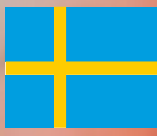
INTERNATIONAL ENERGY AGENCY

# Energy Policies of IEA Countries





# SWEDEN

## 2008 Review

OECD

# Energy Policies of IEA Countries

# SWEDEN 2008 Review

Sweden is one of the leading IEA countries in the use of renewable energy and has a long tradition of ambitious and successful policies to improve energy efficiency. Compared to the other IEA countries, Sweden's $CO_2$ emissions per capita and per unit of GDP are low, partly owing to efficient and low-carbon space heating, and virtually carbon-free electricity generation. The country also remains a forerunner in electricity market liberalisation. Still, even if Sweden has continued to make progress in most areas of its energy policy since the IEA last conducted an in-depth review in 2004, there is room for improvement.

As Sweden plans to further increase the use of renewable energy, it is crucial that these supplies are produced and used in the most sustainable manner for the environment and the economy as a whole. With regard to $CO_2$ emissions, more can be done in all sectors, but as transport is the largest polluter and its emissions are increasing, it is the logical focus for Sweden's efforts to reduce emissions further. This is a significant challenge.

Nuclear provides almost half of the electricity in Sweden, at a low cost and without $CO_2$ emissions. But the future of nuclear power in the national power mix is still uncertain. To provide clear guidance to the electricity sector, Sweden will need to resolve the ambiguity about the future of nuclear power in the country.

This review analyses the energy challenges facing Sweden and provides critiques and recommendations for further policy improvements. It is intended to provide input to Swedish energy policy makers to help them identify a path towards a more sustainable energy future.

(61 2008 17 1 P1) €75
ISBN 978-92-64-04333-6

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## INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-seven of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Poland is expected to become a member in 2008. The European Commission also participates in the work of the IEA.

## ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.



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## EXECUTIVE SUMMARY

Since the previous in-depth review in 2004, Sweden has continued to perform strongly in most areas of energy policy. It is in constant compliance with IEA oil security requirements; it is likely to meet its target under the Kyoto Protocol thanks to its ambitious climate policy; and it is intensifying efforts to improve energy efficiency and increase the use of renewable energy, both from an already high level. As part of the Nordic electricity system, it continues to be one of the forerunners in electricity market liberalisation, and has several plans to develop the market further. By international comparison, Sweden's energy policy is sound and sustainable. The IEA congratulates the Swedish government for the continued outstanding progress during the last four years.

Sweden is steadily moving towards a low-carbon economy. Today, it already has the lowest level of $CO_2$ emissions per GDP of all IEA member countries and the second-lowest per capita. This follows on from having the lowest share of fossil fuels in its primary energy supply, as the country is in reality very energy-intensive. Energy use is generally efficient, largely owing to the wide use of electricity and district heat. Electricity use per capita is one of the highest in the world, and although demand growth has slowed as a result of greater end-use efficiency, investment in new capacity will be needed to maintain security of supply and competitive prices for end-users. New investment, however, is challenged by the uncertainties over the future regulatory framework in the sector, most notably the future form of the European Union Emissions Trading Scheme (EU-ETS), which is an EU-wide issue, and even more so, the future of nuclear power, which is a national issue.

The outlook for nuclear energy remains a major energy policy question, almost three decades after the 1980 popular vote to phase it out. The government may decide on closing down a nuclear power plant (NPP) at a certain point in time, provided it compensates the owner for the losses incurred. Two reactors have been permanently shut down but the current government, in office since October 2006, has decided not to take any decisions to close more nuclear reactors, or to permit constructing new ones. Uprates, however, are possible. A phase-out would be challenging, as around 45% of electricity in Sweden is generated by nuclear power, and in the post-Kyoto period, targets for reducing greenhouse gas (GHG) emissions are likely to be stricter than at present. Against this background, it is hard to see how phasing out nuclear energy could serve Sweden's broader energy policy goals.

The issue is also important for Sweden's neighbours, as developments in Sweden's nuclear power capacity would affect security of electricity supply and electricity prices in the whole Nordic electricity market. Increasing the capacity and extending the operational life of the plants is a cost-effective way to continue using nuclear energy, but the decision on how to renew the fleet of ageing reactors, whether by new nuclear units or alternative forms of power supply, should not be postponed. A firm long-term political decision about the future of nuclear power in the country is needed. Therefore, the government should intensify its efforts to clarify the role of nuclear power in the Swedish energy mix, paying due consideration to electricity prices, climate change mitigation and security of electricity supply.

Sweden's climate policy continues to be ambitious, and is delivering results, largely thanks to long-term policies to switch away from fossil fuels and improve energy efficiency. Under the EU burden-sharing agreement related to the Kyoto Protocol, Sweden is allowed to increase its GHG emissions by 4% from 1990 to 2008-2012. It is likely to meet this target by a wide margin. After 2012, however, more reductions will be needed. Energy-intensive industries will face a binding target under the EU-ETS. In the other sectors of the economy, transport accounts for more than four-fifths of $CO_2$ emissions, and these are increasing. Though the role of sinks and international flexible mechanisms remains to be defined, transport is also the logical focus for efforts to reduce emissions of $CO_2$ after 2012.

In road transport, Sweden's policy is to promote biofuels and diesel to replace gasoline. Fiscal incentives have been introduced recently for both fuels and vehicles, and the results are promising, as shown by registrations of low-emission cars rising at an impressive rate. In addition, emissions in Stockholm are expected to be reduced by the city's congestion charge system, which was launched in 2007. Initial results are promising and could provide valuable lessons to other metropolitan areas in Sweden and abroad.

In a country where electricity is generated practically without $CO_2$ emissions, electric rail transport is an attractive option on both energy and climate policy grounds. More could be done to support both passenger and freight transport. The IEA urges the Swedish government to continue its efforts to reduce oil use in transport, especially by encouraging more efficient vehicles and by promoting alternatives to oil-based road transport, including transport of freight.

Sweden is one of the leading IEA countries using renewable energy, and is sufficiently well endowed to further increase domestic supply. To promote electricity generation from renewable sources, Sweden has set up a quota system with certificate trading. The system is market-based, encourages cost-effective investment, and because it is delivering as planned, can be recommended as a model for other countries.

Sweden derives most of its renewable energy as biomass from its extensive forests, in the form of wood residues from the country's large wood-processing industry. Additional targets for bioenergy should be based on a full assessment of the optimum use of this resource, because reaching specified bioenergy targets could result in resource competition, disrupt the wood supply for other products, and adversely affect GDP and employment.

Increasing the use of biomass to produce biofuels for transport is under evaluation as it may not always provide the same climate and efficiency benefits that Sweden is already gaining in the heat and power sectors. On the basis of today's processing methods, a relatively large quantity of energy is required for producing some biofuels, so that current first-generation processes are unlikely to become very energy-efficient in the near future and GHG reductions may be limited. Setting and meeting additional biofuels targets, either national or imposed by the EU, should therefore be based on a life-cycle analysis of both first- and second-generation biofuels, their costs and benefits, especially for climate change mitigation weighed against those of other forms of renewable energy use. Where fuel supplies can be reliably and sustainably produced from biomass, car users should be encouraged to switch to biofuel blends.

## KEY RECOMMENDATIONS

*The government of Sweden should:*

- *Clarify the conditions for the use of existing and future nuclear power capacity, with due consideration to electricity prices, climate change mitigation and security of energy supply.*
- *Continue efforts to reduce oil use in the transport sector, especially by encouraging more efficient fuel use and by promoting alternatives to oil-based road transport, including transport of freight.*
- *Focus efforts to increase the supply of renewable energy on sources that are deemed the most sustainable, based on an evaluation of their economic, environmental and social benefits.*

# PART I

# POLICY ANALYSIS

Figure 1

## Map of Sweden


Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the IEA.

## COUNTRY OVERVIEW

The Kingdom of Sweden (hereafter Sweden) lies in the north of Europe, bordering on Norway and Finland. Its surface area is about 450 000 $km^2$, most of which is covered by forests. With nine million inhabitants, it is sparsely populated. Most Swedes live in the south of the country, including roughly one-third in the metropolitan areas of Stockholm, Göteborg and Malmö.

Independent since 1523, Sweden has avoided wars in the past two centuries and has built up a reputation for prosperity and stability. It has combined an open market economy with a generous welfare state. Per-capita GDP (34 100 USD at purchasing power parity in 2006) is some 10% higher than the OECD average, and the overall tax rate, 50% of GDP, is the highest within the OECD. Unemployment has decreased over the past several years, and now stands at 6%. Annual real GDP growth amounted to 2.9% in 2005, 4.5% in 2006 and an estimated 3.4% in 2007.

