries of the United Nations Framework Convention on Climate Change (UNFCCC). Likewise, its target of reducing greenhouse gas emissions by 20% independently of the Emissions Trading Scheme is among the highest in the European Union Burden-Sharing Mechanism. The high priority attached to influencing international opinion is also maintained in *Energy Strategy 2050* where it has committed to pushing support for a global green transition in international forums and also a commitment to the establishment of a Global Green Growth Forum.

Domestic policies are strong and Denmark is on track to meet its Kyoto obligations. Efforts to reduce emissions will be stepped up over the coming decade as Denmark aims to meet its ambitious EU 2020 targets. While the government has worked hard to address deficiencies in the transport sector, and has developed policies to promote modal shift and alternative fuels, policies could be further strengthened. Additional emphasis should be placed on the transport sector. Denmark should continue to develop

2. *Harnessing Variable Renewables, A Guide to the Balancing Challenge*, IEA Paris, 2011.

policies and measures to reduce and, in the longer term, to eliminate to the greatest extent possible CO_2 emissions from road transport. Conversely, the development of a Green Transport Policy and the establishment of a Centre for Green Transport are commendable steps.

The IEA has developed 25 energy efficiency policy recommendations encompassing 25 fields of action across seven priority areas. Denmark is regarded as one of the few countries that appear to have fully implemented, or substantially implemented, more than 40% of the IEA recommendations. In the building sector, Denmark is a world leader in energy efficiency standards and requirements. In terms of stringency of building code standards, Denmark stands out as having one of the most advanced set of requirements.

Despite its achievements, Denmark has scope to improve its energy efficiency policy portfolio. For example, it should consider expanding its enforcement and monitoring systems. Compliance with updated requirements for new and existing buildings and energy-saving programmes is important for maximising energy savings and for ensuring the credibility of schemes. Denmark should establish and implement a suite of enforcement actions commensurate with the scale of any non-compliance and the value of lost energy savings. There is also room for developing energy-saving targets for the stock of existing buildings by means of incentives to invest in energy efficiency improvements. There is a need to promote the benefits of energy efficiency investments to financial institutions and to assist them with developing such investments for small and medium-sized enterprises.

The long-term political and commercial focus on energy efficiency, along with the development and support of new technologies, have allowed Danish industry and research and development capacity to bring a strong commercial advantage in new, clean energy technologies. Denmark is now a major exporter of these technologies and is a leading player in wind turbine production, supplying about one-third of the global wind turbine market. Exports of energy technologies and equipment accounted for approximately 9.5% of total Danish goods exports in 2010. If Denmark is to retain this position, while simultaneously meeting its own demanding policy goals, substantial investment will be needed to educate and train the necessary workforce. Denmark must continue to have access to a large pool of highly qualified labour and maintain experienced research communities if it is to sustain progress.

KEY RECOMMENDATIONS

The government of Denmark should:

- ☐ *Develop a reporting mechanism to regularly monitor and evaluate progress of the medium-term implementation of* Energy Strategy 2050 *against its stated goals and to ensure the timely and cost-effective delivery of policy.*
- ☐ *Ensure that the electricity transmission system is developed to accommodate the forecast increase in variable renewable energy. These developments should focus on the ability to import and export large volumes of power from different sources. The development of a smart grid and market rules to facilitate a maximum level of participation in the market by both consumers and producers of electricity should also be a priority.*

- *Continue to support regional harmonisation and co-ordination of energy policy by strengthening relationships with neighbouring countries and international bodies. This will enhance regional energy security and the cost-effectiveness of* Energy Strategy 2050 *policy measures.*
- *Develop training and educational capacity to ensure Denmark has access to highly qualified labour and research communities with skills in research, development, deployment and manufacturing of low-carbon technologies.*

PART I
POLICY ANALYSIS

Figure 1. **Map of Denmark**

This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory covered by this map.

2. GENERAL ENERGY POLICY

Key data (2010 estimates)

Population: 5.5 million

GDP: USD 165 billion (2000 prices and PPPs), +7.0% since 2000

GDP per capita: USD 37 680 in 2009 at current prices and PPPs (OECD average: USD 32 854)

TPES: 19.7 Mtoe (oil 38%, gas 22%, coal 20%, biofuels 17%), +5.6% since 2000

TFC: 14.2 Mtoe in 2009 (transport 31%, residential 31%, industry 18%, other 20%), -0.01% since 2000

Electricity generation: 38.6 TWh (coal 44%, gas 20%, wind 20%, biofuels 13%)

Inland energy production: 23.2 Mtoe, exports 14.7% of production

COUNTRY OVERVIEW

The Kingdom of Denmark (excluding Greenland and the Faroe Islands) has a mainland area of 43 098 km^2 and shares a small land border with Germany to the south. Its closest Nordic neighbour is Sweden to whom it is connected by bridge. The bulk of Denmark is the peninsula Jutland and the rest of the country consists of 406 islands, the largest of which are Zealand and Funen, 78 of which are habited. Denmark also exercises sovereignty over the Faroe Islands in the North Atlantic and Greenland, which is part of the North American continent, both of which enjoy autonomous self-rule. The topography of Denmark is relatively flat with few hills, its highest point being no more than 173 metres above sea level.

The population of Denmark was 5.5 million in 2010, with 126 inhabitants per square kilometre, almost half of whom live on the islands of Zealand and Funen. Almost 87% of the population lives in urban settlements.

Denmark is a relatively rich country; it ranks tenth among OECD countries in terms of GDP per capita, at USD 37 680 in 2009, according to OECD statistics. Unemployment, at 7.4% in 2010, is lower than the OECD average of 9.6%. The average exchange rate of the krone in 2010 was DKK 5.62 for USD 1.0; or DKK 7.45 for EUR 1.0.

Oil and gas production make a significant contribution to Denmark's balance of trade. In 2009, the surplus in external trade in oil and natural gas amounted to DKK 14.6 billion, although lower production levels and falling market prices meant a decline when compared to 2008, when the surplus amounted to DKK 27.1 billion.

Denmark is a constitutional monarchy, with a full parliamentary democracy. Executive power is vested formally in the Monarch, at present Queen Margrethe II, but is exercised through the government headed by the Prime Minister. Legislative power is held by the *Folketing,* the Danish parliament. Following a general election in September 2011, the

incumbent centre-right coalition led by *Venstre* lost power to a centre-left coalition led by the Social Democrats thereby making Helle Thorning-Schmidt the country's first female Prime Minister. The Social Liberal Party and the Socialist People's Party became the partners in the coalition government.

SUPPLY AND DEMAND

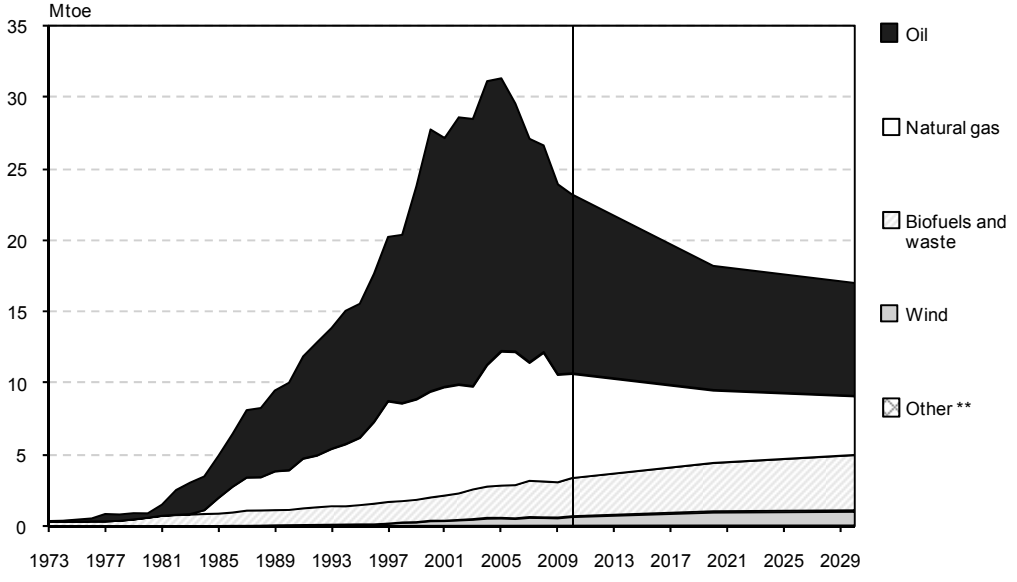
SUPPLY

Total primary energy supply (TPES) in 2010 was 19.7 million tonnes of oil equivalent (Mtoe). Energy production amounted to 23.2 Mtoe, less than 2009 levels and indicative of falling oil and natural gas production over the past six years (see Figure 2). Denmark is a net exporter of oil and natural gas and can be expected to remain so at least until end-2018 for oil and 2020 for gas.

Energy exports were 17.2 Mtoe in 2010 while imports were 13.8 Mtoe, making Denmark a net exporter of energy. The share of renewables in TPES is relatively high at 20.7%, largely wind and biomass.

In 2010, oil accounted for over half (54%) of Denmark's indigenous energy compared to 64% in 2004 when domestic oil production peaked. The share of natural gas in total energy production was 31% in 2010 compared to 34% in 2008. In 2009, the remaining 15% of indigenous energy production came mainly from biomass (12%) and wind power (3%). Denmark generated 38.6 TWh of electricity in 2010, largely from coal (44%), natural gas (20%) and wind power (20%). In 2010, Denmark imported 10.6 TWh of electricity mostly from Norway and Sweden, and exported 11.7 TWh mostly to Germany.

Figure 2. **Energy production by source, 1973 to 2030***

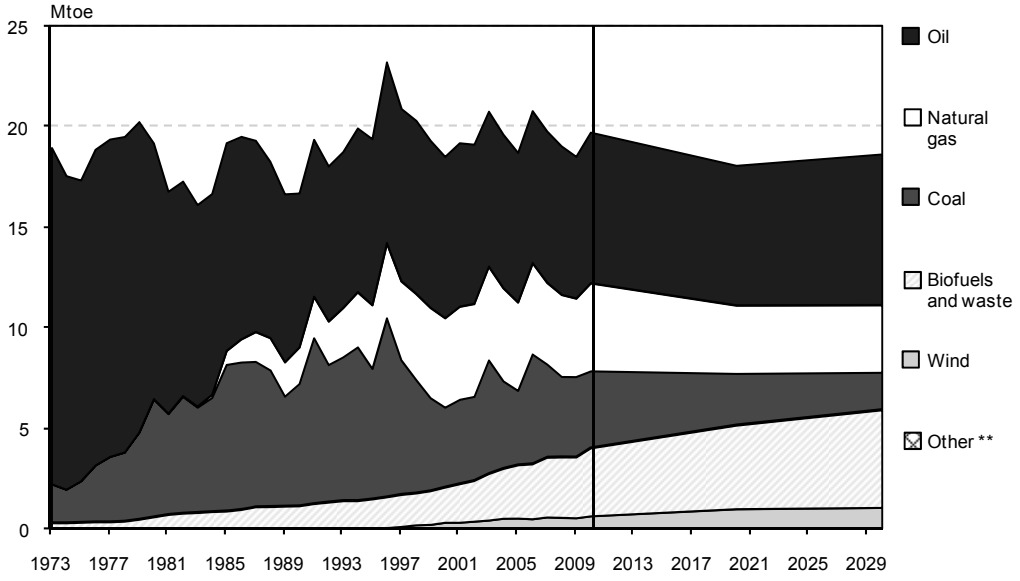


* Estimates for 2010 and government forecasts for 2020 and 2030.

** *Other* includes solar, geothermal and hydro (negligible).

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

Figure 3. **Total primary energy supply, 1973 to 2030***



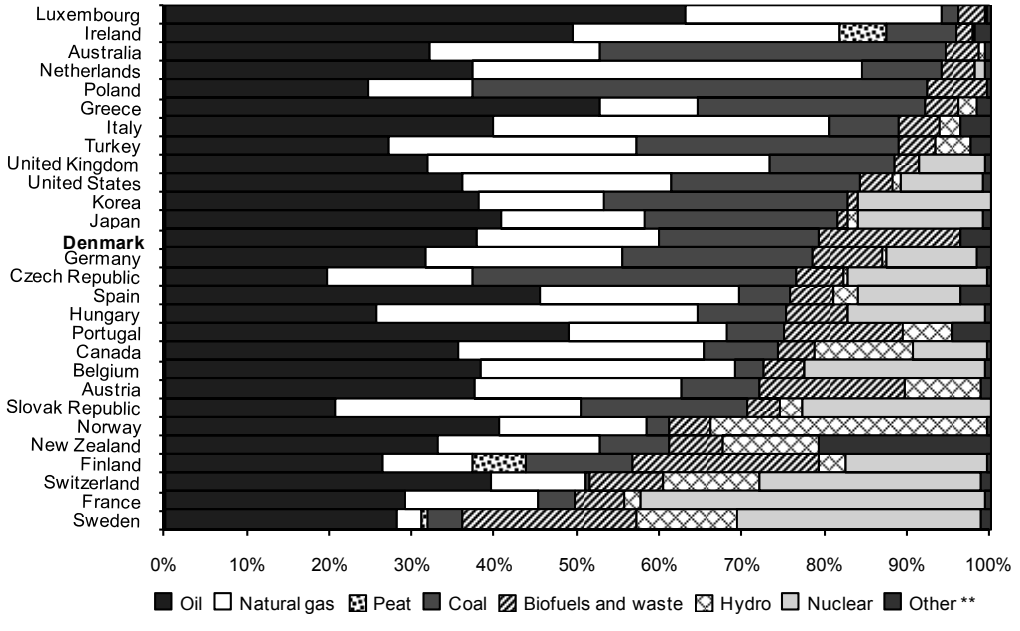
* Estimates for 2010 and government forecasts for 2020 and 2030.

** *Other* includes solar, geothermal and hydro (negligible).

Note: Supply of oil is the residual of two very large and opposite terms, production and exports. As a result, large statistical differences in some years may lead to discrepancies in the growth rates of oil supply and demand.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

Figure 4. **Breakdown of total primary energy supply by source in IEA member countries, 2010***

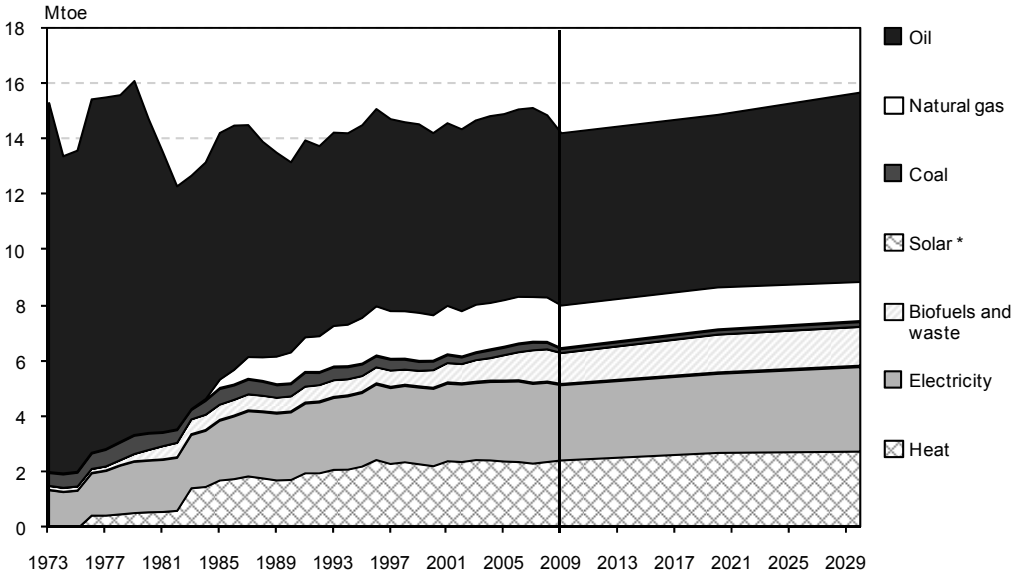


* Estimates.

** *Other* includes geothermal, solar, tide, wave, wind, and ambient heat production.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011.

Figure 5. **Total final consumption by source, 1973 to 2030**



* Negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

DEMAND

Denmark's total final consumption of energy (TFC) was 14.2 Mtoe in 2009, 4% lower than in 2007 and 2008, at the same level as in 2000 but 8% higher than in 1990. Final energy mix has remained relatively stable over the last two decades with oil remaining the largest energy source, at 44% of TFC in 2009, followed by electricity (19%), heat (17%) and natural gas (11%).

Consumption by sector has remained remarkably stable over the period between 1998 and 2009; the residential (31%) and transport (31%) sectors are consistently the largest consumers of energy. The industry sector consumed an average of 21% of TFC over the period while other sectors absorbed the remaining balance. The transport sector is the largest user of oil and oil products, consuming 70% of the total in 2009. The share of heat in TFC, at 17%, is among the highest in the OECD.

INSTITUTIONS

The **Danish Ministry of Climate, Energy and Building** (previously known as the Ministry of Climate and Energy), established in November 2007, was created as a part of the government's increased efforts to promote a greener and more sustainable society.[3] The ministry is responsible for national and international efforts to mitigate climate change, as well as for energy, national geological surveys in Denmark and Greenland, and for meteorology.

3. The Ministry of Energy was established in 1979. In 1994 energy matters were transferred to the Ministry of Environment and Energy. In 2001, energy became part of the Ministry of Economic and Business Affairs, and in 2005 part of the Ministry of Transport and Energy.

The **Danish Energy Agency** (DEA) was established in 1976, and is an agency under the Ministry of Climate, Energy and Building. It is responsible for all tasks related to the production, transmission and utilisation of energy, and its impact on climate change. Its principal function is to ensure the legal and political framework for reliable, affordable and clean supply of energy in Denmark.

Energinet.dk, the transmission system operator, is an independent public enterprise owned by the Danish State represented by the Ministry of Climate, Energy and Building. It owns the natural gas transmission system and the 400 kV electricity transmission systems and is the co-owner of the electricity interconnections to Norway, Sweden and Germany. It is responsible for maintaining security of supply and ensuring the smooth operation of the market for electricity and gas. Energinet.dk was established in 2005 following a merger between Eltra, Elkraft System, Elkraft Transmission and Gastra.

The **Danish Energy Saving Trust** is an independent body established in 2010 as a trust under the auspices of the Ministry of Climate, Energy and Building, replacing the Danish Electricity Saving Trust. The scope of the previous organisation's work has been expanded from electricity savings to cover savings and more efficient use of all forms of energy in every sector other than transport.

The **Danish Energy Regulatory Authority** (DERA) oversees the electricity, natural gas and district heating markets. DERA is an independent authority and its board members are appointed by the Minister of Climate and Energy. Its decisions can be appealed to the Danish Energy Board of Appeal.

The independent Danish **Commission on Climate Change Policy** was established by government in 2007 and was charged with the task of identifying the long-term climate and energy policies needed to achieve independence from fossil fuels. The Climate Commission’s proceedings were attended by the Ministry of Climate, Energy and Building, the Ministry of Economic and Business Affairs, the Ministry of the Environment and the Ministry of Finance. The Commission published its findings in September 2010 and ceased activities in November 2011.

KEY POLICIES

OVERVIEW

Energy policy in Denmark is based on political consensus, stability and a series of Energy Agreements.

On 17 June 2005, the government released *Energy Strategy 2025,* which replaced the previous strategy, Energy 21, published in 1996. *Energy Strategy 2025* focused on initiatives for energy saving and renewable energy, climate change, energy markets and technology.

The government's long-term vision is a Denmark 100% independent of reliance on fossil fuels. In September 2010, an independent Danish Commission on Climate Change Policy (hereafter the Climate Commission) published proposals and detailed recommendations as to how this vision can be achieved. These recommendations formed the basis of *Energy Strategy 2050*, which was published in February 2011.

ENERGY AGREEMENT

The agreement on Danish energy policy for the years 2008 to 2011 was concluded in February 2008. This agreement built on the success of previous agreements between political parties and was a broad-ranging energy agreement to ensure the development of renewable energy, increased energy efficiency and more research into energy technologies.

The parties agreed that renewable energy will account for 20% of Denmark's energy consumption in 2011. The agreement also raised the price paid for wind power, as well as for power from biomass and biogas. Parties also agreed to construct 400 MW of new offshore wind turbines by 2012. The agreement established a compensation scheme for people living near wind turbines, a purchasing rights scheme, a green scheme and a guarantee fund.

Ambitious energy conservation measures were also included; a drop in energy consumption of 4% by 2020 compared to 2006. Hydrogen-fuelled cars will be tax-free, as will electric cars, provisionally until 2012, and a pool of DKK 35 million is to be set aside to cover research into electric cars. For research into solar and wave power and other new renewable energy technologies, a further DKK 25 million is to be set aside each year for four years.

At the same time and as part of the energy agreement, the government, the Danish People's Party and New Alliance entered into an agreement to increase biomass use and to ensure a wider choice of fuel in central power plants.

Box 1. **The agreement on Danish energy policy for the years 2008 to 2011**

- The goal of the agreement is to lower Denmark's dependence on fossil fuels, coal, oil and gas.
- The renewable energy target with respect to gross energy consumption shall be 20% in 2011.
- The agreement sets concrete measures for meeting this intermediate goal.
- Savings and renewable energy targets will be phased on a linear basis.
- In the event of significant deviations from the linear phasing of renewable energy and savings targets, the parties shall discuss supplementary initiatives for attaining the targets.
- Until 2011 a status report of targets and implemented analyses shall be made annually in September.
- By the end of 2010 the parties shall discuss concrete supplementary initiatives for the period after 2011.

Source: Danish Energy Agency (DEA).

AGREEMENT ON GREEN GROWTH

In June 2009, the government and the Danish Peoples' Party signed an agreement on Green Growth. This is a long-term plan defining environment and nature policies and the

agriculture industry's growth conditions. A total of DKK 13.5 billion is to be invested in Green Growth until 2015, which is about a 50% increase in investments compared to previous initiatives. These investments are to ensure that Denmark meets its environmental obligations fully while strengthening growth and employment.

THE CLIMATE COMMISSION

In March 2008, The Danish Government established a Commission on Climate Change Policy (the Climate Commission) and asked it to develop proposals on how the government's long-term vision of independence from fossil fuels can be realised. The Climate Commission's terms of reference state that its work should reflect the European Union ambition of an 80% to 90% reduction in emissions in the developed world. Accordingly, the Climate Commission chose to examine the means by which Denmark can reduce its emissions by more than 80% by 2050.

The Climate Commission concluded that there is significant scope for the reduction of greenhouse gas (GHG) emissions at a surprisingly low cost, when the future price of fossil fuels and carbon emissions are taken into account.

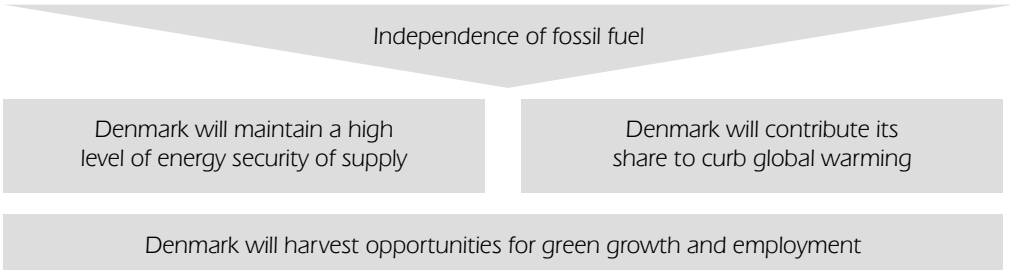
POLITICAL AGREEMENT ON A GREEN TRANSPORT POLICY

Denmark has developed a comprehensive strategy to create a greener transport sector, which was confirmed in the broad agreement on a Green Transport Policy in January 2009. In line with this strategy, a Centre for Green Transport has been established. The centre carries out campaigns, including the promotion of eco-driving and proper inflation levels of tyres; it administrates a scheme for demonstration projects in the area of energy efficient transport solutions.

ENERGY STRATEGY 2050

In February 2011, the government launched *Energy Strategy 2050 (hereafter the Strategy)*, which outlined proposals for the early phases of the process towards meeting the long-term goal of achieving national independence from coal, oil and gas. This far-reaching and visionary strategy, which builds on the findings of the Climate Commission and the outcomes of previous energy strategies and agreements, sets out the energy policy tools needed to deliver Denmark's long-term energy goals and identifies clear medium-term actions for government.

Figure 6. **The goal of the Danish government is independence from coal, oil and gas by 2050**



Source*: Energy Strategy 2050.*

The Strategy outlines a number of new short- to medium-term policy initiatives which, if implemented, are projected to reduce the consumption of fossil fuels in the energy sector (excluding transport and activities related to North Sea exploitation) in 2020 by 33%, compared with 2009 levels, while over the same period, increasing renewable energy's contribution to gross energy consumption to 33%. New initiatives to boost energy efficiency are projected to bring the reduction of energy consumption to 6% in 2020, below the 2006 level.

Regarding climate change challenges, the policy takes the outcomes of the Fifteenth Conference of the Parties (COP15), which Denmark hosted, and COP16, as a starting point. It identifies fossil fuel independence in the energy and transport sectors as a means of taking Denmark a long way towards reducing GHG emissions by approximately 75%. Conversely, the Strategy also recognises the importance of tackling emissions from other sectors, most notably agriculture, which is a significant source of nitrous oxide (N_2O) and methane (CH_4) emissions. In the shorter term, however, greater effort will be required if Denmark is to meet its 2020 target, *i.e.* to reduce non-ETS emissions, which represent 58% of GHG emissions, by 20%. Over the longer term, Denmark has looked to the objective of an 80% to 90% reduction by 2050 relative to 1990 as a starting point.

Table 1. **Government goals and actions**

Government goals	Energy Strategy 2050 actions
Fossil fuel independence by 2050.	Initiatives for increased use of renewable energy and energy efficiency improvements will reduce fossil fuel use in the energy sector by 33% by 2020 compared with 2009.
The share of renewable energy must be increased to 30% of final energy consumption by 2020 as part of an overall EU target of 20% renewable energy by 2020.	Government initiatives for increased use of biomass, wind and biogas will ensure a renewable energy share of 33% by 2020, and thus exceed compliance with the EU target.
The share of renewable energy in the transport sector must be 10% by 2020.	Government initiative for 10% biofuels by 2020 in addition to the government's initiatives to promote electric cars will ensure compliance with the EU target by 2020.
In 2020, primary energy consumption must be 4% less than in 2006.	Government initiatives for energy efficiency improvements in private homes, businesses, the State and municipalities will ensure a reduction of 6% by 2020 compared with 2009, and thus exceed compliance with the national target.
Emissions in the non-ETS sectors must be reduced gradually in 2013-2020 and by 20% by 2020 relative to 2005 as part of an overall EU target to reduce emissions by 20% by 2020 relative to 1990.	Government initiatives to reduce fossil fuels will also reduce non-ETS emissions by 4-5 million tonnes CO_2 in the period 2013-2020.The government will follow up on efforts regularly to ensure compliance with the 2020 climate commitment, and launch new initiatives as required.

Source: *Energy Strategy 2050.*

STRATEGY GOALS

The long-term goal of the Danish government is independence from coal, oil and gas by 2050. A secondary goal of the Strategy is securing the position of Danish industry as world leader in energy, climate and environmental technology. Implementing the Strategy will also allow Denmark to meet other goals and obligations, for example the EU

climate and energy package targets and the 2008 Energy Agreement. The government also wants Denmark to be among the world's top three countries in terms of renewable energy penetration by 2020 and to be among the most energy-efficient OECD members also by 2020.

PRINCIPLES FOR THE TRANSITION TO FOSSIL FUEL INDEPENDENCE

The transition to a fossil fuel-free economy will bring with it costs. Conscious of the fact that the Strategy must be based on sound economic principles, and not disadvantage the Danish economy in any way, the government has developed a set of principles within which the Strategy is framed. Accordingly, the transition to a fossil fuel-free economy must meet the following principles:

- cost effectiveness – The transition must be cost-effective, with a focus on initiatives that provide maximum security of supply and the greatest reduction in fossil fuel use;
- minimal impact on public finances – The distribution of costs and benefits must not create a burden on public finances. Energy consumers will finance the transition;
- retaining competitiveness – The competitiveness of Danish business will have to be taken into account; therefore, energy costs should not increase significantly; and
- full utilisation of international frameworks – The transition must make full use of global opportunities and take advantage of participation in international markets.

Care must also be taken to ensure that the environment remains protected and is not negatively impacted by, for example, infrastructure developments. Sustainable use of biomass will also be required.

A THREE-TRACK APPROACH

Wisely, the government is concentrating its initial efforts on the elements of the Strategy that appear most promising with regard to establishing a cost-effective energy and transport system without fossil fuels. There is general recognition that the transition cannot happen at the same pace throughout the transport and energy systems, for a number of reasons, primarily because of price differences and differences in technological maturity. The Strategy, therefore, has identified three parallel tracks along the transition to fossil fuel independence, with carefully developed initiatives in each track. The process can be summarised as follows:

Track one, the transition phase, is the process of converting to more efficient energy consumption and an energy supply based on renewable energy. This transition can start immediately as existing technologies are cost-effective with long operational life and decision-making processes. The activities involved will also contribute to realising short- and medium-term objectives.

Track two is the preparation and planning of the next phase of the transition, followed by the utilisation and integration of new solutions. It identifies the sectors in which there is a need to ensure the establishment of the framework before specific measures towards 2050 can be initiated.

Track three, the technology development phase, requires investment in research, development and demonstration of cost-effective energy technologies followed by

large-scale demonstration and preparation for market. The final step will be market integration.

Table 2. **Three phases of initiatives in *Energy Strategy 2050***

Track	Initiatives
Track one	More renewable energy with onshore and offshore wind power.
	Increased use of biomass and biogas.
	More efficient energy consumption.
Track two	A green transport sector.
	An intelligent energy system.
	Regulation in a new era of energy policy.
	A global and regional transition to fossil fuel independence.
Track three	Green growth through research, development, demonstration and preparation for market.

Source: *Energy Strategy 2050*.

Table 3. **Government actions under track one**

Track one: the transition phase	
More renewable energy from onshore and offshore wind power	Call for tender on 600 MW offshore wind farm at Kriegers Flak.
	Call for tenders on the smaller offshore wind turbine installations totalling 400 MW.
	Support continued municipal planning for new onshore wind turbines.
	Analyse the opportunities for reducing the distance requirements for wind turbines.
	In co-operation with industry, continue the wind turbine secretariat, including the mobile wind-turbine task force.
Increased use of biomass and biogas	Promote the conversion to biomass at large-scale plants by amending provisions of the Heat Supply Act.
	Allow small-scale power plants a free choice of fuel.
	Introduce a 10% biofuels obligation in the transport sector by 2020.
	Ensure the right framework conditions for biogas production.
More efficient energy consumption	Target the energy-saving obligations of energy companies towards renovation of buildings, conversion of oil and natural gas heating.
	Increase the energy-saving obligations of energy companies by 50% from 2013 and by 75% in 2017-2020.
	Future-proof minimum efficiency standards for building components.
	Convert heating by oil, and eventually also natural gas heating, to district heating, heat pumps and other renewable forms of energy.
	Launch market promotion of energy-efficient heat pumps and solar heating to replace oil boilers.
	Incorporate a “low-energy rating 2020” in the building regulations.
	Enhance energy-saving efforts by the public sector.

Source: *Energy Strategy 2050*.

Table 4. **Government action under track two**

Track two: preparation and planning of the next phase	
A green transport sector	Carry out a technology assessment in 2011, and subsequently every three years, in order to ensure the right framework conditions for new energy technologies.
	Establish a fund of DKK 25 million to support the establishment of recharging stations for electric cars.
	Push in the EU for tightened standards for energy efficiency and CO_2 emissions of vehicles and promote the spread of electric cars in the EU.
	Push in the EU for the establishment of a car recharging infrastructure throughout the EU.
An intelligent energy system	Establish a new international electricity transmission capacity in connection with the future offshore wind park at Kriegers Flak.
	Analyse the need to expand international transmission lines.
	Work for an agreement with the distribution companies to install intelligent electricity meters when electricity consumers install heat pumps or recharging stations for electric cars.
	Prepare a strategy for the promotion of smart grids in Denmark.
	Analyse regulation of future gas infrastructure.
Regulation in a new era of energy policy	Launch an in-depth review of the electricity supply regulation.
	Set aside DKK 20 million for the promotion of strategic energy planning partnerships constituted by municipalities, local enterprises and energy companies.
	Carry out an analysis of the use of biomass for energy-related purposes in Denmark.
	Carry out an examination of the subsidy and tax system in order to assess the need for adjustments of the existing system.
	Improve tendering procedures for offshore wind parks in order to reduce the costs of expansion and prepare the basis for decisions to expand offshore wind turbines in the period after 2020.
A global and regional transition to fossil fuel independence	Work in international forums for ambitious, global actions for the climate, the promotion of a green growth agenda as well as for the phase-out of subsidies for fossil fuels.
	Promote a long-term vision for an EU independent of fossil fuels.
	Endeavour to raise the common EU GHG emissions 2020 target from 20% to 30% compared with the 1990 level.
	Prioritise a doubling of the funds for research, development and demonstration in the energy area by 2020 compared with the level today,

Source: *Energy Strategy 2050.*

Table 5. **Government actions under track three**

Track three: the technology development phase	
Green growth through research, development, demonstration and preparation for market	Undertake a strategic review of public research, development and demonstration initiatives in the climate and energy sector.
	Allocate DKK 10 million for demonstration of large heat pumps in the district heating sector.
	Allocate DKK 20 million for geothermal energy exploration projects.
	Extend the existing public service obligation scheme to support small electricity-producing renewable energy technologies.
	Allocate DKK 10 million to support demonstration projects on solar heating for household solutions.
	Support the establishment of large testing grounds for green solutions in Denmark.
	Enter into partnerships with private enterprises, research institutions and others, where this can contribute to developing, testing and preparing for market of Danish clean technology solutions.
	Carry out technology assessments in a wide range of areas.
	Ensure sufficient recruitment of university graduates and researchers into the green sector.

Source: *Energy Strategy 2050.*

A FLEXIBLE STRATEGY

The path towards fossil fuel independence will require greater efficiency in energy consumption. The Danish government acknowledges that many factors, such as economic growth, commodity prices or technological development, cannot be accurately forecast over the long term; therefore, efforts to determine the most appropriate energy system for 2050 are futile. Technologies change and evolve over time and many, which are relatively expensive at present, may play a greater role in the longer term. Such technologies include electric vehicles, ocean-based energies and carbon capture and storage (CCS). This highlights the need for a flexible strategy open to all technological possibilities.

FINANCING THE TRANSITION

On the basis of the analysis of the Climate Commission, the government forecasts that, in the absence of the new Strategy, consumers are likely to see much higher energy prices and climate-related charges; therefore the long-term financial impact of the Strategy may be limited. At the same time, the Strategy acknowledges there will be transitional problems for some categories of consumer.

The goal of fossil fuel independence will gradually increase pressure on public finances up to 2050 as a result of falling tax revenues caused by reduced use of fossil fuels. Amendments to tax law will therefore be required to allow a shift of taxes to other energies without increasing the overall tax burden.

To replace the loss of tax revenue as a result of new initiatives up to 2020, the government proposes a new revenue-neutral energy security tax on (all) fuels consumed for heating. The business sector will also contribute to the cost of the Strategy by paying a public service obligation (PSO) contribution and a grid tariff.

The Strategy also recognises the need to protect the competitiveness of Danish energy-intensive industry and the need to avoid industry moving elsewhere. In response, the government proposes a tax relief for energy use for industrial processes compared to what was envisaged in the “Spring Package” of 2009. This means that the business community as a whole escapes additional costs imposed as a consequence of tax increases.

The government expects that some businesses will bear increased costs but that some of these costs can be offset by increased subsides for the purchase of more energy-efficient equipment.

Households will also be required to contribute to the cost of the transition by paying the security of supply tax, a PSO contribution and by paying a grid tariff. Nonetheless, the government proposes that household energy bills will be kept at a reasonable level and not significantly higher than what would otherwise have been the case. For example, the government forecasts that by 2020 the Strategy will result in a 3% rise in the cost of household electricity.

Box 2. **Financing the transition to fossil fuel independence**

New energy policy initiatives up to 2020 are financed taking into account existing financial policy. This implies that the transition to fossil fuel independence will primarily be financed by energy consumers. The government proposes that the following funding mechanisms be utilised:

- Energy-saving initiatives will be financed by revenues from grid tariffs paid by energy consumers. The impact of rising grid tariffs will be offset by greater energy efficiency levels and, therefore, lower demand for energy.
- Renewable energy expansion will be funded by revenues from the PSO scheme. At present, PSO charges vary with the market price of electricity but the government forecasts that future PSO unit charges will be relatively static as the cost of larger volumes of renewable capacity will be offset by the falling price of the technology.
- Revenues lost to the State from falling fossil fuel consumption up to 2020 will be recovered by a security of supply tax. Revenue losses will increase gradually in line with the phase-out of fossil fuels and will amount to approximately DKK 1.6 billion in 2020. In order to finance this loss in revenues, the government will introduce a security of supply tax which, mirroring revenue losses, will gradually raise energy taxes on all fuels for space heating.
- Smaller, less-costly initiatives will be financed by reallocating existing funds in the energy and climate budget, for example by redistributing remaining funds from the existing scheme for scrapping oil furnaces.

Source: *Energy Strategy 2050.*

TAXATION

Denmark is a high-tax economy and energy taxes are no exception. There are taxes on coal, oil, natural gas and electricity. There are also taxes on vehicle fuels and vehicle purchases as well as a road-use tax.

Tax rates are determined according to the energy content of the fuel and the tax levies on coal, oil, natural gas and electricity used for heating correspond to around DKK 51 per gigajoule (GJ). Taxes on vehicle motor fuel are higher and determined by taking into account existing demands on mobility, distribution effects, competitiveness and border trade. The tax rates for the different types of fuel are stated in the energy laws per litre, per kilogramme or per cubic metre.

Registration tax on new motor cars is calculated on the dutiable value, which is the vehicle's normal price including VAT on sale. For new cars, the registration tax is generally calculated as 105% of the part of the dutiable value under DKK 76 400 and 180% on the part of the dutiable value exceeding DKK 76 400. For second-hand cars imported to Denmark, the tax is calculated according to the same principle as for new cars but the amounts are lower: for a passenger car between one and two years old, the registration tax of 105% is calculated on DKK 46 600 and 180% on the rest. Commercial vehicles with a total weight of up to 2 tonnes pay no tax on the first DKK16 400 and 50% on the remaining value.

ENERGY SECURITY

In general, Denmark has strong security of supply policies; maintaining high security of supply and the delivery of stable, affordable energy is a fundamental part of *Energy Strategy 2050* and existing policies. Denmark produces much of the oil and natural gas it consumes and the forecast fall in production over the coming decades will be offset by the shift to other forms of energy.