As in all developed economies, services are the biggest sector (71% of GDP in 2005). The country's industry (28% of GDP) is export-led, and has traditionally focused on processing the abundant local forest and mineral resources. Home to several large multinational companies, Sweden has a large pulp and paper and iron and steel industry, but it is also prominent in motor vehicles and telecom equipment. The primary sector (forestry, agriculture and fishing) accounts for 1% of GDP.

Sweden is a constitutional monarchy, where the king has a representative role only. The single-chamber parliament (the Riksdag) is directly elected by proportional representation. Since October 2006, Sweden is ruled by a centre-right government – something of a rarity in a country long governed by social democrats. The next parliamentary elections will be held in the autumn of 2010. Sweden joined the EU in 1995, but it has decided to stay out of the euro area and maintains the Swedish krona.[1]

1. SEK 1 = USD 0.148 = EUR 0.108 in 2007.

# SUPPLY AND DEMAND

## SUPPLY

Sweden's total primary energy supply (TPES) was 51.3 million tonnes of oil equivalent (Mtoe) in 2006 (see Annex B). From 1990 to 2006, TPES increased by 7.9%, while the economy grew by 42%, led by strong growth in services and light industry.

Sweden's TPES has the lowest share of fossil fuels within the IEA countries, around 35% in 2006 (see Figure 2). The country has abundant renewable energy sources, and the strong nuclear energy programme is partly the result of the government's efforts to reduce dependence on oil. Today, electricity generation is almost $CO_2$-free: depending on hydrological conditions, hydro and nuclear power account for some 90% to 92% of total annual generation, roughly one half each. The rest is mostly biomass, which comes in the form of wood residues from the forest industry. More than for electricity, biomass is used for generating heat both in industry and at district heating plants. In recent years, renewable energy has provided some 28% of TPES.

As a result of its TPES structure, Sweden emits little $CO_2$ both per capita and per GDP (see Chapter 3). Energy intensity, however, is one of the highest in the IEA. This is explained by the large energy requirements of the heavy industry, mostly pulp and paper and iron and steel. Other factors at play are the cold climate and sparse population. Sweden has the second-highest space heating requirement in the IEA, measured by degree-days, and the low population density leads to long transportation distances.

In the government's business-as-usual scenario, TPES would increase by 23% from 2006 to 2020 (see Figure 3). By volume, oil and biomass are expected to grow the fastest. These estimates, however, are likely to be revised according to Sweden's share of the EU GHG targets for the post-2012 period.

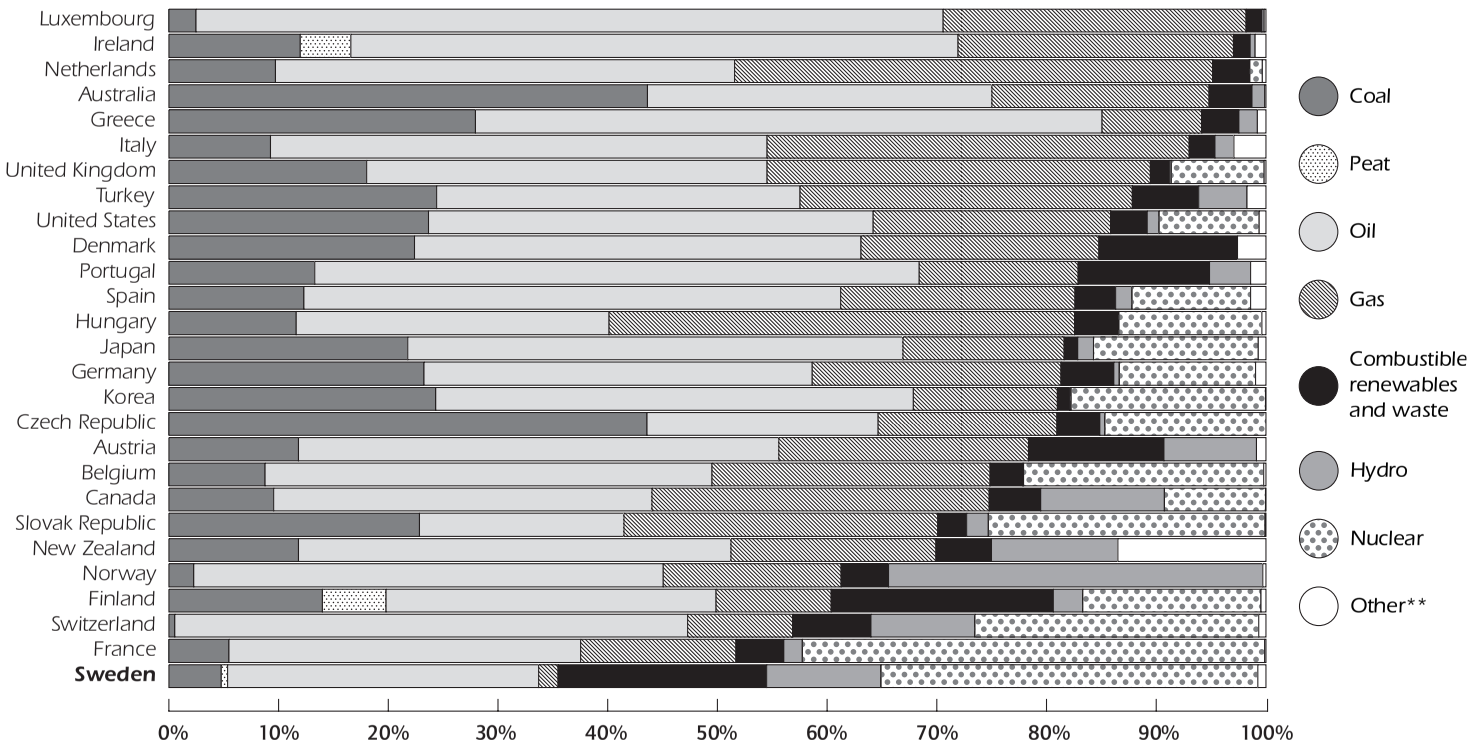
## DEMAND

In 2006, Sweden's total final consumption of energy (TFC) was 35.0 Mtoe, up 7.7% from 1990. Industry was the largest user, accounting for 42% of the total. Transport's share was 24% and the other sectors (residential, services, and the primary sector) used 33% of the total. For comparison, the IEA averages in 2005 were 32% for industry, and 34% for both transport and other sectors.

Since the early 1970s, Sweden's TFC has remained remarkably steady, while TPES has grown by a third. This stability results partly from more efficient use of energy, and a relatively slow economic growth. But it mostly reflects changes in the structure of energy supply: secondary energy – electricity and heat – has replaced on-site use of fuels, mainly oil (see Figure 4). Electricity use

Figure 2

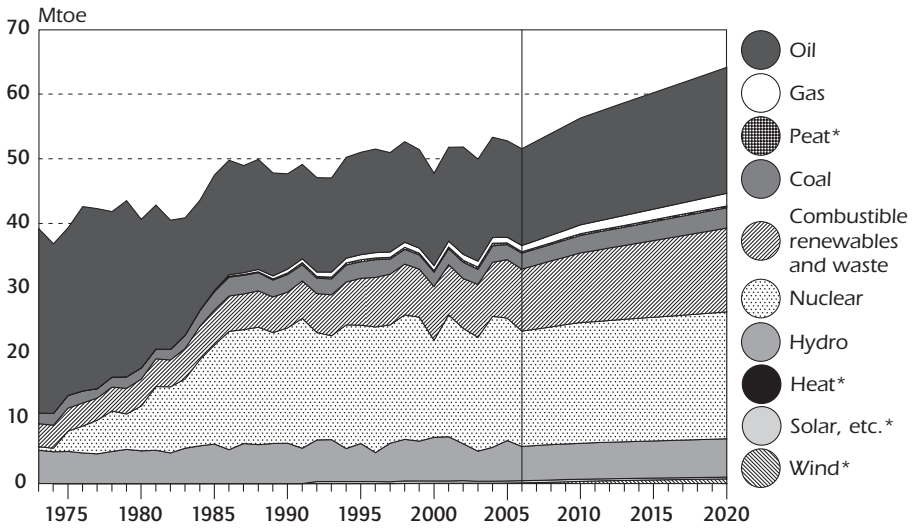
## Total Primary Energy Supply in IEA Countries, 2006*




* estimates. ** includes geothermal, solar, wind, and ambient heat production.
Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007.