OIL

As a net exporter, Denmark has no stockholding obligation to the IEA. As a member of the European Union, Denmark has a stockholding obligation of 67.5 days of consumption. The present government regulations go well beyond this, setting a compulsory stockholding obligation on industry of 81 days of consumption. Some 70% of this is covered by the Danish stockholding agency, FDO, largely in the form of refined products. In an IEA collective action, Denmark would participate with the release of oil from the FDO stocks. Demand restraint measures would only be considered in a severe and prolonged disruption.

NATURAL GAS

Energinet.dk is responsible for maintaining minimum standards and preparing an annual plan for assuring security of supply. In a crisis, Energinet.dk would take over the role of gas supplier to the Danish market, with an obligation to ensure supplies of gas to the non-interruptible end-users. It would do this by drawing on measures only available to Energinet.dk in emergency supply situations, i.e. deliveries from the two underground storage sites in Denmark, re-routing of natural gas supply from the North Sea via the Syd Arne pipeline and limiting supplies to interruptible end-users.

ELECTRICITY

As the electricity transmission system operator, Energinet.dk is also responsible for emergency preparedness in the electricity system and for co-ordinating emergency preparedness of the sector before, during and after a crisis.

The country maintains strong electricity links with Sweden and Norway to the north and east, and with Germany to the south, and is exploring the possibility of interconnection with the Netherlands. In 2010, east and west Denmark were connected when the Great Belt Power Link connecting the two areas with 400 kV direct current cables was commissioned. The projected increase in wind power generation will bring with it additional challenges in terms of its variability.

CRITIQUE

Before the second oil crisis, Denmark relied on fossil fuels as the basis of its energy system. The oil crisis in 1974 came as a wake-up call: in response, the government started to develop policies aimed at a greater security of supply. In the mid-1980s, oil and natural gas were discovered in the Danish North Sea, thereby reducing dependence on imported fossil fuels. District heating systems based on combined heat and power

were developed and the focus of energy policy shifted towards energy efficiency and renewable energy production.

Denmark is one of the most efficient users of energy compared with the other OECD countries. Since 1990, energy consumption has remained more or less constant; the Danish economy has grown by 35%, while CO_2 emissions have reduced by 7.2%. This decoupling of economic growth and energy consumption and emissions is something the Danes can be rightfully proud of.

The present government wants to steer this second phase in energy history towards a new era with an ambitious policy initiative: over the longer term, by 2050, Denmark will no longer be dependent on the use of fossil fuels. This vision serves objectives in relation to climate policy and energy security, as well as economic ones. To assist in this process the government established an independent Commission on Climate Change Policy consisting of ten experts, each possessing special knowledge in the fields of economics, climate and agriculture. In September 2010, the Commission presented their findings

In February 2011, informed by the findings of the Commission, the government published *Energy Strategy 2050*, which outlines the long-term objective and first steps towards achieving independence from coal, oil and natural gas by 2050. This comprehensive and far-reaching Strategy elaborates on the policies and actions that will be required to transform Denmark into a green society with a secure, stable and affordable energy supply.

A BALANCED AND FAR-REACHING STRATEGY

By definition, energy policies must be appropriate to national circumstances, but certain fundamental elements are common to all sound energy policies: strong energy policy requires political consensus and clarity of long-term vision, stable institutions and clearly defined leadership, the ability to adapt to changing circumstances and broad engagement with all stakeholders leading to public acceptance and effective stakeholder partnerships. Furthermore, an energy strategy cannot be developed in isolation and implementation must acknowledge global circumstances. *Energy Strategy 2050* contains all of these elements.

Energy policy in Denmark is characterised by a remarkable level of political consensus, which has allowed a clear long-term vision to emerge, generally uninterrupted by short-term political change. Implementation is vested in strong well-resourced institutions, which maintain a high public profile, with clearly marked responsibilities. For example, all energy policy matters relating to transport rest with the Ministry of Transport and not with a number of institutions as is often the case. Policy making is overseen by the Ministry of Climate, Energy and Building, which also maintains a strong international presence, and is implemented by the Danish Energy Agency. There is broad support for the government's long-term goals among stakeholders, which is indicative of the inclusive and open debate conducted by government on energy policy.

Energy Strategy 2050 is the outcome of a long and stable process, which commenced in the 1980s, and is a continuation of previous policies and political energy agreements, a unique feature of the Danish policy-making environment. In 2007, the government stated in its platform for government that Denmark should be a green and sustainable society with a visionary climate and energy policy. Accordingly, the government elaborated a long-term vision for a Denmark independent of reliance on fossil fuels. An

independent Commission on Climate Change Policy was established and charged with the task of investigating how this vision could be achieved and with identifying the long-term climate and energy policies that will be needed to achieve independence from fossil fuels.

The Climate Commission published its findings in September 2010.[4] It made 40 specific recommendations to the Danish government on how the process leading to a conversion of the present energy system to a fossil fuel-free system can be initiated. The independence of the Climate Commission played an important role by fostering a broad public debate on the future of climate policy, energy consumption and supply in Denmark and ensuring clear lines of communication with all stakeholders. *Energy Strategy 2050* builds on the work of the Climate Commission and outlines the energy policy instruments needed to transform Denmark to fossil-fuel independence.

The Strategy wisely focuses on a series of initiatives that begin in the short term to significantly reduce the country's dependence on fossil fuels by concentrating on strengthening and expanding existing energy efficiency and renewable energy policies. By 2020, the Strategy identifies clear targets and calls for the energy industry to reduce its consumption of fossil fuels by 33%, compared with 2009 levels. In addition, the Strategy will increase renewable energy's share of gross energy consumption to 33% and reduce energy consumption by 6% in 2020, compared with 2006, by means of a strong package of energy efficiency measures. Denmark has one of the lowest energy intensities among IEA countries and the share of non-hydro renewable energy production in total primary energy production is among the highest in the OECD. *Energy Strategy 2050* contains a series of measures to maintain this status and also ensures Denmark will meet its international obligations.

The Strategy clearly defines what is implied by independence from fossil fuels and sets out transparent principles for the transition to independence. This clarity is important for stakeholders and policy makers alike and ensures that there is broad understanding of the government's goals.

The Strategy notes the need for energy policy to be flexible and to retain the ability to respond to changing technologies; it highlights the need for targeted, well-timed measures. It identifies a series of government actions within a framework of three well-defined tracks, each of which takes into account variations in operational life, decision-making processes, technological maturity and prices across the energy system and the time within which actions and initiatives can be implemented. Actions in each track, or phase, fall under a number of clearly-defined headings: energy efficiency, heating and electricity production; transport; and the transition to an intelligent and international energy system.

The Strategy contains financial analysis and acknowledges that transition to fossil fuel independence will not be free. It will require investment, which in the long term may result in lower fuel costs but which in the short term will often be more expensive than currently available fossil alternatives. Four streams of finance will ensure that the Strategy is fully resourced to 2020.

Nonetheless, and despite the comprehensiveness of the government's strategy document, there remains some scope for strengthening Danish energy policy:

4. *Green Energy; The road to a Danish energy system without fossil fuels*, Danish Commission on Climate Change Policy, September 2010

MONITORING AND EVALUATION

Realisation of Denmark's long-term goal of independence from fossil fuels will require ongoing review and evaluation. The government should consider establishing a mechanism to monitor and evaluate progress of the medium-term implementation of the *Energy Strategy 2050* against its stated goals and to ensure the timely and cost-effective delivery of policy. The outcomes of the reviews should be published on a regular basis. Reviews should take into account the costs to the Danish economy, energy security implications and include all technologically and economically feasible policy options.

Energy Strategy 2050 will bring with it large financial and economic risks. At present, there appears to be limited research and analysis of the long-term costs and benefits of the Strategy. The overall competitiveness and economic well-being of the Danish people must not be endangered in the medium term as the country moves towards its long-term goals and the government has clear responsibility to actively manage the inherent risks.

Detailed financial modelling should be developed by the government. The output of this analysis can support policy development, validation and implementation processes. The models, and their parameters, should be made available to all stakeholders so that they can conduct their own analysis if necessary.

Evaluations should also take into account the impact of the Strategy on Denmark's neighbours with whom it trades energy, and note the influence that changes in policy elsewhere will have on the Danish energy system.

SECURITY OF SUPPLY

Security of supply is an equally important element of Danish energy policy. Translating this into fossil fuel independence is an extreme interpretation of energy security. Many countries realise security of supply through a diverse energy mix in terms of fuel supply, supply sources and supply routes. The geographical position of Denmark near the North Sea and the Baltic Sea, and with access to the European natural gas pipeline system, the European electricity system, as well as a well-developed gas storage infrastructure reduce the risk of a long-term gas supply emergency, even when Denmark becomes a net-importer of energy.

Nonetheless, greater consideration should be given to natural gas as a potential bridge between the present largely coal-fired electricity system and the low-carbon system of the future. This should be considered for the following two reasons. The Strategy acknowledges the need for an analysis of the use of biomass for energy-related purposes; it is clear that biomass could be a limited resource in the future and that long-term security and sustainability of supply is far from certain. Therefore, the move towards biomass could take longer than planned or may not occur to the scale envisaged. Natural gas is an ideal technology with which to address any short-term electricity security concerns. Existing gas-fired technologies can deliver the additional flexibility needed to support the large-scale integration of wind power in the medium term.

Analysis of natural gas infrastructure to ensure its optimal use and maintenance and analysis of the use of biomass for energy-related purposes should be co-ordinated with

the emphasis on securing medium-term supply while at the same time reducing potential emissions from electricity production.

INTEGRATION OF RENEWABLES

Besides phasing out fossil fuel use, the issue of integrating the increasing amounts of variable electricity production, largely from wind energy, into the electricity system will be a major challenge. Variable wind energy makes a substantial contribution to Danish and regional electricity supply. At present, the two parts of Denmark (west and east) taken together have approximately 5 440 MW of interconnection with adjacent areas (Nordic and Germany), the equivalent of more than 80% of Danish peak demand. This is the primary reason why Denmark has been able to accommodate such a high penetration of wind power to date. Denmark, thanks to its heavily interconnected nature, can also take advantage of hydropower resources in the rest of the Nordic market to balance its electricity system at short notice. The extent to which Norway will be able to continue to provide hydropower-based balancing resources to Denmark will depend on the level of variable renewable energy deployment in Norway itself as well as in its other neighbours. If these increase, competition for the same flexible resource will result. In purely technical terms, the IEA estimates that penetration of variable renewable energy in Denmark's gross electricity demand could increase to over 60% and still be balanced by existing flexible resources, after existing requirements for flexibility are taken into account.[5]

Nevertheless, even if the total amount of future variable renewable energy is lower than technically possible a significant transformation of the electricity and transmission system is already under way. Investment in the electricity infrastructure should remain a priority. Regional interconnections will need to be strengthened and the preparation of a strategy for a smart electricity grid and advanced metering technology should be accelerated.

Greater potential for the development of wind power, both onshore and especially offshore, remains. Under the present regulatory framework, much of the development risk for project developers is shared with government. For example, in the most recent government tender for the development of offshore wind, the environmental impact assessment and the licences were arranged by the government. Adding that the cost of connecting to the onshore grid under tendering procedure is socialised, this framework creates a very favourable starting position for private investors. Nonetheless, the tender attracted just one bid. This suggests that the tender process is far from optimal and its structure will require closer examination and corrective action if the future government goals are to be realised.

INTERNATIONAL CO-OPERATION

Continued international co-operation regarding supply and development of energy infrastructure will improve the security of supply of Denmark. The government should continue to strengthen co-operation among national and regional stakeholders. Future challenges should be debated among all stakeholders in the region, such as energy producers, consumers, neighbouring countries and the European Union. Denmark

5. *Harnessing Renewable Variables; A Guide to the Balancing Challenge*, IEA Paris, 2011.

should maintain its leadership position in international forums to secure a low-carbon future.

It is also important to bear in mind that the costs associated with policies to increase energy security and fossil fuel independence will be paid for by end-users. Consumers, via higher transmission and distribution tariffs, public service obligations and higher taxes, pay for new capacity. Care must be taken to ensure that the costs of new capacity additions are correctly allocated and that users who directly benefit from the security of capacity or energy supply contribute to the cost. This means that higher costs in Denmark must not translate into subsidies elsewhere without appropriate compensation mechanisms.

RECOMMENDATIONS

The government of Denmark should:

- ☐ *Ensure the timely and co-ordinated delivery of analysis of the potential for biomass, and analysis of the potential of existing natural gas infrastructure, in order to address any shortfalls in energy security in the medium term.*
- ☐ *Ensure that the electricity transmission system is developed to accept the forecast increase in variable renewable energy. These developments should focus on the ability to import and export large volumes of power from different sources and the development of a smart grid and market rules to facilitate a maximum level of participation in the market by both consumers and producers of electricity.*
- ☐ *Continue to strengthen regional co-operation with neighbouring countries and international bodies to enhance regional energy security and the cost-effectiveness of the policy measures described in* Energy Strategy 2050.

3. ENERGY AND CLIMATE CHANGE

Key data (2009)

Total GHG emissions: 62.3 Mt CO_2-eq (-10.2% compared to base year 1990); 2008-2012 target: -21%

CO_2 emissions from fuel combustion: 46.8 Mt (-7.6% since 2000)

Emissions by fuel: oil 43%, coal 33%, gas 20%, biomass 4%

Emissions by sector: electricity and heat generation 47%, transport 28%, industry 8%, residential 6%, other 11%

GREENHOUSE GAS TARGETS

Denmark is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Kyoto Protocol. The EU reduction target is 8% in relation to the Kyoto Protocol and the reduction target of Denmark is 21% in the EU15 Burden-Sharing Agreement. For the period 2013-2020 Denmark has a 20% reduction obligation relative to 2005 emissions for the non-ETS sectors according to the EU Climate and Energy Package. Preliminary 2009 statistics suggest that 2009 domestic emissions are 10.3% lower than base-year emissions.[6] Including the effect of land use, land-use change and forestry (LULUCF), domestic emissions are 15.9% lower than base-year emissions. The production of energy and energy-related activities are the largest contributors to greenhouse gas emissions in Denmark, accounting for 38% of the country's total emissions of greenhouse gases, primarily CO_2.

The long-term goal of the Danish government is to make Denmark fully independent of fossil fuels. Meeting this ambition will result in significant reductions in greenhouse gas emissions. Present efforts to reduce greenhouse gas emissions are determined by Denmark's second National Allocation Plan (NAP2), which sets out a strategy containing a series of initiatives that are being implemented in order to meet the Danish reduction target of 21%. More recently, *Energy Strategy 2050* outlines a number of energy policy initiatives for the period up to 2020 and identifies energy efficiency and renewable energy as key sectors where policy implementation will result in reduced emissions. A number of these initiatives will reduce non-ETS greenhouse gas emissions and thus contribute towards meeting the 2020 reduction target.

CO_2 EMISSIONS FROM FUEL COMBUSTION

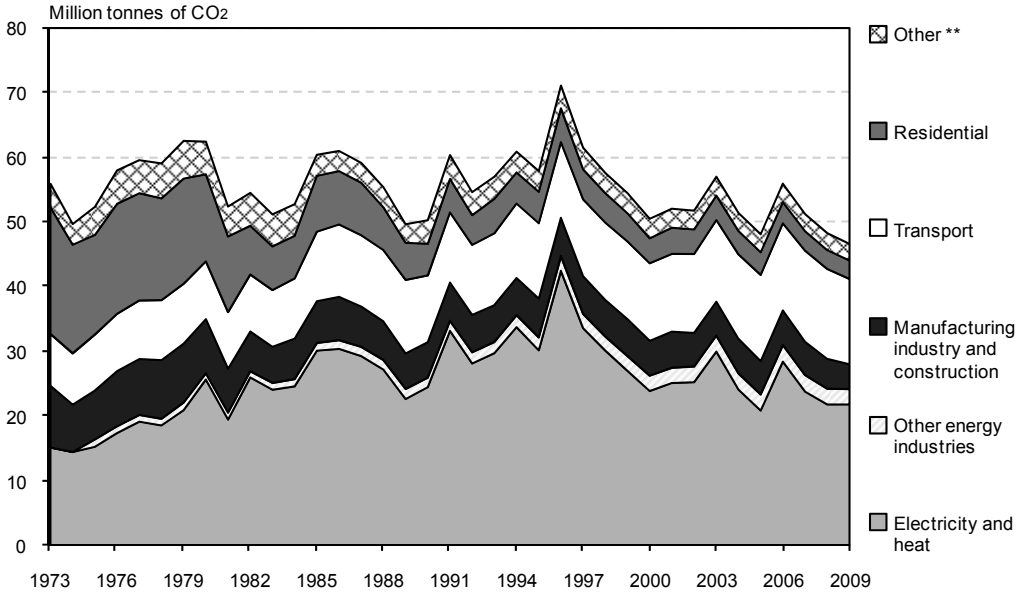
Between 1990 and 2009, CO_2 emissions from fuel combustion decreased by 7% to 46.8 Mt. A significant portion of this reduction is related to the shift in energy production

6. Denmark's National Inventory Report 2011, *Emission Inventories 1990-2009,* submitted under the UNFCCC and the Kyoto Protocol.

from coal to natural gas and also to growth in renewable energy, as well as greater use of combined heat and power (CHP) and improved energy efficiency.

In 2009, emissions from fuel combustion accounted for 98% of all CO_2 emissions and 78% of all GHG emissions in Denmark. Almost all energy-related CO_2 emissions come from three sources: the combustion of coal, used in the production of electricity and heat, oil consumed by the road transport sector; and to a lesser extent natural gas. In 2009, the production of electricity and heat is the source of 22 million tonnes of CO_2-equivalent of emissions, of which almost 75% is coal-based.[7] Oil accounts for 43% (20.2 Mt CO_2-eq) of CO_2 emissions, 13.1 Mt CO_2-eq of which is consumed by the transport sector. CO_2 emissions fluctuate from year to year owing to electricity trade with other countries, primarily Denmark's Nordic neighbours; imports are very sensitive to exogenous factors such as rainfall in Norway and Sweden and the operational stability of nuclear plants in the region.

Figure 7. **CO_2 emissions by sector*, 1973 to 2009**



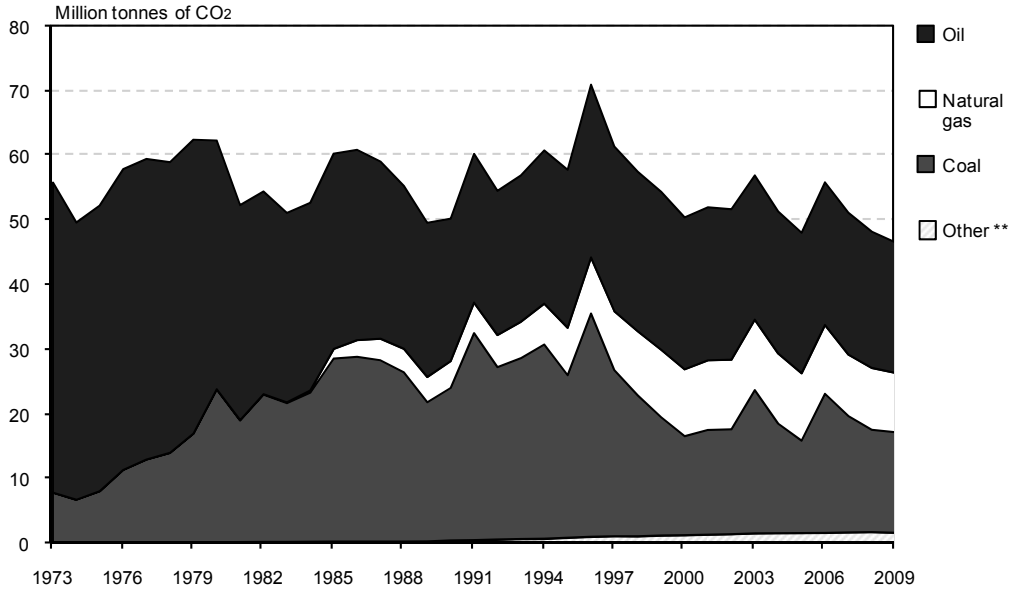
* Estimated using the IPCC Sectoral Approach.

** *Other* includes emissions from commercial and public services, agriculture/forestry and fishing.

Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2011.

7. Denmark's Fifth National Communication on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

Figure 8. **CO_2 emissions by fuel*, 1973 to 2009**



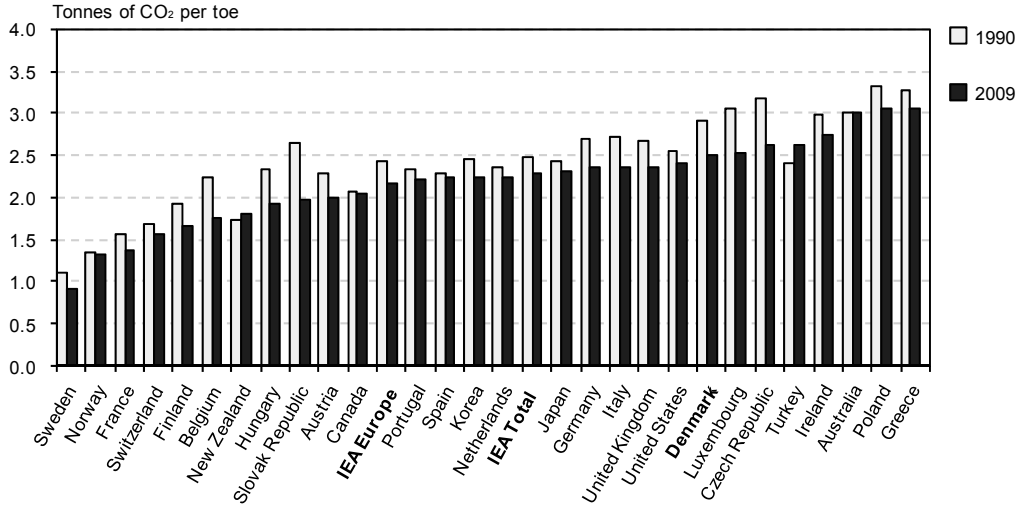
* Estimated using the IPCC Sectoral Approach.

** *Other* includes industrial waste and non-renewable municipal waste.

Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2011.

Compared to other European IEA member countries, Denmark's CO_2 emissions per tonne of primary energy supply are above the average, mainly because of the large share of coal in its energy mix. In 2009, emissions were 2.5 tonnes of CO_2 per tonne of oil equivalent (toe), while IEA Europe average was 2.2 tonnes of CO_2 per toe, 12% lower. CO_2 emissions from the electricity and heat sector are very low, about 303 grammes of CO_2 per kilowatt-hour, very low compared to the OECD average of 420 grammes CO_2 per kWh.

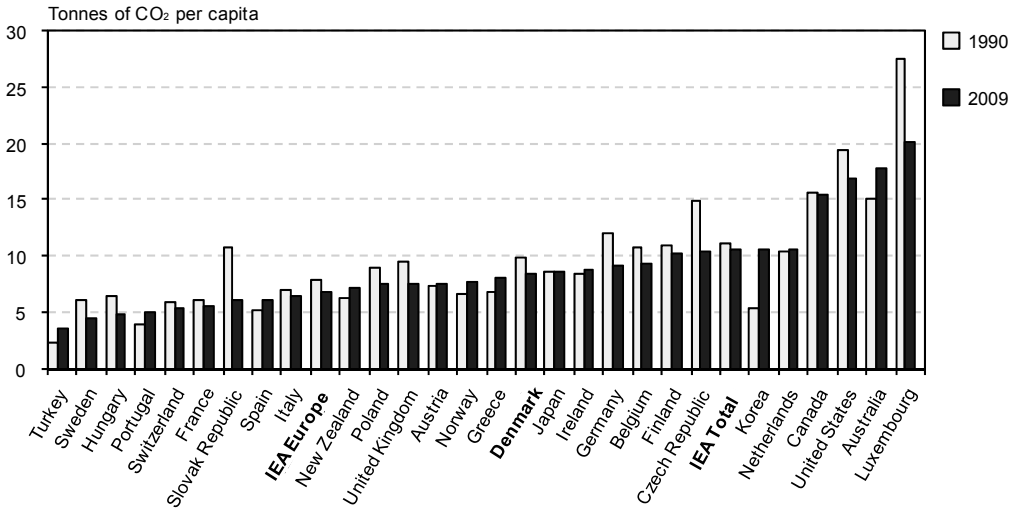
Figure 9. **Energy-related CO_2 emissions per TPES in IEA member countries, 1990 and 2009**



Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2011.

In per-capita terms, energy-related CO_2 emissions in Denmark are closer to the IEA average. With 8.5 tonnes of energy-related CO_2 per capita in 2009, Denmark is slightly higher than coal-consuming European economies such as Poland and Greece, and significantly higher than the IEA Europe average of 6.8 tonnes of CO_2 per capita.

Figure 10. **Energy-related CO_2 emissions per capita in IEA member countries, 1990 and 2009**



Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2011.

CO_2 EMISSIONS PROFILE

The Danish Energy Agency calculates both observed CO_2 emissions and adjusted CO_2 emissions. Adjusted CO_2 emissions take annual temperature variations and trade in electricity into account. In 2008, total emissions of greenhouse gases (without adjustments) were 63.8 Mt CO_2-eq, which is 7.9% lower than base-year emissions of 69.3 Mt CO_2-eq. Including adjustments in the energy statistics for fluctuations in temperature and net exports of electricity, the level in 2008 was 65.7 Mt CO_2-eq, corresponding to a drop of 15% relative to an adjusted base year.[8]

At 79.4% of emissions, CO_2 makes the largest contribution to GHG emissions. Nitrous oxide (N_2O) is the next largest contributor with 10.5% followed by methane (CH_4) with 8.7%. While the energy sector makes the largest contribution to CO_2 emissions, agricultural activities are the largest source of N_2O and CH_4.

The European Union Emissions Trading Scheme (EU-ETS) covers approximately half of the emissions from the energy sector, largely in oil and natural gas production and the transformation sector (power plants and district heating). Preliminary estimates indicate that GHG emissions in 2009 were 62.1 Mt CO_2-eq, of which 36.4 Mt CO_2-eq was outside the EU-ETS.

8. *Energistatistik 2009*, Danish Energy Agency, November 2010.

Table 6. **Observed CO_2 emissions from energy consumption in 2008 and 2009 ($MtCO_2$-eq)**

	Total		EU-ETS		Non-ETS	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
Total	50800	48694	24863	24336	26051	24725
Energy sector	2364	2037	2479	2404	0	0
Transformation sector	21997	22028	19758	19859	2239	2170
Final energy consumption	26439	24629	2627	2073	23812	22556
of which:						
Transport	*16128*	*15224*	*0*	*0*	*16128*	*15224*
Agriculture and industry	*6458*	*5660*	*2627*	*2073*	*3831*	*3587*
Trade and services	*816*	*766*	*0*	*0*	*816*	*766*
Households	*3037*	*2979*	*0*	*0*	*3037*	*2979*

Source: Energy Statistics 2009, Danish Energy Agency.

PROJECTED EMISSIONS PROFILE

Updated projections of Denmark's emissions were published in June 2011.[9] These projections indicate that GHG emissions will decrease over the projection period from 2009 to 2030. These projections are based on policies already in place. This means that projections do not take proposed new initiatives such as the package of policy initiatives in *Energy Strategy 2050* into account. In general, the share of emissions from the energy production sector is declining while emissions from the transport sector are increasing. The total emissions in 2010 are estimated to be 62.5 Mt CO_2-eq and 51.7 Mt CO_2-eq in 2030, corresponding to a decrease of about 17%. Road transport is estimated to be the main source of GHG emissions in 2010 and emissions from this sector are forecast to increase by about 40% from 1990 to 2030. Emissions from the power sector are projected to decrease by 60% over the same period owing to a large shift from coal to renewables, including biomass and municipal waste.

In the shorter term, from 2009 to 2020, GHG emissions are expected to decline by approximately 14%, including a decrease in energy-related CO_2 of approximately 15%.[10] Part of this reduction is attributed to the fact that Denmark is becoming a net importer of electricity rather than an exporter as was the case in the past.

INSTITUTIONS

The **Ministry of Climate and Energy** is responsible for national and international efforts to mitigate climate change. The ministry was established to facilitate the achievement of Denmark's long-term climate goals and to deliver Denmark's contribution to global efforts to reduce CO_2 emissions.

The **Danish Energy Agency** (DEA) is an agency under the Ministry of Climate and Energy which has delegated to the DEA much of the implementation of tasks relating to the Kyoto Protocol; alongside responsibility for legislation and administration of the EU

9. Projection of Greenhouse Gas Emissions 2010 to 2030, NERI, June 2011.

10. *Danish Energy Outlook 2011*, Danish Energy Agency, April 2011.

Emissions Trading Scheme as well as the national registry. A secretariat has been established in the DEA to manage operation and administration of the registry.

The **Ministry of the Environment** is responsible for administrative and research tasks in the areas of environmental protection and planning. The ministry includes three important agencies: the Agency for Spatial and Environmental Planning, the Environmental Protection Agency and the Forest and Nature Agency.

The **Danish National Environmental Research Institute** (NERI), part of Aarhus University, serves as scientific advisor to the Ministry of the Environment and the Ministry of Climate, Energy and Building. NERI is responsible for producing Danish greenhouse-gas emission inventories and annual reporting to the UNFCCC.

The Ministry of Climate, Energy and Building works closely with **Local Government Denmark** (LGDK) and the municipalities to reduce energy use. A 2007 agreement with LGDK ensures that municipalities are obliged to implement the same energy-saving schemes as state institutions. The agreement with LGDK will run until 2012, when a joint assessment of the initiative will be conducted.

POLICIES AND MEASURES

2008 ENERGY AGREEMENT

In February 2008, the Danish government signed a broad-ranging energy agreement with a majority of parliamentary parties, the purpose of which was to support the development of renewable energy, increase energy efficiency and further research into energy-related technologies.

Parties to the agreement accepted that, by 2011, renewable energy will account for 20% of Denmark's energy consumption. This was to be achieved by raising the price paid for renewable energy and the construction of 400 MW of new offshore wind capacity. The agreement also created a number of other support schemes and a compensation scheme for people living nearby wind turbines. At the same time, political parties also entered into an agreement to increase biomass use and to ensure a wider choice of fuel in central (large-scale) power plants.

The primary goals of the Energy Agreement for the period 2008-2012 are to achieve:

- 20% renewable energy in gross energy consumption by 2011;
- Annual energy savings of 1.5% of the final energy consumption for 2006; and
- A 4% reduction in gross energy consumption relative to 2006 by 2020.

COMMISSION ON CLIMATE CHANGE POLICY

The Danish government established the Commission on Climate Change Policy and asked it to develop proposals on how the government’s long-term vision of independence from fossil fuels can be realised. The Climate Commission terms of reference state that its work should reflect the European Union ambition of an 80% to 90% reduction in emissions in the developed world. Accordingly, the Climate Commission chose to examine the means by which Denmark can reduce its emissions by more than 80% by 2050.

The findings of the Commission are discussed elsewhere in this report but it concluded that there is significant scope for the reduction of GHG emissions at a surprisingly low cost, when the forecast future price of fossil fuels and carbon emissions are taken into account.

DANISH STRATEGY FOR ADAPTATION TO A CHANGING CLIMATE 2008

In 2008, the Danish government published a Strategy for Adaptation to a Changing Climate. The purpose of the strategy was twofold: to initiate an information campaign highlighting the effects of climate change and to ensure that climate change was incorporated into planning and development. The strategy comprises the following measures:

- a targeted information campaign, which included the creation of a web portal operated by an information centre;
- a research strategy including the establishment of a co-ordinating body to ensure that Danish climate research focuses on the adaptation question to a greater extent; and
- establishing an organisational framework, including setting up a horizontal co-ordination forum for adaptation that will ensure a co-ordinated effort among public authorities.

The strategy identified a number of key sectors likely to be impacted by changes in climate: coastal management, buildings and construction, water and energy supply, agriculture, fisheries and forestry, nature management and land-use planning, and health. The strategy also examined rescue preparedness and insurance impacts of climate change. It highlighted a number of cross-sectoral initiatives necessary to have stakeholders more involved in climate-related activities. These initiatives included a web portal on climate change that provides targeted information on *e.g.* climate data and tools on adaptation measures. Further, the strategy includes a forum for research on climate and climate change and the establishment of a cross-sectoral Coordination Forum for Climate Change Adaptation.

ENERGY STRATEGY 2050

In February 2011, the government launched its *Energy Strategy 2050*, which outlined proposals for the early phases of the process towards meeting the long-term goal of achieving national independence from coal, oil and gas. The Strategy, which builds on the findings of the Climate Commission, sets out a series of energy policy actions and initiatives needed to deliver Denmark's long-term energy goals as well as actions needed to meet a number of medium-term targets.

Energy Strategy 2050 has introduced a package of new energy policy initiatives to be implemented before 2020. If these initiatives are successfully implemented, the consumption of fossil fuels in the energy sector (excluding transport and consumption related to North Sea oil and gas production) will be reduced by 33%, compared with 2009 levels (this percentage is likely to be revised upwards in line with the new baseline projections published in 2011). If fully implemented, these new initiatives will increase renewable energy's contribution to gross energy consumption to 33%. Complete implementation of new energy efficiency measures will reduce energy consumption by

6% in 2020, compared with 2006 (likewise, this percentage is likely to be revised upwards according to the new baseline projections published in 2011).

Regarding climate change challenges, the policy takes the outcomes of the Fifteenth Conference of the Parties (COP15), which Denmark hosted, and COP16, as a starting point. This implies a long term objective of an 80% to 95% reduction in emissions by 2050 relative to 1990. The Strategy identifies fossil fuel independence in the energy and transport sectors as a means of taking Denmark a long way towards reducing GHG emissions. Phasing out fossil fuels for energy and transport purposes will reduce total Danish emissions by approximately 75%. Conversely, the Strategy also recognises the importance of tackling emissions from other sectors, most notably agriculture, which is a significant source of N_2O and CH_4 emissions.

Implementation of new energy policy initiatives contained in the Strategy will also deliver emissions reductions in the short to medium term as well, although meeting the 2020 target for non-ETS emissions, which represent 58% of GHG emissions, will require additional measures.

In addition to a number of commitments relating to emissions from the agricultural sector, the Strategy states explicitly that the government will:

- endeavour to raise the common EU greenhouse gas emissions 2020 target from 20% to 30% compared with the 1990 level in a way that ensures employment, competitiveness and fair burden sharing;
- push for the adoption of minimum standards for energy and CO_2 taxes in the EU in connection with the revision of the EU Energy Tax Directive.

However, cost-effective reductions in emissions, both CO_2 and other gases, will require greater efforts to limit GHG emissions outside the energy sector. The Strategy estimates that the government's new policy initiatives will reduce non-ETS emissions by 4 - 5 Mt CO_2-eq in the period 2013-2020, largely from enhanced efforts to improve energy efficiency. Further reductions will be achieved by no longer using oil and gas for heating, greater use of biofuels, and an improved framework for using biogas.

EMISSIONS TRADING

The European Union Emissions Trading Scheme (EU-ETS) was launched in 2005 and its first commitment period ran until the end of 2007. The EU-ETS limits the amount of CO_2 emissions from installations in nine energy-intensive industries: combustion installations, hydrocarbon refineries, coke ovens, metal ore roasting or sintering installations, production of pig iron and steel, production of cement clinker, manufacture of glass, manufacture of ceramic products and production of pulp and paper. Each installation is allocated emission allowances and must surrender allowances to cover its total CO_2 emissions. If its emissions are higher than expected, it shall purchase more allowances on the allowance market to cover the shortfall between allocation and actual emissions. If, in turn, it needs fewer allowances than it holds, it can sell them. Allocation in the first two phases of the EU-ETS is based on a National Allocation Plan that is prepared by the national government and approved by the EU Commission. Allocation criteria are laid out in Annex III to the EU Emissions Trading Directive (2003/87/EC).

In 2007, the European Commission approved Denmark's second National Allocation Plan (NAP2) for the period 2008-2012. NAP2 regulates almost half of Denmark's total

greenhouse gas emissions. Approximately 380 Danish installations are covered by the EU-ETS. Most of these are generators of power and heat, the remainder are industrial installations plus a few production units within the offshore energy production sector. The Danish Act on CO_2 Allowances defines which installations are subject to the scheme and, in some instances, which new installations may receive free allowances. NAP2 differentiates the reduction obligations between non-exposed electricity producers and exposed industry. Industries, including offshore, which are normally exposed to external competition, receive a total of free allowances corresponding to about 92% of the allowance basis. The heat production sector receives allowances corresponding to about 87% of the allowance basis. Electricity producers receive allowances corresponding to about 57% of the allowance basis.

Denmark is committed to reducing its national greenhouse gas emissions by 21% in 2008-2012, compared to 1990-1995 levels. This means that emissions must be reduced to an average 54.8 Mt CO_2-eq annually for the period. This also means that, over the second commitment period, Denmark can allocate 54.8 Mt of CO_2 allowances per year to incumbents. For new entrants, a total of 2.5 million allowances was set aside for the period 2008-2012, corresponding to an average of 0.5 million allowances annually.

Table 7. **Key figures in Denmark's National Allocation Plan 2008-2012**

	Expected annual CO_2 emissions 2008-2012 (Mt)	**Annual allowance allocation 2008-2012 (Mt)**	**Annual allowance allocation 2005-2007 (Mt)**
Electricity and heat production	20.5	15.8	21.7
Other industries, including offshore	9.2	8.2	9.2
New enterprises	-	0.5	1.0
Auctioning	-		1.7
Total CO_2 emissions/allowances in ETS sectors	29.7	24.5	33.5
Non-ETS sectors and gases in total	38.1	-	-
Total greenhouse gas emissions	67.8	-	-
Emissions target	54.8	-	-
Deficit	13.0	-	-

Source: Danish Energy Agency.

At the time of NAP2 approval in 2007, the deficit between expected Danish emissions of CO_2 and the committed target was expected to be 13 Mt for the period 2008-2012, should no further initiatives be implemented. The Danish government has since implemented a number of measures to reduce the deficit to zero, including a combination of domestic and foreign environmental and energy measures. Recent projections suggest that the Kyoto target will be overachieved by a margin of approximately 0.8 Mt CO_2-eq per year. This is a result of a decline in emissions from the non-ETS sectors of approximately 2.3 Mt CO_2-eq, from 38.1 Mt CO_2-eq to 35.8 Mt CO_2-eq.

DOMESTIC MEASURES OUTSIDE EMISSIONS TRADING

Box 3. **Danish targets arising from the EU Climate and Energy Package**

The share of renewable energy will be increased to 30% of final energy consumption by 2020 as part of an overall EU target of 20% renewable energy by 2020.