Figure 3

## Total Primary Energy Supply, 1973 to 2020

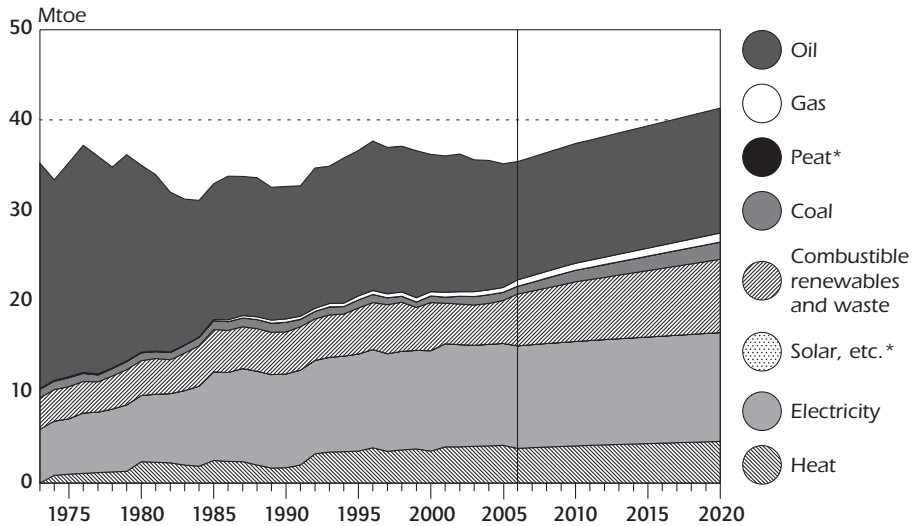



* negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

Figure 4

## Total Final Consumption of Energy by Source, 1973 to 2020




* negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

has almost doubled in the period, and space heating is now dominated by district heating, electric heating and heat pumps. In addition, combined heat and power generation (CHP) is widely used.

After the decreases in recent years, the government expects TFC to increase by 7% from 2006 to 2010 and by 18% from 2006 to 2020. Energy use is expected to grow primarily in industry, by one-third until 2020, whereas consumption in transport and households and services is projected to remain relatively steady.

## INSTITUTIONS

Sweden has a unitary government with active local authorities. Development of energy policy rests with the central government. The main government bodies active in energy policy are listed below.

**Ministry of Enterprise, Energy and Communications (Näringsdepartementet)**

The ministry is in charge of energy policy. Within the ministry, the Division for Energy has an overall co-ordination and planning role for energy policy. The division has a staff of around 25 people.

**Ministry of the Environment (Miljödepartementet)**

The ministry is in charge of climate policy. Within the ministry, the Division for Environmental Quality is responsible for EU and global climate negotiations, and also for climate policy instruments. The Division for Sustainable Development is responsible for energy in buildings.

**Swedish Energy Agency (Statens Energimyndighet)**

The Swedish Energy Agency (SEA) is the main government body responsible for implementing energy policy. It is a separate agency under the Ministry of Enterprise, Energy and Communications. It was responsible for co-ordinating and implementing the National Energy Policy Programme, which ran from 2002 to 2007. The SEA's responsibilities include:

- Planning and running energy and environment computer modelling projections to develop forecasts.
- Implementing and overseeing the long-term energy policy programme for R&D.
- Administering the electricity certificate programme for support of renewable energy.
- Implementing energy efficiency measures.
- Managing testing, labelling and certification of energy use in household appliances and other consumer goods.

### Energy Markets Inspectorate (Energimarknadsinspektionen)

An independent body since 1 January 2008, the Energy Markets Inspectorate (EMI) is the regulator for electricity, natural gas and district heating markets.

### Svenska Kraftnät

Svenska Kraftnät is the transmission system operator. It owns and operates the national high-voltage electricity grid and is also responsible for the electricity system's short-term balance. Since 2005, it has also operated the gas transmission system. Svenska Kraftnät is 100% owned by the government.

### Other government bodies

*The Swedish Competition Authority (Konkurrensverket)* promotes effective competition in the private and public sectors for the benefit of consumers.

*The National Board of Housing, Building and Planning (Boverket)* promotes efficient use of energy in buildings, notably reducing electricity use for space heating.

*The Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion, SKI)* regulates nuclear activities with regard to safety, nuclear waste management and nuclear non-proliferation. It is also responsible for government-funded nuclear safety research.

*The Swedish Environmental Protection Agency (Naturvårdsverket)* is the government's central environmental authority. Among other areas, it works on climate change mitigation, often in co-operation with the SEA.

## KEY POLICIES

Sweden's energy policy strives for a sustainable energy system with a long-term vision for a growing supply from renewable energy sources. In line with that vision, Sweden is concentrating its efforts to improve energy efficiency and increase renewable energy use from an already high level. In its energy market policy, the government aims to promote efficient markets with well-functioning competition that ensures a reliable energy supply at internationally competitive prices.

Today, many of Sweden's energy policy goals are derived from the EU level, and the trend is for more commonly agreed targets and directives. For example, EU law now sets requirements for electricity and natural gas markets, and for energy efficiency in appliances and buildings. The EU member states have non-binding targets for energy saving and for the share of renewable energy in TPES, electricity supply and transport fuels. What is more, they have

binding targets for total GHG emissions and, through the EU-ETS, for $CO_2$ emissions from heavy industry and power and heat generation.

The future of nuclear energy remains a major policy issue, almost three decades after the 1980 popular vote to phase it out. The government can decide on closing down an NPP at a certain point in time, provided it compensates for the losses incurred by the owner. The current government, in office since October 2006, has decided not to take any decisions to close more nuclear reactors nor to permit constructing new ones. Uprates, however, are possible.

Sweden's vision of a sustainable energy system implies phasing out oil, and other fossil fuels, in the long term. The previous government appointed a commission to study the issue, and the commission presented its proposals in June 2006 *(Making Sweden an Oil-free Society)*. It suggested reducing oil dependence in transport by 40% to 50% and in industry by 25% to 40%, and entirely phasing out oil in space heating. The commission's work also received considerable interest abroad. Its proposals, however, are not politically binding and the current government has not endorsed them.

## SECURITY OF SUPPLY

All fossil fuels are imported, but they only account for 35% of TPES, the lowest share within the IEA. Oil and coal supplies to Sweden are well diversified by country of origin. All natural gas, however, is imported from Denmark through one pipeline, but improvements are in sight as gas companies are planning to diversify supply routes. Sweden is a net exporter of oil products, and consistently holds more oil stocks than required under the IEA obligations. Coal and natural gas use is relatively small. Gas-fired heat and power plants are obliged to store backup fuels, mostly oil.

Security of electricity supply has repercussions beyond Sweden's borders, given the country's role in trade and transit in the Nordic electricity market. Projects to increase transmission capacity and reduce congestion are planned in the Nordic context, and three major projects are to be finalised by 2012. From 2003 to 1 March 2008, maintaining a peak load reserve was the responsibility of the transmission system operator (TSO), which entered into agreements with generators and big consumers. In the future, the plan is to leave it to the market to ensure enough electricity is available.

## CLIMATE CHANGE MITIGATION

Climate change mitigation is one of the priorities of the Swedish government. Sweden's target under the EU burden-sharing agreement related to the Kyoto

Protocol is to limit its GHG emissions to no more than 4% above their 1990 level in 2008-2012. It also has a national target to further reduce total GHG emissions by 4% from 1990 to 2008-2012. A stricter target for 2020 will follow from a future EU burden-sharing agreement.

Sweden's efforts to limit $CO_2$ emissions have focused on taxation, promoting energy efficiency and renewable energy sources through various measures, as well as on R&D. Some 40% of the country's $CO_2$ emissions from fuel combustion are within the EU-ETS. The country is also involved in developing projects to gain credits from international flexible mechanisms (Joint Implementation and Clean Development Mechanism, [JI/CDM]), though it is likely to reach the +4% Kyoto target without resorting to them.

## MARKET REFORM

As part of the Nordic electricity system, Sweden continues to be one of the forerunners in electricity market liberalisation. The network regulator is transparent and fully independent from the government. The power grid is open to all competitors, and the TSO is fully unbundled. To complement the well-functioning Nordic wholesale market, plans to form a common Nordic retail market by 2010 are progressing.

Sweden's natural gas market has been reformed since the last IEA review in 2004, and it now has a regulator and an independent system operator. But, as in many other countries, the gas market in Sweden remains dominated by a small number of vertically integrated companies, with limited competition between them. The district heating sector, in turn, remains largely unregulated, but the government is planning to stimulate competition and greater efficiency in the industry through regulation.

# TAXES

Sweden has a long tradition of using taxes to steer energy policy. Energy taxation is aimed at improving the efficiency of energy use, promoting renewable energy production and use, and encouraging companies to reduce their environmental impact.

Sweden's energy tax system is very diverse, and comprises many exemptions (see Tables 1 and 2). It includes different taxes on electricity and fuels, on $CO_2$ and sulphur emissions, and a levy system on $NO_x$ emissions. Taxes also vary depending on whether the fuel is being used for heating or in transport, whether by manufacturing industry, energy industry or households, and, in the case of electricity, what it is being used for and whether it is being used in the north or in the rest of the country.

Energy taxes can be divided into an excise tax on energy, and environment-based taxes, foremost being the $CO_2$ tax and the sulphur tax. Although both the excise tax and the $CO_2$ tax have fiscal functions and steering effects, the excise tax is primarily a fiscal one, whereas the $CO_2$ tax is by definition aimed at reducing emissions.

Table 1

**Energy Taxation at 1 January 2007, Excluding VAT**

| *Energy source* | *Excise tax* | *$CO_2$ tax* | *Sulphur tax* | *Total taxes* | *Tax SEK/kWh* |
|---|---|---|---|---|---|
| Gas oil (<0.05% sulphur), SEK/m³ | 750 | 2 663 | – | 3 413 | 0.343 |
| Bunker oil (0.4% sulphur), SEK/m³ | 750 | 2 663 | 108 | 3 521 | 0.333 |
| Coal (0.5% sulphur), SEK/tonne | 319 | 2 317 | 150 | 2 786 | 0.369 |
| LPG, SEK/tonne | 147 | 2 801 | – | 2 948 | 0.23 |
| Natural gas, SEK/1 000 m³ | 243 | 1 994 | – | 2 237 | 0.202 |
| Unrefined tall oil, SEK/m³ | 3 413 | – | – | 3 413 | 0.348 |
| Peat, 45% moisture (0.3% sulphur), SEK/tonne | – | – | 50 | 50 | 0.018 |
| Domestic refuse, SEK/tonne fossil carbon | 150 | 3 374 | – | 3 524 | 0.148 |
| **Motor fuels** | | | | | |
| Gasoline unleaded, environmental class 1, SEK/L | 2.9 | 2.2 | – | 5.1 | 0.555 |
| Diesel, environmental class 1, SEK/L | 1.1 | 2.7 | – | 3.8 | 0.373 |
| Natural gas/methane, SEK/m³ | – | 1.1 | – | 1.1 | 0.103 |
| LPG, SEK/kg | – | 1.4 | – | 1.4 | 0.108 |
| Biogas, SEK/m³ | – | – | – | 0 | 0 |
| Ethanol, SEK/L | – | – | – | 0 | 0 |
| Rapeseed oil methyl ester, SEK/L | – | – | – | 0 | 0 |
| **Electricity use** | | | | | |
| North of Sweden, SEK/kWh | 0.204 | – | – | 0.204 | 0.204 |
| Rest of Sweden, SEK/kWh | 0.265 | – | – | 0.265 | 0.265 |
| Industrial processes, SEK/kWh | 0.05 | – | – | 0.05 | 0.05 |

Source: Country submission.

In 2006, revenues from energy taxation totalled SEK 67.1 billion, or 2.5% of GDP. The largest sources of tax revenue are typically oil use (65% of total in 2006), electricity use (28%) and nuclear power (5%). Nuclear power is taxed on the basis of the maximum permissible thermal power rating of the reactors. The tax was increased by 85% in 2006, to SEK 10 200/MW per month, following strong growth in profits from nuclear power generation, which was attributed to the effects of the EU-ETS.

The $CO_2$ tax was introduced in 1991, at a rate of SEK 250 (EUR 27) per t $CO_2$. Since then it has been continuously raised, reaching SEK 930 (EUR 101) per t in 2007. As a general rule, the tax is paid on all fuels except bioenergy and peat, although several user groups are wholly or partly exempt. Full $CO_2$ tax is paid in transport, space heating and non-CHP heat generation. Owing to the many exemptions, oil accounts for 96% of the revenues from the $CO_2$ tax, although it produces less than three-quarters of $CO_2$ emissions from fuel combustion.

Table 2

**Exemptions from Energy Taxation at 1 January 2007**

| *Sector* | *Payable share of* | |
|---|---|---|
| | *$CO_2$ tax, %* | *Excise tax, %* |
| Services and households | 100 | 100 |
| Heat production | 100 | 100 |
| Heat in industrial processes | 21 | 0 |
| Heat production in highly efficient CHP plants | 21 | 0 |
| Industrial boilers | 21 | 0 |
| Manufacturing | 21 | 0 |
| Farming, aquaculture, forestry | 21 | 0 |
| Horticulture | 21 | 0 |
| Electricity production | 0 | 0 |

Source: Country submission.

## CRITIQUE

Since the previous in-depth review in 2004, Sweden has continued to perform strongly in most areas of energy policy. Arguably, it is part of the best-functioning regional electricity markets in the world; it is in constant compliance with the IEA oil security requirements; it is likely to exceed its

Kyoto target, thanks to its ambitious climate policy; and it is increasing efforts to promote energy efficiency and renewable energy from an already high level. In short, Sweden's energy policies are sound and sustainable, and the IEA congratulates the government for the continued outstanding progress in the last four years.

Sweden is striving to increase energy efficiency and the use of renewable energy. This goal is ambitious indeed because Sweden is already a top performer in both sectors by international comparison, but increased efforts are considered desirable in mitigating climate change and securing energy supplies and competitiveness. Stricter targets are also likely to follow from the EU level.

The future of nuclear power remains open. The current government, in office since October 2006, has decided not to take any decisions to close more nuclear reactors, nor to permit constructing new ones. The issue is important for Sweden and also for its neighbours, as developments in Sweden's nuclear power capacity would affect the security of electricity supply and prices in the whole Nordic electricity market. The government is urged to clarify the issue as soon as possible.

In this regard, it is encouraging that the government is negotiating on the principles for mid- and long-term energy policy with all parties in the parliament. Reaching a wide consensus on future energy policy, including nuclear, would be very welcome. Climate change obligations are set to become more challenging, and regulatory certainty is vital for sufficient and appropriate investment in generating capacity and energy infrastructure. For these purposes, the IEA encourages Sweden to prepare a comprehensive energy and climate strategy for the medium and long term.

The approval and licensing process for electricity generation, gas supply, and energy infrastructure projects is lengthy. This is an obstacle to increasing electricity generation from renewables, and a challenge to security of supply. It is a hurdle for potential new entrants. A more rapid, more efficient and more transparent permitting process for investing in energy infrastructure would also increase competition and market efficiency, particularly in electricity. Therefore, the government should shorten and streamline the approval and licensing process.

Sweden has a long tradition of using taxation to steer energy and climate policy. The tax system seems to be delivering the expected revenue, but over the years its structure has become relatively complex. Taxes on energy use have changed several times in the recent past, while new steering measures, most notably the EU Emissions Trading Scheme, have been introduced. Interaction and possible overlap between energy taxes and other measures should be assessed and clarified once the post-2012 EU-ETS becomes clear. To compensate for any revenue lost from reducing $CO_2$ in the ETS sector, the

government could consider increasing taxes on the existing nuclear power and hydropower plants. In general, the government should increase efforts to simplify the structure of the energy tax system.

## RECOMMENDATIONS

*The government of Sweden should:*

- *Prepare a comprehensive energy and climate strategy for the medium and long term, including a clear role for the future use of nuclear energy.*
- *Streamline and significantly shorten the approval and licensing process for electricity generation, gas supply and energy infrastructure projects.*
- *Review, with the aim of simplifying, the energy-related tax structure.*

## CLIMATE CHANGE

### OVERVIEW

Sweden is a party to the Kyoto Protocol. The related EU burden-sharing agreement (2002/358/EC) limits its greenhouse gas (GHG) emissions to no more than 4% above their 1990 level in 2008-2012. In addition to this binding target, Sweden has a national target to reduce total GHG emissions by 4% from 1990 to 2008-2012.

Emissions of the six GHGs have remained below their 1990 levels since 1999. In 2005, the latest year for which data are available, total GHG emissions amounted to 67.0 million tonnes of $CO_2$ equivalent (Mt $CO_2$-eq), which is 5.3 Mt $CO_2$-eq less than in the 1990 base year[2] (see Table 3). Emissions of $CO_2$, $CH_4$ and $N_2O$ are decreasing, whereas those of F-gases continue to increase. In 2005, $CO_2$ accounted for 78.5% of GHGs, $N_2O$ for 11.3%, $CH_4$ for 8.4% and the F-gases for 1.8%.