The share of renewable energy in the transport sector will be 10% by 2020.

Emissions in the non-ETS sectors will be reduced gradually in 2013-2020 and by 20% by 2020 relative to 2005 as part of an overall EU target to reduce emissions by 20% by 2020 relative to 1990.

Source: Danish Energy Agency.

Taxes and duties

Throughout the 1990s a number of environmental taxes were introduced and placed on consumer goods that were deemed to cause pollution or were of finite quantity (water, fossil fuels, electricity) or on discharges of polluting substances (CO_2, hydro fluorocarbons, polyvinylchloride, sulphur hexafluoride, sulphur dioxide, and sewage). Taxes are imposed on mineral oil, tobacco, and alcohol in accordance with EU legislation.

Renewables and CHP

Increasing the use of CHP and enlarging the reach of district heating schemes have been part of the Danish energy strategy since the end of the 1970s. Energy from renewable sources has been promoted by a number of means, including the tax system and production grants.

Transport sector

The transport sector, largely road transport, accounts for 26% of Denmark's energy-related CO_2 emissions. In order to implement reductions in the sector, the government has developed a Green Transport Vision, which has been formulated with the overall objective of improving mobility while reducing transport-related CO_2 emissions in a cost-effective way. The Ministry of Transport has established the Centre for Green Transport to develop and implement initiatives to reduce transport-related CO_2. The role of the Centre is to create synergy between specific initiatives and to promote knowledge gained, and research results achieved, for new forms of transport with a view to reducing CO_2 emissions in the sector.

Between 2010 and 2013, the Centre has been allocated DKK 200 million to conduct a number of test projects, which will examine different options for energy-efficient transport solutions. These monies will be used to develop projects that promote environment-friendly and energy-efficient public transport, including test projects with alternative fuels.

The Centre will also work with measures that increase energy efficiency such as:

- alternative fuels for buses;
- large fleets of clean vehicles in collaboration with public and private sector operators; and
- partnerships with private sector companies and municipal authorities on transport planning and system solutions.

The Centre is also examining proposals relating to aerodynamic trucks, eco-driving, energy labelling of light commercial vehicles, a certification scheme for municipalities and companies that prioritise environment-friendly transport and transport network, research and development.

The Energy Agreement of 2008 also set aside DKK 5 million per year for 2010 to 2012 for testing electric cars. The purpose of the test scheme is to generate practical experience with electric cars and understand the required infrastructure.

Taxes are also used as a means to promote the use of fuels with lower CO_2 emissions, mainly biofuels. Since 2000, registration taxes for privately owned motor vehicles have been differentiated according to their fuel efficiency. In 2007, the tax rates were increased or decreased according to the fuel efficiency of the vehicle generating an estimated additional emissions reduction of 0.05 Mt CO_2-eq per year. Gasoline-driven passenger cars and vans receive a tax credit of DKK 4 000 for each kilometre in excess of 16 kilometres the vehicles run per litre of gasoline. In the case of diesel vehicles, the efficiency increase sought is 18 kilometres. Conversely, a tax increase of DKK 1 000 has been imposed for each kilometre less than 16 kilometres gasoline-powered vehicles run per litre gasoline (18 kilometres in the case of a diesel-powered car).

Table 8. **Examples from the Danish structure of tax incentives based on annual taxes on motor vehicles (2008/09)**

Fuel type	Class of vehicle	Fuel consumption (km per litre)	Annual tax (DKK per year)
Gasoline	1	>20	520
	11	10 - 10.5	5 500
	24	<10.5	18 460
Diesel	1	25 - 22.5	1 960
	12	10.2 - 11.3	9 620
	24	<5.1	25 060

Source: Ministry of Taxation.

In addition, *Energy Strategy 2050* contains a number of actions relating to transport. The government will:

carry out a technology assessment in 2011 and subsequently every three years in order to ensure the right framework for new technologies to support the targets of reducing greenhouse gas emissions from the transport sector in the short term up to 2020, and in the long term up to 2050;

- secure a 10% requirement for biofuels by 2020;
- push in the EU for more comprehensive sustainability requirements for first generation biofuels, and the option to prioritise second-generation biofuels;

- establish a fund of DKK 25 million to provide state co-financing for the establishment of recharging stations for electric cars in order to kick-start development in the area and design appropriate regulation;
- push in the EU for the promotion of electric cars, among other things through enhanced harmonisation and standardisation of technologies for electric cars; and push for the establishment of a car recharging infrastructure throughout the EU, which is to be co-ordinated with the regulation of intelligent infrastructure;
- push in the EU for more intensive research and development efforts within green transport technologies; and
- enforce stricter requirements for the efficiency of motor vehicles and tighter limits to carbon emissions from cars.

Business sector

Initiatives to reduce GHG emissions in the business sector include the promotion of energy savings and energy efficiency improvements, a move towards cleaner fuels and initiatives to reduce the emissions of industrial gases. An independent evaluation of the main energy-saving activities was published in December 2008 showing that is was a cost-effective scheme. As a follow-up on the evaluation, the Danish parliament in December 2010 passed a bill on the establishment of a ten-year energy-saving programme (2010 to 2020). The aim of the programme is to strengthen energy-saving efforts in order to deliver a more coherent and efficient approach.

Since 2006, the main measure – beside energy and CO_2 taxes – to promote energy efficiency in the business sector has been the energy-saving obligations for energy utilities. As part of this scheme, the utilities are involved in the realisation of savings by consultancy, subsidies, etc. Around 50% of the reported saving has been realised in the business sector. Other initiatives include:

- promotion of sales of energy services. Efforts for business and industry is organised so that energy services are promoted. Information campaigns are still running to give the market a push;
- promotion of energy management, energy-conscious planning, energy-correct procurement and bench-marking of energy consumption; and
- promotion of exploitation of surplus heat.

Energy Strategy 2050 includes initiatives to increase the effort. The obligations for energy utilities will be increased and target the reduction in consumption of fossil fuels in the business sector and renovation of existing buildings.

Buildings

Several measures are in place to promote energy efficiency in buildings and to reduce the use of fossil fuels for heating. There are very strong requirements for new buildings and the building codes have also tightened energy efficiency requirements in relation to several components of existing buildings. Building owners are obliged to meet these requirements when the components are changed. The energy utilities also promote energy efficiency in buildings as part of their energy-saving obligations.

To ensure a reduction in CO_2 emissions from domestic housing, DKK 400 million has been made available for subsidies for the replacement of inefficient oil-fired boilers with more energy-efficient heating systems. *Energy Strategy 2050* includes several measures to increase energy-saving activities and to replace oil-fired boilers in buildings.

Forestry sector

In 1989, the government announced its intention to double the Danish afforestation within a century. Various steps have been taken towards achieving this goal. For example, a government grant scheme has been established that supports private afforestation on agricultural land and the State also works to plant new forests.

Recent data suggest that the forest cover in Denmark is larger (14%) than previously estimated (11%) and that these forests are older than previously thought. This could change the status of Danish forests from being a net sink to be a net source in 2008-2012. An extensive survey of Danish forests will be conducted in 2011, improving the present estimates with up to date figures. The survey will be finalised in 2012.

Municipalities and local governments

In addition to the 2007 agreement between local governments and the Ministry of Climate, Energy and Building, many municipalities are also making efforts to reduce CO_2 emissions and energy consumption. Both parties have developed a municipal CO_2 calculator, an interactive tool designed for use by local councils to calculate its CO_2 baseline, as well as to prioritise which instruments should be considered in future climate initiatives.

Another example was the EcoCities programme, which ended in 2009, where the cities of Kolding, Skive, Copenhagen, Aarhus, Albertslund and Herning were designated by the ministry as model examples of the way in which municipalities can work counter the climate and energy challenges. The EcoCities programme has been superseded by the Nordic Energy Municipality programme, which will focus on sustainable energy, green growth and energy-related climate efforts across Nordic countries. The purpose of the project is to recognise those municipalities that are making a significant effort to carry out pioneer energy projects.

INTERNATIONAL MEASURES

Joint implementation projects (JI)

Contracts for the acquisition of approximately 10.2 million tonnes of CO_2 credits from 21 projects in Central and Eastern Europe have been entered into. Furthermore, two contracts are currently in place with suppliers of indirect CO_2 credits: the Testing Ground Facility (TGF) under the Nordic Environment Finance Corporation (NEFCO) and the World Bank.

Clean development mechanism (CDM) projects

Collaboration with developing countries on CDM projects is managed by the Ministry of Climate, Energy and Building with the goal of delivering the greatest possible synergy

between CDM collaboration and Denmark's international effort within development assistance. The Ministry of Climate, Energy and Building has approximately 30 contracts on credit purchase from CDM projects.

Denmark works with Malaysia, South Africa and Thailand, and has recently expanded to include Indonesia, Armenia, Cyprus, China and Egypt. General agreements have also been entered into with Chile, Nicaragua and Argentina with a view to developing possible CDM credit trades with these countries. A similar relationship has also been entered into with Mexico and India.

REGIONAL AIR QUALITY

Denmark has implemented the EU Directives 2008/50/ECE and 2004/107/EC on Air Quality. Denmark complies with the limit or target values for the following substances: sulphur dioxide, nitrogen oxides, particles PM_{10} and $PM_{2.5}$, lead, benzene, carbon monoxide, ozone, arsenic, cadmium, nickel and benzopyrene.

Denmark does not comply with the limit values for nitrogen dioxide (NO_2). An air quality action plan has been published in February 2011 and the Climate Commission has been notified of the Danish application to postpone by five years the NO_2-attainment deadline in Copenhagen, Aarhus and Aalborg from 2010 to 2015.

CRITIQUE

Denmark takes climate change very seriously as evidenced by the depth of domestic policies and, more significantly, its wide-ranging efforts in the international arena. The country has played an influential role in a number of international negotiations, most notably in the European Union but also within the context of COP15, which Denmark hosted. The government has adopted one of the most stringent greenhouse gas emissions reduction target (21% reduction from the base-year level) of all Annex I countries of the UNFCCC. Likewise, its target of non-ETS GHG reductions of 20% is among the highest in the European Union Burden-Sharing Agreement. The high priority attached to influencing international opinion is also maintained in Denmark's long-term *Energy Strategy 2050* where it has committed to pushing support for a global green transition in international forums and also its commitment to the establishment of a Global Green Growth Forum.

Domestically, the government, with strong parliamentary support has begun a process to transform, within a generation, the Danish energy sector from one heavily reliant on fossil fuels to one of Europe's first low-carbon societies. A full phase-out of fossil fuels for energy and transport purposes will in itself reduce total emissions by approximately 75%. While this is very much a long-term strategy many of the emissions savings will be delivered in the medium term by increasing energy efficiency targets and phasing out coal-fired power by replacing it with biomass and wind energy. Furthermore, implementation of a series of measures aimed at the transport sector should also reduce emissions from the largest oil-consuming sector in Denmark. While much of the remaining emissions are largely from agriculture, the government has highlighted the role agriculture will play as a green energy supplier in the transition to fossil fuel independence. In accordance with the national Green Growth Agreement, the

government wants Denmark to aim for the exploitation of large natural biogas resources, especially in the form of livestock manure.

In the short term, in line with the EU Renewable Energy Directive, Denmark has committed itself to an ambitious target of 30% renewable energy in final energy consumption by 2020, thereby displacing a portion of the country's coal-fired CO_2-emitting capacity (the government has not excluded some utilisation of coal-fired power with carbon capture and storage (CCS) should it prove cost-efficient). Projections included in the Fifth Communication on Climate Change suggest that Denmark will meet its EU Burden Sharing targets and at the same time maintain a reserve to support additional JI and CDM initiatives if needed. International mechanisms such as JI and CDM can provide a high degree of freedom and cost-effectiveness in reaching the climate and energy targets and the prudence of the Danish government in this regard is notable. Should many of the policies proposed in the *Energy Strategy 2050* be successfully implemented, emissions reductions in the non-ETS sector should be even higher.

Nonetheless, and despite the positive impact existing policies are having, there remains room for improvement, specifically in the transport sector. At present, the share of renewable energy in the transport sector is estimated at 1.0%, largely from electric trains and first-generation biofuels. The transport sector is the second-largest source of CO_2 emissions from fuel combustion after power generation. The government has developed policies which plan to increase the share of renewable energy in the transport sector in order to meet the EU target of 10% renewable energy in transport by 2020. By 2020, an increase in electric vehicles is expected, as well as an increased consumption of first- and second-generation biofuels. *Energy Strategy 2050* strengthens existing policies in the transport sector, which include some of the heaviest transport taxation policies in Europe, by adding a series of new measures such as greater support for electric vehicles and a firm commitment to biofuels. Nonetheless, the Strategy appears to omit any measures that support modal shift from privately owned vehicles to public transport.

RECOMMENDATIONS

The government of Denmark should:

- ☐ *Develop and implement the policies contained in* Energy Strategy 2050 *and prepare clearly articulated roadmaps and targets for non-ETS sectors of the economy.*
- ☐ *Place special emphasis on the transport sector and continue to develop policies and measures to reduce and, in the longer term, eliminate to the greatest extent possible CO_2 emissions from road transport.*

4. ENERGY EFFICIENCY

Key data (2010 estimates)

Energy supply per capita: 3.6 toe per capita (OECD average: 4.4), +2% since 2000

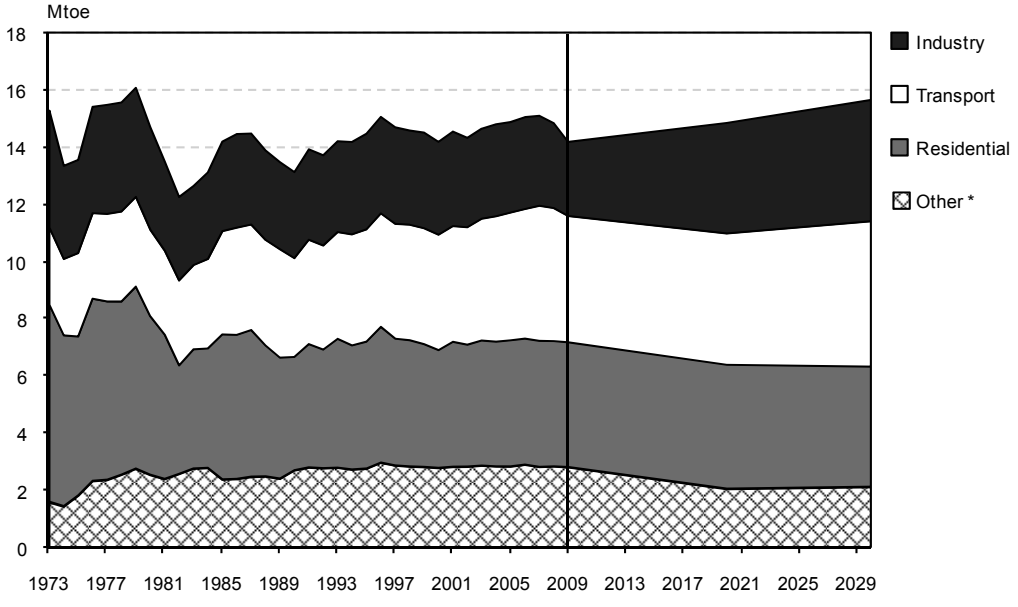
Energy intensity: 0.12 toe per USD 1 000 (OECD average 0.16), -1.2% since 2000

Total final consumption: 14.2 Mtoe in 2009, transport sector 31%, residential sector 31%, industry 18%, commercial and agriculture 20% (OECD average: transport 33%, residential 20%, industry 31%, other 16%)

OVERVIEW

In 2009, Denmark's total final energy consumption (TFC) was 14.2 Mtoe, at the same level as in 2000 but less than either in 2007 or in 2008 (Figure 11). Industry accounted for 18% of this total, transport for 31%, the residential sector for 31% and services, agriculture and fishing for 20% of TFC. Between 2000 and 2009 the transport sector was responsible for almost two-thirds of the growth in energy TFC. Over the same period, energy consumption in industry and in the residential and commercial sectors grew at a very moderate rate.

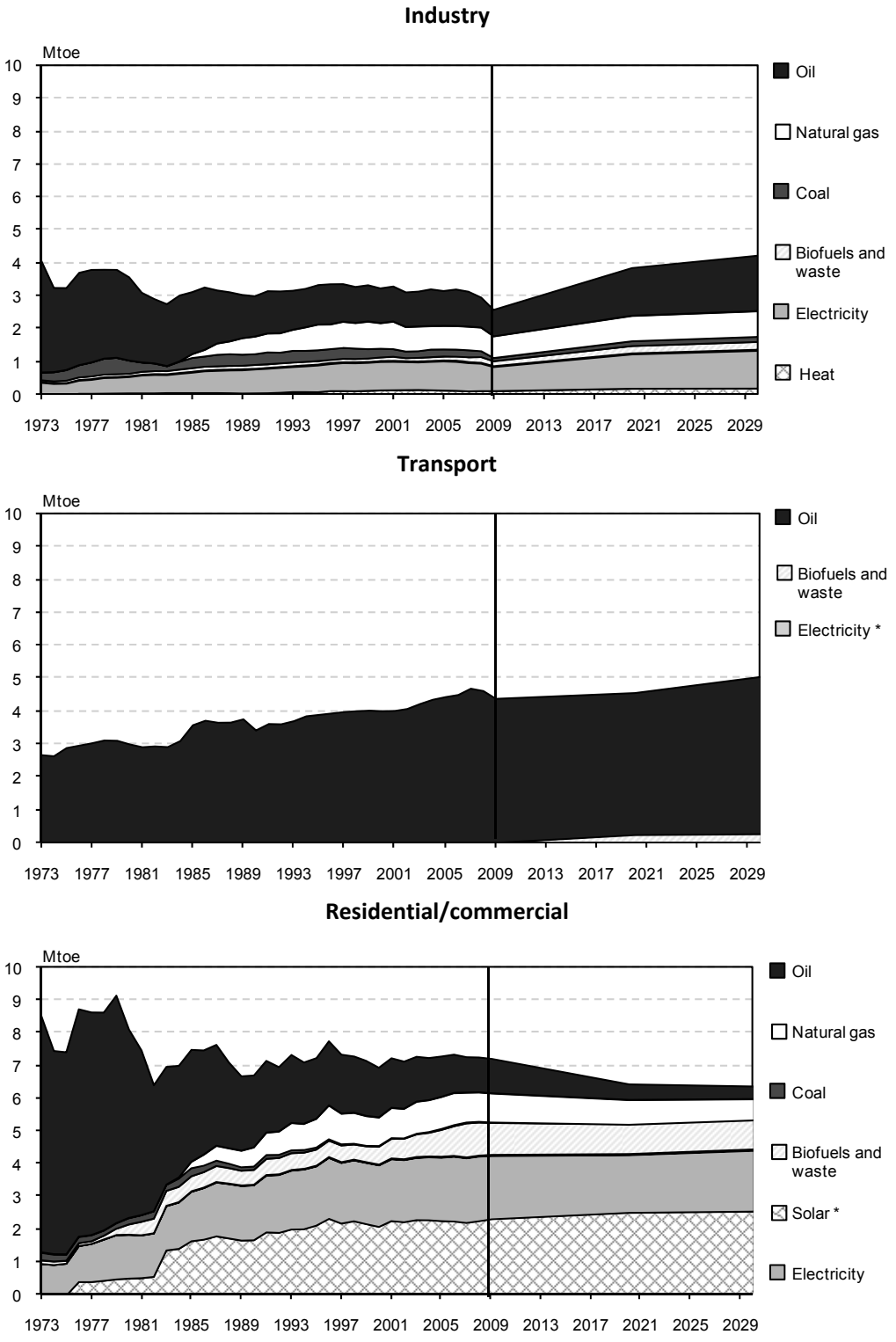
Figure 11**. Total final consumption by sector, 1973 to 2030**



* *Other* includes commercial, public service, agricultural, fishing and other non-specified sectors.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

Figure 12. **Total final consumption by sector and by source, 1973 to 2030**

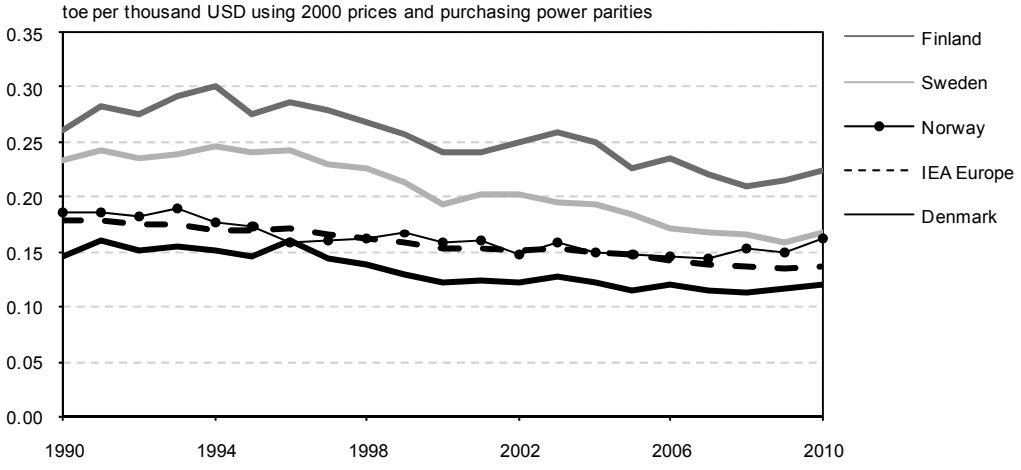


* Negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

Energy intensity in Denmark – the amount of primary energy used in a country per unit of GDP – is lower than the IEA European average and has decreased by 1% in the last decade (see Figure 13), which appears weaker than its Swedish and Finnish neighbours but this is largely because of its better performance ten years ago. The decrease in energy intensity is to some extent due to structural changes in the economy.

Figure 13. **Energy intensity in Denmark and in other selected IEA member countries, 1990 to 2010**



Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and *National Accounts of OECD Countries*, OECD Paris, 2011

INSTITUTIONS

The Danish **Ministry of Climate, Energy and Buildings** is charged with the development of policies that provide a stable, sustainable and efficient production, distribution and use of energy throughout Danish society.

The **Danish Energy Agency** engages nationally and internationally in policies to reduce energy consumption and increase savings. It oversees overall planning and prioritisation of energy-saving measures, including determining the framework for measures involving other bodies.

On 1 March 2010, the Danish Electricity Saving Trust became the Danish **Energy Saving Trust.** The scope of the organisation's work has been expanded from electricity savings to cover savings of all forms of energy in all sectors other than transport. The Trust is financed by a special energy savings charge payable by households and the public sector. The Trust is an independent, public authority with its own board appointed by the Minister of Climate and Energy.

The electricity network companies, the natural gas network companies and the district heating companies have been given annual energy-saving obligations. As part of this, they help the end-use consumers implement energy savings by providing advice, consultancy and/or subsidies.

The **Danish Enterprise and Construction Authority** is responsible for building codes and the **Ministry of Transport** has responsibility for energy efficiency policy in its own sector.

POLICIES AND MEASURES

Policies on energy use, and on energy efficiency in particular, are often made following general agreement among all political parties in Denmark, which allows for stable long-term policies that are less likely to be dislodged by changing governments.

NATIONAL ENERGY EFFICIENCY ACTION PLAN

According to Article 14(2) of the EU Directive, member states were required to submit their first National Energy Efficiency Action Plan (NEEAP) to the European Commission by 30 June 2007.[11] Member states must adopt and achieve an indicative energy saving target of 9% by 2016 in the framework of a National Energy Efficiency Action Plan (NEEAP). The NEEAP is also required to describe how member states intend to comply with the provisions on the exemplary role of the public sector and the provision of information and advice to final consumers.

Denmark submitted its first NEEAP, based on the June 2005 Agreement on Energy Saving Initiatives, in September 2005, which was augmented by further amendments in June 2007. A new NEEAP is being developed at present and will be submitted to the European Commission by June 2011.

The objective of the 2005 NEEAP was to reduce total energy consumption (excluding transport) and increase efforts to save energy which can be documented, corresponding to an average of 1.15% per year, or 7.5 petajoules (PJ), during the period 2006-2013. Successful implementation should result in total energy consumption (excluding transport) of 430 PJ in 2013.

In 2007, the government suggested an amendment to the plan, which includes a suggestion to increase the annual energy saving target to 1.4%. Furthermore, it suggested inclusion of transmission and distribution losses in the basis for the calculation of the annual energy saving target. Taken together, this increases the annual energy saving target from 7.5 PJ to 9.6 PJ, or an average increase of 2.1 PJ over the period 2008-2013.

2008 ENERGY AGREEMENT

In February 2008, the Danish government signed a broad-ranging energy agreement with almost all parties in the Parliament that ensures the development of renewable energy, increased energy efficiency and more research into energy technologies. The 2008 Energy Agreement, which covers the period from 2008 to 2011, adopted the following ambitious energy conservation measures:

- *Gross energy consumption*: gross energy consumption must fall by 4% by 2020, relative to 2006. The goal is for gross energy consumption to fall by 2% by 2011 compared with 2006, corresponding to a drop from 863 PJ in 2006 to 846 PJ in 2011.
- *Higher targets for energy efficiency*: annual savings must be increased to 1.5% of final energy consumption in 2006, corresponding to annual savings of 10.3 PJ.

11. Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC.

- *Stricter obligations*: from 2010, the energy companies' obligations must be increased from the current 2.95 PJ annually to 5.4 PJ annually. Implementation of the stricter obligations was agreed with the companies.
- *Reduction of energy use in buildings*: for new buildings there must be energy savings of at least 25% in 2010, at least 25% in 2015 and at least 25% in 2020, corresponding to a total reduction of at least 75% by 2020.
- *Campaigns to promote energy savings in buildings*: DKK 20 million will be allocated annually over the period 2008-2011, and DKK 5-10 million annually thereafter. This measure was implemented immediately.
- *Knowledge Centre for Energy Savings in Buildings*: of the DKK 20 million earmarked for promoting energy savings, up to DKK 10 million will be allocated annually in 2008-2011. The Centre will be evaluated in 2011.

REVIEW OF ENERGY SAVING ACTIVITIES

In early 2008, the DEA initiated an independent review of energy saving activities. The review was carried out in accordance with the political agreement of June 2005, which states that a review of combined Danish energy saving activities should be carried out in the course of 2008. The main focus of the review is concentrated on the saving activities of the grid and distribution companies, energy labelling of buildings, and the activities of the Danish Electricity Saving Trust.

ENERGY STRATEGY 2050

Energy Strategy 2050, published in early 2010 following the publication of the findings of the Commission on Climate Change Policy, outlines the energy policy instruments needed to deliver the Danish government's vision of becoming independent of coal, oil and gas. In the period up to 2020, the Strategy aims to reduce the use of fossil fuels in the energy sector by 33% compared with 2009. The Strategy will also increase the share of renewable energy in total energy supply to 33% by 2020 and it will reduce primary energy consumption by 6% by 2020 compared with 2006 thanks to a strong focus on energy efficiency improvements.

The Strategy identifies energy efficiency and renewables as the two key focus areas to put Denmark on track to meeting the long-term goal of fossil fuel independence and to help meet the 2020 targets. Accordingly, many of the early objectives of the Strategy focus on policy in these two sectors.

Box 4. **Energy efficiency actions contained in *Energy Strategy 2050***

- Obligations on energy companies will be raised by 50% from 2013 and by 75% in 2017-2020. Efforts will be financed via network tariffs.
- Denmark will push for the EU to achieve at least 20% improvement in energy efficiency by 2020 by means of instruments and policies at EU level and at national level.
- Public sector energy-saving efforts from 2012 will be enhanced and, late in 2011, a proposal will be presented to replace the existing requirements for a 10% reduction in energy consumption by the State, relative to 2006.

Box 4. **Energy efficiency actions contained in *Energy Strategy 2050*** *(continued)*

- When the present agreement on energy savings with Local Government Denmark and Danish Regions expires, budget agreements with municipalities and regions will be amended to include voluntary agreements on energy consumption in buildings.
- Denmark will continue to support the efforts by the Knowledge Centre for Energy Savings in Buildings.
- The Strategy also identifies a series of actions targeted on efficiency improvements in households and in buildings.
- Government will target the saving obligations of energy companies towards renovation of buildings and the phase-out of oil and natural gas for heating. Obligations will moreover be increased by 50% from 2013 and by 75% in 2017-2020. Efforts will be financed via network tariffs.
- Minimum efficiency standards for building components (windows, insulation etc.) will have to be met when renovating buildings relative to future challenges, and expected energy prices will be future-oriented. The standards will be determined by taking into account the financial situation of home-owners, a healthy indoor climate and freedom of architectural expression. Initiatives which can ensure greater compliance with the standards will be considered.
- Convert heating by oil, and eventually also natural gas heating, to district heating, heat pumps and other renewable forms of energy. This will be achieved by implementing a ban on installing oil furnaces in existing buildings from 2017 and a ban on installing oil and natural gas furnaces in new buildings from 2012. Derogations may be allowed in cases where no suitable alternatives are available.
- Increased support for market promotion of initiatives for energy-efficient heat pumps and solar heating, including labelling schemes, certification schemes, package solutions and energy service companies (ESCOs) models.
- Rules on compensation for gas companies converting individual natural gas heating to district heating.
- A model and timetable for the phase-out of natural gas furnaces, taking account of the need for gas for production purposes in industry and potentials for utilising biogas.
- Incorporate a “low-energy rating 2020” in the building regulations with a view to promoting the construction of new buildings with very low energy consumption.
- In the transport sector, the government will push in the EU for the promotion of electric cars, among other things through enhanced harmonisation and standardisation of technologies for electric cars; and push for the establishment of a car recharging infrastructure throughout the EU, which is co-ordinated with the regulation on intelligent infrastructure.
- Push in the EU for more intensive research and development efforts within green transport technologies; and for tighter requirements for the energy efficiency and carbon emissions of cars.

Source: *Energy Strategy 2050*.

TRANSPORT

While total final consumption of energy in Denmark has remained relatively static over the past decade, consumption in the transport sector has increased by 9% and in 2009 accounted for 31% of energy consumption or 70% of oil consumption. Existing efficiency measures in the transport sector are based on a political agreement on transport, taxation measures, efforts to promote modal shift and switching to alternative fuels.

Denmark has developed a comprehensive strategy to create a greener transport sector, which was confirmed in the broad political agreement on a green transport policy in January 2009. In line with this strategy, a Centre for Green Transport has been established. The centre carries out campaigns, including the promotion of eco-driving and proper inflation levels of tyres; and administrates a scheme for demonstration projects in the area of energy-efficient transport solutions. Denmark is also implementing European regulations to improve proper tyre inflation and lower CO_2 emissions from light-duty vehicles.

Transport demand (modal shift)

In December 2008 the government presented a strategy giving priority to public transport, which was subject to an agreement among a majority of parties in the Danish Parliament in January 2009.

The agreement defines a number of projects related to improving infrastructure for rail transport and public transport in major cities and to the promotion of bicycle use in cities. The agreement also covers the costs of financing of the projects.

Promoting alternative fuels

In February 2008, the government and a majority of parties within the Danish Parliament agreed to promote the use of renewable fuels. It was decided that electric vehicles should be tax-exempted until 2012, a measure that was recently extended to 2015. In addition, biofuels were mandated to account for 5.75% of the total use of fuel in the transport sector by 2010, increasing to 10% by 2020. Finally, a test scheme for electric cars was agreed and during the period 2008-2012 the government will provide a subsidy to support testing of approximately DKK 33 million.

Vehicle taxes

Since 2000, registration taxes for privately owned motor vehicles have been differentiated according to their fuel efficiency. In 2007, the tax rates were increased or decreased according to the fuel efficiency of the vehicle generating an estimated additional emissions reduction of 0.05 Mt CO_2-eq per year.[12] Gasoline-fuelled passenger cars and vans receive a tax credit of DKK 4 000 for each kilometre in excess of 16 kilometres the vehicles run per litre of gasoline. In the case of diesel vehicles, the efficiency increase sought is 18 kilometres. Conversely, a tax increase of DKK 1 000 has been imposed for each kilometre less than 16 kilometres gasoline-powered vehicles run per litre of gasoline (18 kilometres in the case of a diesel-powered car).

12. Denmark's Fifth National Communication on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, Ministry of Climate and Energy, 2009.

Table 9. **Examples from the Danish structure of tax incentives based on annual taxes on motor vehicles, 2008/09**

Fuel type	Class of vehicle	Fuel consumption (km per litre)	Annual tax (DKK per year)
Gasoline	1	>20	520
	11	10 - 10.5	5 500
	24	<10.5	18 460
Diesel	1	25 - 22.5	1 960
	12	10.2 - 11.3	9 620
	24	<5.1	25 060

Source: Ministry of Taxation.

BUILDINGS

Denmark has very substantial energy efficiency policies for buildings and is a world leader when it comes to building standards and requirements. The Danish government estimates that between 30% and 40% of Danish energy consumption is used for heating, ventilation and lighting in buildings. Accordingly, the government has developed a series of regulations designed to reduce energy consumption in buildings.

The Danish building code is among the strictest in the world, and Parliament has decided that these requirements will be strengthened by 25% to 30% first in 2010, then again in 2015 and 2020. Denmark, along with a few other countries, is implementing policies to support the construction of buildings with very low or no net energy consumption (Passive Energy Houses and Zero Energy Buildings). Denmark has established targets for new builds in 2015 and 2020 at, or lower than, the passive energy house standard. By 2010, all new buildings must meet requirements for low-energy houses, *i.e.* less than 50 kWh per square metre per year. By 2015, energy consumption of new buildings will have to be reduced by 60 % compared to actual requirements. Requirements for new residential buildings will, by 2015, be equivalent to current voluntary German standards for passive houses. The overall vision of the Danish government is that, in the long run, all buildings should be "plus-energy houses", that is, houses that produce more energy than they consume.

In addition, Denmark has energy requirements for the refurbishment of existing buildings. Energy certification for the sale and rental of all types of buildings has been mandatory for more than a decade. Public buildings have mandatory requirements for energy efficiency improvements, based on the regular certification of these buildings every five years.

Box 5. **Danish building code requirements**

Energy labelling of buildings in connection with a sale is mandatory every five years when a building is over 1 000 square metres. The results of the labelling are public and the rating (A to G), shall be included when advertising buildings for sale.

Inspection of boilers and heating installations: these regulations apply to boilers fired by oil, gas, coal or coke; energy inspections of large ventilation plants take place every five years

Building regulations are to ensure that construction of new buildings and the renovation of existing ones prevent unnecessary energy consumption.

Furthermore, a number of initiatives have been launched to promote energy savings in buildings. These include:

- DKK 30 million for the promotion of heat pumps in areas situated outside the collective supply grid;
- DKK 10 million annually over a three-year period for campaigns on energy savings in buildings; and
- DKK 10 million per year for the support for a Knowledge Centre on Energy Savings in Buildings.

Source: Danish Energy Agency.

WINDOWS

Improvement of the energy efficiency standards of windows and glazing are important elements in Danish energy conservation measures. Current measures consist of three elements:

New provisions in the building code have established standards for energy properties in facade windows for both new buildings and replacement of windows in existing buildings.

In December 2010, the Association of Danish Window Manufacturers − a branch association that represents the interests of 70 window and door manufacturers − and the Minister of Climate and Energy signed a new voluntary energy labelling scheme for windows. The purpose is to make it easier for consumers to find energy-efficient windows. The schemes categorise products into a scale from A to C, where C is the mandatory target in the building code. Companies and products subject to the scheme will be regularly checked and companies will have to state the energy properties of their products.

According to an earlier agreement on the phasing-out of traditional sealed units and promotion of energy-efficient window solutions, the glazing industry has a voluntary labelling system for double glazing. Consequently, energy-efficient sealed units have become standard products and a campaign to promote their sales and those of other energy-efficient window solutions has been launched.

KNOWLEDGE CENTRE FOR ENERGY SAVINGS IN BUILDINGS

As part of the 2008 Energy Agreement, the government established a Knowledge Centre for Energy Savings in Buildings, which opened for the general public in January 2009.

The objective of the Knowledge Centre's work is to raise awareness in the construction sector of how energy savings in buildings can be achieved, and to ensure greater awareness of the building code requirements and hereby increase energy savings. The primary target group is tradesmen, contractors, advisors and consultants as well as smaller enterprises in the construction sector.

APPLIANCES

European Union regulations have to a large extent harmonised national measures relating to the publication of information on the consumption of energy and of other essential resources by household appliances, thereby empowering consumers to choose appliances on the basis of their energy efficiency.[13] In September 2010, the European Commission published a series of delegated regulations, which will enter into force in 2011. The aim of energy labelling is to provide incentives for industry to develop further improved products and innovations beyond the minimum mandatory energy efficiency levels.

These regulations will require manufacturers to declare the energy efficiency of televisions, refrigerators, dishwashers and washing machines, using an A to G scale, with A being the highest rating. The new labelling system allows up to three classes (A+ to A+++) to be added on top of class A so as to provide consumers with more differentiation between products. Energy labels are mandatory for all appliances placed on the EU market and they must be clearly displayed on each appliance at the point of sale.

The Danish Energy Saving Trust complements European measures with its Energy Saving Label scheme. The scheme, launched in 2006, is typically used on Denmark's top 20% most energy-efficient appliances, equipment and light bulbs in any given product category. The Trust ensures that the requirements are fulfilled through ongoing monitoring and carries out random testing on products. The Trust also provides purchasing and energy savings advice to consumers.

PUBLIC SECTOR

Since January 2006, all public buildings larger than 1 500 square metres must renew their energy label every five years. From July 2009, this provision was extended to all buildings. In addition to regular energy labelling of buildings, there are a number of requirements that state institutions must comply with so as to ensure energy efficiency.

The Danish Regions and Local Government Denmark have entered into agreements whereby regions and municipalities are to comply with the same requirements as the State regarding energy efficiency.

13. Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication, by labelling and standard product information, of the consumption of energy and other resources by energy-using products.

Curve Breaker Agreements

The Energy Saving Trust has introduced Curve Breaker Agreements with a number of municipalities. Municipalities that sign this agreement pledge themselves to reducing their annual electricity consumption by a certain percentage over an agreed number of years. The aim of the agreements is to reverse energy consumption trends by setting fixed targets for how to achieve savings.

The idea behind these agreements is to save energy, as well as providing a greener profile to the organisations making the efforts. As part of the agreement, organisations benefit from a range of tools to help them fulfil their targets. These cover user behaviour, purchasing and operations.

INDUSTRY

Total final consumption in the industry sector has been relatively flat over the past decade averaging 3.1 Mtoe per year. This suggests that industry has stabilised energy consumption while maintaining considerable growth at the same time. The government utilises two related tools to drive energy efficiency in the sector: taxation and voluntary energy agreements.

Since 1996, when the Green Tax Package was introduced, energy consumption by the sector has been subject to CO_2 and energy taxes.[14] The revenue from the taxes is redirected to trade and industry, and energy-intensive companies can receive a tax rebate.