Energy use in Sweden produces relatively low $CO_2$ emissions per unit of GDP (see Figure 5) and per capita. In 2005, Sweden emitted 0.19 kg of $CO_2$ per USD of GDP (in 2000 prices and purchasing power parities), 56% less than the OECD average, and, together with Switzerland, the best result in the IEA. Also, Sweden's $CO_2$ emissions per capita, at 5.64 tonnes, were second only to Turkey within the IEA. This good performance is linked to the lowest carbon-intensity of energy supply among IEA countries: although overall energy use is high, electricity supply is almost completely $CO_2$-free, and renewable energy produces a high share of heat supply.

### $CO_2$ EMISSIONS FROM FUEL COMBUSTION

$CO_2$ emissions from fuel combustion decreased by 4.5% from 1990 to 2005, to 51.0 Mt. In 2005, fuel combustion accounted for 97% of all $CO_2$ emissions

2. 1995 for the F-gases: HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and $SF_6$ (sulphur hexafluoride).

Table 3

## Total Greenhouse Gas and $CO_2$ Emissions in Sweden, 1990 to 2020

| *Year* | *Total GHG, Mt $CO_2$-eq* | Change from base year, % | *$CO_2$ Mt* | Change from base year, % |
|---|---|---|---|---|
| Base year | 72.3 | | 56.4 | |
| 1991 | 72.6 | 0.5 | 57.0 | 1.0 |
| 1992 | 72.4 | 0.1 | 56.8 | 0.6 |
| 1993 | 72.0 | –0.3 | 56.2 | –0.3 |
| 1994 | 74.7 | 3.4 | 58.9 | 4.4 |
| 1995 | 73.7 | 2.0 | 58.0 | 2.9 |
| 1996 | 77.4 | 7.0 | 61.6 | 9.1 |
| 1997 | 72.8 | 0.7 | 56.9 | 0.9 |
| 1998 | 73.2 | 1.2 | 57.5 | 1.9 |
| 1999 | 69.8 | –3.4 | 54.6 | –3.1 |
| 2000 | 68.3 | –5.5 | 53.4 | –5.3 |
| 2001 | 69.0 | –4.6 | 54.2 | –4.0 |
| 2002 | 70.0 | –3.2 | 55.3 | –2.0 |
| 2003 | 70.7 | –2.2 | 56.3 | –0.2 |
| 2004 | 69.7 | –3.6 | 55.2 | –2.2 |
| 2005 | 67.0 | –7.4 | 52.6 | –6.8 |
| *2010** | *69.3* | *–4.1* | *56.4* | *0.0* |
| *2015** | *70.4* | *–2.6* | *58.6* | *3.9* |
| *2020** | *70.7* | *–2.1* | *59.6* | *5.7* |

* Estimates

Source: National Inventory Report to the UNFCCC.

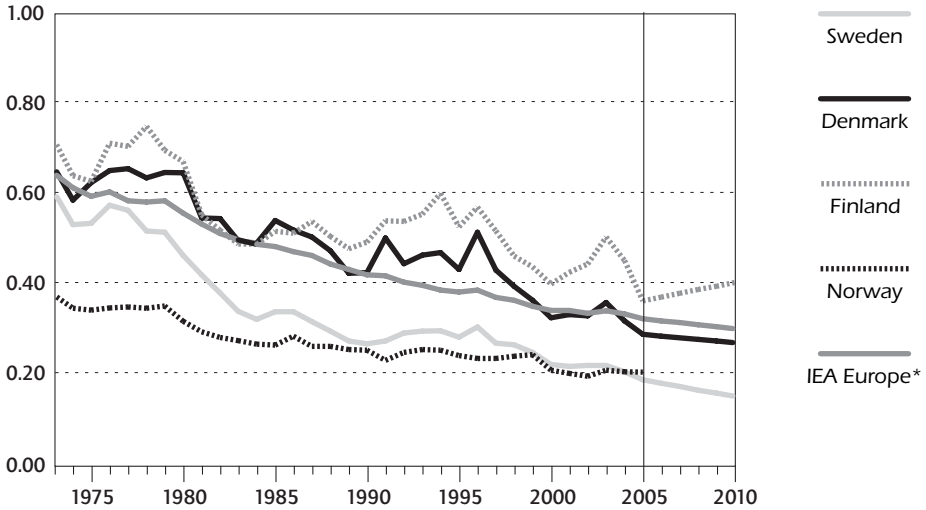
in Sweden. 2005 was a relatively rainy year, with mild temperatures, and emissions were 6% lower than in 2004. Transport emitted 45% of $CO_2$, manufacturing 23%, power and heat plants 18%, services and the primary sector 6%, other energy industries 5%, and the residential sector 3%.

Compared to 1990, emissions from the residential sector decreased by 70% in 2005, from services and the primary sector by 44%, and from manufacturing industry by 9% (see Figure 6). Emissions from transport increased by 14%, and from power and heat plants by 15%. Driven by capacity increases, emissions from oil refining grew by 44%.

Figure 5

**Energy-Related $CO_2$ Emissions per GDP in Sweden and in Other Selected IEA Countries, 1973 to 2010**

($kg$ of $CO_2$ per USD using 2000 prices and purcharsing power parities)



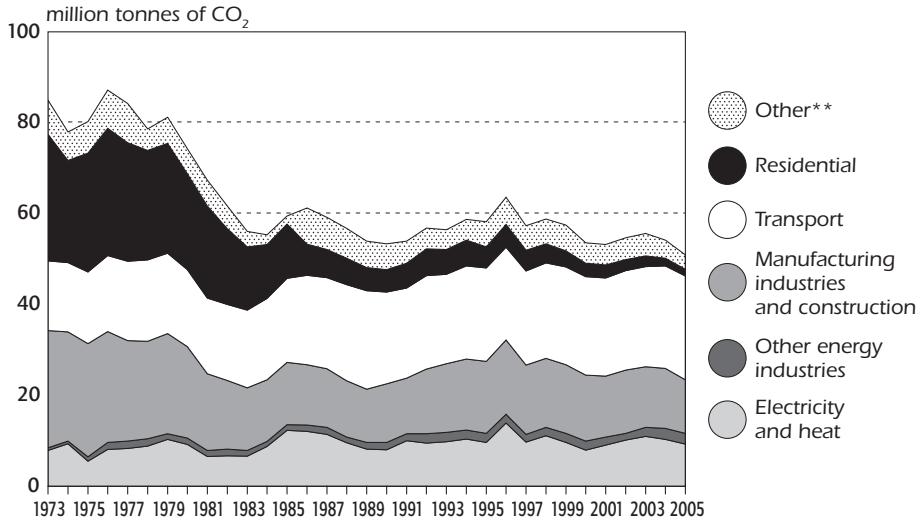

* excluding Luxembourg and Norway throughout the series, as forecast data are not available for these countries.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007; *National Accounts of OECD Countries*, OECD Paris, 2007 and country submissions.

On a fuel basis, oil remains by far the dominant source of $CO_2$ (see Figure 7). In 2005, it accounted for 73% of emissions, down from 76% in 1990. Coal accounted for 17% of emissions, slightly less than in 1990. The growing use of waste, gas and peat at CHP plants and in industry has increased their share: industrial and municipal waste from 2% to 4% in recent years, and both gas and peat from 2% to 3%.

Figure 6

## $CO_2$ Emissions by Sector*, 1973 to 2005



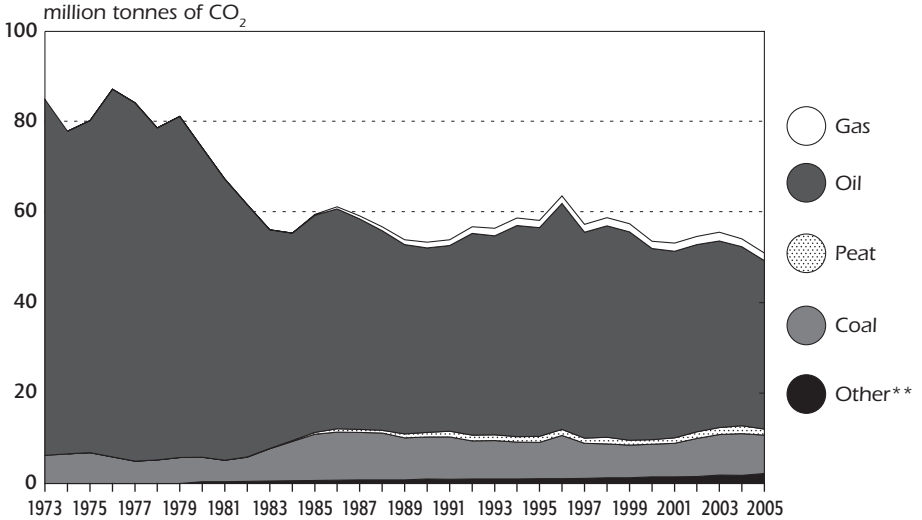

* estimated using the IPCC Sectoral Approach.