Voluntary agreements on energy efficiency

Since 1996, Denmark has used voluntary agreements on energy efficiency as an important instrument to improve energy efficiency in energy-intensive companies. The voluntary agreement scheme is closely integrated with the Green Tax Package as companies that enter an agreement receive a rebate on the green taxes. The agreement system has two main objectives; first, to encourage energy-intensive companies to improve their energy efficiency, and second, to ensure that the international competitiveness of energy-intensive companies is retained.

The agreement system contains three essential elements:

- energy management;
- industry-specific investigations focusing on improving energy efficiency; and
- production processes investments in projects improving energy efficiency.

Each agreement contains a number of key elements: energy management, special investigations, and investments in energy efficiency. In addition, a number of measures are introduced in order to monitor and verify the process. All agreements cover a three-year period and are based on estimates of the company's production potential and estimated investments in the agreement period. Agreements can be renegotiated during the agreement period if the original estimates change considerably.[15] Each participating

14. Since 1995, a number of green taxes have been introduced for trades and industries as follow-up to the 1993 tax reforms and the 1994 report, *Green Taxes and Trades and Industries*.

15. *Voluntary Agreements on Energy Efficiency – Danish Experiences*, Danish Energy Agency.

company must submit reports on its compliance with the agreement to the Danish Energy Agency and all aspects of an agreement must be verified by accredited institutions. In rare cases of non-compliance, the agreement is rescinded and the company becomes subject to full taxation and tax rebates received by the company must be reimbursed.

Table 10. **Participation in Energy Agreements and tax levels**

	Heavy process		Light process		Space heating	
	With agreement	Without agreement	With agreement	Without agreement	With agreement	Without agreement
Energy tax (The full tax is EUR 6.8/GJ)	0%	0%	0%	0%	78%	100%
CO_2 tax (The full tax is EUR 13.4 per tonne CO_2)	3%	25%	68%	90%	78%	100%

Source: Danish Energy Agency.

In 2006, the Danish Energy Agency published an evaluation of the effectiveness of the voluntary agreements.[16] The report was unable to quantify the effect of the agreements but acknowledged that they improved overall energy efficiency by about 0.7% per year.

UTILITIES

Annual savings obligations are set for all energy distribution companies. In January 2010 the obligations were increased by 100%. The target corresponds to more than 1.2% of total final energy consumption. From 2011 savings are weighted in relation to lifetime, CO_2 emissions reductions and savings in areas outside the EU Emissions Trading Scheme. The obligations of energy distribution companies will be raised by 50% from 2013 and by 75% in 2017-2020.

COMBINED HEAT AND POWER AND DISTRICT HEATING

Denmark has the most extensive co-generated heat and electricity system in the EU and more than half of Danish electricity is co-generated with heat. There are more than two and a half million domestic heating installations in Denmark and more than half of these are district heating (DH) installations. Approximately 60% of heat consumers receive their heat from public heat supply.

Danish local authorities are the central players in the public heat supply; they develop heating plans and have responsibility for expanding district heating and for implementing any changes made necessary by amendments to the regulations in the Law on Heat Supply.

16. *Evaluation of the Danish Voluntary Agreements on Energy Efficiency in Trade and Industry*, Danish Energy Agency, 2006.

District heating (DH) consumers can receive heat from either heating plants or combined heat and power plants (CHP). Typically, CHP facilities are either centralised or decentralised; centralised CHP plants usually have much larger capacity than decentralised CHP. At present, there are approximately 16 centralised and 415 decentralised plants supplying public heating in Denmark.

One in three of the decentralised DH plants and one in seven of the decentralised CHP plants use environment-friendly fuels (straw, wood chips, wood pellets, biogas or waste). The remainder – by far the majority – use natural gas.

The Danish Energy Agency has set the general conditions for the establishment and operation of district heating. These conditions are intended to ensure that both cost-effectiveness and consumers' heating costs are taken into consideration.

The Danish Energy Regulatory Authority (DERA) and the Energy Supplies Complaint Board monitor the district heating sector and handle complaints regarding prices and conditions. The district heating sector is owned and operated in various ways. There are co-operatives, joint-stock companies and local authority companies (often interest group companies and local authority supply bodies).

In the district heating market, both production and network companies are monopolies and regulated as non-profit undertakings. DERA monitors their prices and delivery terms, and takes regulatory action if the prices and terms of the network companies are not in line with the non-profit regime.

The district heating sector comprises about 600 suppliers, which together supply about 60% of Danish housing with district heating. The 55 to 60 largest enterprises supply 60% of district heating. About 75% of DH production is at CHP plants. The remaining 25% is produced at smaller plants which primarily produce heating. DERA regulates the full consumer price of district heating, apart from the VAT element. There are no special taxes on district heating. Instead, taxes and duties are imposed on the fuel used to produce district heating.

Prices from district heating plants are adjusted in accordance with the “non-profit” principle. In contrast to enterprises operating under ordinary market conditions, where the market sets prices, district heating plants’ prices may only reflect necessary production and administration costs. The Heating Supply Act stipulates which necessary costs can be included in heating prices and DERA supervises these.

The price differences between the individual district heating plants therefore reflect the different levels of costs of the plants, for example differences in construction costs, type of plant, size, etc. There are also differences in the framework conditions to which the individual plants are subject, such as the choice of fuel and mandatory connection for customers.

DERA publishes consumer prices of district heating for residential flats and single-family houses on the DERA website and here consumers can compare suppliers’ prices. The published prices are those (including VAT) most recently notified to DERA by the individual district heating suppliers.

However, the prices provide no information about the heating costs for a specific given residence. In order to calculate the actual price, the consumer must start from the actual consumption of the residence (variable contribution) and the actual basis for calculating the fixed contribution (subscription and output contribution).

CRITIQUE

Energy intensity, adjusted for purchasing power parity (PPP), in Denmark is among the lowest in the IEA. Denmark has very substantial energy efficiency policies for buildings and is a world leader when it comes to building standards and requirements. The Danish Parliament has decided that these requirements will be strengthened once more; by 25% to 30% first in 2010, then again in 2015 and 2020.

The 2008 Energy Agreement determined ambitious goals for energy-saving initiatives. Total annual energy savings must be raised to 1.5% of the final energy consumption for 2006 (10.3 PJ per year), which corresponds to the combined energy consumption of about 110 000 Danish homes. Furthermore, Denmark must reduce gross energy consumption by 4% by 2020 relative to 2006. At the same time, it has been decided that the energy-saving requirements of energy companies will be increased by about 85% from 2010.

Energy Strategy 2050 identifies energy efficiency and renewable energy as the two key activities to put Denmark on track to meeting the long-term goal of fossil fuel independence and to help meet the 2020 targets of increasing the share of renewables, reducing gross energy consumption, and reducing non-ETS greenhouse gas emissions. The Strategy projects that in 2050 Danish energy consumption could be more than 50% more efficient than at present.

Denmark has built strong well-resourced institutions to support its energy efficiency activities. The remit of the Danish Electricity Saving Trust has been expanded with the creation of the Danish Energy Saving Trust with the mission to promote energy efficiency in households, the public sector, and the commercial and industrial sectors for all forms of energy use. The Trust promotes energy savings through information campaigns, knowledge sharing, market introductions, the development and presentation of standard energy-saving products and solutions, and project financing. Denmark has also established an Energy Saving Centre, where energy-saving practices in buildings and industry sector are promoted.

The energy utilities are the main actor providing help to actual implementation of energy saving, especially in existing buildings and private enterprises. From 2010, their annual energy saving obligations increased by more than 100% and will count towards 60% of the total annual energy-saving target.

To support member governments with their implementation of energy efficiency, the IEA has developed 25 energy efficiency policy recommendations. This consolidated set of recommendations covers 25 fields of action across seven priority areas: cross-sectoral activities, buildings, appliances, lighting, transport, industry and electric utilities. Denmark is regarded as one of only five countries that appear to have “fully implemented” or “substantially implemented” more than 40% of the IEA recommendations.

In the building sector, Denmark is a world leader in energy efficiency standards and requirements. In terms of stringency of building code standards, Denmark stands out as having one of the most advanced set of requirements

The building codes contain relatively strong measures that apply to both new and existing buildings. Building codes for existing buildings apply when the building undergoes a major renovation or when replacing components such as roofs, windows,

pumps, etc. Energy certification for the sale and rental of all types of buildings has been mandatory for more than a decade. Public buildings have mandatory energy efficiency improvement requirements, based on their regular certification every five years.

A system for successive strengthening of energy efficiency requirements for new buildings is in place and, from 2015, all new buildings will require less energy use than a passive house. The government's long-term vision, adopted in April 2009, is for all buildings to be "plus-energy" houses, meaning they produce more energy than they use. E*nergy Strategy 2050* builds on existing measures and will incorporate a "low-energy rating 2020" in the building regulations with a view to promoting the construction of new buildings with even lower energy consumption levels.

Denmark is also addressing the building workforce through an innovation and education programme. This work is important as low-energy buildings require new knowledge and more quality awareness from the construction workers and material suppliers. Furthermore, monitoring the implementation of the measures proposed by the government will require a large corps of suitably qualified inspectors.

In the commercial and public-sector buildings, Denmark is continuing its efforts to implement energy-efficient lighting systems. Specifying minimum efficiency performance standards (MEPS) for general service lighting in commercial buildings and targeted measures to stimulate better control of lighting in unoccupied spaces have a significant potential to improve Denmark's energy efficiency.

For industry there is significant use of obligation for energy utilities. That means that the energy utilities have a yearly obligation to assist its customers in introducing energy-saving measures. Denmark also has a tradition of voluntary agreements with industry, combined with economic incentives. But these agreements tend to be out-of-date because of the ETS and EU constraints (legal regulations).

For domestic appliances, Denmark is in the process of implementing the relevant EU directives. These regulations are supported by the innovative Energy Saving Label scheme, which identifies the most efficient appliances and bulbs to consumers. Voluntary agreements with industry are to be adopted in the areas of Set Top Boxes and Digital Television Adaptors. The Energy Saving Trust supports these measures with various information and certification schemes and efficiency-related tools and calculators aimed at consumers and small business.

Despite its achievements, Denmark has some scope to improve its energy efficiency policy portfolio. For example, Denmark could consider expanding its enforcement systems. Enforcement of energy efficiency policy is important for maximising energy savings and for ensuring the credibility of schemes. Denmark should establish and implement a suite of enforcement actions commensurate with the scale of any non-compliance and the value of lost energy savings.

There is also room for improvement with respect to policies promoting the financing of energy efficiency; there is a need to promote the benefits of energy efficiency investments to financial institutions and to assist them with developing energy efficiency investments for small and medium-sized enterprises.

The Danish government has worked hard to address deficiencies in the transport sector and has developed policies to promote modal shift and alternative fuels. The development of a Green Transport Policy and the establishment of a Centre for Green Transport are commendable steps.

Notwithstanding Denmark's impressive progress to date, the government should continue efforts to fully implement the IEA recommendations for improving energy efficiency (see Box 6). In particular, it should consider bringing together its various policies and measures under a single national strategy on energy efficiency.

RECOMMENDATIONS

The government of Denmark should:

- ☐ *Develop measures to ensure continued compliance and monitoring of updated building codes and energy-saving programmes.*
- ☐ *Develop energy-saving targets for the stock of existing buildings by means of incentives for investments in energy efficiency improvements.*
- ☐ *Continue its efforts to implement energy-efficient lighting systems and introduce targeted measures to stimulate better control of lighting in unoccupied spaces.*

Box 6. **IEA 25 energy efficiency recommendations**

To support governments with their implementation of energy efficiency, the IEA recommended the adoption of specific energy efficiency policy measures to the G8 summits in 2006, 2007 and 2008.

In 2011, in order to reflect emerging priorities, the IEA, in consultation with international experts and member countries, streamlined and updated the 25 recommendations. The updated 25 recommendations cover a robust portfolio of policies that member and non-member countries should consider in the context of their energy economies.

This portfolio of recommendations includes policies to cost-effectively increase energy efficiency by establishing market signals to motivate effective action, accelerate the introduction of new technologies, and strengthen and enforce minimum energy performance standards (MEPS) for appliances, lighting, equipment and building energy codes.

1. To improve energy efficiency across all sectors, the IEA recommends action in the following areas:

- energy efficiency data collection and indicators;
- strategies and action plans;
- competitive energy markets, with appropriate regulation;
- private investment in energy efficiency; and
- monitoring, enforcement and evaluation of policies and measures.

2. To achieve savings in the buildings sector, the IEA recommends:

- mandatory building energy codes and minimum energy performance requirements
- aiming for net zero energy consumption buildings;
- improving energy efficiency of existing buildings;

Box 6. **IEA 25 energy efficiency recommendations** (continued)

- building energy labels and certificates; and
- energy performance of buildings components and systems.

3. To achieve significant energy savings in the appliances and equipment sector the IEA recommends:

- mandatory energy performance standards and labels for appliances and equipment; and
- test standards and measurement protocols for appliances and equipment.

4. To achieve significant energy savings in the lighting sector, the IEA recommends:

- phase-out of inefficient lighting products and systems; and
- energy-efficient lighting systems.

5. To achieve significant energy savings in the transport sector, the IEA recommends:

- mandatory vehicle fuel efficiency standards;
- measures to improve vehicle fuel efficiency;
- fuel-efficient non-engine components;
- improving operational efficiency through eco-driving and other measures; and
- improve transport system efficiency.

6. To achieve significant energy savings in the industrial sector, the IEA recommends:

- energy management in industry;
- high-efficiency industrial equipment and systems;
- energy efficiency services for small and medium-sized enterprises; and
- complementary policies to support industrial energy efficiency.

7. Energy utilities and end-use energy efficiency

- Governments should establish regulatory and other policies to ensure that energy utilities support cost-effective, verifiable end-use energy efficiency improvements.

PART II
SECTOR ANALYSIS

5. RENEWABLE ENERGY

Key data (2010 estimates)

Share of renewable energy: 20.7% in TPES and 33.5% in electricity generation (IEA average: 7.7% and 17.7%), up from 11.4% and 17.1% in 2000

Biofuels and waste: 17.1% of TPES and 13.2% of total electricity generation

Wind: 3.4% of TPES and 20.2% of total electricity generation

Other renewable energy: 0.15% in TPES and 0.06% in electricity generation

OVERVIEW

Renewable energy policies have been at the heart of Danish energy strategy for almost three decades and with no hydropower resources of note, Denmark relies on wind and biomass for most of its renewable energy. It was an early mover in the wind energy industry and today Danish technology is a world leader. Should *Energy Strategy 2050* be fully implemented the renewable energy sector will form the cornerstone of the new energy economy.

SUPPLY AND DEMAND

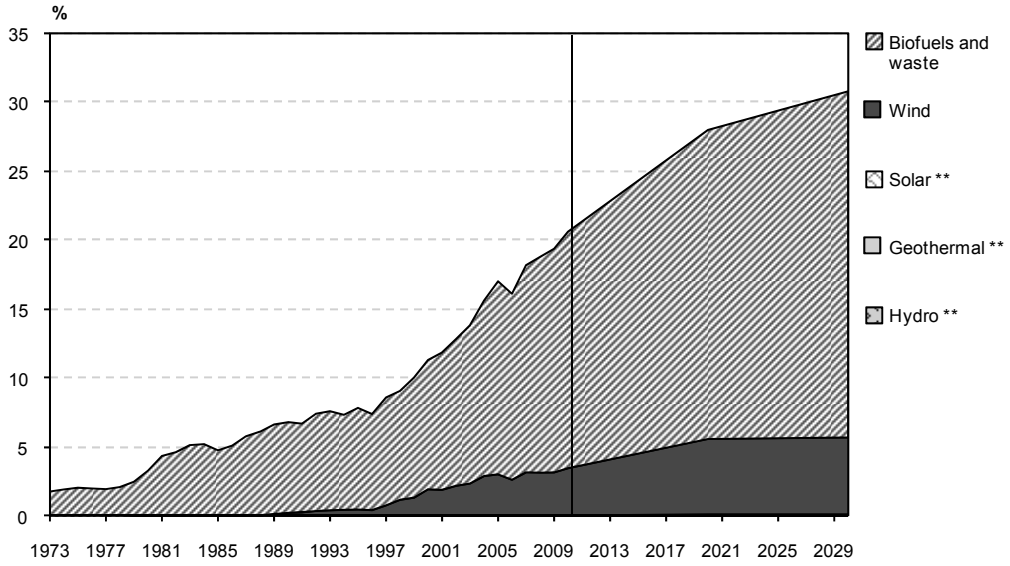
Over the past decade, Denmark has developed an enviable record of growing the share of renewable energy in its total primary energy supply (TPES). Since 2000, it increased at an average rate of 6.6% per year reaching 19.4% of TPES in 2009. Estimates indicate that production of renewable energy increased by a further 13% in 2010.

Biomass and waste is the largest renewable energy source, representing 17.1% of TPES in 2010, followed by wind, which contributed 3.4%, with a negligible contribution from other sources. Sources of biomass include fuel wood and vegetal products such as straw, which represent 12% of TPES, followed by waste, which represents approximately 5% of TPES, with the remainder coming from biofuels.

Among IEA-member countries, Denmark is a leader in terms of energy produced from waste, followed by Switzerland and far ahead of IEA third- and fourth-placed Sweden and Austria. In terms of consumption, 91% of waste is used in CHP plants and the remaining part in heat-only plants. In 2009, nearly half of solid biomass supply was used for heating purposes in the residential sector, 29% in CHP plants, and 17% in heat-producing plants.

Over the longer term to 2030, the Danish government forecasts a similar growth trend during the next decade, with renewable energy sources adding up to nearly 30% of total primary energy supply in 2020 in business-as-usual/without new initiatives and stabilising at this level until 2030. The large part of the increase will come from the biomass and waste sector and is expected to replace the drop in coal supply over this period.

Figure 14**. Renewable energy as a percentage of total primary energy supply, 1973 to 2030***

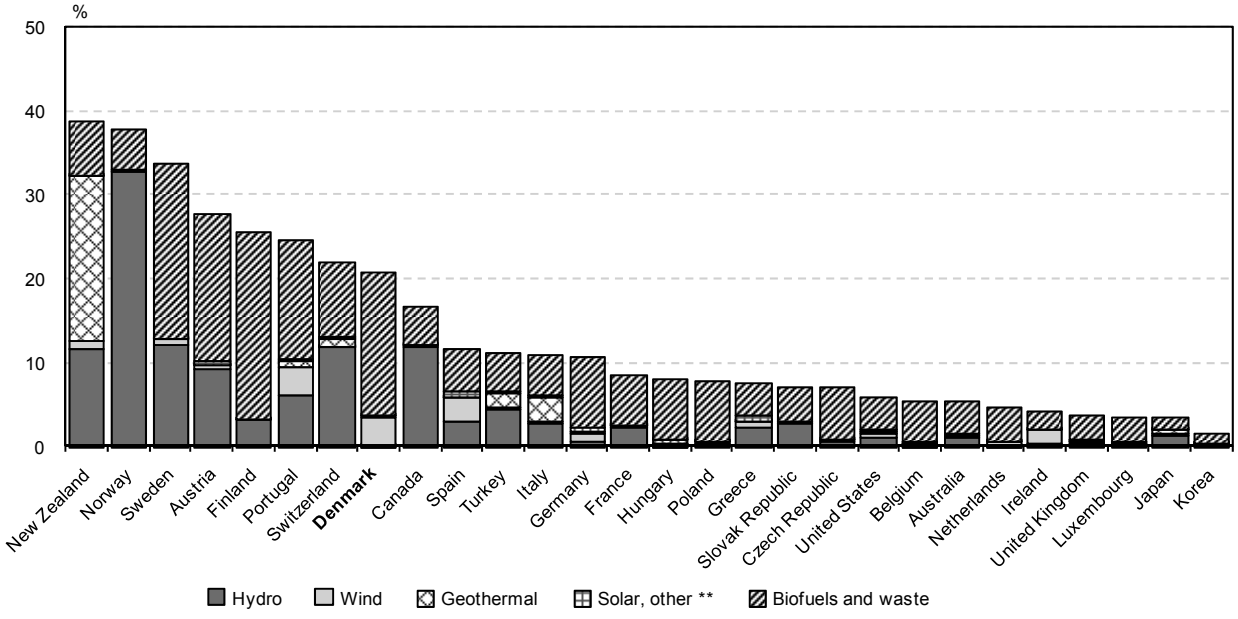


* Estimates for 2010 and government projections for 2020 and 2030.

** Negligible.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011.

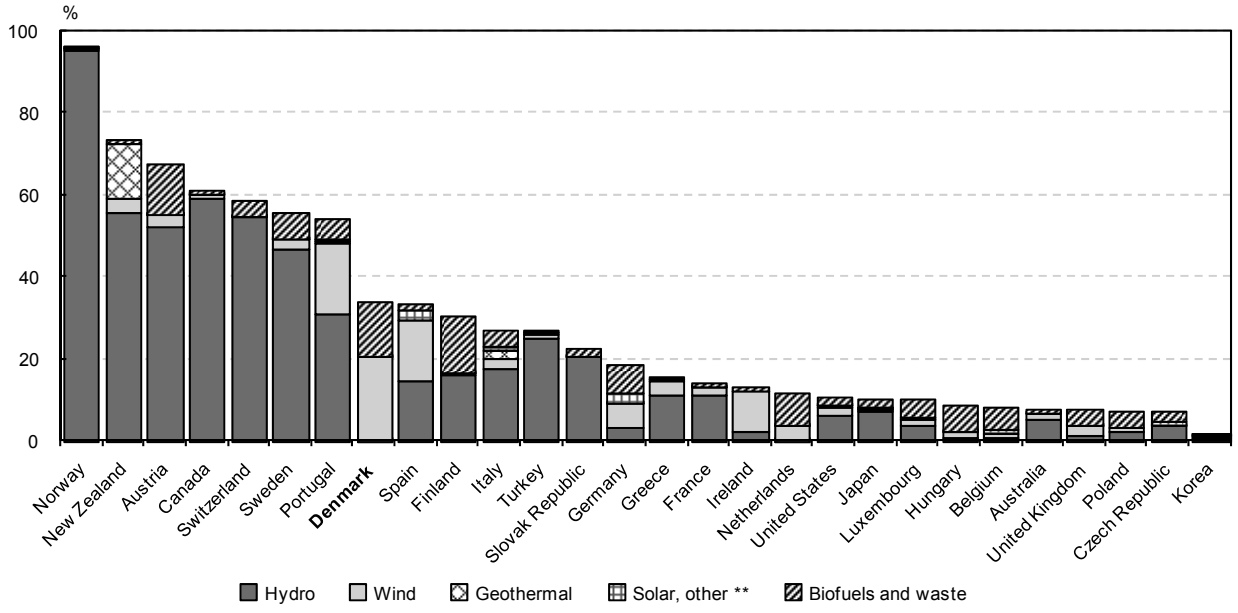
Figure 15. **Renewable energy as a percentage of total primary energy supply in IEA member countries, 2010***



* Estimates.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011.

Figure 16. **Electricity generation from renewable energy as a percentage of all generation in IEA member countries, 2010***



* Estimates.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011.

The long-term goal of the Danish government is independence from coal, oil and gas by 2050. Achieving this goal will require the development of a greenhouse gas neutral energy sector, which utilises 100% renewables, or a combination of renewables and coal/biomass with carbon capture and storage (CCS). Satisfying this ambition will also require a renewable energy-based transport sector. The transition to this long-term goal will pose strong challenges to the renewable energy sector.

INSTITUTIONS

The **Ministry of Climate, Energy and Building** is the lead ministry with responsibility for the development of renewable energy policy, energy agreements, legislation and regulations. The ministry and its agencies represent Denmark at international forums and energy-related regional co-operation.

The **Danish Energy Agency** (DEA), established in 1976, is an agency under the Ministry of Climate, Energy and Building. Its responsibilities in relation to renewable energy policy include: preparing energy agreements, legislation and regulations, the permitting wind turbines construction and managing tender processes for offshore wind farms.

Energinet.dk owns and operates the electricity transmission system. It administers a number of schemes aimed at promoting increased use of renewables energy sources and is responsible for ensuring that the power system is able to handle the increasing amounts of wind-generated electricity.

The **Ministry of the Environment** is in charge of administrative and research tasks in the area of environmental protection and planning. The administration at state level is

managed by the Ministry of the Environment. At regional and local levels, much of the administrative responsibility has been delegated to municipalities.

POLICIES AND MEASURES

OVERVIEW AND TARGETS

Danish energy policy has long supported renewable energy and energy efficiency policies as a means to reaching its broader energy policy goals. Danish renewable energy policy is to a large extent influenced by European Union energy policy and Denmark supports the view that EU member states should also work together to avoid any inappropriate competition between them.

Domestically, the Energy Policy Agreement of 21 February 2008, between the government and a number of other parliamentary parties, has the most significant influence on renewable energy policy. Proceeding energy agreements and energy laws also shape Danish renewable energy policy.

DOMESTIC MEASURES

2008 Energy Policy Agreement

In accordance with the 2008 Energy Policy Agreement, renewable energy must make up 20% of Denmark's gross energy consumption by 2011. The agreement improved framework conditions and enhanced support for wind, biomass, biogas, waste and other sources of renewable energy. The agreement also contains a series of initiatives to ensure that Denmark is able to meet these targets.

In addition to raising the price premium of power from the country's wind turbines, biomass and biogas, parties to the agreement committed to constructing 400 MW of new offshore wind turbines by 2012. The agreement also covered the creation of a compensation scheme for people living near wind turbines, a purchasing rights scheme, a green scheme and a guarantee fund. The agreement also set aside a further DKK 25 million for research into solar and wave power and other renewable energies each year for the four years of the arrangement.

The Promotion of Renewable Energy Act implements important parts of the political agreement. It entered into force in January 2009.

Green Growth Agreement 2009

In June 2009, the government and the Danish People's Party signed an Agreement on Green Growth. The purpose of the agreement was to ensure that a high level of environmental, nature and climate protection goes hand in hand with modern and competitive agriculture and food industries. The agreement includes a plan for the expansion of agriculture's role as a supplier of green energy, such as energy crops and biogas, and established the goal that up to 50% of livestock manure in Denmark is to be used for green energy in 2020. In 2012, the status of development of the biogas plants

will be assessed, including an evaluation of the need for any further initiatives to achieve greater energy exploitation of livestock manure.

EUROPEAN UNION MEASURES

Renewable energy policy in Denmark is also guided by EU requirements. The Directive 2009/28/EC on Renewable Energy sets ambitious targets for all member states, such that the EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share specifically in the transport sector.[17] Previous non-binding targets for 2010 for biofuels and electricity from renewable sources have been replaced by a binding target to increase the share of renewable energy in gross final energy consumption by 2020. Under Directive 2009/28/EC, Denmark must increase this share from 17% in 2005 to 30% in 2020.

Article 4 of Directive 2009/28/EC requires member states to submit national renewable energy action plans by 30 June 2010. These plans, to be prepared in accordance with the template published by the Commission, provide detailed roadmaps of how each member state expects to reach its legally binding 2020 target for the share of renewable energy in its final energy consumption.

Member states must set out the sectoral targets, the technology mix they expect to use, the trajectory they will follow and the measures and reforms they will undertake to overcome the barriers to developing renewable energy. Denmark submitted its National Action Plan in June 2010.

Table 11. **National 2020 target and estimated energy share from renewable energy sources in heating and cooling, electricity and transport**

	2005	2010	2015	2020
RE sources for heating and cooling (%)	23.2	30.8	36.0	39.8
RE sources for electricity (%)	26.8	34.3	45.7	51.1
RE sources for transport (%)	0.2	1.0	6.7	10.1
Overall share of RE sources (%)	**16.5**	**21.9**	**22.6**	**30.0**

Source: National Action Plan for renewable energy in Denmark.

ENERGY STRATEGY 2050

In early 2011, the Danish government published its long-term energy strategy, *Energy Strategy 2050*. This document elaborated on Denmark's vision of a future completely independent of reliance on fossil fuels by 2050. The Strategy contained a number of policies designed to increase the share of renewable energy. With the policies implemented, its share in total energy supply is projected to reach 33% by 2020. The Strategy identifies energy efficiency and renewables as the two key focus areas to put Denmark on track to meeting the long-term goal of fossil fuel independence and to help

17. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

meet the 2020 targets. Accordingly, many of the early objectives of the Strategy focus on policy in these two sectors.

Energy Strategy 2050, published in early 2011 following the publication of the findings of the Commission on Climate Change Policy in 2010, outlines the energy policy instruments needed to deliver the Danish government's vision of becoming independent of coal, oil and gas. The government's goal is a greenhouse gas-neutral energy sector, which utilises 100% renewables or a combination of renewables and coal/biomass with room for CCS if the technology in the long term proves to be commercially attractive. The ambition is also for a renewable energy-based transport sector; however, this goal is less certain in the medium term. The Strategy identifies the potential elements in an energy and transport system independent of fossil fuels (see Box 7).

Box 7. **Key elements of the Danish energy system of the future**

- Highly-efficient energy consumption.
- Electrification of heating, industry and transport.
- More electricity from wind power.
- An efficient utilisation of biomass resources.
- Utilisation of biogas.
- Photovoltaic solar modules and wave power as supplements.
- Spreading renewable energy-based district heating and individual heating.
- An intelligent energy system.

Source: *Energy Strategy 2050*.

In the Strategy, the government presents a package of energy and climate policy initiatives. The package includes initiatives with immediate effect, initiatives setting out long-term frameworks, and initiatives that encourage technological development.

In the period up to 2020, the new initiatives are projected to reduce the use of fossil fuels in the energy sector by 33% compared with 2009. If fully implemented, the Strategy will also increase the share of renewable energy in total energy supply to 33% by 2020 and it will reduce primary energy consumption by 6% by 2020 compared with 2006 owing to a strong focus on energy efficiency improvements.

The Strategy identifies a large number of actions relating to the expansion of renewable energy under each of the relevant initiatives.

Strategy 2050 initiatives

Increased expansion of wind power: Over the longer term, Denmark expects that wind will be able to compete with the costs of conventional electricity production. Therefore, subsidy mechanisms for onshore wind turbines can gradually be phased out. *Energy Strategy 2050* acknowledges that in the future most development will happen offshore, since there are only a limited number of suitable locations available onshore. In order to maximise the potential of offshore wind, newly developed turbines will have to be erected and operated on a continuous basis, ideally closer to the coast than was the case

in the past. For this to happen, the Strategy identifies a number of government actions that need to be completed as soon as possible. These actions are summarised in Table 14.

Greater use of biomass: the Strategy sees considerable potential for biomass to cost-effectively replace large amounts of coal and natural gas in the short term. At present, the majority of large-scale power plants in Denmark have the technical ability to utilise biomass for part of their production. The Strategy acknowledges that, in the long term, conversion from fossil fuels to renewable energy outside Denmark will lead to pressure on biomass resources and thus rising prices, and possible challenges to security of supply.

A solid foundation for biogas expansion: agriculture will play a key role as a green energy supplier in the transition to fossil fuel independence. In accordance with the national Green Growth Agreement, the government wants Denmark to aim for the exploitation of up to 50% of livestock manure for green energy. There are large unexploited biogas resources, especially in the form of livestock manure in agriculture. These can replace natural gas, oil and coal for energy purposes. Greater use of livestock manure will also benefit the aquatic environment and will contribute to reducing emissions of greenhouse gases from agriculture, which in turn will contribute significantly to meeting Denmark's international climate commitments.

A transition to green energy in the transport sector: as a major consumer of fossil fuels, the transport sector will have to go through a radical transformation before 2050. In the short term, greater use of biofuels is expected as is more efficient combustion engine technology. In the long term, electric power will be the likely source of energy. Therefore, the necessary infrastructure will be needed. Work to establish the required framework and infrastructure is already well under way in Denmark, and incentive and supports are already in place.

PLANNING

The political framework conditions for onshore wind turbines have been agreed in part in the Energy Policy Agreement 2008 and subsequently implemented in the Danish Promotion of Renewable Energy Act, which was adopted by the Danish Parliament in December 2008 and entered into force on 1 January 2009. As a general rule, the municipalities are responsible for the planning of onshore wind turbines. The Agency for Spatial and Environmental Planning, part of the Ministry of the Environment, manages legislation on planning activities in connection with onshore wind turbines.

Following the local government reform in 2007, the planning authority for onshore wind turbines up to 150 metres has passed to the municipalities. The regulations for municipal planning ensure that citizens, associations, authorities and other stakeholders are continuously involved in the process. In order to be able to assist the municipalities in this work, the Danish Ministry of the Environment has set up the Wind Turbine Secretariat under the Agency for Spatial and Environmental Planning.

The Promotion of Renewable Energy Act contains four new schemes to promote the development of wind turbines on land: loss of value to real property due to the erection of wind turbines, local citizens' option to purchase wind turbine shares, a green scheme to enhance local scenic and recreational values and a guarantee fund to support financing of preliminary investigations by local wind turbine owners' associations.

The Danish Energy Agency is the planning authority for electricity-generating installations at sea. Thus, investors need to receive licences from the Danish Energy Agency when an offshore wind power project is to be established. The Danish Energy Agency serves as a ”one-stop-shop” for permits to offshore wind farms in the way that the Danish Energy Agency co-ordinates with other relevant authorities with regard to their interests and conditions. Thus, the project developer does not have to rustle alone with the many, often opposing, interests connected to the establishment of offshore wind power projects.

In 2005, the Ministry of Energy and Transport requested the Danish Energy Agency to appoint a committee to identify suitable sites for the development of large-scale offshore wind parks. The committee examined 23 specific possible sites, each of 44 square kilometres to an overall area of 1 012 square kilometres divided between 7 offshore areas. The committee recommended that any forthcoming expansion of offshore wind farm construction should take place in a prioritised order and recommended that the first farm be constructed at Djursland-Anholt in the Kattegat.

In order to ensure that the necessary transmission infrastructure is ready for commissioning at the time the offshore wind turbines enter operation, the committee recommended that a long-term localisation plan must be drafted for the expansion of offshore wind power. Co-ordination between central, regional and local authorities, when implementing a localisation plan, is crucial to streamlining administrative procedures.

Energinet.dk is responsible for connecting wind turbines and other energy sources to the electricity grid, paying subsidies for environment-friendly electricity production and the handling of system operations, securing sufficient production capacity and ensuring that the electricity infrastructure supports the increasing use of renewable energy.

Box 8. **Promotion provisions in the Renewable Energy Act (RE Act)**

National targets for the combined local authority planning for wind turbines.

Four new schemes for the promotion of wind turbines:

- compensation for loss of property value due to the erection of wind turbines;
- model for local ownership through purchasing rights to wind turbines for local inhabitants;
- a green plan for reinforcing local countryside and recreational values; and
- a guarantee scheme for financing preliminary investigations by local wind turbine associations.

Rules for authorisation of offshore electricity generation (including the tendering of offshore wind farms).

Rules for connecting wind turbines to the electricity network.

Technical and safety requirements for wind turbines.

Rules on the regulation of electricity generation from tendered offshore wind turbines.

Box 8. **Promotion provisions in the Renewable Energy Act (RE Act)** (continued)

Subsidies for utilities generating electricity from renewable energy sources.

Pool for small renewable energy technologies.

Onshore wind turbines are regulated by the Planning Act. The rules for spatial planning do not apply offshore, which is why licences for the establishment of electricity-generating installations (primarily wind power, although they can also be wave power, or similar) are issued in pursuance of the Renewable Energy Act. These acts also contain regulations on environmental impact assessment (EIA) and other impact assessments.

Source: Ministry of Climate, Energy and Building.

ELECTRICITY FROM RENEWABLE ENERGY SOURCES

Renewable energy sources provided 28% of Denmark's electricity supply in 2009. Of this, wind power generated 6.7 TWh or 18.5% of total electricity generation, which is the largest share of wind among IEA member countries. Electricity generated from biomass and waste provided 11% of electricity in 2009, the second-largest share among IEA member countries, only Finland having more, with 12.4%. The contribution of other sources of renewable energy to electricity has been negligible to date but Denmark has invested in research related to a number of other technologies, most notably ocean and wave power.

Between 1990 and 2008, net generating capacity from renewable and waste sources grew from 413 MW to 4 120 MW with the majority of this increase coming from wind energy, which added approximately 2 850 MW of capacity over the period, increasing by an annual average of 13.1%. Output from renewable capacity increased from 848 GWh in 1990 to 10 693 GWh in 2009 or at an average of 15.2% per year. Approximately 36% of electricity was produced as combined heat and power fuelled by solid biomass, waste and biogas.

WIND POWER

Climate and location confer a strong advantage on Denmark and favours wind power as a renewable energy source. Wind conditions are generally more favourable for electricity production than in many other European countries. Denmark also enjoys first-mover advantage in the wind power sector and has built up a strong technological and research capacity, which supports a solid manufacturing base. The Danish Energy Agency (DEA) estimates the combined global market share of the two largest Danish wind turbine manufacturers was just over 27% in 2008.

Table 12 shows key figures for power generation in eastern and western Denmark in 2009 when both electricity systems were not interconnected.

Investment in recent years has been focused on fewer – but larger – wind turbines, while the combined wind turbine capacity has been relatively constant. Additional wind power capacity in the coming years will come from offshore wind farms. In 2009, wind power capacity in Denmark increased by approximately 319 MW, of which 75% came from offshore wind farms. More recently, DONG Energy won the tender for Anholt

Offshore wind farm, and has been awarded the concession for building and operating the wind farm, which includes permission for further preliminary investigations and permission to establish the wind farm. DONG Energy will get a feed-in tariff of DKK 1.051 per kWh for 20 TWh. Energinet.dk will be responsible for financing and constructing the substation at sea and connecting the farm to the electrical grid on land.

Table 12. **Renewable energy, 2009**

	Eastern Denmark	**Western Denmark**	**Denmark**
Wind share of net generation in area	13.7%	22.5%	19.6%
Wind share of consumption in area	11.5%	25.5%	19.8%
RE share of net generation in area	26.3%	29.5%	28.5%
Electricity accounts for the grid 2009	**GWh**	**GWh**	**GWh**
Electricity generation ex facility (gross, including own consumption)	12348	24077	36425
Electricity generation ex facility (net, including own consumption)	11552	22738	34290
Imports, gross	4965	6299	11264
Exports, gross	2443	8487	10930
Grid loss in transmission grid	326	426	752
Sale to distribution	13747	20124	33872
Specification of electricity generation			
Electricity from wind turbines	1587	5123	6710
Electricity from hydropower and photovoltaics	0.1	20	20
Electricity from thermal production on RE-fuels	1454	1575	3029
Electricity from thermal production on non-RE-fuels	8510	16021	24531

Source: Energinet.dk.

As of May 2010, Energinet.dk estimates that there were 5 052 wind turbines in Denmark with an installed wind power capacity of 3 545 MW, offshore wind power accounting for 505 MW. Since then, Horns Rev II and Rødsand II have been commissioned. Therefore, in 2010, Denmark had approximately 870 MW of offshore wind capacity. As of 2010, wind power production accounts for approximately 22% of domestic electricity supply and produced 7 818 GWh of electricity.

The share of wind power varies slightly from year to year, for two reasons; first, because the wind energy content can vary by up to between 15% and 20% from normal levels from one year to the next, and second, because it reflects the level of generation at the remaining power stations and plants, which itself depends on the demand for electricity and heating as well as international trade in electricity.

Figure 17. **Location of offshore wind farms**

This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory covered by this map.

Source: Danish Energy Agency.

Table 13. **Denmark's offshore wind capacity**

Location	Number of turbines	Capacity
Vindeby	11	5 MW
Tunø Knob	10	5 MW
Middelgrunden	20	40 MW
Horns Rev I	80	160 MW
Rønland	8	17 MW
Nysted	72	165 MW

Table 13. **Denmark's offshore wind capacity** (continued)

Samsø	10	23MW
Frederikshavn	30	7 MW
Horns Rev II	91	209 MW
Avedøre Holme	3	10 - 13 MW
Sprogø	7	21 MW
Rødsand	90	207 MW
Planned offshore wind parks		
Anholt	-	400 MW

Source: Danish Energy Agency.

As part of the objective for renewable energy to constitute 20% of gross energy consumption in 2011, the Danish government entered into an agreement with Local Government Denmark that the municipalities, through their planning mechanisms, should reserve areas that can accommodate onshore wind turbines with a total output of 150 MW and 75 MW in each of the years 2010 and 2011 respectively.

SUPPORT MECHANISMS

In Denmark, the production of electricity from renewable resources is supported by price premiums and fixed feed-in tariffs. Historically, the level of support has changed many times, but it is a general rule that the support scheme, which was in place when a production unit was connected to the grid, applies for the lifetime of the production unit. As a result, there is a high level of certainty about future support at the time of investment.

In 2008, the level of support was increased for electricity produced from biomass, biogas and wind turbines. The support level for production from solar PV, wave power, fuel cells running on renewable fuels, among others, remained unchanged, but a special fund of DKK 25 million per year for four years was introduced to support projects which promote these technologies. Development and demonstration of new energy technologies is supported by the Energy Technology Development and Demonstration Programme (EUDP) fund which distributed DKK 750 million in 2009 and DKK one billion in 2010 and each year onwards.

New units producing electricity by burning biomass receive DKK 0.15 per kWh electricity. New units producing electricity only from biologically or thermally gasified biomass receive a fixed feed-in tariff of DKK 0.745 per kWh. If the biogas is mixed with other fuels, the part of the electricity produced from biogas receives a price premium of DKK 0.405 per kWh. In combined heat and power plants, the heat produced from biomass is exempt from energy taxes.

Special renewable energy technologies such as wave power, solar PV, fuel cells running on renewable fuels receive a fixed feed-in tariff of DKK 0.60 per kWh for 10 years and DKK 0.40 per kWh for the following 10 years. There is no feed-in tariff or price premium

for solar PV units below 6 kW that are connected to the installation in private homes. However, these units are exempt from energy taxes, and can in popular terms let the electricity meter "run in reverse", corresponding to a feed-in tariff of approximately DKK 200 per kWh.

The Agreement on Green Growth has introduced a starter pool of DKK 85 million annually for the establishment of new common biogas plants and farm unit-related investments associated with connection to a common plant from 2010 to 2012.

Danish support for the environmentally benign production of electricity is paid by a public service obligation (PSO) by all electricity consumers.

Box 9. **Tariffs for electricity produced by wind turbines**

The development of wind power in Denmark has been promoted since the late 1970s by paying wind turbine owners a supplement to the electricity production price. Even though the electricity market in Denmark was liberalised in 1999 and the market price could fluctuate according to supply and demand, wind turbine owners were guaranteed a fixed feed-in tariff.

The Energy Policy Agreement of 2004 granted wind turbine owners a production subsidy of DKK 0.10 for 20 years as a supplement to the market price. In the Energy Policy Agreement of February 2008, it was decided to increase the production subsidy to make it more attractive to investment in onshore wind turbines.

As the 4 700 or so onshore wind turbines were erected at different times, the production subsidy varies, depending on the date of grid connection and the size of the turbines. The detailed conditions are set out in the Danish Promotion of Renewable Energy Act, which contains all the tariffs for electricity produced by wind turbines.

New onshore wind turbines connected to the grid after the Energy Policy Agreement of 21 February 2008 receive a supplement to the market price of DKK 0.25 per kWh. This supplement applies for the first 22 000 full-load hours, after which the wind turbine owner only receives the market price. Furthermore, a supplement of DKK 0.023 per kWh is paid to cover balancing costs for the full lifetime of the turbine.

New wind turbines established with a scrapping certificate receive an extra supplement of DKK 0.08 per kWh for 12 000 full-load hours. Offshore wind turbines established under an open-door procedure receive the same supplement as new onshore wind turbines, *i.e.* DKK 0.25 per kWh plus DKK 0.023 per kWh. In the case of offshore wind turbines established as part of a government tender, the supplement depends on the price at which the tendering party is prepared to produce electricity. This price will usually depend on the estimated construction costs, the local wind conditions, and the project developer's financing terms.

Source: *Wind Turbines in Denmark*, Danish Energy Agency.

WIND INTEGRATION

Wind power brings variability and uncertainty to power systems. This has potential impacts on power system reliability and efficiency. These impacts can be either positive

or negative; however, large amounts of wind power usually turn even positive impacts to negative at some stage of penetration level with regard to the cost of integration.[18] High penetration of wind power has impacts that have to be managed through proper wind power plant interconnection, integration of the generation, transmission planning, and system and market operations.

Current levels of wind penetration in Denmark suggest that wind power can make a substantial contribution to electricity capacity without significant reconfiguration of the electricity system. Nonetheless, Denmark's ambitious targets for 2020 and beyond will require the integration of even higher volumes of wind power, much of it offshore, and this will create a whole series of new challenges for policy makers and stakeholders. To achieve its goals, Denmark will have to review the design and operation of the electricity system, grid connection policies and mechanisms, network infrastructure expansion and market rules.

For Danish policy makers to achieve their objectives, detailed consideration will have to be given to all measures to increase system flexibility – more flexible generation, greater demand-side response mechanisms, higher levels of interconnection and exploration of storage opportunities. Accurate wind forecasting combined with complementary market rules, for example short gate-closure times, can to some extent reduce the need for additional reserve capacity at higher levels of wind penetration. Greater use can be made of existing plants, especially gas-fired open-cycle gas turbines (OCGT) or combined-cycle gas turbines (CCGT). Higher interconnector capacity will also allow sharing of reserves and ancillary services with other markets.

The European Wind Energy Association estimates that 1% to 15% of reserve capacity is required at a wind penetration level of 10%, and 4% to 18% at a penetration level of 20%. A 2007 energinet.dk study went further and investigated the impact of doubling Denmark's wind power capacity by 2025, noting that approximately 60% of the increase in capacity will happen offshore.[19] This increase in capacity will deliver an increase in wind power's share of electricity output to 50%.

Energinet.dk made assessments of the energy balance, fuel consumption, emissions, power balance, the need for ancillary services and the transmission grid. The study found that meeting the target will call for greater exploitation of both domestic flexibility and international power markets. Greater integration can be facilitated by the use and further development of couplings of the wind power-dominated electricity system to district heating systems, the transport sector (*e.g*. via electric vehicles) and energy storage systems. Countermeasures could also be implemented on several sides of the power system:

- *At the market side*: market coupling (*e.g.* Nord Pool-EEX) to increase the possibilities of sharing reserves, improvement of intra-day trading possibilities and international exchange of ancillary services.

18. *Design and operation of power systems with large amounts of wind power final report*, Phase One 2006-2008, IEA Wind Task 25. VTT Technical Research Centre of Finland, 2009.

19. Eriksen, P.B.; Orths, A.: *Challenges and Solutions of Increasing from 20 to 50 Percent of Wind Energy Coverage in the Danish Power System until 2025*; Invited Keynote Paper; Proceedings of the 7th international Workshop on Large Scale Integration of Wind Power and on Transmission Networks for Offshore Wind Farms; 26/28 May 2008, Madrid, Spain.

- *At the electricity production side*: utilisation of an electricity management system for wind power plants, which regulates the generation, geographical dispersion of offshore wind farms, mobilisation of regulating resources and new types of plants, and further improvement of local scale production units working on market terms.
- *At the electricity transmission side*: reallocation of the grid connection points for offshore wind power plants, increased grid transmission capacity, *e.g.* including the utilisation of high-temperature conductors, and reinforcement and expansion of the domestic grid and interconnections.
- *At the demand side*: further development of price-dependent demand, using and strengthening the coupling of the power system to heating systems (electric boilers and heat pumps), developing and exploiting coupling of the power system to the transport sector (electric vehicles as price-dependent demand), and introduction of energy storage (hydrogen, compressed air energy storage, batteries).

Table 14. **Challenges and countermeasures to large-scale integration of wind**

System design and operation	Reserve capacities and balance management
	Short-term forecasting
	Demand-side management
	Electricity storage
	Wind contribution to system adequacy
Grid connection	Power quality
	Grid codes
Network infrastructure	Congestion management
	Extension and reinforcement
	Offshore connections
	Interconnections
	Smart grids
Market design	Market rules

Source: European Wind Energy Association.

IEA STUDY ON GRID INTEGRATION OF VARIABLE RENEWABLES

A recent IEA study addressed the impacts of large, centralised variable renewable power plants on the balancing of electricity supply and demand.[20] The study found that, in Denmark, from a purely technical perspective, some 63% penetration of variable renewable energy (VRE) in gross electricity demand could be balanced by existing flexible resources. More generally, the report concluded that power systems have greater capacity to handle variable renewable electricity (wind, solar, tidal and wave

20. *Harnessing Variable Renewables, A Guide to the Balancing Challenge*, IEA Paris, 2011.

power) than commonly believed. The study rated Denmark highest on its Flexibility Index, mainly the result of its strong interconnection to adjacent areas, with which it is balanced as part of one market, highlighting the importance of interconnection to areas with different variable and flexible resources.[21]

Box 10. **IEA recommendations to policy makers**

The IEA publication *Harnessing Variable Renewables* contained a number of recommendations for policy makers:

Policy makers should look to the specific resource mix in their jurisdictions when considering the flexible resource portfolio.

A balanced approach to increasing flexibility is needed as variable power plant capacity grows.

Adjacent power markets should collaborate to share their portfolios of flexible resources, using the whole more efficiently to balance increasing shares of variable renewables.

The latest variable renewable energy (VRE) output forecasting techniques should be taken up in areas targeting significant deployment, and these should have material impact on the commitment of power plants in the system. Markets should feature short gate-closure times, allowing trading of electricity to continue up to within the hour before time of operation, to minimise the "lock-in" of valuable flexible resources.

Policy makers should assess the adequacy of economic incentives presented by the market (through fluctuating prices) for provision of the flexibility services.

Policy should remove (unnecessary) regulatory barriers to the provision of flexibility services, such as non-electrical constraints on the use of hydro plants for balancing.

Policy makers should encourage holistic, early planning of energy system development. VRE power plants should be dispersed as widely as possible within the bounds of high quality resources (*e.g.* strong winds) to maximise the smoothing of their aggregated output.

Policy makers should therefore urgently ascertain where grid weaknesses exist, and where congestion is likely therefore to occur, and commence planning any remedial measures as soon as possible. Smart grid technologies such as dynamic line temperature monitoring may be of significant benefit in this regard.

Areas with more ambitious plans for variable renewables deployment may need immediately to start planning how they will increase their flexible resources (for when the availability of existing resources has been optimised).

Policy makers should consider the operational costs of greater wear and tear resulting from increased cycling of existing and new dispatchable plants due to increasing variability in the net load.

21. A Flexibility Index (FIX) is a simple measure, which takes into account existing needs for flexibility, and normalises flexible resources across the different case study areas by dividing their technical flexible resource by their peak demand.

Box 10. **IEA recommendations to policy makers** (continued)

In future, it is possible that quickly dispatchable generating capacity will cease to be the sole primary driver of flexibility. New storage technologies may emerge that are less dependent on geographically limited resources like rainfall, or geological features.

Policy makers are encouraged to view the electricity system as only a part of a wider energy system, including the heat and transport sectors. Technologies such as electric vehicles and increased electrical heating (in effect the storage of electricity in car batteries or as heat) are becoming increasingly significant. Thus, policy initiatives in the electricity sector have important implications for the other two sectors, and vice versa, and should take them into account.

Source: IEA.

ELECTRICITY FROM BIOMASS

In 2010, solid biomass and biogas contributed 3 400 GWh to gross renewable electricity production, representing 26% of total gross renewable electricity production. All of this electricity was generated in the form of CHP. Biomass-fuelled CHP plants have been a common part of the Danish electricity and district heating supply for decades. There are over 200 district heating plants and 15 CHP plants fuelled by solid biomass and 30 biogas-fired CHP plants.

Biomass consumption (wood and straw) in the Danish electricity sector is divided between both power stations and local CHP plants. Around two-thirds of the straw and wood is consumed by power stations, while one-third is fired at the 15 or so small local biomass plants. Some 147 local CHP plants – with a combined capacity of 80 MW – use biogas as a fuel.

In 2010, power generation from biofuels totalled 3 068 GWh. It has remained relatively stable from one year to the next, but biofuels-based power generating capacity has been increasing in Denmark in recent years. The most recent addition is a separate straw-fired unit commissioned at Fyn Power Station in 2009.

FUTURE OF BIOMASS SUPPLY

The Danish Ministry of Food, Agriculture and Fisheries conducted a study on the outlook for Danish biomass production.

It found that Danish production of biofuels based on first-generation exploitation of starch and sugar products will hardly be competitive, even if the EU maintains high tariff barriers against imports of bioethanol. Therefore, there are no expectations of a considerably changed crop composition in Danish agriculture as the bulk of the crops will continue to be used in the animal sector.

The Danish agricultural sector's contribution to bioenergy production is already relatively high as 12% of Danish energy consumption is covered by the use of residual products such as straw, wood chips and slurry. This is, in particular, a result of the use of these residual products in the CHP sector.

In Denmark, however, the potential for producing bioenergy from biomass is greater, and also without any particularly negative impact on the production of animal feed and

foods. Estimates show that it is possible to raise Danish agricultural production of biomass for bioenergy four to five times through greater exploitation of straw at CHP plants, slurry for biogas, animal fat for biodiesel and by using perennial energy crops as well as grass from low-lying areas. It will, however, be necessary to include part of the former set-aside land in the production of perennial energy crops. It is a matter of technical potential, which may not necessarily be realised within the economic framework that applies today. The previous Danish settlement price for electricity from biogas plants constitutes a barrier, but has now been improved. Nor is it certain that the farmers will consider the profit from utilising low-lying areas sufficiently large to harvest this biomass.

POWER GENERATION FROM HYDROPOWER

Hydropower makes a very small contribution to renewable electricity supply. Denmark has 38 small-scale hydroelectric power plants, which in 2009 generated a total of 19 795 MWh. The largest plant, Tangeværket at Gudenåen, has an installed capacity of 3.9 MW.

OCEAN AND WAVE ENERGY

Energy from wave and ocean power makes no contribution to Danish energy supply at present. Instead, development work is focusing on new technology and conducting sea tests of large-scale models. Denmark is also interested in the possible synergy effects between ocean power and offshore wind farms. In 2009, there were seven wave-power plants with permission to test in Danish seas.

HEATING AND COOLING

District heating is widespread in Denmark. The sector supplies around 60% of domestic housing with heat, corresponding to 45% of the total heat requirement. Almost half of district heat is produced from biomass and organic waste. The Danish Energy Agency's studies have demonstrated that there remains much economic and environmental potential in replacing natural gas with district heat for heating and the DEA has encouraged local authorities to promote projects for the conversion of natural gas to district heating.

The DEA forecasts that biomass consumption for heating is expected to increase from 1 759 thousand tonnes of oil-equivalent (ktoe) in 2005 to 2 643 ktoe in 2020 (74 petajoules in 2005, 111 in 2020). At present, a number of conditions promote the use of renewable energy in district heat generation, among them the fact that biomass is non-taxable. Co-generation and district heating plants that supply co-generation areas are able to use electricity for heat, taking advantage of heating elements with a lower tax.

The Green Growth Agreement introduced subsidies for biomass installations and subsidy equality for the sale of biogas to both co-generation plants and the natural gas network. The agreement focuses on breaking down the non-economic barriers for expansion of biomass. The Planning Act will also be amended to allow further penetration of biomass.

A smaller contribution is also expected from solar energy. Over the last few years, large solar installations for district heating have been established in a number of locations in Denmark. The contribution from solar energy is expected to be 16 ktoe by 2020 as opposed to 10 ktoe in 2005 (0.4 PJ in 2005, 0.7 in 2020).

Geothermal use is limited in Denmark. At present, there are small installations at Thisted and at Mariagerholm near Copenhagen. Nonetheless, interest in geothermal is growing and the Danish Energy Agency has accepted a number of applications for licences for the investigation and reclaiming of geothermal energy. A new facility is expected to come into operation in Sønderborg in 2011.

For obvious reasons, cooling in buildings is only used in Denmark to a very limited extent. The Municipal District Cooling Act, passed in 2008, allows local authorities that own district heating companies to establish and operate district cooling activities. Currently, there is one district cooling project in Copenhagen run by Energy Copenhagen. This will also use a small amount of sea water for district cooling.

TRANSPORT FUELS

Fuel mixing obligations were introduced with the Act on Sustainable Biofuels (Act No. 468 of 12 June 2009). The act aims to promote the use of sustainable biofuels in land transport so that Denmark can meet its international climate commitments.

Accordingly, an importer or manufacturer of petrol or diesel has an obligation to ensure that biofuels make up at least 5.75% of the company's total annual sale of fuel to land transport, measured according to energy content. This target is being phased in over a three-year period: 0.75% in 2010, 3.35% in 2011 and 5.75% in 2012. Furthermore, biofuels are also exempt from the CO_2 tax levied on petrol and diesel.

The government plans to meet its 10% 2020 target by increased use of biofuels in the transport sector and by promoting electric vehicles. The Energy Technology Development and Demonstration Programme (ETDDP) has contributed DKK 200 million for the development and demonstration of second-generation biofuels.

FUNDING FOR SMALL-SCALE RENEWABLE ENERGY TECHNOLOGIES

Funding will be allocated for the spread of smaller capacity electricity-producing installations, generally solar cells, wave power and biogas installations that use technologies that have significance for the future production of electricity from renewable sources.

Support is provided from a fund comprising DKK 25 million per year for four years, from 2008 to 2011. Finance is provided to promote the introduction of installations onto the market including, to a lesser extent, support for pilot projects. Support is conditional on the installation being network-connected.

Support can also be provided for the establishment of installations, the operation of installations for a given period, or information on the energy properties of installations. Support for establishment and operation can be given together with the price subsidy for other renewable energy installations.

The support fund is administered by Energinet.dk, who makes a call for applications once a year.

CRITIQUE

Denmark has an enviable record among OECD nations in terms of developing non-hydro renewable resources. According to most recent data, renewable energy provides approximately 21% of total primary energy supply and 34% of electricity production. Furthermore, renewable energy contributes about 30% of energy production in district heating, largely from bioenergy (straw, wood, waste and biogas). The district heating network presents a valuable asset that can be used as an energy storage mechanism which will help integrate the large amounts of variable renewable electricity into the grid.

Denmark has shown leadership in the development of wind power and has successfully integrated large amounts of wind power into its grid. Denmark is a leading wind turbine manufacturer, creating substantial employment and a large export base.

Energy Strategy 2050 places significant emphasis on the electricity system as a major source of energy in the future. Moreover, the Strategy sees a major role for wind power and biomass in the generation portfolio in the future. In the shorter term, Denmark has adopted a strong 2020 renewable energy target and aims to satisfy this goal with an increase in wind power capacity largely from offshore.

Much potential for the development of wind power, both onshore and especially offshore, remains. Generally, Denmark's policy on wind energy promotion seems to be consistent with the key recommendations of the 2009 IEA wind energy roadmap (see Box 11). Denmark is to be complimented for its present regulatory framework. Under present arrangements, much of the risk is taken off project developers and offshore development takes place in carefully chosen locations following detailed examination by a government committee. An example of the Danish approach to offshore wind development is the most recent government tender for the development of an offshore wind park at Anholt. In this case, the environmental impact assessment and the planning consents were arranged by government. Adding that the cost of connecting to the onshore grid under the tendering procedure is socialised, this framework should, in theory, create a very favourable starting position for private investors. Nonetheless, just one bid was attracted. This suggests the tender process is sub-optimal and its structure will require closer examination and corrective action if the future government goals are to be realised.

Nonetheless, *Energy Strategy 2050* contains a number of initiatives that hope to attract further investment in offshore wind energy; the Strategy includes provision of a new tender for a 600 MW wind park at Kriegers Flak, an additional 400 MW of capacity in smaller offshore parks, new planning and consenting regulations and mechanisms to facilitate developments closer to the shore. If implemented, many of these measures should facilitate administratively efficient construction of large volumes of capacity. The Strategy also recognises the need to remedy weakness in tendering procedures and improve tendering mechanisms for offshore wind parks. Measures are being developed in order to reduce the costs of offshore wind capacity expansion and prepare the basis for offshore wind turbine expansion decisions in the period after 2020.

The matter of technical challenges presented by integrating the increasing amounts of variable electricity produced from wind energy into the electricity system will be a major test. These challenges are not unique to Denmark, and with its extensive experience and knowledge, it is better placed than most to meet it.

At present – taken together – the two parts of Denmark (west and east Denmark) have approximately 5 440 MW of interconnection with adjacent areas (Nordic and Germany), the equivalent of more than 80% of Danish peak demand. This is the primary reason Denmark has been able to accommodate such a high penetration of wind power to date. Denmark, thanks to its heavily interconnected network, can also take advantage of hydropower resources in the rest of the Nordic market to balance its electricity system at short notice. The extent to which Norway will be able to continue to provide hydropower-based balancing resources to Denmark will depend on the level of variable renewable energy deployment in Norway itself – as well as in its other neighbours – if these increase, competition for the same flexible resource will result. In purely technical terms, IEA estimates that penetration of variable renewable energy in Danish gross electricity demand could increase to around 60% and still be balanced by existing flexible resources. Conversely, the amount of wind power Denmark can export to Germany depends to a large extent on renewable developments there.

Nevertheless, this share of variable renewable energy assumes optimal grid and market conditions, which is not yet the case. A significant transformation of the electricity and transmission system is already under way. Investment in electricity infrastructure should remain a priority. Regional interconnections will need to be strengthened and the preparation of a strategy for a smart electricity grid and advanced metering technology should be accelerated.

The government forecasts that, by 2020, use of biomass, wind, biogas and biofuels will increase significantly. With a significant increase in solid biomass, biogas as well as biofuels, bioenergy will continue to make up the majority of total renewable energy consumption in 2020.

Denmark foresees an enormous growth potential for biogas production, *i.e.* an additional 14 PJ up to 2020. Although this is a costly option, with almost no cost reduction potential as a result of the learning curve, this is considered to serve multiple purposes. Biogas will help to reduce GHG emissions in the agricultural sector, help to develop the agricultural sector (green growth) and play a role in water protection. Biogas will be used to displace natural gas in a large number of small-scale CHP units.

Sustainable use of solid biomass will also play a major role in the electricity system of the future. At present it makes a large contribution to Danish energy supply. Consumption of solid biomass used for electricity production in Denmark increased by an annual average of 8.3% between 1990 and 2009, almost all of which was used to produce combined heat and power. At present, almost half of Danish electricity comes from coal-fired power. *Energy Strategy 2050* foresees a significant fuel shift from coal to biomass at large-scale heat and power plants via revised rules on pricing of heat supplies. The strategy also envisages a shift away from natural gas in small-scale CHP-plants towards biomass.

The government has committed to carrying out an analysis of the use of biomass for energy-related purposes. This work will focus on whether the right framework conditions for efficient and sustainable use of biomass resources are in place. The analysis will prepare a long-term strategy for the use of biomass resources for energy

purposes. Care must be taken with this analysis to ensure the long-term sustainability of a major shift towards biomass consumption. It is unlikely that local production of biomass products will be cost-competitive; therefore, supply will have to be imported, much of it over long distances. While global production is forecast to grow, so is demand. Therefore, it is likely that cost will also be a concern as Denmark competes for supply in the global market. Any analysis should take these factors into account and also examine the implications of the shift towards biomass in term of energy security and ensure that electricity security in not compromised.

Box 11. **Key recommendations of the IEA Wind Energy Roadmap**

Set long-term targets, supported by predictable market-based mechanisms to drive investment, while pursuing cost reductions; set mechanisms for appropriate carbon pricing.

Advance planning of new plants to attract investment, taking account of other power system needs and competing land/sea usage.

Appoint lead agencies to co-ordinate advance planning of transmission infrastructure to harvest resource-rich areas and interconnect power systems; set incentives to build transmission; assess power system flexibility.

Increase social acceptance by raising public awareness of the benefits of wind power (including CO_2 emissions reductions, security of supply and economic growth), and of the accompanying need for additional transmission.

Exchange best practice with developing countries; target development finance at wind power deployment bottlenecks; further develop carbon finance options in developing regions.

Source: Technology Roadmap – Wind Energy. IEA/OECD Paris, 2009.

RECOMMENDATIONS

The government of Denmark should:

- *Continue to support studies into the impact of large-scale integration of wind into the energy system. These studies should be co-ordinated with work in neighbouring systems and take into account long-term developments in European electricity networks.*
- *Review the tender mechanisms for large-scale offshore wind farms to ensure the most cost-efficient and timely delivery of new capacity.*
- *Progress analysis into the long-term potential of biomass as part of a broader study into medium-term energy security. This study should also take into account the sustainability of importing large volumes of biomass.*
- *Develop and implement measures to ensure appropriate, cost-effective production of biomass supplies that are consistent with longer-term agricultural goals.*

6. ELECTRICITY

Key data (2010 estimates)

Installed capacity: 13.4 GW

Total electricity generation: 38.6 TWh (+7% since 2000)

Peak demand: 6.2 GW

Electricity generation mix: coal 48%, gas 20%, wind 20%, biofuels and waste 13%, oil 2%

OVERVIEW

The Danish electricity system is notable for its high level of renewable electricity capacity and also for the level of integration with neighbouring systems. A highly interconnected electricity system is needed not only for balancing the system, but to do so in an economically efficient manner, and as part of a large regional market.

Denmark's long-term policy goal of independence from fossil fuels brings with it a number of significant challenges, and opportunities, for electricity. *Energy Strategy 2050* has identified electricity as an important tool by which the entire energy sector can be decarbonised over the longer term. The challenge of integrating increasing volumes of wind power combined with the transformation to lower fossil fuel consumption will require detailed strategic planning and closer co-ordination with neighbouring countries and markets. At present 20% of the Danish energy system is electricity-based; in the longer term this could increase to 70%, should the vehicle fleet become electrified.

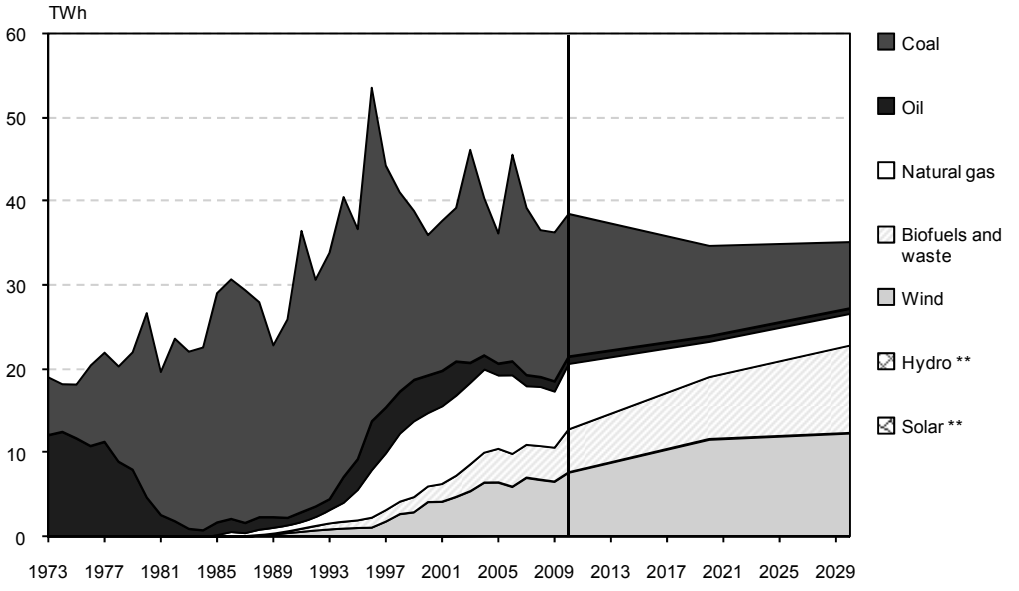
SUPPLY AND DEMAND

SUPPLY

Denmark has strong interconnections with neighbouring countries. Thus, depending on hydrological conditions elsewhere, electricity generation output can vary significantly. In 2010, electricity generation amounted to 38.6 TWh, a level similar to that of 2007, but down 15% from the peak in 2006, when generation output was 45.6 TWh.

While the generation portfolio in Denmark (Figure 18) is characterised by the high penetration of wind (7.8 TWh or 20%) and biofuels and waste (5.0 TWh or 13%), coal remains the dominant source of generation (16.9 TWh or 48%). The contribution of coal to the generation mix varies with peaks in either demand or exports, which are met by coal-fired power. Since 1996, the importance of coal has been decreasing as other energy sources have been developed. In 2010, the second-largest power source was natural gas, accounting for 20.4%, closely followed by wind, and biomass and waste. The use of oil for electricity generation is very limited and accounted for only 2% in 2010.

Figure 18. **Electricity generation by source, 1973 to 2030**



* Negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

The government expects electricity generation to decrease gradually, by almost 10% until 2020, and remain around 35 TWh until 2030. The generation mix is expected to change over this period; the government forecasts that wind will become the largest electricity generation source by 2030, accounting for 35%, and biomass and waste the second-largest, with 30% of total electricity generation. Electricity generated from coal – and natural gas – is expected to fall by 50%.

Together, the two parts of Denmark (west and east)), have 5 440 MW of interconnection with adjacent areas. This is one of the primary reasons why Denmark has been able to accommodate such a high penetration of wind power to date. Electricity imports and exports are important in Denmark's electricity supply; in 2008, the country exported around 30% of its production and imported about the same amount. Denmark has interconnections with Germany, Norway and Sweden, and electricity exchanges are very high in the region. Since 1993, Denmark has been a net exporter of electricity, with high peaks in 1996, 2003 and 2006 corresponding to drought years in Norway and Sweden, countries that depend largely on hydro-power.

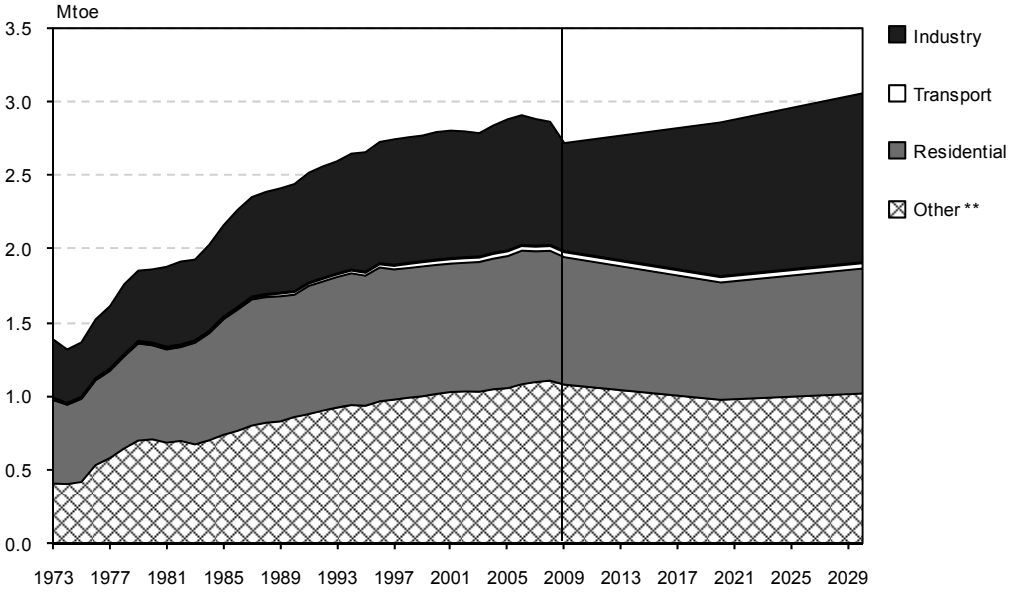
Historical electricity exchanges between Denmark, Norway and Sweden each follow similar patterns, while exchanges with Germany follow the opposite path. For example, in 2008, Denmark imported 7.8 TWh from Germany and exported 4.8 TWh to Sweden and 4.4 TWh to Norway. Thus, in dry years Denmark exports to Norway and Sweden, and exports less to Germany, while in wet years Denmark imports from its Nordic neighbours and exports more to Germany. In reality, Denmark is neither an importing nor an exporting country, but functions as a transit country between the Nordic and central-western European systems.

DEMAND

The demand side of the electricity balance is more stable and has increased steadily with an average of 0.4% growth over the last decade, reaching 32.5 TWh in 2009. The services sector is the largest electricity user, consuming 40%, followed by the residential sector (32%) and industry (27%). Over the last decade, all three sectors have enjoyed similar growth rates, so shares have remained about the same. In its 2030 business-as-usual forecast scenario, the government expects industrial consumption to increase the most, along with the services sector in contrast to the residential sector where demand is expected to remain constant.

Demand for electricity usually peaks in winter; it reached 6.2 GW in 2009. Seasonal and daily demand curves are identical to other Nordic countries; however, seasonal differences of system load are relatively smaller than in other countries because of the lower penetration of electric heating.

Figure 19. **Electricity consumption by sector, 1973 to 2030**



* *Other* includes commercial, public service, agricultural, fishing and other non-specified sectors.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2010 and country submission.

GENERATING CAPACITY

Denmark maintains more than 13 GW of installed capacity, including 3.5 GW of wind power. Large-scale units (or central power plants) represent 60% of total installed capacity and these are mostly combined heat and power (CHP) plants, which also supply heat for industrial process and district heating. More than 650 large and small-scale CHP plants provide 77% of the total district heating production. Their primary fuel is coal but biomass is also used, albeit on a much lower scale (less than 10%).

Figure 20. **Transmission grid with international connections**

This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory covered by this map.

Source: Danish Energy Agency.

DONG, the largest owner of coal-fired capacity, has suspended 25% of its coal-fired capacity and stopped the development of future coal-fired plants. In addition, some of its plants are planned to be converted to biomass firing.

While large-scale plants which represent 60% of total capacity are connected to 132 kV, or higher voltage, transmission lines, the rest (40%), which includes small-scale CHP and wind generators, are connected at 20 kV or lower as decentralised generation. Small-scale CHP is typically powered by natural gas and waste; biomass and biogas are also used. Large-scale units and small-scale CHP have another important role of heat supply to district heating systems.

About 5 100 wind turbines are producing electricity in Denmark and they represent 26% of total generating capacity. More than 80% of wind turbine units are less than 1 MW despite the recently accelerated decommissioning of small-scale wind turbines.

Efficiency of coal-fired generation plants

Some of the most efficient coal-fired power plants in the OECD are located in Denmark, where new-generation pulverised-coal supercritical plants with sliding pressure were introduced in the 1990s as a result of initiatives by Elsam (now part of DONG) to move to much higher efficiency levels by working with the major suppliers to develop plant design.

Efficiency of coal-fired power plants is around 40%. For power plants commissioned between 1990 and 2000, efficiency is slightly higher. The most recent plant, commissioned in 1999, can achieve annual average efficiencies of up to 44%. Theoretical efficiencies are higher than the annual average. Of particular interest is the Nordjylland (Nordjyllandsværket) power station. When operating to export power and heat, the efficiency of Nordjylland unit 3 is 90%, while, in power-only mode, its electrical generation efficiency is 47% (net) on a lower heating value (LHV) basis. This is equivalent to an estimated efficiency on a higher heating value (HHV) basis of 44.9% net. The plant is regarded by some as the most efficient coal-fired unit in the world.

REGULATORY FRAMEWORK AND MARKET DESIGN

REGULATION OF ELECTRICITY AND HEAT TARIFFS

Denmark followed other Nordic countries and commenced the process of electricity supply-market liberalisation in the early 1990s. Nord Pool was established in 1996 and became the integrated regional electricity market for the entire Nordic region. Partial retail competition commenced in 1998 and was followed by full market opening in 2003.

The Danish Energy Regulatory Authority (DERA) is the independent regulatory body that oversees the electricity, natural gas and district heating markets. DERA regulates network tariffs for transmission and distribution and determines the level of obligation to supply tariffs (a last-resort service). DERA monitors both prices and terms of supply for district heating supply, which is a non-profit activity.

REGIONAL CO-OPERATION

Danish electricity system, part of the Nordic system, is one of the best examples of regional co-operation among European transmission system operators (TSOs) in terms of system planning and operation, regional market integration and regulatory co-ordination.

As a member of the Nordic Energy Regulators (NordREG), DERA closely co-operates with energy regulators of other Nordic countries. NordREG members actively promote the legal and institutional frameworks as well as the conditions necessary for developing the Nordic and European electricity markets. It is also part of a much broader policy co-operation mechanism among Nordic countries under the Nordic Council and Nordic Council of Ministers.

In November 2010, the Nordic Prime Ministers announced a major programme of work in the electricity sector. This included the development of the regional grid to enable large increases in power supply from variable renewable sources, expanding interconnection capacity to other market areas, and developing a common Nordic end-user market, an essential prerequisite should Denmark wish to realise its long-term energy goals. Denmark is also actively engaged with its other non-Nordic Baltic Sea neighbours.

MARKET DESIGN

Nord Pool is the world's largest power exchange in terms of physical electricity trade and Denmark has been part of the fully integrated regional power market since western Denmark joined Nord Pool in 1999 and eastern Denmark joined in 2000. Spot-trading volumes in 2009 reached 288 TWh, representing more than 70% of total consumption in the Nordic countries. In April 2010, the Estonian market was connected to the Nordic market.