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

Source: *$CO_2$ Emissions from Fuel Combustion*, IEA/OECD Paris, 2007.

Figure 7

## $CO_2$ Emissions by Fuel*, 1973 to 2005




* estimated using the IPCC Sectoral Approach.

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

Source: *$CO_2$ Emissions from Fuel Combustion*, IEA/OECD Paris, 2007.

# POLICIES AND MEASURES

## Policies

Sweden has devoted considerable attention to mitigating climate change, which is one of the priorities for the current government. The main policy document is the climate strategy, adopted in 2002 and revised in 2006 (Government's Bill 2005/06:172, *National Climate Policy in Global Co-operation*). The current government, in office since October 2006, has endorsed the strategy, and is planning to present a new climate policy bill to parliament in 2008.

The strategy reconfirms a national target for total GHG emissions of 4% below their 1990 level to 2008-2012. The target goes beyond Sweden's obligation in the EU, and it is to be reached without resorting to carbon sinks or using flexible mechanisms. Sweden will face a binding target for 2020 under a future EU burden-sharing agreement, but the level of the target depends on the negotiations on how to share the EU overall target of –20% across member states. The previous government had set a national target to reduce GHG emissions by 25% from 1990 to 2020.

Sweden's long-term climate objective is to reduce its GHG emissions per capita to 4.5 t $CO_2$-eq by 2050, to equal the global per-capita average estimated for keeping GHG concentrations in the atmosphere at less than 550 parts per million $CO_2$-eq. This would imply a reduction of 39% from 2005 when Sweden's per-capita emissions amounted to 7.4 t $CO_2$-eq.

## EU Emissions Trading Scheme

The EU-ETS limits the amount of $CO_2$ emissions from installations in six energy-intensive industries: power and heat; iron and steel; cement; glass and ceramic construction materials; pulp and paper; and oil refining.

The overall scarcity of emission allowances on the market is caused by the allocation process. The member states submit proposals for their National Allocation Plan (NAP) to the European Commission, and these proposals must be in line with the criteria defined in the Emissions Trading Directive (2003/87/EC). After reviewing the proposals, the European Commission assesses the proposed allocations against the various criteria, and, if needed, adjusts them. The sum of the member states' allocations represents the cap on overall emissions from the EU-ETS sectors. Individual industrial installations must abide by the emissions limit set for them. The EU-ETS allows them to do so in a flexible way, by trading the emission allowances, thereby reducing emissions at least cost.

The EU-ETS was launched in 2005 and its first commitment period ran until the end of 2007. For 2008–2012, the second commitment period, Sweden can allocate 22.8 million allowances per year. This is roughly 10% less than what it had proposed in its submission to the European Commission, and some 17% less than in its estimated business-as-usual scenario for the trading sector. For 2008-2012, the government decided in October 2007 to allocate free allowances to the process industries that face global competition, but not to power and heat plants. The government also reserves 2.62 Mt per year for new entrants. The European Commission allows Swedish installations to use JI and CDM credits for 10% of their total emissions obligation.

Sweden has some 700 installations in the trading sector; they account for around 40% of the country's $CO_2$ emissions. In comparison with the EU as a whole, the EU-ETS sets a higher burden on process industries in Sweden, as opposed to the electricity and heating sector. In 2005, process industries' share of the emissions in the trading sector was 40% in the EU as a whole, but 82% in Sweden.

## Domestic Measures Outside the EU-ETS Sector

Climate change mitigation is one of the driving forces among Sweden's ambitious policies to promote energy efficiency and renewable energy. The government's efforts to limit $CO_2$ emissions have focused on taxation, and on promoting energy efficiency and renewable energy sources through various measures, including R&D. More detailed descriptions can be found in the relevant chapters of this report. Not mentioned elsewhere, the Climate Investment Programme (KLIMP) offers municipalities and companies financial support for reducing GHGs, *e.g.* installing district heating systems, converting to biofuels, and improving energy efficiency. From its launch in 2003 to mid-2007, SEK 1.5 billion had been appropriated for more than 700 measures, which are expected to reduce GHG emissions by 0.9 Mt $CO_2$-eq.

The government has also decided recently to spend SEK one billion more on climate change policies and measures from 2008 to 2010. The money will be spent on climate research (SEK 24 million); wind power (SEK 40 million); sustainable yield of bioenergy in agriculture and forestry (SEK 40 million); climate investments abroad (SEK 96 million); pilot and demonstration projects for second-generation biofuels (SEK 150 million); energy efficiency measures (SEK 310 million); and on a programme for sustainable cities (SEK 340 million) to support companies and local authorities in using new technology and integrated planning in order to significantly raise standards for environmental performance in existing and future urban areas.

The government included a so-called Climate Tax Package, representing a total of more than SEK 3 billion in increased energy and climate taxes, in the 2008 Budget Bill. The package consists of measures mostly on transport fuels and car use. For example, the $CO_2$ tax will be increased by SEK 60 to SEK 1 010 per t $CO_2$. Also, the energy tax on diesel will be increased by SEK 0.20 per litre. For consumers, the increase in $CO_2$ and energy taxes will mean a total tax increase of SEK 0.287 per litre for gasoline, SEK 0.55 per litre for diesel and SEK 292.50 per $m^3$ for fuel oil. At the same time, vehicle tax on most light lorries and buses will be increased by 45%, but the vehicle tax on diesel-driven passenger cars will be reduced.

### International Measures

Since 2002, Sweden has been developing and carrying out JI and CDM projects under the Swedish International Climate Investment Programme (SICLIP). So far, programme funding has amounted to SEK 200 million. The programme includes bilateral CDM projects in Brazil, India and China, and JI projects in Estonia, Romania, Ukraine and Russia. Sweden has also invested in multilateral JI/CDM facilities through the World Bank, the Asian Development Bank, the European Development Bank and the Nordic Environment Finance Corporation.

Total emissions reductions resulting from SICLIP, including additional future projects, and the multilateral efforts are estimated to amount to about 6 Mt $CO_2$-eq, equal to about 1.6% of projected Swedish GHG emissions in 2008-2012. Emissions reductions from these projects are estimated at SEK 50-100 per t $CO_2$-eq, which is clearly less than the past and expected average price for emission allowances in the EU-ETS, and a very attractive price compared to the SEK 500-2 000 per t $CO_2$-eq for reductions in Sweden.

## ENERGY EFFICIENCY

## OVERVIEW

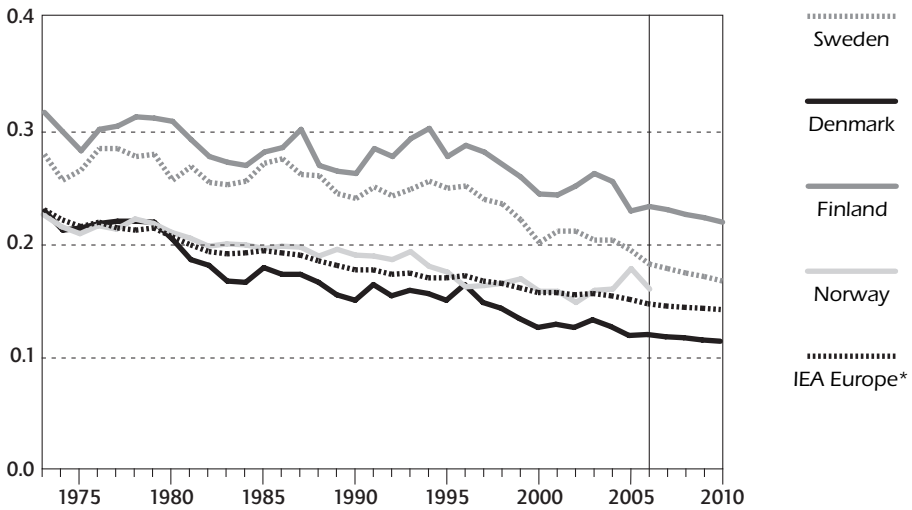
Sweden is an average IEA country in terms of energy intensity. In 2006, for each USD of gross domestic product (GDP), the country needed 0.18 toe of primary energy. This implies high energy efficiency to counterbalance the effects of the large heating requirements of a cold climate, and the energy needs of the dominant heavy industries, primarily pulp and paper and iron and steel. Intensity has decreased by 25% from 1990, mainly owing to structural changes in the economy – services and light industry are growing faster than the energy-intensive sectors – but there are also improvements in energy efficiency (see Figure 8).