Nord Pool Spot As is the operator of physical electricity markets. The company is owned by the four national TSOs in the region. ELSPOT is a market for hourly power contracts, traded daily, for physical delivery in the following 24-hour period. Prices are calculated on the basis of the balance between bids and offers from all market participants. The price also takes available trading capacity within the region into consideration. An implicit auction is used to allocate interconnection capacity while electricity is traded among areas within the Nordic region in order to achieve economic optimisation under a given transmission capacity. The market currently has ten bidding areas and these areas may be split if there is congestion. Denmark is divided into two areas, western (DK1) and eastern (DK2), separated by the Great Belt Power Link, the high-voltage direct current (HVDC) interconnection between Funen and Zealand, connecting the two power transmission systems.

ELBAS is the cross-border physical balancing market, which includes the Nordic countries plus Germany and Estonia. It continuously adjusts trades made at ELSPOT until one hour before delivery. This balancing market contributes not only to maintenance of supply and demand and stable system operation, but also to allow market participants to mitigate the risk of imbalance payments by providing real-time market signals before delivery.

In 2008, an intra-day capacity trading platform was introduced on one of the Denmark-west Germany interconnection lines. It is a continuous capacity-trading platform, using a

first-come first-served capacity nomination, operated by E.ON Netz and Energinet.dk. The same mechanism is already used on other European borders. The other interconnection lines, including Germany-Denmark East, are part of the Nordic ELBAS intra-day market, offering continuous co-ordinated trading of energy, including access to interconnection lines.

Since Denmark is located at the interface between the Nordic region and Germany, it is impacted not only by the Nordic market but also by Central-Western European (CWE) market. Accordingly, in November 2009, the European Market Coupling Company (EMCC) on the Danish-German border coupled the Nordic and German day-ahead markets at two interconnections.

INDUSTRY STRUCTURE

GENERATION

DONG Energy is the largest player in the Danish energy market. The company was founded in 2006 when six Danish energy companies merged: DONG, Elsam, ENERGI E2, Nesa, Copenhagen Energy, and Frederiksberg Forsyning. It is present not only in the generation market, but also in retail and distribution of electricity and natural gas, as well as in the exploration and production of oil and gas and energy trading. DONG Energy is a public limited company, in which the State (the Kingdom of Denmark) is the principal shareholder.

Between them, DONG Energy and the Swedish-owned utility Vattenfall own the bulk of large-scale power plants in Denmark and significant capacity in other categories, including offshore wind parks. While nominal market shares of these two companies are high in Denmark, market concentration is best considered in a regional context as the Danish electricity market functions as part of a larger regional market. In terms of installed capacity, DONG Energy has only a 6.4% share in the Nordic market. Conversely, Vattenfall has the largest share in the region at little less than 17%.

Within Denmark, in the small-scale CHP and small-scale wind sector, ownership is more diverse. Many of CHP plants provide heat for district heating and in many cases the local authority owns these plants.

TRANSMISSION

The electricity transmission system in Denmark is separated both operationally and geographically into two parts, the west (Jutland and Funen) and the east (Zealand). In 2005, Energinet.dk was established, as a single state-owned transmission system operator, by merging two system operators: Elkraft in western Denmark and Eltra in eastern Denmark. Geographical separation ended in 2010 when the Great Belt Power Link connecting western and eastern areas with 400 kV direct current (DC) cables was commissioned. Despite separation within Denmark, the eastern area was already connected with Sweden and the western area was connected with Norway and Sweden. Therefore, both areas had been able to trade electricity through the Nordic market even without the Great Belt Power Link.

The 6 300 km-long Danish transmission system consists of 400 kV and 150/132 kV lines. Energinet.dk is the owner of the 400 kV facilities, as well as part of the 132 kV facilities,

the Great Belt Power Link and interconnection lines with Norway, Sweden and Germany. Most of the 150/132 kV transmission facilities are owned by nine regional grid companies.

In the past, the western system (Elkraft) was part of the Union for the Coordination of the Transmission of Electricity (UCTE) and the eastern system was part of the Association of TSOs from Norway, Finland, Denmark, Sweden and Iceland (NORDEL). At that time, regional level network planning was under each framework. Since UCTE and NORDEL were wound up in 2009 and all operational tasks were transferred to the European Network of Transmission System Operators for Electricity (ENTSO -E), Energinet.dk has co-operated with ENTSO-E's ten-year network development plan for security of supply, integration of renewable sources and European internal energy market.

Transmission tariffs are calculated on a cost-plus basis; the calculation methodology and tariff are subject to *ex ante* approval by DERA. It consists of three parts: network tariff for transmission network costs, system tariff for system operation and ancillary services costs and public service obligation (PSO) tariff mainly for subsidies to renewable generation and local CHP. Each element of the tariff is determined separately in the western and eastern areas.

The Great Belt Power Link is a 400 KV DC line connecting the electricity systems of western and eastern Denmark. NORDEL proposed the idea in 2005 and the DKK 1.3 billion project commenced in 2005 for the purpose of enhancing the electricity market, improving energy security and facilitating the integration of more wind power. In August 2010, the Great Belt Power Link between Funen and Zealand commenced operations and connected the previously unsynchronised systems.

INTERCONNECTIONS

Denmark has strong interconnections with Norway, Sweden and Germany; western Denmark has two DC interconnections with Sweden, three DC connections with Norway and four AC connections with Germany. Eastern Denmark has four alternating current (AC) connections with Sweden and a direct current (DC) connection with Germany. Total physical export capacity amounts to 5.6 GW and import capacity amounts 4.6 GW, while system peak load is about 6.3 GW.

Congestion on interconnections between Nordic countries is managed using market mechanisms. Since market coupling with Germany started in 2009, all capacity with the neighbouring system has been managed by implicit auction. Thus, the flow of energy is based on short-term market transactions and affected by prices of widespread neighbouring markets.

Despite large interconnection capacity, congestion is common, for example, between western Denmark and Norway 61% of the time, and between western Denmark and Sweden 44% of the time.

Expansion of capacity between Jutland and Germany is under construction and expected to increase by 500 MW in both directions by the end of 2012. In the medium term, further upgrades will increase capacity by up to 2 500 MW in both directions by 2017.

One of the prioritised projects in the Nordic region is Skagerrak 4, a DC submarine cable, which expands interconnection capacity between western Denmark and Norway by

700 MW. The project was agreed by Energinet.dk and Statnett in 2010 and expected to become operational in 2014.

New interconnections between western Denmark and the Netherlands are also under development; the COBRA Cable project, a HVDC submarine cable will add 600 to 700 MW of capacity between the Nordic and Central-Western European markets. It is expected to be operational in 2016 and will contribute to the accommodation of more wind energy in both Denmark and the Netherlands.

The Kriegers Flak project is multi-terminal connection between Denmark, Sweden and Germany, centred by a large offshore wind farm in the Baltic Sea. This will work both as grid connection with offshore capacity and interconnection among the three countries. In 2010, the EU agreed to award EUR 150 million to this project under the European Energy Programme for Recovery.

DISTRIBUTION

In 2009, there were 84 distribution network companies, serving 3.2 million customers, largely co-operative or municipal companies. The majority (77 out of 84) have less than 100 000 customers and between them supply less than 40% of customers both by number and by energy consumption. Conversely, DONG Energy Group has three network companies and supplies 27% of energy.

Distribution network tariffs are regulated *ex ante* by DERA. Each distribution company determines its network tariff based on a revenue cap approved by DERA annually.

Public service obligations

Public service obligations (PSOs) are compulsory services to financially support energy policy programmes in line with public interest. All customers pay the PSO tariff which is included in the final price of electricity.

PSO revenues are allocated in support of environment-friendly power generation, security of supply and energy-related research and development. The bulk of PSO revenue is for wind power generation and decentralised (small-scale) CHP.

Since renewable generators receive a feed-In tariff, while the energy is delivered by the TSO to Nord Pool Spot, for which it receives market prices, any resulting surplus or deficit is offset against PSO revenues.

RETAIL MARKET AND PRICES

WHOLESALE PRICES

Nord Pool spot prices are market-based and reflect changes in consumption, generation and transmission conditions in the Nordic market area. Hydropower generation ranges from 150 TWh to 250 TWh per year and is a key to determining the general spot price level. In wet years, wholesale prices are dominated by cheap hydropower, while in dry years, more expensive thermal power, especially coal-fired power, in Denmark and Finland is generated to compensate for low hydropower production in Norway and Sweden. Increased market integration with Central Europe is expected to reduce price fluctuation in the Nordic market.

RETAIL SUPPLY AND COMPETITION

Retail customers fall into two broad categories: large customers, metered hourly, who use more than 100 MWh annually, and 3.2 million load-profile customers not metered by the hour. By the end of 2008, 14% of customers were equipped with remotely read or smart meters. An additional 240 000 customers installed these meters in 2009 and a further 840 000 meters will be rolled out by the end of 2011.

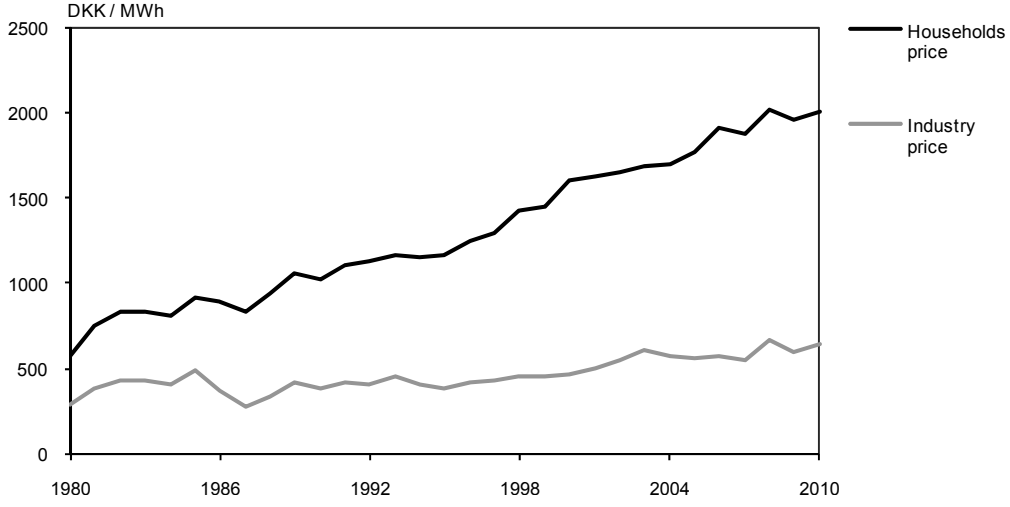
All customers have enjoyed the right to choose their supplier since 2003. There are 79 electricity suppliers, of which 44 have an obligation-to-supply licence. A last-resort supplier is a supplier licensed to supply small business and household customers who have not chosen an alternative competitive supplier within a defined geographic area.

Obligated supply prices are regulated by DERA and prices reflect market prices. In 2009, the customer-switching rate, although low, increased compared to 2008: 6% of customers representing 4% of electricity consumption. On the other hand, large customers equipped with hourly meters have been more active: 16% of large customers, representing 9% of total consumption, switched supplier in 2009.

Several initiatives have been taken to promote competition especially for load-profile customers, including limiting maximum contract period to six months. A price comparison website to promote switching is being promoted and a national data-hub is under development and expected to promote competition by enabling equal access to customer information.

RETAIL PRICES

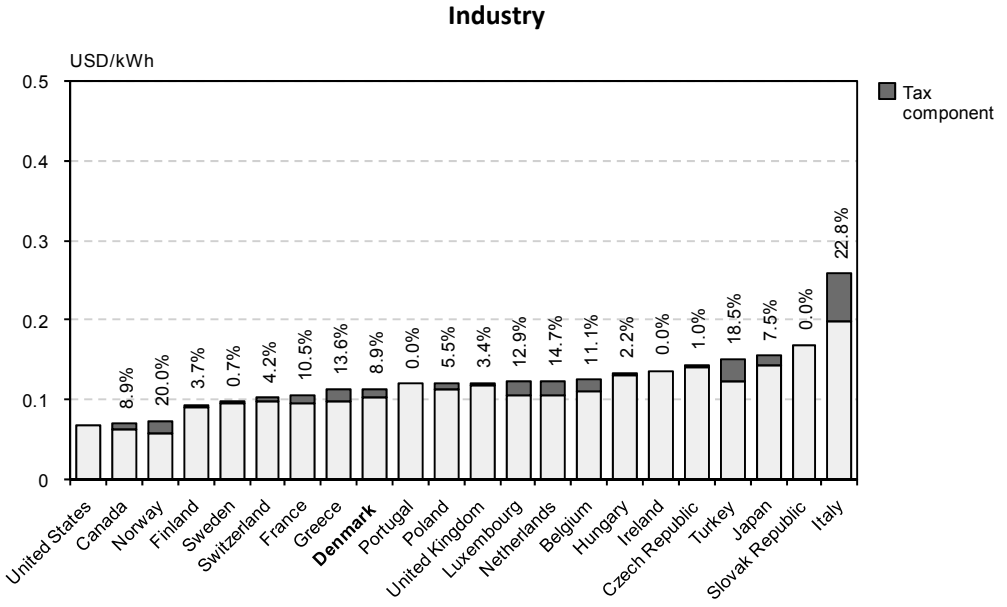
Figure 21. **Electricity prices for industry and households, 1980 to 2010**



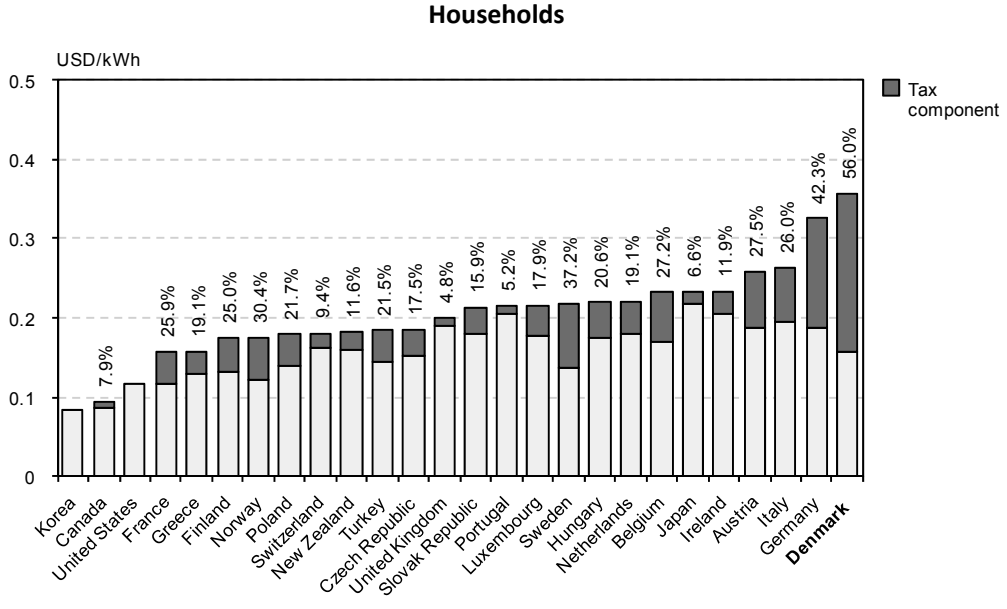
Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2011.

Electricity prices for industrial customers in Denmark are lower than the average of IEA Europe while prices for household customers are among the highest. Taxes, including value-added tax and PSO payments, constitute 60% of the end-use price of electricity. When market prices are higher, the energy portion increases and PSO payment falls owing to its linkage to market prices and vice versa.

Figure 22. **Electricity prices in IEA member countries, 2010**



Note: Tax information not available for the United States. Data not available for Australia, Austria, Germany, Korea, New Zealand and Spain.



Note: Tax information not available for Korea and the United States. Data not available for Australia and Spain.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2011.

POLICIES

SUPPLY

The goal of the Danish government is independence from coal, oil and gas by 2050. The transition outlined in *Energy Strategy 2050* will have a significant impact on the electricity industry. Key elements of the Strategy include a series of measures that directly impact on the future development of the electricity system. Electrification of heating, industry and transport, integration of large volumes of variable renewable energy, the shift away from coal-fired power production, and smarter use of electricity infrastructure are all ways in which the fundamentals of the electricity system will be impacted. Electricity policies will be the cornerstones of each of the three phases of the transition, not least in the initial phase.

Box 12. ***Energy Strategy 2050*: framework conditions for electricity and heat production in the future**

- The government will launch an in-depth review of electricity-supply legislation and regulation in order to ensure that incentives and rules support the transition to fossil fuel independence. In the long term, other areas of energy supply will also be reviewed.
- The government will allocate DKK 20 million for strategic energy planning partnerships between municipalities, local companies and energy companies. This money will be used to promote the integrated development of energy demand and energy supply, which will underpin the transition to fossil fuel independence.
- The government will allocate DKK 10 million for the demonstration of large heat pumps in the district heating sector, and analyse the conditions for, and implications of, the phasing-in of large heat pumps.
- The government will allocate DKK 20 million for geothermal energy exploration projects.
- The government will extend the existing public service obligation scheme, which supports small electricity-producing renewable energy technologies such as wave power, bio-gasification and solar photovoltaics, for a further four years, so that a total of DKK 100 million is allocated for the period.
- The government will allocate DKK 10 million to support demonstration projects on solar heating for household solutions, including the use of solar heating in combination with other renewable energy solutions such as heat pumps. Efforts will also include an information campaign and the launch of a certification/quality assurance scheme.
- The government will support efforts for a revision of the EU's Directive on Combined Heat and Power Production towards an efficient energy system in a future European Union free of fossil fuels.

Source: *Energy Strategy 2050*.

Important initiatives in this phase of the Strategy include electrification of heating and process installations and the expansion of wind power. The first phase will also include initiatives to promote the establishment of recharging stations for electric cars, expansion of the international electricity transmission grid, the development of a smart grid and the roll-out of advanced metering technology as well as a series of measures to support the expansion of other renewable energies.

AN INTELLIGENT ELECTRICITY SYSTEM

Medium-term growth in electricity demand, changes in demand patterns and higher levels of variable renewable energy will require changes to the electricity system. Flexible consumption will become more important for the operation of the system. Denmark will have to strengthen cross-border transmission capacity even further to accommodate greater flows of wind energy and balancing power.

Box 13. **Actions to build a cohesive and intelligent energy system**

- Establish new international electricity transmission capacity in the form of a transmission line to Germany and possibly also to Sweden in connection with the future offshore wind farm at Kriegers Flak. This project is supported financially by the EU with approximately DKK 1.1 billion of funding.
- Analyse the need to expand international transmission lines in order to achieve their socio-economically optimal expansion as well as ensure the necessary reserves/backup in an electricity system with a large share of wind power.
- Work for an agreement with the electricity distribution companies to install intelligent electricity meters when electricity consumers install heat pumps or recharging stations for electric cars. Furthermore, the limit for installation of intelligent meters will be lowered in 2013 from 100 000 kWh to 50 000 kWh of annual consumption. The government will also ask the distribution companies to replace all electricity meters which are to be replaced after 2015 by an intelligent electricity meter.
- Continue to encourage the electricity sector to perform demonstration projects with dynamic tariffs in specific distribution grids and prepare a strategy for the promotion of smart grids in Denmark, and determine investment needs and a financing model.
- Analyse regulation of the gas infrastructure in future years in order to ensure optimal use and maintenance of the existing gas infrastructure, both in the transitional phase, while natural gas still plays a role, and in the future, when biogas and other renewable gases have taken over.
- Work for strengthened electricity grid infrastructure in the European Union in order to ensure a well-functioning electricity market.

Source: *Energy Strategy 2050.*

The system will require more tools within which to maintain the balance between demand and supply. In this regard, increased use of electric boilers for district heating

production, flexible electricity consumption in industry, and flexible recharging of electric cars will be important.

The Strategy foresees expansion of wind power and makes a number of provisions in this regard, including calls for tenders for up to 1 000 MW of offshore capacity as well as changes to the planning regime and subsidy mechanisms. The Strategy also provides for a move away from fossil fuels in the heating sector towards biomass and biogas.

It is obvious that the present electricity system is not yet prepared for the planned consumption and production patterns of the future, which will require greater flexibility and the ability to store and use energy off peak. The Strategy sets out a large number of actions to strengthen the system.

CRITIQUE

Energy Strategy 2050 is explicit in its actions in relation to long-term energy policy and Denmark's path towards independence from fossil fuels; most notably, it recognises that electricity will be at the centre of the future intelligent energy system with wind power providing up to half of Denmark's energy consumption.

As part of the Nordic electricity system, the Danish electricity system has contributed to, and benefited from, a well-functioning regional wholesale market and ready access to abundant low-carbon energy. More than 3 000 MW of wind power capacity has provided clean energy, not only to Denmark, but also to neighbouring countries in times of high wind, while hydropower in Norway contributes significantly to regulating power in times of low wind, while nuclear power in Sweden and Finland can support baseload demand at times of peak. This mutually beneficial trade is enabled through large interconnection capacity and an established regional electricity market, Nord Pool.

The Strategy contains actions that, if implemented, will deliver closer integration of the Nordic and northern European electricity markets by further expansion of international electricity links. Physical expansion of existing interconnector capacity between Denmark and Norway, the Great Belt Power Link to integrate eastern and western systems and the launch of the European Market Coupling Company (EMCC) with Nord Pool and the European Power Exchange (EEX) are all activities which do so and support the broader integration of the European electricity market. Domestically, these activities also mitigate the relatively high level of concentration in the Danish generation market and contribute flexibility, which facilitates integration of additional wind power capacity.

The government forecasts that by 2020, 50% of generating capacity will be wind; therefore, Denmark will need a dynamic and operationally flexible electricity system so that it can react immediately to unexpected events such as a sudden increase or fall in generation. At present, with approximately 20% wind capacity, oversupply occurs for nearly 100 hours a year. Oversupply is expected to become three to four times greater in a few years under present circumstances and if no other measures are introduced. In response, Energinet.dk is conducting extensive research and development in relation to handling the increasing amounts of wind power in the power system. It is focusing on integrated planning of the energy systems within electricity, heat and transmission to enable the market to use wind power in a more flexible manner and organising demand in such a way that it can adapt to changing wind power production. Widespread deployment of a smart grid is therefore a critical step for securing a cost-effective and clean energy future for Denmark.

In order to cost-effectively accommodate greater wind capacity into the grid, consistent with the longer-term policy target of independence from fossil fuels, the government must continue to support the conduct of holistic and long-term analysis of various options for enhancing electricity system flexibility, not only within Denmark, but also within the Nordic and European contexts. Consequently, harmonisation of different incentive schemes for renewable power among connected countries should be considered in the analysis.

Interconnection with Norway for the regulation of hydropower is one of the most important options to enhance the flexibility of the electricity system. However, careful consideration is needed as to whether excessive dependence on Norwegian hydropower is feasible since neighbouring countries themselves have their own policies to increase wind power production. Therefore, planning the Danish electricity system, including interconnection resources, must be done in close harmonisation with neighbouring TSOs and governments with analysis of future scenarios, including changes of their generation portfolio. In this regard, Denmark's role in the Nordic Ministers of Energy Electricity Market Group under the Nordic Council of Ministers is an important means of securing higher levels of co-operation.

Energinet.dk, the Danish TSO, participates in the European Network of Transmission System Operators for Electricity (ENTSO-E) ten-year network development plan. In the longer term, ENTSO-E forecasts that the import capacity in Denmark will increase by approximately 80% while export capacity will increase by approximately 53%. However, given the Danish political will to transform its electricity system towards more wind power and ultimately fossil fuel independence, Denmark should also develop a detailed long-term region-wide resource plan, including a transition plan to a generation portfolio and domestic interconnection plan with short-term periodic updates. Through such planning process, a better package of cost-effective and secure electricity supply options can be found and the necessary policy measures will be identified.

Along with greater wind power penetration to the existing system, the long-term goal of independence from fossil fuels will affect the future generation portfolio. Policy measures are being taken to reduce coal-fired capacity and increase biomass (wood pellets) by blending with or replacing coal. In the longer term (2030), biomass is expected to account for 35% of generating capacity. This will change the situation of not only large-scale power generation but also small-scale CHP plants. The long-term future generation composition, a mix of wind and biomass-fired generation, is technically feasible. However, it is still unclear what path will be taken to transition to this future generation mix and whether the choice generation portfolio will deliver an economically viable secure electricity supply. In this case, natural gas may have a role to play as an efficient bridge between coal consumption and a low-carbon future.

Since liberalisation of the retail market, competition for large customers has been successful and supplier switching has been highly visible. However, competition for smaller customers, especially households, still needs improvement. Simplified switching processes and information infrastructure are important tools with which to increase competition in this sector. In this regard, the establishment of a price-comparison website and the development of a data-hub are sensible steps. It will also contribute to the establishment of a common Nordic electricity retail market. Furthermore, deployment of smart meters will promote competition by providing customers with a variety of supply options but also the necessary infrastructure to participate in the

electricity market of the future. This will also contribute to enhancing the flexibility of the electricity system.

In order to achieve this challenging target in a cost-effective and secure manner, the various supply and demand sectors and technologies in the entire Nordic energy system must be well connected and co-ordinated intelligently to increase its flexibility. It will include various types of generation sources, including hydropower, cleaner coal or flexible gas generation, with gas storage when domestic instruments are appropriate. Geographical diversification of wind power and technological diversification will also reduce the supply burden. Broader demand response, flexible heat supply through heat-pumps with storage, or CHP in the district heating system, and the deployment of electric vehicles are also important options. Thus a smart grid, which integrates all of these factors intelligently, is critical for the Danish electricity system.

RECOMMENDATIONS

The government of Denmark should:

- *Continue to encourage further integration of the Nordic electricity market, both internally and with other market areas, to improve overall efficiency, flexibility and security of power supply.*
- *Enhance co-ordination with regional TSOs, markets and governments of neighbouring countries on long-term planning, and conduct analyses with region-wide scenarios.*
- *Continue efforts to promote retail competition, especially for household customers, through the establishment of information infrastructure and seek demand-side participation to the market through accelerated deployment of smart meters.*
- *Continue to support investment in electricity infrastructure and seek to deploy smart grid technologies at the earliest possible opportunity.*

7. FOSSIL FUELS

Key data (2010 estimates)

Oil

Crude oil production: 12.1 Mt (-37% compared to historical high in 2004)

Net crude oil exports: 5 Mt (-55% compared to 2004)

Oil products: refinery output 6.9 Mt, imports 6.6 Mt, exports, 4.9 Mt

Reserves: 194 mcm

Share of oil: 38% of TPES and 2% of electricity generation

Inland consumption: 7.5 Mt (transport 62%, industry 11%, residential sector 7%, agriculture and forestry 5%, power and heat generation 5%)

Consumption per capita: 1.4 t (OECD average: 1.6)

Natural gas

Production: 8.2 bcm (+0.2% compared to 2000)

Reserves: 105 bcm

Share of natural gas: 22% of TPES and 20% of electricity generation

Exports: 3 bcm, 41% of production (Netherlands 41%, Sweden 30%, Germany 29% in 2009)

Inland consumption: 4.9 bcm (power generation 45%, industry 17%, residential 16% in 2009)

Coal

Inland consumption: 13.8 Mtoe (19.5% of TPES)

Imports: 100%

OVERVIEW

Oil and natural gas represented 38% and 22% respectively of Denmark's total primary energy supply (TPES) in 2010. While the combined share of the two fuels in the supply mix has remained relatively stable over the past thirty years, at around 60% of TPES, oil's share has fallen significantly from the nearly 90% it represented in the early 1970s. At the same time, Denmark has one of the lowest energy intensities in the world, and while its economy has grown by 78% since 1980, its energy use has remained almost unchanged over the period.

Denmark is a net exporter of oil and natural gas and can be expected to remain so at least until end-2018 and 2020, respectively. Extending self-sufficiency beyond these

dates will, for the most part, depend on future upstream technological developments, but should the country become a net importer, this is likely to be marginal in the period before 2035.

Oil and gas production makes a significant contribution to Denmark's balance of trade. In 2009, the surplus in external trade in oil and natural gas amounted to DKK 14.6 billion, although lower production levels and falling market prices meant a decline when compared to 2008, when the surplus amounted to DKK 27.1 billion.

The government earns revenues from North Sea oil and gas production via direct revenue from various taxes and fees: corporate income tax, hydrocarbon tax, royalties, the oil pipeline tariff, compensatory fee and profit-sharing. With a share of approximately 35%, the hydrocarbon tax is the main source of state revenue. The government also receives indirect revenue from the North Sea by means of its shareholding in DONG Energy and, in the longer term, by means of the Danish North Sea Fund. The Danish North Sea Fund was established in 2005 as Denmark's state-owned oil and gas company, and is a partner with a 20% ownership interest in all newer Danish licences for oil and gas exploration.

The goal of the Danish government is independence from coal, oil and gas by 2050. While production of oil and natural gas will have ended before this date owing to declining resources, there is scope in the medium term for natural gas to play a significant role in Denmark's energy future. Furthermore, revenues from petroleum activities play a major role in supporting the prosperity of Denmark and the government expects energy-related revenues to decline by as much as 50% by 2050, to about 1.1% to 1.2% of GDP.

OIL

UPSTREAM

Resources and production

Oil production in Denmark began in 1972 and rose steadily until reaching a peak in 2004, when production averaged nearly 390 thousand barrels per day (kb/d). Production has since declined steeply and in 2009 it averaged 260 kb/d. Danish oil production comes exclusively from offshore installations in the North Sea, where there are 19 producing fields. The main crude stream, Danish crude blend, is a medium light-sweet quality that has a high middle-distillate yield. Ten companies have interests in the producing fields and oil production on the Danish Continental Shelf is dominated by three companies: Maersk (the operator of 15 fields), DONG (three fields) and Hess (one field).

The Danish Energy Agency (DEA) makes an assessment of the country's oil and gas reserves annually. DEA classification system divides Danish oil and gas resources into four classes: reserves, contingent resources, technological resources (estimations of additional volumes are possible from future new technologies such as CO_2 injection) and prospective resources (estimated additional volumes recoverable from new discoveries). On this basis, DEA establishes its production forecast which, together with its forecast for consumption, is used to predict when the country will become a net importer of oil and gas.

Oil production is expected to continue to decline in the coming years. According to DEA's expected production profile, which is based on the assessed reserves and risk-weighted contingent resources, Denmark will remain a net exporter of oil up to and including 2018. The oil consumption forecast associated with this estimate is for moderate increases, averaging 0.4% per year to 2030.

Denmark's period of self-sufficiency in oil can potentially be prolonged with additional production coming from technological developments and new discoveries. However, the estimates for these resources, unlike the expected production profile, are subject to a high level of uncertainty. If realised, these resources would be expected to contribute substantially over the period 2020 to 2035 and decline thereafter. Such a scenario would likely result in Denmark, over this period, alternating between being a net exporter and a (marginal) net importer of oil, with oil import dependence growing steadily in the years after 2035.

DEA estimate of technological resources is based on increasing the average oil recovery rate by 5%. Currently, the recovery rate (the ratio of ultimate oil recovery to total oil originally in place) of Danish oil production is relatively low, averaging around 24%. The 5% increase is expected to derive primarily from new techniques used for CO_2 injection. Government initiatives for enhanced oil recovery include an independent assessment, prepared by the North Sea Fund, the DEA and Maersk Oil and Gas, of the existing worldwide experience with different methods to recover more oil from the fields.

Exports

Denmark has been a net exporter of crude oil since the mid-1990s. In 2009, roughly 170 kb/d out of the 260 kb/d of domestic production was exported. In the same year, Denmark imported just over 70 kb/d of crude oil, primarily from Norway, for domestic refining. Denmark's total net exports of oil in 2009 equated to 100 kb/d. In terms of refined products, Denmark is marginally a net importer. In 2009, product net imports were less than 10 kb/d. Generally, Denmark is a net exporter of gasoline and fuel oil and a net importer of middle distillates. The main markets for exports of Danish oil are the Netherlands, Sweden and the United Kingdom.

DOWNSTREAM

Demand

In 2009, indigenous crude production averaged 260 kb/d. In the same year, Danish refineries processed 7.8 million tonnes (Mt) of crude oil, equal to approximately 160 kb/d.

Oil product demand in Denmark was 7.2 Mt in 2009, or an average of 150 kb/d. This represents a decline in total oil use at an average rate of 2% per year since 2000. In this period, demand for oil use in the transformation and residential sectors declined substantially. The use of fuel oil in power generation is declining and the use of heating oil is also falling owing to the higher number of homes connected to district heating. At the same time, demand for transport diesel continued to grow and averaged 2.9% per year from 2000 to 2009.

Total oil demand is not expected to change significantly in the coming years. The Danish Energy Agency's projection for oil demand, which is the basis for forecasting the country's oil self-sufficiency, assumes oil consumption to grow moderately, averaging 0.4% annually to 2030. The Danish oil industry association, as well as the independent public stockholding agency, Foreningen Danske Olieberedskabslagre (FDO), expect total oil consumption to decrease gradually in the coming decade (-0.5% per year), with demand to 2020 declining for gasoline (-4% per year), heating oil (-8%) and fuel oil (-10%). Nevertheless, demand for transport diesel is expected to continue to grow at a rate of 2% annually, which would equate to some 67 kb/d in 2015 and 74 kb/d in 2020, compared to 61 kb/d currently.

The transport sector accounts for two-thirds of all oil used in Denmark. Diesel is the single largest component in the mix of oil products used in Denmark and in 2009 it represented over 55% of the fuels consumed in the country for road transportation. Automotive diesel has a price advantage for consumers because of a lower tax rate compared to gasoline. The government maintains excise duties on diesel (EUR 0.383/litre in 2009) lower than those it places on motor gasoline (EUR 0.562/litre).

Retail supply

In the downstream oil sector, approximately 90% of the market is represented by five companies: Statoil, Shell, Kuwait Petroleum, Uno-X and OK. All are members of the Danish Petroleum Association (EOF). Since the previous in-depth review in 2006, consolidation in the Danish oil industry has continued, with many smaller players being purchased by the larger companies. The acquisition of Conoco/Jet by Statoil is one of the more significant examples of this consolidation in recent years. Statoil has also announced that it will put its retail and industry sales organisation into a separate, publicly traded company.

INFRASTRUCTURE

Refineries

Denmark has two refineries, one in Kalundborg and the other in Fredericia, with a total crude distillation capacity of 173 kb/d. The Kalundborg refinery (102.5 kb/d), owned by Statoil, primarily runs Norwegian crude, but is flexible to run condensates and other crudes (*e.g.* Danish crude). All crude oil, including condensates, is supplied by ship. The Fredericia refinery (70 kb/d), owned by Shell, processes mostly Danish North Sea crude oil supplied by pipeline from Danish offshore production.

In comparison to Danish oil demand, the domestic refineries produce a surplus of gasoline and residual fuel oil and a deficit of middle distillates. Trade in refined products is thus necessary to balance domestic supply and demand. At the same time, market players often import products from other suppliers rather than purchase from their competitors operating domestic refining.

Ports and pipelines

Denmark has one crude oil pipeline connecting some of the offshore production to the refinery and export terminal, both at Fredericia. Owned and operated by DONG Oil Pipe A/S, the pipeline is 330 km long and has a capacity of 360 kb/d.

A product pipeline system, NEPS (Northern European Pipeline System), extends from Heide (Germany) to North Jutland and is owned and operated by the Danish military forces. In addition, the public stockholding agency FDO owns and operates a number of product pipelines in Jutland and in Zealand, including one from the Kalundborg refinery to the Hedehusene terminal. This pipeline supplies a large volume of oil products to the Copenhagen area.

In addition to the ports at the refineries, the main terminals for loading and offloading oil products on tankers are the ports of Aalborg, Aabenraa, Copenhagen and Stigsnaes. The various other ports are used for only importing oil products.

STORAGE

Storage capacity in Denmark is just over 49 mb (7.8 million cubic metres). Nearly 5.9 mb of this capacity is for crude oil at the two refineries (Fredericia and Kalundborg). As a proportion of refining operations in 2009, this is the equivalent of roughly 37 days of refinery intake.

Denmark has a number of coastal and inland product storage facilities that also serve as terminals for the distribution system, which is mainly carried out by trucks. The major product storage sites are located at the refineries and at a major terminal on Zealand at Stigsnæs.

Approximately 12.6 mb (2 mcm) of the country's storage capacity is owned by the stockholding agency, FDO. This includes a network of 15 underground storage sites, operated directly by the FDO, with total capacity of some 5.3 mb for gasoline and gasoil. The amount also includes FDO's two above-ground storage facilities in connection with the two domestic refineries. These are integrated with the operations of the refineries and are operated by refinery personnel to facilitate the refreshment (or turnover) of products. In Fredericia, capacity is close to 5 mb (800 000 m^3) for gasoil and heavy fuel and in Kalundborg the capacity is approximately 2 mb (330 000 m^3) for gasoil.

The compulsory stockholding obligation (CSO) in Denmark is 81 days of consumption. This equates to roughly 10.8 mb (1.7 mcm) of storage capacity necessary to meet the entire CSO. The FDO covers approximately 70%, thus leaving industry to cover some 3.24 mb of the obligation.

Under normal operating conditions, the minimum operating requirements (MOR) of the Danish oil industry is estimated at 11 days (forward demand) for crude oil and 17 days for refined products. These figures are based on an IEA study conducted in 2002, and correspond to the European average for MOR found in the same study. The Administration noted that while it has not reassessed the issue since the time of the study, it assumes that the figures remain valid as there have been no substantial changes in the market over the period (*e.g.* same number of refineries, storage sites, etc.).

PRICES AND TAXES

Upstream taxation

Taxes and fees imposed on the production of oil and gas make a substantial contribution to government resources (DKK 257 billion in 2009 prices in the period 1963-2009). Falling production and lower international prices resulted in a 39% significant drop in

revenues in 2009 (DKK 24.6 billion) when compared to the 2008 record levels. The Ministry of Taxation estimates that state revenues earned from hydrocarbon production will range from DKK 21 billion to DKK 27 billion per year from 2010 to 2014, on the basis of a USD 95 per barrel oil price scenario.

Corporate income tax and hydrocarbon tax are collected by SKAT (the Danish Central Tax Administration), while the Danish Energy Agency administers profit-sharing and the collection of royalty, the oil pipeline tariff and compensatory fee.

Downstream taxation

The energy tax system is differentiated between space heating (in businesses and households) and energy used in production processes. The energy taxes are balanced according to the energy content of the different fuels.

In January 2008, the CO_2 tax levied on VAT-registered enterprises was DKK 150 per tonne, an increase of DKK 60 per tonne. In addition to the carbon tax, a wide variety of other taxes are applied to energy consumption and use with the exception of fuels for electricity generation.

Motor taxation

There are two types of taxes levied on motor vehicles: a registration tax and an annual circulation tax. The registration tax (or passenger car tax) is a tax on the purchase price of new motor vehicles.

If a vehicle is used for transporting goods, it is exempt from the passenger car tax: instead, it is taxed on the weight of the vehicle. Since 1 July 1997 the annual tax on motor vehicles has been based on energy consumption (the green-owner tax) measured in accordance with EU Directive 93/116/EC.

Petrol-driven (diesel) passenger cars and vans receive a tax reduction of DKK 4 000 for each kilometre in excess of 16 kilometres (18 km) the vehicles run per litre of petrol (diesel). Similarly, a tax increase of DKK 1 000 for each kilometre less than 16 kilometres (18 km) the vehicles run per litre of petrol (diesel) is received. This is expected to lead to a yearly emissions reduction of 0.05 million tonnes CO_2. This incentive replaces a reduction in the registration tax for highly energy-efficient private cars, which was introduced in January 2000.

SECURITY OF SUPPLY

Stockholding obligation

As a net exporter, Denmark has no stockholding obligation to the IEA. But as a member of the EU, it has a stockholding obligation of 67.5 days of consumption. The present arrangements go well beyond this, setting a compulsory stockholding obligation on industry of 81 days of consumption. Some 70% of this is covered by the Danish stockholding agency FDO, largely in the form of refined products. In an IEA collective action, the government would likely participate with the release of oil from the FDO stocks. Demand restraint measures would only be considered in a severe and prolonged disruption.

In an oil supply crisis, the government can utilise oil stocks held by FDO. Specific demand restraint measures have not been prepared and do not form part of an initial response. In a severe and long-lasting crisis, however, the Administration would consider light-handed measures to supplement the use of FDO stocks.

NATURAL GAS

UPSTREAM

Resources and production

In 1984 Denmark began natural gas production in the North Sea and has been a net exporter since then. Production comes primarily from the Tyra, Halfdan, Dan and Tyra SE fields, which account for three-quarters of total Danish gas production. Approximately 10% of total production is used in the field as fuel for injection or is flared. The proportion of natural gas used as lift gas in wells with increasing water production could grow significantly in the coming years as oil extraction becomes increasingly difficult from ageing fields.

Production peaked in 2005, with a total of 10.4 billion cubic metres (bcm) produced. Total production has declined steeply since and was 8.2 bcm in 2010.

While Danish gas production is expected to continue to decline sharply in the very short term, it will increase substantially in 2014 and 2015 thanks to the development of new and existing fields. According to DEA's expected production profile, Denmark will likely remain a net exporter of gas up to and including 2020. The gas consumption forecast associated with this estimate is for a decline in gas demand, averaging roughly -1.3% per year to 2030.

As with oil production, there is the potential for prolonging the period of self-sufficiency in gas supplies. When including technological and prospective resources, the DEA estimates that Denmark will be a net exporter of gas beyond 2030.

At the same time, it should be noted that, as Swedish gas demand (1.2 bcm in 2009) is supplied entirely with gas that flows through the Danish network, there could be a need for Denmark to import gas much sooner than forecasts for self-sufficiency suggest. In particular, the near-term decline in production reflected in DEA expected production profile indicates that in 2013, imports will be required to meet the combined gas demand of both Denmark and Sweden.

On the basis of its Open Season 2009 process, which solicited bids for long-term transport contracts concerning newly established transmission capacity, the TSO, Energinet.dk, assesses that the Danish market will have to receive supplies from Germany in the near future. The necessary interconnection to Germany involves establishing a compressor station as well as looping the Frøslev-Egtved pipeline (see Figure 24). The investment was approved by the Danish Minister of Climate and Energy in May 2010 but awaits the completion of a parallel Open Season process in the German system, an environmental impact assessment (EIA) in Denmark and a final decision from Germany at the end of 2010 regarding expansion. The operation of the interconnection is forecast for October 2013. The government is also looking into establishing a

connection to Norwegian gas supplies through existing offshore infrastructure or directly to shore, in order to assure the longer-term supplies of gas to the Danish and Swedish markets.

Exports

Denmark is currently a net exporter of gas, and this situation is expected to continue until 2020 inclusive. In 2009, natural gas production was 8.4 billion cubic metres (bcm), approximately half of which was exported to Sweden, Germany and the Netherlands. Almost 1.6 bcm was exported via the Tyra installation to the NOGAT pipeline, while around 1.2 bcm was exported to Sweden. In addition, almost 1.1 bcm of gas was exported to Germany.

TRANSPORT INFRASTRUCTURE AND OPERATIONS

Access to the transport system

For existing pipelines, there is regulated third-party access to all capacities. Shippers book capacity online. Contracts can be booked for one year and for any duration below. All information about firm and interruptible capacities is available as real-time online data.

Energinet.dk lets the market players' demand for capacity influence whether new capacity is required.

In 2009, and in the future, this will be done by performing an Open Season process. If shippers will commit contractually for long-term contracts to the business case related to the infrastructure concerned, Energinet.dk will undertake the construction.

DOWNSTREAM

Demand

Demand for natural gas in 2010 was around 4.9 bcm, up from 4.4 bcm in 2009, the latest year for which data on consumption by sector are available. In that year, the bulk of gas consumption, 45%, was used for power generation in the transformation sector. Industry made up the second-largest group, representing 17% of gas use, while the energy sector, where gas is used for oil extraction, represented another 16%.

Daily gas consumption in Denmark normally ranges from a level of around 4 million cubic metres per day (mcm/d) in the summer to 20 mcm/d in the winter. The expected maximum daily consumption when temperatures reach minus 13°C is about 25.3 mcm/d (24.0 million normal m^3/day).

Future Danish gas consumption, according to government forecasts, is expected to decrease by 1.3% per year from 2010 to 2030. This infers gas demand of 4 bcm in 2015 and 3.8 bcm in 2020. The reason for the forecast decline is greater energy efficiency, a decrease in gas use at power plants, a decrease in gas consumption at decentralised CHP

as a consequence of wind power development and a shift towards biogas. This fall is offset by the use of gas in connection with upstream oil production, which could potentially grow as oil extraction becomes harder from ageing fields.

Distribution and infrastructure

Denmark has one transmission system, owned and operated by Energinet.dk, on behalf of the Danish State. Transmission tariffs are based on an entry-exit model and the same tariffs apply to all entry and exit points. The natural gas transmission system consists of upstream pipelines in the Danish part of the North Sea and onshore transmission pipelines. The transmission pipelines go north-south (Aalborg-Ellund) and west-east (Nybro-Dragør). The natural gas transmission system also includes a gas treatment plant (Nybro) and two underground gas storage facilities (Stenlille and Lille Torup).

The Danish gas transmission grid is connected to the German gas transmission grid at Ellund on the Danish/German border and to the Swedish gas system at Dragør. Sweden is solely supplied with gas via the Danish gas system.

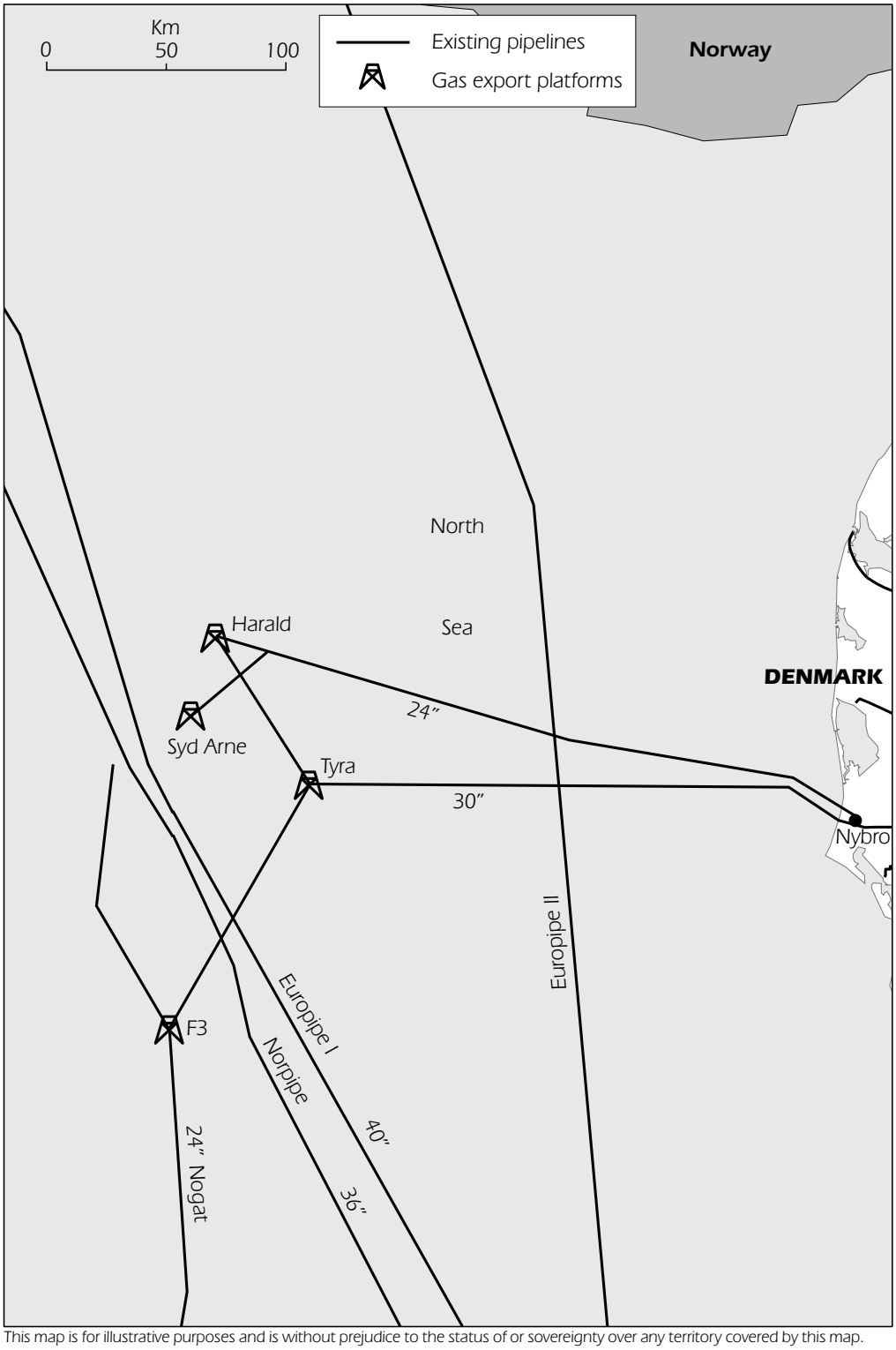
Natural gas from the Danish section of the North Sea is transported through two offshore pipelines from the Tyra and Syd Arne fields to the shore north of Esbjerg at a maximum pressure of 138 bar. In summer with lower daily quantities, the outlet pressure is reduced to minimise the energy consumption for compression. In winter, the pressure is increased to also ensure large volumes of line pack (*i.e.* the gas volume naturally stored in the actual gas pipelines) in the event of disruptions and emergency situations. The Tyra-Nybro pipeline has a capacity of approximately 28.5 mcm/d (27 million Nm^3/day); the Syd Arne-Nybro pipeline capacity is 13.7 mcm/d (13 million Nm^3/day).

Onshore, natural gas passes through a gas treatment plant in Nybro, where the quality of the gas is checked and measured, and pressure is reduced to the maximum pressure for land pipelines of 80 bar. The plant can also reduce the content of impurities such as heavy hydrocarbons, and remove any hydrogen sulphide if necessary for the gas to comply with the agreed specifications. If the gas is to be cleaned, only reduced volumes can be supplied (about 50%).

With existing pipeline configurations, it is not possible to import gas. Recently, a decision was taken to build a new compressor station that will enable import via the pipeline through South Jutland to Germany. In the period until then, other temporary solutions will be needed to secure the supply of gas.

There are three Danish distribution network companies which operate the distribution system in five distribution areas: Naturgas Fyn Distribution, DONG Gas Distribution and HMN Naturgas. DONG Gas Distribution is an integrated part of DONG Energy which is state-owned and represented by the Minister of Finance. Each of the two other distribution companies are also part of integrated undertakings which are owned by municipalities.

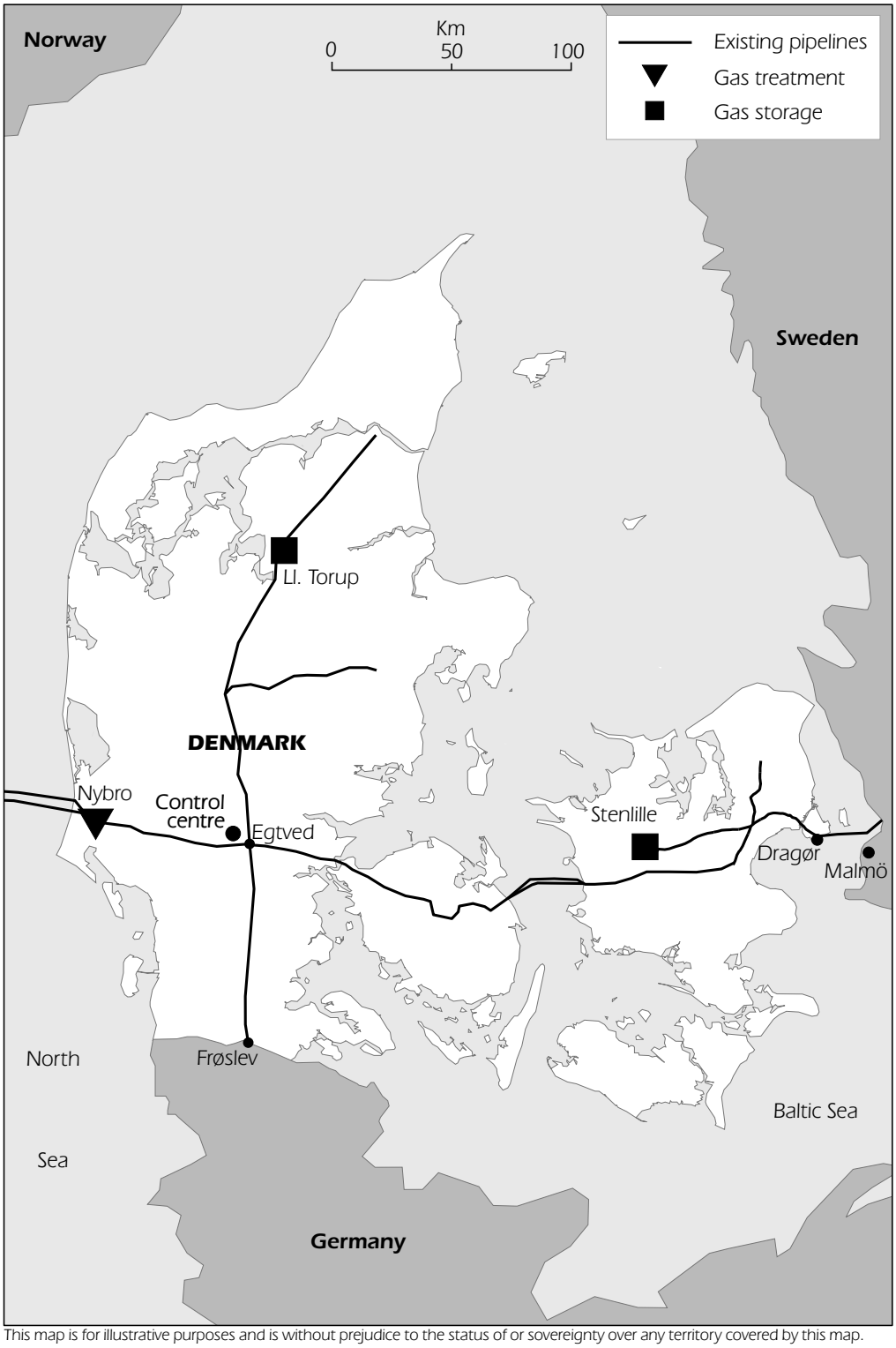
Figure 23. **Offshore natural gas transmission system**



This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory covered by this map.

Source: IEA.

Figure 24. **Onshore natural gas transmission system**



This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory covered by this map.

Source: IEA.

Storage

There are two natural gas storage facilities in Denmark with a combined capacity of 1.0 bcm of working gas. The storage facilities are primarily used to even out seasonal fluctuations, as daily demand for natural gas during the winter can reach levels six to seven times that of the summer. Storage can also be used as emergency supply facilities in case of interruptions to gas deliveries. The TSO, Energinet.dk, has access to a volume of this gas, fixed annually (approximately 215 mcm in 2009/10), as part of the available emergency response measures.

The storage facility in Lille Torup (Northern part of Jutland) is owned by Energinet.dk Gas Storage and comprises seven salt caverns with a combined firm working volume of 420 mcm. Firm injection capacity is 3.6 mcm/d and firm withdrawal capacity is 14 mcm/d. However, because of restrictions in the transmission system, withdrawals are limited to 8 mcm.

The storage facility in Stenlille (western part of Zealand) is an aquifer structure owned by DONG Energy and has a firm working volume of 588 mcm. Firm injection capacity is 4.8 mcm/d and firm withdrawal capacity is physically 11 mcm/d. However, owing to restrictions in the transmission system, the storage is only able to offer 9.5 mcm/d. The Stenlille gas storage facility can be expanded relatively easily to a working volume of up to 750 mcm.

Storage capacity is sold partly on long-term contracts, negotiated between storage facility owner and customer, and partly by auctioning short-term contracts (one to five years). In 2010 Energinet.dk introduced a short-term (monthly) product sold on first-come first-served. In the 2009/10 gas year, approximately 30% of storage capacity was sold in one-year contracts, 20% was reserved by Energinet.dk for emergency supply and 4% and 8% of the capacity was sold in the form of five- and three-year contracts, respectively. Danish storage capacity can be traded at the secondary market in the Danish transmission system.

Markets

The Danish natural gas market was liberalised in January 2004. There are no barriers to new entrants, and all consumers are free to choose their supplier. The state-owned TSO, Energinet.dk, owns and operates the transmission network. There are three distribution network operators and five active participants in the retail market, three of whom have an obligation to supply (DONG Energy Gasforsyning, NGF Gazelle Gasforsyning and HNG Midt-Nord Salg). An independent regulator, the Danish Energy Regulatory Authority (DERA), oversees the operation of the market. A newly opened gas exchange (Nord Pool Gas) is also expected to contribute to the transparency and efficiency of natural gas price formation.

SECURITY OF SUPPLY

Emergency response policy

In the natural gas market, Energinet.dk is responsible for maintaining minimum standards and preparing an annual plan for assuring security of supply. In a crisis, Energinet.dk would take over the role of gas supplier to the Danish market, with an

obligation to ensure supplies of gas to the non-interruptible Danish end-users. It would do this by drawing on measures only available to Energinet.dk in emergency supply situations, *i.e.* deliveries from the two underground storage sites in Denmark, rerouting of natural gas supply from the North Sea via the Syd Arne pipeline and limiting supplies to interruptible end-users.

Emergency organisation

The Danish Minister of Climate and Energy is responsible for energy policy, including security of oil supply and relations with the IEA and the EU. Within the DEA, the National Emergency Sharing Organisation (NESO) is the body that co-ordinates among all and ad-hoc groups that may be established in the event of an oil crisis. The emergency unit handles all matters regarding the compulsory stockholding obligation, tasks related to the stockholding agency FDO and dialogue with the companies regarding their CSO. It also handles stockholding ticket applications and bilateral agreements with other EU member states. The data unit is responsible for collecting all relevant oil data and calculating the CSO of companies as well as data reporting to the IEA Secretariat.

OIL AND NATURAL GAS IN *ENERGY STRATEGY 2050*

The government's long-term vision is for Denmark to be 100% independent of reliance on fossil fuels. In September 2010, an independent Danish Commission on Climate Change Policy (the Climate Commission) published proposals and detailed recommendations as to how this vision can be achieved. These recommendations formed the basis of the E*nergy Strategy 2050*, which was published in February 2011.

Predictably, the Strategy envisages little use for fossil fuels in Denmark after 2050 but it does not ignore its potential uses before then. The strategy acknowledges the huge impact the industry has on the Danish economy; oil and gas activities have created economic growth and a large skill base which can, in the longer term, help transform Denmark into a low-carbon economy.

The Strategy also acknowledges that the industry will continue to make a contribution to the economy over the medium term and identifies a series of government actions that can maximise this potential.

Oil use in the transport sector

Another obvious goal of *Energy Strategy 2050* is to lower oil consumption in the transport sector. The Strategy notes that there is unlikely to be substantial conversion to a non-fossil-powered transport sector in the immediate future but instead forecasts that that the use of oil will stabilise because of greater use of biofuels and increased vehicle efficiency. A more efficient transport sector will provide a sound basis for subsequent reductions in the transport sector's use of oil as an alternative to petrol and diesel will become more competitive. A technology shift from oil-based transport to non-fossil alternatives is the challenge that will have to be dealt with after 2020.

Box 14. **Government actions towards an efficient and environmentally sound utilisation of North Sea resources**

- Secure a more transparent framework for using the existing infrastructure in order to improve possibilities to expand economically marginal oil and gas occurrences.
- Implement a review of the framework for oil and gas extraction for future tendering rounds and for the use of CO_2 injection to improve extraction rates.
- Analyse the exploration potential in Denmark and assess when, and on what terms, new exploration licences can be offered (7th round).
- Promote a new phase of the Joint Chalk Research collaboration between Danish and Norwegian authorities and oil companies with a view to increasing oil extraction from chalk fields.
- Promote exploration for new oil and gas fields in deeper layers through a project led by the Geological Survey of Denmark and Greenland (GEUS) in research collaboration with oil companies. The project will assess opportunities for new oil/gas finds and reassess existing finds in deep layers.
- Negotiate with oil companies for a new action plan to replace the existing plan for more energy-efficient extraction of oil and gas from the North Sea.
- Examine possibilities to improve and co-ordinate authority administration of oil and gas activities onshore.
- Analyse opportunities to secure recruitment for the oil sector through education initiatives in the fields of oil and gas.
- Negotiate a new environment action plan with the oil companies to secure lower environmental impact from oil and gas extraction in the North Sea, and evaluate and possibly revise the Strategy for inspection by the Danish Energy Agency of safety and health conditions in the North Sea.

Source: *Energy Strategy 2050*.

Natural gas use in the medium term

Energy Strategy 2050 contains a number of initiatives aimed at reducing natural gas use in the medium term – these include actions to create incentives to switch from natural gas to biomass use in combined heat and power production, and to the phase out gas boilers and the use of natural gas for space heating.

Conversely, the Strategy also acknowledges that there may be an important role for the natural gas grid and its associated storage facilities in the future energy system, provided that it can be utilised to transport biogas and other types of gas from organic sources. The Strategy forecasts that these gases can be used at CHP plants and behave as a foil to fluctuating electricity production from wind turbines.

The Strategy mandates the government to analyse future regulatory mechanisms for gas infrastructure in future years to ensure optimal use and maintenance of the existing gas infrastructure. The analysis will examine its use in the transitional phase, and in the future when biogas and other renewable gases have entered large-scale usage.

Nonetheless, the Strategy should give greater consideration to the use of natural gas as a potential bridge between the present largely coal-fired electricity system and the low-carbon electricity system of the future. The movement towards biomass and wind power will bring some energy security risks and natural gas can be used to temper those risks. The Strategy acknowledges the need for an analysis of the use of biomass for energy-related purposes; it is clear that biomass could be a limited resource in the future and that long-term security and sustainability of supply is far from certain. Therefore, the move towards biomass could take longer than planned or may not occur to the scale envisaged. Natural gas is an ideal technology with which to address any short-term electricity security concerns. Existing gas-fired technologies can deliver the additional flexibility needed to support the large-scale integration of wind power in the medium term.

COAL

SUPPLY AND DEMAND

Denmark has no indigenous coal resources and imports all its coal needs. In 2010, coal represented 19.5% (or 3.8 Mtoe) of TPES, all of which is steam coal, largely imported from Russia, South Africa and Colombia (75% of supply combined). Almost 95% of demand comes from the power-generating sector (35% of output in eastern Denmark, 46% in western Denmark) with the remaining balance used by the industrial sector.

Coal imports increased notably in 2003 and 2006; in these years thermal-power plants were operated more intensively to replace drought-affected hydropower and more coal-generated electricity was exported to neighbouring countries. The government expects coal imports to be reduced by 50% and to be phased out in the longer term as part of its long-term energy strategy.

Denmark's twelve coal-fired power plants provide 5 201 MW of electricity capacity, although not all units run exclusively on coal. The Danish coal-fired fleet contains some of the most efficient coal-fired power plants in the world, where new-generation pulverised-coal supercritical plants with sliding pressure were introduced in the 1990s.

At present, the average efficiency of coal-fired power plants is around 40%. For power plants commissioned between 1990 and 2000, efficiency is slightly higher. The most recent power plant commissioned in 1999 can achieve annual average efficiencies of up to 44%. Theoretical efficiencies are higher than the annual average. Coal-fired power plants are equipped with SO_x- and NO_x-reducing technologies, except for one older unit where de-NO_x equipment will be retrofitted in 2013.

The Nordjylland power station is a sea-water-cooled power station; while in power-only mode, it has an electrical generation efficiency of 47% net, on a lower heating value (LHV) basis. This is equivalent to efficiency on a higher heating value (HHV) basis of 44.9% net. The plant is regarded by some as the most efficient coal-fired unit in the world.

The Danish government is expected to announce plans that will require large power stations to convert from coal to biomass. It has been estimated that the conversion to biomass will cost the government DKK 900 million annually through the loss of levies on coal.

The Directive on Carbon Capture and Storage (2009/31/EC) will be implemented primarily in the Danish Subsoil Act. CCS may be used in the future to mitigate greenhouse gas emissions, provided it can be demonstrated as cost-effective and safe to humans and the environment. CO_2 injection for enhanced oil recovery (EOR) from the Danish oilfields in the North Sea is being evaluated by oil companies in Denmark. One project on CO_2 EOR is being supported by the Danish National Advanced Technology Foundation.

CRITIQUE

OIL AND NATURAL GAS

The first oil and gas field was discovered in Denmark in 1966; production has continued since 1972 and peaked at around 20 mcm between 2000 and 2005. Since then, production has been in decline; falling to about 14.2 mcm in 2010.[22] This rate of decline is expected to continue in the coming years; production in 2014 is expected to be as low as 9.6 mcm and according to the Danish Energy Agency's (DEA) baseline forecast for the next 20 years Denmark will be a net importer of oil from 2019. This forecast is based on a number of assumptions about technological progress, prices, economical development etc, and it is assumed that no new initiatives or policy instruments will be implemented.

Nonetheless, technological developments and new discoveries are expected to contribute to additional production and thus prolong Denmark's period of self-sufficiency in oil. According to the DEA assessment of Danish oil resources, the use of proven secondary recovery methods, such as horizontal wells and water injection, has increased the average recovery factor up to almost 30%. At present, about 20% of known reserves have been recovered, and the DEA estimates that at least 6% more can be recovered with the use of known technologies. Therefore, the duration of production activities will depend on how the overall average recovery factor develops and the DEA estimates that this rate can be increased by 5% when the contribution from technological developments is taken into account.

Government initiatives supporting enhanced oil recovery include an independent assessment, prepared by the North Sea Fund, the Danish Energy Agency and Mærsk Olie og Gas, of existing worldwide experience with different methods to recover greater volumes of oil from remaining fields, but it is unclear if industry needs additional financial incentives to produce from these resources.

Oil production on the Danish Continental Shelf is dominated by a few companies; Mæersk, DONG and Hess. Mæersk is the operator of 15 fields; DONG has three and Hess one field. Denmark should make a greater effort to attract more producers to the Shelf in order to maximise the value of their resources. One means to do so is via the licensing regime.

Licences for exploration in Denmark are granted through licensing rounds and via an Open Door procedure, where oil companies do not have to commit to exploratory drilling when the licence is granted. The Open Door policy was introduced in 1996 and covers the area east of 6°15' longitude. No commercial discoveries have been made in

22. Update of the Danish Energy Agency's Five-Year Forecast of Danish Oil and Gas Production, Danish Energy Agency, December 2010.

this area. Denmark has licensing rounds for the area west of 6°15' eastern longitude. The latest licensing rounds comprised all non-licensed areas west of 6°15' eastern longitude.

In general, the IEA welcomes the government's efforts to encourage increases in oil and natural gas production and recovery, and recommends it to continue to do so by opening new acreage for exploration and by offering additional favourable fiscal and regulatory incentives, when appropriate.

Environmental considerations are long integrated to government policy on the use of petroleum resources. Following the Deepwater Horizon spill in the Gulf of Mexico, Denmark decided to review all energy safety rules and opened a dialogue with other countries in the North Sea to ensure overall safety levels.

The natural gas market of Denmark is fully liberalised and there are no barriers to new entrants. Energinet.dk owns and operates the transmission network across the country and there are three distribution system operators as well as five active players in the retail market. Denmark maintains two gas storage facilities with a combined working capacity of over one billion cubic metres, which is sufficient to cover two months of national consumption, even at a time of gas disruption. Currently the gas storage facilities are owned and operated by DONG and Energinet.dk respectively. A well resourced independent regulator, the Danish Energy Regulatory Authority (DERA), oversees the operation of the market. A newly opened gas exchange (Nord Pool Gas) is also expected to contribute to the transparency and efficiency of natural gas price formation.

In February 2011, the government launched its *Energy Strategy 2050,* which outlined proposals for the early phases of the process towards meeting the long-term goal of achieving national independence from coal, oil and gas. The Strategy identifies a series of actions the purpose of which is to phase out the use of natural gas and oil throughout much of the energy system. The strategy takes a pragmatic approach with regard to the transport sector, the largest consumer of oil in Denmark, and recognises that there will be no major shift away from oil in the medium term. Instead, it focuses on measures to stabilise oil use in the sector such as increasing biofuels use and support for electric vehicles.

Nonetheless, implementation of the Strategy needs to examine the energy security risks posed by a shift in the power sector away from coal towards biomass and biogas, as well as the displacement of fossil-fuel generation by higher levels of wind power penetration. Natural gas and existing transportation infrastructure is likely to be an efficient tool with which to manage this risk and the government should conduct detailed analysis of this potential.

COAL

Coal is the main source of fuel for the Danish fleet of thermal-powered electricity generation plants at present and Denmark operates one of Europe's most efficient coal-fired fleets. The government plans to phase out the large-scale use of coal in the power sector as it implements its *Energy Strategy 2050*. A key initiative contained in the Strategy is a fuel shift from coal to biomass at large-scale heat and power plants. It is likely that this shift will only happen after a thorough analysis of the potential of biomass as a major source of energy supply.

Nonetheless, given its geological resources (oil and gas fields), its position as a fossil-fuel supplier and the potential of CCS in certain production processes, CCS may have a future role to play in reducing GHG emissions should the large-scale conversion to biomass not happen in the long term.

The Danish government has not explicitly ruled out future use of coal with CCS if this proves to be a cost-effective and environmentally responsible solution in the future energy system. Nonetheless, adoption of CCS in Denmark would be in the long term following successful implementation of the technology elsewhere. If this were to be the case, government and industry will need to consider how CCS might contribute to CO_2 emissions reductions taking into account the development of other low-carbon technologies and low-carbon options for power generation.

The IEA understands that an application for permission to store CO_2 in the Vedsted structure in North Jutland was submitted to the Danish Energy Agency in 2010, indicating interest in the technology within the national energy context. The government must therefore clarify if CCS will form part of its long-term strategy to reduce emissions.

RECOMMENDATIONS

The government of Denmark should:

Oil

- ☐ *Maintain and develop policies favourable to investments in new technologies and new recovery methods to prolong the life of existing oilfields.*
- ☐ *Promote exploration activity by means of supportive policy instruments to increase the expected production profile (reserves plus contingent resources) of oil in order to fully explore the potential of oil reserves.*

Natural gas

- ☐ *Promote exploration activity by means of supportive policy instruments to increase the "expected production profile" (reserves plus risk-weighted contingent resources) of natural gas in order to fully explore the potential of conventional and unconventional gas reserves.*
- ☐ *Ensure diversification of natural gas supply, in terms of sources and routes, in order to enhance the supply security over the next few decades.*
- ☐ *Enhance competitiveness of the wholesale natural gas market through Nord Pool Gas to increase the transparency of natural gas price formation.*
- ☐ *Examine the medium-term potential of natural gas to support the transformation of the electricity sector to a low-carbon future and as a tool to manage the system risks related to the integration of large amounts of wind power.*

Coal

- ☐ *Clarify its position regarding, and the prospects for, CCS in Denmark and, if necessary, ensure that funding is in place to support a robust regulatory framework complemented by a programme on CCS outreach/engagement to educate the general public on the possible impacts of CCS.*

PART III
ENERGY TECHNOLOGY

8. ENERGY TECHNOLOGY RESEARCH, DEVELOPMENT AND DEPLOYMENT

Key data (2010 estimates)

Government energy R&D spending: DK 1057 million, +39% from 2009, renewable energy projects receiving 33% of funding

Share in GDP: 0.6 per 1 000 units of GDP (IEA median: 0.32)

R&D per capita: USD 34 (IEA median: USD 11)

OVERVIEW

Energy technology research, development, demonstration and deployment are a priority for Denmark. Over the period 2006 to 2010, energy technology research and development budgets more than doubled and many new policies and programmes, many focusing on clean energy technologies, were established.

Energy-related research policy is largely consistent with national energy policy. Energy technology research and development (R&D) for bioenergy, wind, and energy efficiency represents 26%, 17% and 13% of research spending. Hydrogen cells and fuel cells (16%) for the transport and building sectors, and energy systems (13%) complete the majority of programmes, with the remainder of support allocated to solar, wave, geothermal and other technologies.

RECENT DEVELOPMENTS

Energy Strategy 2050

The government's long-term *Energy Strategy 2050* recognises that the development of more efficient and cost-effective energy technologies is required if the government is to achieve its goal of fossil fuel independence by 2050. Therefore, the Strategy provides that the government will take action, in co-operation with relevant players, to identify and assess energy technology research, development and demonstration (RD&D) initiatives, in order to identify sectors where strategic support for RD&D will deliver the greatest value to society.

On the basis of such an assessment, a number of specific flagship programmes could be established to support the Strategy as well as current Danish commercial strengths. In addition, the Strategy identifies where investment in RD&D can support actions in other sectors such as transport.

The Strategy establishes a number of principles for the transition to independence, which are explored elsewhere in this book. In summary, the transition will be cost effective, with initiatives providing maximum security of supply and the greatest reduction in the use of fossil fuels for every Danish krone of expenditure afforded the

highest priority. Accordingly, the technology focus is on research, development and demonstration of new technologies, which in the longer term can be competitive, at low levels of subsidy, if at all.

The Strategy, if successfully implemented, will allow the private sector to assist in developing new solutions in order to establish the best setting for developing new export technologies without undermining the competitiveness of the rest of the Danish economy.

The third phase of the Strategy – the research, development and demonstration track – focuses on the sectors in which the primary need is for more knowledge, analysis, research and development. It also emphasises demonstration and preparation for market efforts before incorporation into the energy and transport systems of the future can be implemented.

The government has already launched a number of initiatives to support Denmark becoming an attractive place for research, development, demonstration and testing of energy technologies for Danish as well as foreign companies. With the Erhvervsklimastrategien (climate strategy for companies), the government presented its vision to create a new green growth economy in Denmark.

Under this strategy, the framework conditions for clean technology companies were strengthened by establishing Green Labs DK and the market maturity efforts of the Innovation Foundation. In 2010, the government allocated more than DKK 1.5 billion for research, development, demonstration and market preparation of new clean-energy solutions. Furthermore, the government initiated establishment of a national test centre for wind turbines in Østerild in the north-western part of Jutland. This test centre will support the wind turbine industry and its research institutions by providing full-scale test facilities.

In addition to energy and climate effects, initiatives in *Energy Strategy 2050* will also support Denmark's position as a laboratory for green technology research, development and demonstration, notably for energy technology. Government initiatives aim at stronger focus and co-ordination of allocations for energy technology RD&D. The government will seek partnership with the private sector to strengthen co-ordination of private and public efforts in the areas mentioned above, for example.

The government will also increase its focus on providing Danish and foreign clean technology companies in Denmark with access to highly qualified labour and research communities with skills in green energy.

Government initiatives will attempt to strengthen cohesion between development, testing, production and sale of new technology, and thereby strengthen companies' opportunities for innovation and demonstration of new clean energy solutions. The purpose of this approach is to support the export activities of Danish industry.

Box 15. **Actions in *Energy Strategy 2050***

Oil and gas sector

The government will promote a new phase of the Joint Chalk Research collaboration between Danish and Norwegian authorities and oil companies with a view to increasing oil extraction from chalk fields.

Box 15. **Actions in *Energy Strategy 2050*** *(continued)*

The government will support a project to assess opportunities for new oil/gas finds and reassess existing finds in deep layers led by the Geological Survey of Denmark and Greenland (GEUS) in research collaboration with oil companies.

Transport sector

The government will support a technology assessment in 2011, and subsequently every three years, in order to ensure the right framework for new technologies to support the targets for reducing GHG emissions from the transport sector in the short term up to 2020, and in the long term up to 2050. The government will also support efforts in the European Union for more intensive research and development efforts in green-transport technologies.

Research, development and deployment

Government initiatives will encourage greater cohesion between development, testing, production and sale of new technology, and thereby strengthen companies' opportunities for innovation and demonstration of new green solutions.

Undertake a strategic review of the public research, development and demonstration initiatives in the climate and energy area in order to support the transition to fossil fuel independence as well as the needs of the business community. Ways to improve co-ordination and interaction between relevant programmes and councils will also be identified.

The government will prioritise a doubling of the funds in the EU future budget for research, development and demonstration up to 2020 in the energy and climate change areas, particularly for renewable energy, smart grids and energy efficiency.

The government will enter into partnerships with private enterprises, research institutions and others, where this can contribute to developing, testing, and preparing for market of Danish clean technology solutions, *e.g.* wind solutions and bio-based products.

The government will actively support the establishment of larger test environments for green solutions in Denmark such as the wind turbine test centre at Østerild. Large, green support programmes such as the EUDP, Green Labs and the Innovation Foundation will be supplemented by partnerships or additional support for setting up more specific testing grounds such as Samsø (as a fossil fuel-free island).

The government will also develop and present a plan for test turbines.

The government will carry out a series of research and technology assessments in collaboration with the private sector in order to support a cost-effective framework for using renewable energy. The technology assessments will focus on a wide array of technologies.

The government will also investigate the need and opportunities for ensuring sufficient recruitment of university graduates and researchers into the clean energy sector.

Source: *Energy Strategy 2050.*

Energy Technology Development and Demonstration Programme (EDDP)

In November 2006, following a political agreement on research priorities, the Danish government established the Energy Technology Development and Demonstration Programme (EDDP). EDDP is charged with allocating programme funds for public-private partnerships and consortia between industry, research institutions and public authorities. Projects are chosen not only on the basis of energy and environmental merits, but also on commercial merits such as market potential and financial considerations.