Sweden's total final consumption of energy (TFC) was 35.0 Mtoe in 2006, up 7.7% from 1990. Industry was the largest user, accounting for 42% of the total. Transport's share was 24% and the other sectors (residential and services, and the primary sector) used 33% of the total. In comparison, the

Figure 8

**Energy Intensity in Sweden and in Other Selected IEA Countries, 1973 to 2010**

(toe per thousand USD at 2000 prices and purcharsing power parities)



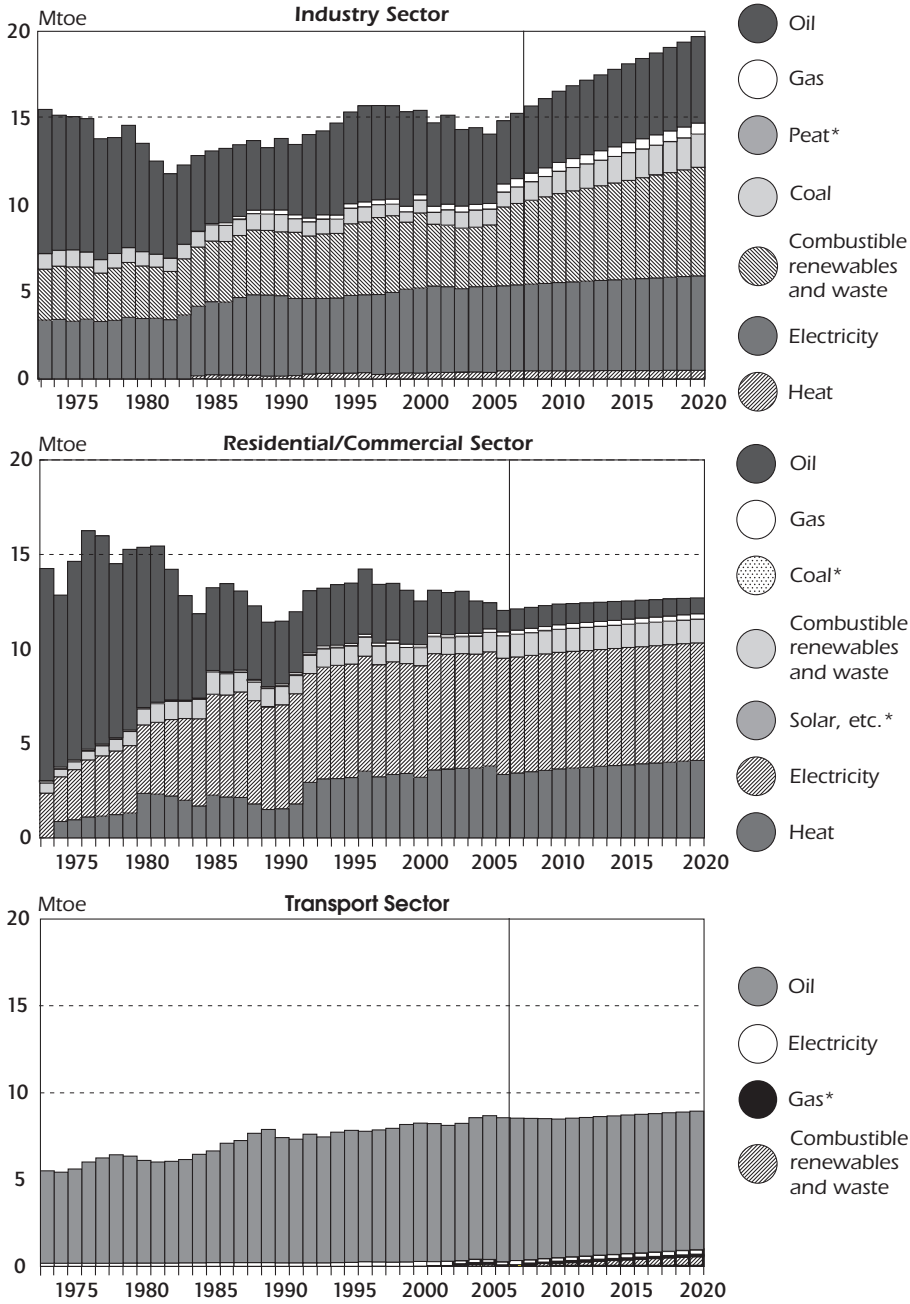

* excluding Luxembourg and Norway throughout the series, as forecast data are not available for these countries.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007; *National Accounts of OECD Countries*, OECD Paris, 2007 and country submissions.

IEA averages in 2005 were 32% for industry, and 34% for both transport and other sectors. Energy use in industry and the residential/commercial sector remains below the mid-1990 highs, whereas use in transport is steadily increasing. After the decreases in recent years, the government expects TFC to increase from 2006 by 7% up to 2010 and by 18% up to 2020. Energy use is expected to grow primarily in industry, by one-third until 2020, whereas consumption in transport and households and services is projected to remain relatively steady (see Figure 9).

Figure 9

## Total Final Consumption of Energy by Sector and by Source, 1973 to 2020




* negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

# POLICIES AND MEASURES

Energy efficiency has long been one of the priorities of Sweden's energy policy. Steering methods fall into four groups: legislation, regulations and guidelines; financial mechanisms such as taxes and subsidies; voluntary energy efficiency agreements; and education and communication.

Energy efficiency policy is increasingly guided by EU directives and non-binding goals, which, however, leave room for Sweden to decide how to implement them. The most important directives are described below.

The Directive on Energy End-Use Efficiency and Energy Services (2006/32/EC) contains an indicative national energy savings target of 9% up to 2016, to be reached by way of energy services and other energy efficiency improvement measures in the sectors that are not part of the EU-ETS. The reduction is calculated against the annual average TFC in the non-ETS sectors over the most recent five-year period previous to 2008 for which official data are available.

The Directive on the Energy Performance of Buildings (2002/91/EC) sets requirements for a more energy-efficient building code. Requirements for energy labelling of household appliances, in turn, are based on several directives adopted over the past 15 years. They also include compulsory minimum efficiency requirements. Over the longer term, the Directive Establishing a Framework for Setting Ecodesign Requirements for Energy-Using Products (2005/32/EC) will improve the energy efficiency of all new products outside the transport sector. The directive will be transposed into national law in the spring of 2008. Furthermore, the EU-ETS has an indirect, but strong effect on energy efficiency in heavy industry and the heat and power sector.

## Buildings

Energy use in buildings accounts for around one-third of TFC in Sweden, close to the IEA average of 30%. It has gradually become more efficient. The average consumption per floor area for heating, hot water and electrical appliances in new detached and semi-detached houses has decreased by one-fifth from the 1980s: it is now close to 129 kWh/$m^2$, down from an average 146 kWh/$m^2$ in 1990-1995 and 159 kWh/$m^2$ in 1980-1989. Comparable figures for apartment buildings are not available, but they would undoubtedly show a similar trend. Sweden's housing stock is relatively new, and in the coming years, some one million apartments built in the 1960s are set to be renovated, proving a good opportunity for energy efficiency improvements.

Energy efficiency is set to improve further. The government has a target to reduce energy use per heated floor area in residential buildings and other premises by 20% from 1995 to 2020 and by 50% from 1995 to 2050. The goal is also to break the dependence on fossil fuels by 2020 and increase the share of renewable energy in total energy use in buildings. The goals are stated in the 2006 National Programme for Energy Efficiency and Energy Smart Buildings.

## Legislation

The building code is the main legal instrument for improving energy efficiency. It was revised in 2006 to include new limit values for new residential buildings. The specific energy efficiency requirements on components were replaced by a single limit value on the total energy use for space heating, cooling and hot water, expressed in kWh per $m^2$ and year. The limit value is 110 kWh/$m^2$ in the southern part of the country, and 130 kWh/$m^2$ in the northern part. For single and semi-detached houses with direct electric heating, the limit value is 75 kWh/$m^2$ in the south and 95 kWh/$m^2$ in the north. For premises, it is 100 kWh/$m^2$ in the south and 120 kWh/$m^2$ in the north.

Under the revised building code, limit values for individual building components can still be applied, instead of the overall limit values, if the building has a floor area of less than 100 $m^2$; or if its door and window area is 20% or less of the floor area; or if no cooling is needed. The limit values are shown in Table 4. For buildings with direct electric heating, these U-values[3] are stricter: 0.08 for ceilings; 0.10 for walls; 0.10 for floors; and 1.1 for windows.

To verify compliance with limit values, the new buildings must be equipped with a system for measuring energy use. Before construction, the likely energy use is estimated. Once the building is in use, the actual energy consumption is measured over a 12-month period. The building code requires adequate safety margins for complying with the limit values, but does not say what will happen if the limit values are exceeded.