In 2009, tax reforms lowered income taxes while increasing taxes on energy, climate and transport, for example an excise tax on new combustion-engine vehicles. The 2009 Green Growth Agreement between the government and one political party of Parliament made provisions for strengthening research and innovation initiatives, calling for investments to improve greenhouses or energy storage technologies in order to reduce energy and water consumption. The provisions of the agreement generally concern the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment.

Research and innovation initiatives within the agricultural and food sectors will be reorganised to become more dynamic, including environmental technology related to the industry, such as a Green Development and Demonstration Programme (GDDP). Political Agreements have also made provision for the creation of three to five Green Labs, or large test centres for new energy technologies. Designed to be operated in co-operation with multiple stakeholders from public, private and technology-transfer institutes, the first consultation and call for proposals (open tenders) was carried out in late 2010.

A new Agreement on Green Transportation was approved by the Danish Parliament in 2009, focusing on green transportation systems with better mobility and reductions in CO_2 emissions. The Agreement makes plans for strengthening the railway system, introducing an excise tax on private cars (internal combustion), and the creation of new sustainable technologies.

As part of the Green Transport Policy, the Ministry of Transport created the Centre for Green Transport. The Centre will conduct, in collaboration with private sector companies and municipal authorities, research projects in large-scale energy-efficient transport solutions such as energy-efficient buses in the public transport system and large private sector coach fleets.

Through these initiatives, and the increased funding for demonstration programmes through public-private partnerships, the Danish government has given a much larger place to industry and commercial considerations, and has taken steps to fill the gap between fundamental research and market uptake. This is commendable for the viability of certain technologies.

INSTITUTIONAL FRAMEWORK

The institutional landscape for Energy Technology Research and Development (ETRD) in Denmark is complex. Priorities are set by a number of bodies and programmes are carried out by as many others. In addition, the role of the private sector in ETRD priority setting is increasing.

Organisations responsible for setting ETRD priorities include the Ministry of Climate, Energy and Building, the Ministry for Science, Technology and Innovation and the Advisory Body on Research. Other ministries contributing include the Ministry of Transport and the Ministry of the Environment.

Agencies and intermediary bodies include the Danish Energy Agency, the Danish Agency for Science, Technology and Innovation, the Danish Environmental Protection Agency, the Danish Board of Technology, the Board of Danish Research Councils (and six Danish Research Councils), the Danish Road Directorate, the Fund for Advanced Technology (independent government board) and the TSO Energinet.dk.

The **Energy Technology, Development and Demonstration Programme** (EDDP) secretariat is an independent entity within the Danish Energy Agency. Its role is to support the demonstration and deployment of new energy technologies and ensure that projects support Danish business opportunities. The EDDP is managed by an independent supervisory board of seven members appointed by the Danish Minister of Climate and Energy.

The **Agency for Science, Technology and Innovation**, an agency under the Ministry of Science, Technology and Innovation, serves and oversees a wide range of independent councils, commissions and committees which support and advise on research and innovation in general. It supports and supervises the scientific research councils that allocate funds for independent research, for strategic research and for innovation.

In May 2011, the **Danish Council for Strategic Research** (DCSR), a council reporting to the Danish Council for Technology and Innovation, issued a call for projects under its Strategic Research in Sustainable Energy and Environment programme:

- Energy and Environment – Energy Systems of the Future (DKK 234 million);
- Competitive Environmental Technologies (DKK 29 million); and
- Climate and Climate Adaptation (DKK 15 million).

The role of the **Danish National Advanced Technology Foundation** is to enhance growth and strengthen employment by supporting strategic and advanced technological priorities within the fields of research and innovation. The Foundation typically funds 50% of selected projects, with the private sector accounting for 33% and universities approximately 17%. A quarter of its projects are energy technology-related *(e.g.* second-generation bioethanol and biodiesel, fuel cells, enhanced oil recovery, wind turbine blades and, most recently, nanotechnology-based photovoltaics.

Energinet.dk, the owner of the electricity and natural gas transmission networks in Denmark, carries out research, in partnership with external Danish and international partners from universities, research institutions and the corporate sector. The work is supported by means of a public service obligation and research focused on electricity production (ForskEl) and consumption (Elforsk), as well as on natural gas distribution systems. Energinet.dk has invested in reearch related to thermal gasification of waste and biomass, hydrogen and fuel cells, integrated energy systems, and control of electricity systems and electricity consumption.

POLICIES AND PROGRAMMES

In 2008, the Danish Council for Strategic Research's e Commission on Sustainable Energy and Environment supported six strategic energy projects with a grant of approximately DKK 165 million, including a research centre for bioenergy and one dedicated to zero-emission buildings.

In 2009, EDDP distributed DKK 300 million, and DKK 400 million, in 2010 for development and demonstration projects of new energy technologies. Owing to increased public budgets for the DSCR Energy Commission and the EDDP, the overall Danish public budget for RD&D in energy technologies reached DKK one billion in 2010. This level of support is expected to continue in the medium term. Funding for specific programmes is included under each of the following technologies:

Bioenergy: the Agreement on Green Growth has introduced a starter pool of DKK 85 million annually for the establishment of new common biogas plants and farm unit-related investments associated with connection to a common plant from 2010 to 2012. The purpose is to promote, as a minimum, rapid establishment of common biogas plants which are necessary to achieve a significant increase in energy exploitation of livestock manure. Under this scheme, a plant grant can be awarded for up to 20% of the investment. The remaining funds will be provided by a 60% municipal-guaranteed loan and 20% own financing. Under the scheme, grants can be awarded to common biogas plants and farm unit-related investments for connection to a common gas plant. In addition, the EDDP set aside nearly DKK 100 million to develop second-generation bioethanol, including a demonstration plant in Kalundborg.

Wind: aside from significantly raising the transfer rate (feed-in tariffs) for electricity from land wind turbines, biomass and biogas, Denmark plans to install 400 MW from new offshore wind turbines by 2012. Plans to invest in two new 75 MW land-based facilities in 2010 and 2011 have also been announced. The deal also provides incentives and a compensation scheme for local residents to allow land-based wind farms to be located in their area, including a new stakeholder model.

Transport: ETRD priorities for the transport sector include biofuels (bioethanol, biodiesel, Fischer-Tropsch-related technologies) for existing vehicles, demonstration programmes for electric vehicles, and improving or extending the public transport system. The Danish Energy Agreement 2008-2011 includes DKK 10 million per year for 2008/09 and DKK 5 million per year for 2010-2012 for an electric vehicle test scheme.

The Electric Car Power Scheme will gather experience in the practical operation of electric cars, charging systems and the cohesion with the electricity system. The EDISON project will examine the load generated from charging electric cars, which is expected to pave the way for up to 400 000 Danish electric cars by 2020.

The EcoGrid project, to be completed in 2011, examines ways to integrate electric vehicles or a high share of wind and other renewable sources into the grid. Better Place and DONG Energy have made an agreement to invest in the Danish Better Place network for electric cars. DONG Energy will invest in the infrastructure and sustainable energy sources. Lastly, the research goals for electric vehicles are completed with the Smart Grid platform with other European countries under the auspices of the European Union.

In addition, the 2009 Agreement on Green Transportation sets out to improve or expand public transportation for which DKK 284 million have been earmarked from 2009 to

2013 (DKK 30 million will be allocated in 2010, DKK 30 million in 2011, and DKK 30 million in 2012), part of a total allocation of DKK 150 billion through to 2020.

Energy storage and systems: the Green Growth Agreement refers to a certain number of clean technologies, largely for the agriculture and food industries, but also including a reduction in consumption of energy, water, nutrients, and pesticides in the horticultural sector. This includes, for example, investments to improve greenhouses or energy storage technologies.

Solar, wave and bio-gasification: DKK 25 million per year over four years has been allocated to projects which promote solar photovoltaic, wave power and bio-gasification. CO_2 injection for enhanced oil recovery (CO_2 EOR) from the Danish oilfields in the North Sea is being evaluated by privately owned oil companies established in Denmark. One of these projects is also supported by the Danish National Advanced Technology Foundation.

STRATEGY AND PROGRAMME EVALUATION

Denmark does not have any general planning, procedure or criteria for evaluating the effectiveness of national research strategies. Rather, evaluations are designed and implemented on an *ad hoc* basis in specific situations. For example, an evaluation will be conducted after the first round of applications for the grant scheme for biogas from livestock manure (a programme that is part of the Green Growth Agreement 2010-2012) as well as an evaluation of the first four years of EDDP will take place in 2011.

There is insufficient information on the results of these spot-checks on programme effectiveness nor whether or how they are taken into consideration in future research planning, either by the ministries or any of the co-ordinating boards. Evaluations are not currently carried out according to any general procedures or criteria. The Danish Agency for Science, Technology and Innovation, however, has established Research Evaluation Guidelines. These guidelines are designed as a tool for assuring quality evaluations and provide advice on the object, stakeholders, process, action plan, study, roles and responsibilities and report drafting.

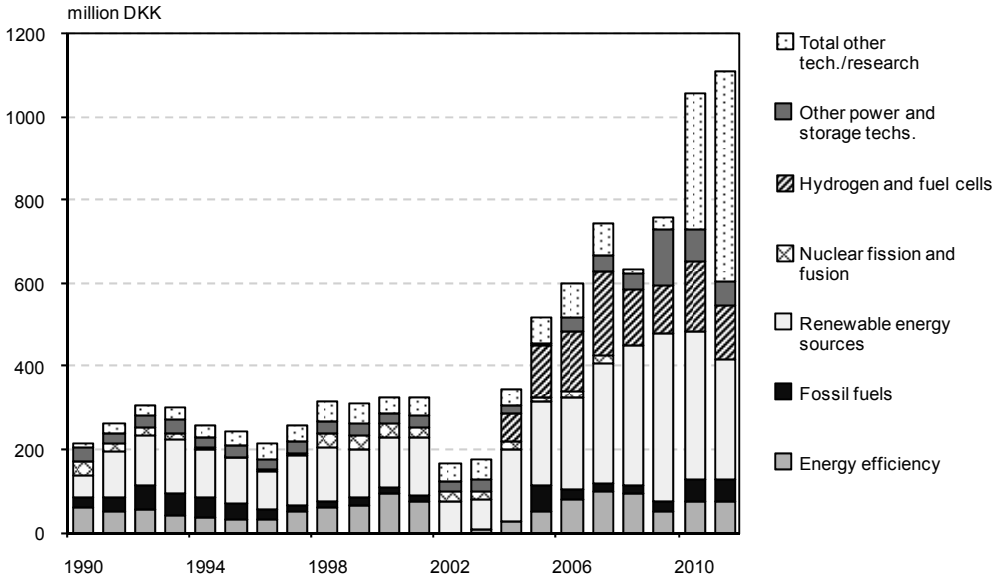
FUNDING MECHANISMS AND LEVELS

In 2009, Denmark ranked sixth among all IEA member countries in terms of research intensity (R&D/GDP), well ahead of the majority of the G8 countries.

Between 2006 and 2010, public energy-RD&D budgets have doubled; from under DKK 400 million in 2006 to a little more than DKK 1 billion in 2010. The Danish government has agreed to a significant increase in energy technology research, development and demonstration (ETRD&D).

The government supports RD&D directly by funding institutions and programmes. To a great extent, public funding is prioritised on the basis of strategies devised jointly between industry, research communities and authorities, and a relatively high amount of funds is spent on promoting the demonstration and supporting the market penetration of newly developed energy technologies.

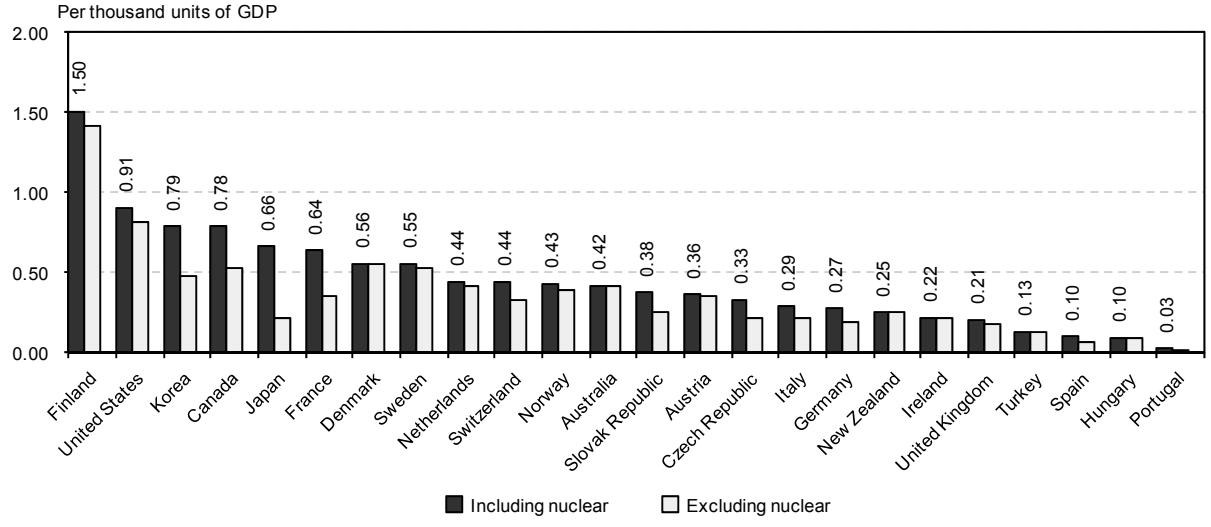
Figure 25. **Government RD&D spending on energy, 1990 to 2011***



* Estimates for 2010 and 2011.

Sources: *OECD Economic Outlook*, OECD Paris, 2011 and country submission.

Figure 26. **Government spending on energy RD&D per GDP in IEA member countries, 2009**



Sources*: OECD Economic Outlook,* OECD Paris, 2011 and country submission.

INTERNATIONAL COLLABORATION

International ETRD efforts and policies include participation in the EU-ETRD framework programme, activities under the Strategic Energy Technology Plan, the Nordic Energy Research Programme and the Nordic Top Research Initiative.

Denmark participates in 21 of the IEA multilateral technology initiatives (Implementing Agreements) in both supply and demand technologies, on a broad range of topics (end-use, renewables, fossil fuels) as well as cross-cutting themes:

- Cross-cutting: energy technology research database, energy technology systems modelling, R&D priority setting and evaluation.
- End-use buildings: buildings and community systems, district heating and cooling, efficient electrical end-use equipment, energy storage.
- End-use electricity: demand-side management, electricity networks.
- End-use industry: industrial energy-related technologies and systems.
- End-use transport: advanced fuel cells, advanced motor fuels.
- Fossil fuels: clean coal, enhanced oil recovery, greenhouse gas reduction.
- Renewables: bioenergy, hydrogen, ocean (tidal, wave, thermal gradients), photovoltaic power systems, renewable energy technology deployment, solar heating and cooling, wind.

In addition, the Danish Power Group participates as a sponsor in an Implementing Agreement relating to fossil fuels.

Denmark also participates in several regional – in particular Nordic – programmes. Nordic Energy Research (NER) is the funding institution for energy research under the Nordic Council of Ministers – an intergovernmental body between Sweden, Denmark, Finland, Norway and Iceland. NER funds and co-ordinates research, but also provides administrative expertise, network building and advice.

NordForsk is a Nordic research board with responsibility for co-operation on research and researcher training in the Nordic region. NordForsk is the Nordic Council of Ministers' advisory body in the area of research; it co-ordinates funds and provides policy advice. The objective of NordForsk's co-ordination role is to develop the Nordic Research and Innovation Area (NORIA) into an attractive, cutting-edge region for research and innovation.

PUBLIC-PRIVATE PARTNERSHIPS

Historically, there has been a close link between industry and universities for clearly defined technologies. In addition, there are programmes (public service obligations) that are designed and implemented by Danish utilities (after approval of the Danish Energy Agency). Industry is also involved in submitting and evaluating research proposals.

One of the tasks of the EDDP is to support the establishment of partnerships within relevant technologies. The goals of these partnerships are to:

- improve conditions for co-operation between industry, research institutions and public authorities:
- improve conditions for ETRDD;
- define ETRDD strategies; and
- develop project proposals.

CRITIQUE

Energy research policy in Denmark is a national priority and is largely consistent with energy policy. In 2009, Denmark ranked sixth overall among IEA countries in terms of R&D per unit of GDP. Support for research, development and deployment of new energy technologies will form a vital part of the implementation of *Energy Strategy 2050.*

Following a political agreement of November 2006 on research priorities, the government established the Energy Technology Development and Demonstration Programme (EDDP). EDDP is charged with allocating programme funds for public-private partnerships and consortia between industry, research institutions and public authorities. Projects are chosen on the basis not only of the energy and environmental aspects, but also of the commercial aspects (market potential, financial considerations). In the Energy Agreement of 2008, the government significantly increased support for research, development and demonstration efforts in energy technology, from DKK 750 million to DKK 1 billion from 2010.

The inauguration of EDDP underlined the government's goal to move technologies to the markets. The Danish Council for Strategic Research represents fundamental research with a large representation from universities; the Danish National Advanced Technology Foundation bridges the gap between private companies and public universities. However, because of the independence of each board to establish technology priorities, there is still considerable potential for overlaps or gaps in the technology portfolios. While the directors of each programme meet once or twice a year to discuss their work, a more systematic, transparent process by which the technologies in the respective portfolios are chosen would increase synergies.

A 2009 Agreement between the government and the political parties relating to Globalisation Funding made arrangements for the creation of three to five Green Labs. Designed to be operated in co-operation with multiple stakeholders from public, private and technology transfer institutes, the first consultation and call for proposals (open tenders) was carried out in the second quarter of 2010.

By establishing EDDP and Green Labs the Danish government has taken steps to fill the gap between fundamental research and market uptake of new technologies. Not surprisingly, the government has given a much larger place to industry and commercial considerations. This is a commendable form of support for the viability of certain technologies.

Denmark is also in a position to capitalise on energy from ocean technologies (wave, tidal, current, or thermal gradients). Though largely still in the pilot/demonstration phase, additional research in this area will be needed. Given Denmark's experience with wind deployment, it would be well placed to take the lead in this area. Denmark has set an ambitious goal to be independent of fossil fuels; therefore, viable alternatives will be needed, particularly in the transport sector. To help achieve this goal, Denmark has placed a priority on research for biofuels and electric vehicles. Three pilot programmes are under way for electric vehicles (covering charging, infrastructure and network integration issues). In addition, Denmark participates in the Smart Grids platform under the auspices of the European Union with other countries. Three of the five research boards have projects on biofuels.

Denmark fails to exploit indirect funding through tax credits for companies that invest in ETRD. This would spur innovation in the small and medium-sized enterprise sector, and, given the large energy players in Denmark, would send a strong signal to foster competition.

There remains considerable untapped potential for renewable energies other than wind, including wave (4% of ETRD budgets in 2010) and other ocean technologies such as current, tidal or thermal gradient. For geothermal, only 1 PJ currently feeds into the district heating and cooling network, yet there is some 40 PJ of capacity, and some estimates show this figure could be twice that amount.

International co-operation, for example the IEA multilateral technology initiatives (implementing agreements), represents 2% of Danish RD&D budgets at present. Denmark participates in 21 of the IEA implementing agreements in all areas except nuclear fusion. Denmark could also consider sharing best practices with wind deployment and apply these to research programmes of other leading-edge technologies (*e.g.* ocean).

RECOMMENDATIONS

The government of Denmark should:

- ☐ *Formalise co-ordination between the programme boards on the technology priorities to increase transparency, leverage resources, and avoid gaps.*
- ☐ *Put in place a systematic mechanism for evaluating the effectiveness of research programmes.*

PART IV
ANNEXES

ANNEX A: ORGANISATION OF THE REVIEW

REVIEW CRITERIA

The *Shared Goals*, which were adopted by the IEA Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews conducted by the IEA. The *Shared Goals* are presented in Annex C.

REVIEW TEAM

The in-depth review team visited Copenhagen from 14 June to 19 June 2010. During the week-long visit, the review team met with government officials, representatives from ministries and government agencies, energy producers and suppliers, interest groups and various other organisations and stakeholders. This report was drafted on the basis of these meetings and the government response to the IEA energy policy questionnaire and other information. The team is grateful for the co-operation and hospitality of the many people it met during the visit. Thanks to their openness and candour, the review visit was highly productive.

In particular, the team wishes to express its gratitude to Mr. Hans-Jørgen Koch, Deputy State Secretary, Ministry of Climate, Energy and Building, for his personal engagement in briefing the team on current energy policy issues. His willingness to share information and gracious hospitality contributed in no small way to a successful and productive visit. The author is particularly thankful to Mr. Steffen Nielsen from the Permanent Delegation of Denmark to the OECD and Mr. Peter Larsen from the Danish Energy Agency, for co-ordinating the team visit and for their ongoing support throughout the drafting process.

The members of the IEA Review Team that visited Copenhagen were:

IEA member countries

Mr. Bert Roukens, Netherlands (team leader)

Mr. Eric Eijkelberg, Netherlands

Mr. Anoop Kapoor, Canada

Mr. Kjetil Andreas Osen, Norway

Mr. Mattias Törnell, Sweden

European Commission

Ms Monika Eordoghne Zsigri

International Energy Agency

Mr. Shinji Fujino

Mr. Hideomi Ito

Ms Carrie Pottinger

Mr. Akira Yabumoto

Mr. Kieran McNamara (desk officer)

Kieran McNamara managed the review and drafted the report with the exception of Chapter 6 on Electricity which was drafted by Akira Yabumoto and Chapter 8 on Energy Technology Research, Development and Deployment, which was drafted by Carrie Pottinger. Hideomi Ito made a substantial contribution to the sections on natural gas in Chapter 7 and Akihiro Tonai contributed to the sections on oil and emergency preparedness in the same chapter. Ulrich Benterbusch, Shinji Fujino, Douglas Cooke, Hugo Chandler, Georg Bussmann and Rebecca Gaghen contributed helpful comments throughout.

Georg Bussmann and Bertrand Sadin prepared the figures. Karen Treanton, Alex Blackburn and Davide D'Ambrosio provided support on statistics. Muriel Custodio, Jane Barbière, Anne Mayne, Angela Gosmann and Astrid Dumond managed the production process. Viviane Consoli provided editorial assistance and Marilyn Ferris helped in the final stages of preparation.

ORGANISATIONS VISITED

Association of Danish Energy Companies

Commission on Climate Change Policy

Confederation of Danish Industries

Danish Consumer Council

Danish Council for Independent Research and Social Sciences (FSE)

Danish District Heating Association

Danish Energy Agency (DEA)

Danish Energy Regulatory Authority (DERA)

Danish Organisation for Renewable Energy (OVE)

Danish Society for Nature Conservation

DONG Energy Distribution

Energinet.dk

Greenpeace Denmark

Ministry of Climate, Energy and Building

The Ecological Council

Vattenfall

World Wide Fund for Nature Denmark

ANNEX B:
ENERGY BALANCES
AND KEY STATISTICAL DATA

Unit: Mtoe

SUPPLY		1973	1990	2000	2008	2009	2020	2030
TOTAL PRODUCTION		**0.43**	**10.08**	**27.74**	**26.62**	**23.91**	**18.51**	**17.36**
Coal		-	-	-	-	-	-	-
Peat		-	-	-	-	-	-	-
Oil		0.07	6.11	18.26	14.41	13.25	8.65	7.87
Natural Gas		-	2.77	7.41	9.02	7.53	5.08	4.10
Biofuels & Waste[1]		0.35	1.14	1.69	2.57	2.53	3.44	3.93
Nuclear		-	-	-	-	-	-	-
Hydro		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind		-	0.05	0.37	0.60	0.58	1.01	1.07
Geothermal		-	0.00	0.00	0.01	0.01	0.03	0.02
Solar/Other[2]		-	0.00	0.01	0.01	0.01	0.31	0.36
TOTAL NET IMPORTS[3]		**19.00**	**7.12**	**-9.53**	**-6.35**	**-5.02**	**0.05**	**1.97**
Coal	Exports	0.04	0.03	0.07	0.09	0.04	-	-
	Imports	1.91	6.25	3.86	4.44	3.97	2.58	1.88
	Net Imports	1.87	6.22	3.78	4.35	3.93	2.58	1.88
Oil	Exports	2.85	5.82	18.40	14.14	13.59	2.02	1.41
	Imports	21.43	8.57	9.91	9.59	8.98	1.90	2.58
	Int'l Marine and Aviation Bunkers	-1.42	-1.53	-2.06	-1.79	-1.29	-1.59	-1.55
	Net Imports	17.15	1.22	-10.55	-6.34	-5.90	-1.71	-0.38
Natural Gas	Exports	-	0.93	2.88	4.93	3.58	1.68	0.74
	Imports	-	-	-	-	-	-	-
	Net Imports	-	-0.93	-2.88	-4.93	-3.58	-1.68	-0.74
Electricity	Exports	0.11	0.42	0.67	0.98	0.94	-	0.00
	Imports	0.09	1.03	0.72	1.10	0.96	0.12	0.29
	Net Imports	-0.02	0.61	0.06	0.13	0.03	0.12	0.29
TOTAL STOCK CHANGES		**-0.44**	**0.16**	**0.43**	**-1.05**	**-0.28**	**-**	**-**
TOTAL SUPPLY (TPES)[4]		**18.99**	**17.36**	**18.63**	**19.22**	**18.61**	**18.56**	**19.33**
Coal		1.93	6.09	3.99	4.01	4.01	2.58	1.88
Peat		-	-	-	-	-	-	-
Oil		16.72	7.65	8.02	7.37	7.04	6.94	7.49
Natural Gas		-	1.82	4.45	4.08	3.90	3.40	3.36
Biofuels & Waste[1]		0.35	1.14	1.75	3.01	3.02	4.16	4.85
Nuclear		-	-	-	-	-	-	-
Hydro		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind		-	0.05	0.37	0.60	0.58	1.01	1.07
Geothermal		-	0.00	0.00	0.01	0.01	0.03	0.02
Solar/Other[2]		-	0.01	0.01	0.02	0.02	0.32	0.37
Electricity Trade[5]		-0.02	0.61	0.06	0.13	0.03	0.12	0.29
Shares (%)								
Coal		*10.2*	*35.1*	*21.4*	*20.9*	*21.6*	*13.9*	*9.7*
Peat		-	-	-	-	-	-	-
Oil		*88.1*	*44.0*	*43.0*	*38.4*	*37.8*	*37.4*	*38.7*
Natural Gas		-	*10.5*	*23.9*	*21.2*	*21.0*	*18.3*	*17.4*
Biofuels & Waste		*1.9*	*6.6*	*9.4*	*15.6*	*16.2*	*22.4*	*25.1*
Nuclear		-	-	-	-	-	-	-
Hydro		-	-	-	-	-	-	-
Wind		-	*0.3*	*2.0*	*3.1*	*3.1*	*5.4*	*5.6*
Geothermal		-	-	-	*0.1*	*0.1*	*0.1*	*0.1*
Solar/Other		-	-	*0.1*	*0.1*	*0.1*	*1.7*	*1.9*
Electricity Trade		*-0.1*	*3.5*	*0.3*	*0.7*	*0.2*	*0.6*	*1.5*

0 is negligible, - is nil, .. is not available

TPES for a given year strongly depends on the amount of net import of electricity, which may vary substantially from year to year. Geothermal and Solar/Other have been partially estimated by the IEA Secretariat due to incomplete data in the original Danish submission.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2008**	**2009**	**2020**	**2030**
TFC	**15.31**	**13.17**	**14.23**	**14.88**	**14.23**	**14.89**	**15.69**
Coal	0.46	0.43	0.31	0.23	0.14	0.15	0.17
Peat	-	-	-	-	-	-	-
Oil	13.31	6.86	6.57	6.58	6.22	6.22	6.83
Natural Gas	-	1.12	1.65	1.61	1.55	1.53	1.43
Biofuels & Waste[1]	0.16	0.56	0.65	1.18	1.13	1.38	1.41
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	0.00	0.01	0.01	0.01	0.01	0.02
Electricity	1.39	2.44	2.79	2.86	2.72	2.86	3.05
Heat	-	1.76	2.25	2.41	2.47	2.74	2.78
Shares (%)							
Coal	*3.0*	*3.3*	*2.2*	*1.6*	*1.0*	*1.0*	*1.1*
Peat	-	-	-	-	-	-	-
Oil	*86.9*	*52.0*	*46.2*	*44.2*	*43.7*	*41.8*	*43.5*
Natural Gas	-	*8.5*	*11.6*	*10.8*	*10.9*	*10.3*	*9.1*
Biofuels & Waste	*1.1*	*4.3*	*4.6*	*7.9*	*7.9*	*9.2*	*9.0*
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	-	*0.1*	*0.1*	*0.1*	*0.1*
Electricity	*9.0*	*18.5*	*19.6*	*19.2*	*19.1*	*19.2*	*19.5*
Heat	-	*13.3*	*15.8*	*16.2*	*17.3*	*18.4*	*17.7*
TOTAL INDUSTRY[6]	**4.06**	**3.00**	**3.23**	**2.96**	**2.58**	**3.85**	**4.23**
Coal	0.23	0.32	0.27	0.18	0.10	0.15	0.17
Peat	-	-	-	-	-	-	-
Oil	3.38	1.22	1.05	0.91	0.80	1.45	1.68
Natural Gas	-	0.54	0.78	0.72	0.66	0.77	0.78
Biofuels & Waste[1]	0.06	0.11	0.11	0.17	0.15	0.22	0.24
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	-	-	-	-	-
Electricity	0.40	0.73	0.86	0.84	0.73	1.04	1.15
Heat	-	0.07	0.16	0.14	0.14	0.22	0.22
Shares (%)							
Coal	*5.6*	*10.8*	*8.2*	*6.1*	*3.8*	*3.9*	*3.9*
Peat	-	-	-	-	-	-	-
Oil	*83.2*	*40.8*	*32.5*	*30.7*	*31.0*	*37.5*	*39.8*
Natural Gas	-	*17.8*	*24.1*	*24.3*	*25.5*	*20.1*	*18.4*
Biofuels & Waste	*1.4*	*3.8*	*3.4*	*5.9*	*5.8*	*5.7*	*5.6*
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	-	-	-	-	-
Electricity	*9.7*	*24.2*	*26.7*	*28.2*	*28.4*	*27.1*	*27.1*
Heat	-	*2.5*	*5.1*	*4.8*	*5.5*	*5.6*	*5.2*
TRANSPORT[4]	**2.70**	**3.45**	**4.03**	**4.64**	**4.41**	**4.58**	**5.07**
OTHER[7]	**8.55**	**6.73**	**6.97**	**7.28**	**7.24**	**6.46**	**6.39**
Coal	0.23	0.11	0.04	0.05	0.04	-	-
Peat	-	-	-	-	-	-	-
Oil	7.24	2.20	1.52	1.07	1.05	0.47	0.38
Natural Gas	-	0.59	0.87	0.90	0.89	0.76	0.65
Biofuels & Waste[1]	0.10	0.45	0.54	1.00	0.97	0.92	0.91
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	0.00	0.01	0.01	0.01	0.01	0.02
Electricity	0.98	1.70	1.90	1.99	1.95	1.78	1.87
Heat	-	1.68	2.09	2.26	2.32	2.52	2.56
Shares (%)							
Coal	*2.7*	*1.6*	*0.6*	*0.7*	*0.6*	-	-
Peat	-	-	-	-	-	-	-
Oil	*84.7*	*32.7*	*21.8*	*14.6*	*14.5*	*7.3*	*6.0*
Natural Gas	-	*8.7*	*12.5*	*12.3*	*12.3*	*11.7*	*10.2*
Biofuels & Waste	*1.2*	*6.7*	*7.7*	*13.7*	*13.4*	*14.2*	*14.2*
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	*0.1*	*0.2*	*0.2*	*0.2*	*0.3*
Electricity	*11.5*	*25.2*	*27.2*	*27.4*	*26.9*	*27.5*	*29.3*
Heat	-	*25.0*	*30.0*	*31.1*	*32.1*	*39.0*	*40.0*

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2008**	**2009**	**2020**	**2030**
ELECTRICITY GENERATION[8]							
INPUT (Mtoe)	**4.59**	**7.09**	**8.36**	**8.43**	**8.49**	**7.68**	**7.53**
OUTPUT (Mtoe)	**1.64**	**2.23**	**3.10**	**3.15**	**3.13**	**2.99**	**3.03**
(TWh gross)	19.12	25.98	36.05	36.64	36.36	34.77	35.22
Output Shares (%)							
Coal	*35.8*	*90.7*	*46.2*	*47.6*	*48.6*	*30.9*	*22.3*
Peat	-	-	-	-	-	-	-
Oil	*64.1*	*3.4*	*12.3*	*3.1*	*3.2*	*1.7*	*1.7*
Natural Gas	-	*2.7*	*24.3*	*19.3*	*18.5*	*12.4*	*11.0*
Biofuels & Waste	-	*0.8*	*5.1*	*10.9*	*11.1*	*21.2*	*29.5*
Nuclear	-	-	-	-	-	-	-
Hydro	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Wind	-	*2.3*	*11.8*	*18.9*	*18.5*	*33.8*	*35.4*
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	*0.1*	-	-	-	-
TOTAL LOSSES	**3.77**	**4.17**	**4.41**	**4.77**	**4.60**	**3.67**	**3.65**
of which:							
Electricity and Heat Generation[9]	2.94	2.65	2.41	2.24	2.24	1.64	1.44
Other Transformation	0.57	0.11	0.09	0.49	0.31	0.07	0.07
Own Use and Losses[10]	0.26	1.41	1.90	2.03	2.05	1.96	2.14
Statistical Differences	**-0.09**	**0.02**	**0.00**	**-0.43**	**-0.22**	**-**	**-**
INDICATORS	**1973**	**1990**	**2000**	**2008**	**2009**	**2020**	**2030**
GDP (billion 2000 USD)	89.96	123.89	160.08	176.95	167.73	204.76	239.04
Population (millions)	5.02	5.14	5.34	5.49	5.52	5.70	5.86
TPES/GDP[11]	0.21	0.14	0.12	0.11	0.11	0.09	0.08
Energy Production/TPES	0.02	0.58	1.49	1.39	1.29	1.00	0.90
Per Capita TPES[12]	3.78	3.38	3.49	3.50	3.37	3.26	3.30
Oil Supply/GDP[11]	0.19	0.06	0.05	0.04	0.04	0.03	0.03
TFC/GDP[11]	0.17	0.11	0.09	0.08	0.09	0.07	0.07
Per Capita TFC[12]	3.05	2.56	2.67	2.71	2.58	2.61	2.68
Energy-related CO_2 Emissions (Mt CO_2)[13]	56.0	50.4	50.6	48.4	46.8	40.0	38.9
CO_2 Emissions from Bunkers (Mt CO_2)	4.4	4.7	6.4	5.5	3.9	4.8	4.7
GROWTH RATES (% per year)	**73-79**	**79-90**	**90-00**	**00-08**	**08-09**	**09-20**	**20-30**
TPES	1.3	-1.5	0.7	0.4	-3.2	-0.0	0.4
Coal	14.4	3.1	-4.2	0.1	-0.1	-3.9	-3.1
Peat	-	-	-	-	-	-	-
Oil	-1.3	-6.2	0.5	-1.0	-4.5	-0.1	0.8
Natural Gas	-	-	9.4	-1.1	-4.3	-1.2	-0.1
Biofuels & Waste	6.9	7.3	4.3	7.0	0.4	3.0	1.6
Nuclear	-	-	-	-	-	-	-
Hydro	-	-	4.1	-4.9	-	-	-
Wind	-	43.2	21.5	6.3	-3.0	5.2	0.6
Geothermal	-	-	4.1	18.9	-	7.3	-2.6
Solar/Other	-	15.8	8.2	5.6	5.9	30.0	1.3
TFC	0.8	-1.8	0.8	0.6	-4.4	0.4	0.5
Electricity Consumption	4.9	2.5	1.4	0.3	-5.0	0.5	0.7
Energy Production	14.7	23.7	10.7	-0.5	-10.2	-2.3	-0.6
Net Oil Imports	-2.6	-20.2	..	..	..	..	..
GDP	2.0	1.8	2.6	1.3	-5.2	1.8	1.6
Growth in the TPES/GDP Ratio	-0.6	-3.3	-1.9	-0.8	1.8	-1.8	-1.2
Growth in the TFC/GDP Ratio	-1.1	-3.6	-1.7	-0.7	1.2	-1.4	-1.0

Please note: Rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. Other includes ambient heat used in heat pumps.
3. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels and trade of heat.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial, public services, agriculture, forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
9. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 100% for hydro, wind and photovoltaic.
10. Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Toe per thousand US dollars at 2000 prices and exchange rates.
12. Toe per person.
13. "Energy-related CO_2 emissions" have been estimated using the IPCC Tier I Sectoral Approach from the *Revised 1996 IPCC Guidelines*. In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 2009 and applying this factor to forecast energy supply. Future coal emissions are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

ANNEX C: INTERNATIONAL ENERGY AGENCY "SHARED GOALS"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The "Shared Goals" were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

*Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: GLOSSARY AND LIST OF ABBREVIATIONS

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for many of the abbreviations used.

b/d	barrels per day
bcm	billion cubic metres
CCGT	combined-cycle gas turbine
CDM	clean development mechanism (under the Kyoto Protocol)
CSO	compulsory stockholding obligation,
CCS	carbon capture and storage
CHP	combined production of heat and power
DC	direct current
DEA	Danish Energy Agency
DERA	Danish Energy Regulatory Authority
DH	district heating
DSO	distribution system operator
EEA	European Economic Area
EEX	European Energy Exchange
EIA	environmental impact assessment
ENTSO	European Network of Transmission Operators
EU-ETS	European Union Emissions Trading Scheme
FDO	Danish Stockholding Agency
GHG	greenhouse gas
HHV	higher heating value
IPCC	Intergovernmental Panel on Climate Change
JI	joint implementation (projects under the Kyoto Protocol)

ktoe	thousand tonnes of oil-equivalent
kW	kilowatt, or 1 watt x 10^3
LHV	lower heating value
LNG	liquefied natural gas
LULUCF	land use, land-use change and forestry
mcm	million cubic metres
Mtoe	million tonnes of oil-equivalent
MEPS	minimum efficiency performance standards
MW	megawarr, or 1 watt x 10^6
PPA	purchasing power parity: the rate of currency conversion that equalises the purchasing power of different currencies, *i.e.* estimates the difference in price levels between countries
PSO	public service obligation
R&D	research and development, especially in energy technology, may include the demonstration and dissemination phases as well
RES	renewable energy sources
TFC	total final consumption of energy
toe	tonne of oil-equivalent; defined as 10^7 kcal
TPA	third-party access
TSO	transmission system operator
TPES	total primary energy supply
TSO	transmission system operator
UNFCCC	Unites Nations Framework Convention on Climate Change
VAT	value-added tax

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