By international standards, Sweden sets high requirements for energy efficiency in buildings. A recent IEA comparison of energy efficiency requirements of the building codes in IEA countries shows that Sweden sets the highest overall requirements. The four highest-ranking countries, all with fairly similar climates, are shown in Table 4.

3. The U-value represents the rate of heat loss, *i.e.* how much energy passes through one square metre of a material by a difference of one degree in temperature. It is measured in watt (W) per degree Kelvin (K) per $m^2$.

Table 4

**Energy Efficiency Building Standards in Nordic Countries, 2007**

| | *Component U-values* | | | | *Overall U-values*[1] | |
|---|---|---|---|---|---|---|
| | *Ceiling* | *Wall* | *Floor* | *Windows* | *Overall* | *Average* |
| **Sweden** | **0.13** | **0.18** | **0.15** | **1.3** | **0.72** | **0.72** |
| Denmark[2] | 0.15 | 0.20 | 0.12 | 1.5 | 0.77 | 0.77 |
| Norway[3] | 0.13 | 0.18 | 0.15 | 1.2 | 0.70 | 0.80 |
| | 0.18 | 0.22 | 0.18 | 1.6 | 0.90[4] | |
| Finland[3] | 0.15 | 0.24 | 0.15-0.24 | 1.4 | 0.91 | 1.01 |
| | 0.18 | 0.29 | 0.29 | 1.7 | 1.10[5] | |

1. Overall U-value sums the U-values from the ceiling, walls and floor, and then adds 20% of the window value.

2. The values correspond to requirements for renovations; new buildings have lower component U-values, but a more stringent energy performance standard.

3. The two sets of values correspond to two different ways to calculate compliance, either based on U-values alone or an overall frame value with some maximum U-values.

4. This overall value results when the U-values are combined with a maximum energy frame value for the whole building.

5. This overall value results when the U-values are combined with heat recovery from exhaust air and meet air-tightness requirements.

Source: Laustsen, Jens, "Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings", IEA working paper forthcoming.

Energy performance certificates are required for multi-apartment buildings from the end of 2008 and for other buildings from the beginning of 2009. The certificate, an obligation derived from the relevant EU directive, will provide information on the overall energy performance of the building; the performance of the ventilation system; the radon level; and proposals for measures to improve energy efficiency.

## Energy-Efficient Technology

District heating and heat pumps are widely used in Sweden. Triggered by government policy to phase out the use of oil for heating, district heating increased substantially since 1990, and now supplies close to 50 TWh of heat per year, or about half of the heat for end-users. It is the most common form of heat supply in the urban centres of 232 of the country's 292 municipalities, and it is also used for industrial purposes. Almost 77% of all apartments are heated with district heating. District heating produced in combined heat and power plants, in which efficiency can exceed 90%, accounts for about two-fifths of the total production. Conversion to CHP has increased since 2004, when fuels for heat production at CHP plants were exempted from the energy

tax. Electricity produced by CHP plants has more than doubled since 1990, amounting to 13 TWh in 2006. Advanced technology and high load factors are keeping the losses from transformation and distribution comparatively low, at around 14%.

Outside the district heating areas, heat pumps have become a standard solution for family houses. Almost 80% of new family houses in Sweden are heated with electric heat pumps, of which over 60% are ground source heat pumps. Sales of these heat pumps have averaged 40 000 units annually in 2004–2006. Half of all heat pumps, excluding air-to-air ones, in European family houses are installed in Sweden. In 2007, about 15 TWh of free heat is estimated to be captured by all heat pumps, corresponding to 10% of total heat energy for buildings in Sweden. Heat pumps require around 7.5 TWh of electricity to operate. For heat pumps, except air-to-air, there is a robust supply chain available in the country. This performance of heat pumps has been demonstrated in practice and marketed heat pumps are rated annually by SP-Technical Research Institute of Sweden.

Another expanding energy-efficient technology is district cooling. It was first introduced in 1992, and by 2006 there were over 500 sites operating and producing around 0.8 TWh of cooling per year. Cooling services are offered by 26 companies, mainly to the commercial sector for shops and offices, and industry for process cooling. A survey carried out by the Swedish District Heating Association showed there is potential for a further 2–5 TWh of cooling.

The most common means of producing district cooling in Sweden is to use waste heat or lake water as the heat source for heat pumps. The water from which heat has been abstracted provides the district cooling water, while the heated output water from the heat pumps is sometimes used for district heating. Another common method of production is simply to use cold water from the bottom of the sea or a lake, *i.e.* free cooling.

Sweden is also in the forefront in promoting automated meter-reading (AMR) as a way to reduce electricity use. AMR is already being used in several parts of the country, and on 1 July 2009, it will become obligatory for power distributors to start monthly readings. As AMR will provide customers information on their actual electricity use, it is expected to give incentives to reduce consumption. It is also expected to increase security of electricity supply by allowing for faster demand-side responses at peak consumption times.

## Subsidies

Both district heating and heat pumps are benefiting from an investment grant to convert family houses and apartment buildings away from direct electric heating. The grant also applies to bioenergy-fuelled boilers. Introduced in 2006, the grant

can cover the whole investment cost, and it extends until the end of 2010. A similar grant for oil heating in residential buildings was phased out in 2007.

The government also has other grant schemes. Owners of one-family or two-family houses may obtain a grant for the installation of new windows with a maximum U-value of 1.2. The entire window – glass, frame and casement – must be replaced in order to qualify. In addition, the owner must live in the house. This grant is available until the end of 2008.

The government also provides grants for energy efficiency investments in public buildings. The programme offers a 30% support to public buildings for energy audits, energy saving measures and conversion from electric or fossil-fuelled heating to renewable energy sources and district heating. Maximum support per building is SEK 10 million. The programme also provides 70% support for installation of photovoltaic systems (maximum SEK 5 million per building). It was launched in 2005 and will end in 2008.

## Appliances

Mandatory energy labelling of domestic appliances is based on the EU directives. It covers lamps, ovens, refrigerators, freezers, washing machines, tumble-dryers and dishwashers. Appliances are classified from A to G, where class A is for the most energy-efficient appliances. In 2004, two new classes were introduced: compared to class A, electricity use in class A+ is 25% lower and in class A++ 40% lower. The Swedish Consumer Agency estimates that energy labelling has cut energy requirements of new domestic appliances by 25% to 35%. It has also helped the most inefficient appliances to gradually disappear from the market.

## Industry

Since 2004, electricity use in industrial processes has been taxed EUR 0.5 per MWh. The Programme for Energy Efficiency in Energy-Intensive Industry (PFE) offers an exemption from this tax for the participating companies. The companies must implement standardised energy management systems; audit their energy use; invest in efficient use of electricity, with a payback period of maximum three years; and adhere to the life-cycle costs principle in equipment purchases. The programme is voluntary. Participating companies failing to meet the requirements must retroactively pay the taxes of which they were exempt.

The programme was launched in January 2005 and runs until 2010. It is aimed at electricity-intensive manufacturing industries. Currently, 126 companies are participating, mainly from the pulp and paper industry (47 companies), but also from the metals and non-metallic minerals industry as well as food and wood products. These companies account for more than half of the electricity used in industry. It is estimated that the programme has resulted in electricity savings of 1 TWh per year and in total energy efficiency

investments of EUR 110 million, with an average payback time of 2.5 years. The tax exemption has amounted to EUR 15 million per year.

The programme is co-ordinated by the Swedish Energy Agency (SEA) in co-operation with the Swedish Tax Agency and a programme council representing the industries. The SEA is to review the programme by March 2008.

The SEA also co-ordinates the Technology Procurement Programme, the aim of which is to trigger the production and facilitate the market entry of new energy-efficient products. The SEA canvasses potential buyers of selected technologies to determine their criteria for the products regarding performance, energy efficiency and price. Suppliers can then choose to compete to manufacture these products if they can meet the criteria. If one or more suppliers qualify, they can proceed with manufacture in the knowledge that demand is guaranteed.

Since the programme was launched in 1990, 56 technology procurements have been performed. Current technology procurement projects include demand-controlled ventilation in new apartment buildings; climate screen-integrated systems for solar shading and daylight penetration; and industry-standardised information in the sawmill industry.

## Transport

Sweden's energy use in transport is growing, reflecting a global trend. The country's efforts to limit the resulting challenges for security of supply and climate change mitigation are strongly focused on promoting alternative fuels (see Chapter 7), but also on improving energy efficiency.

Private cars remain the dominant form of passenger travel in Sweden (see Table 5). To encourage buyers to favour low-emission alternatives, Sweden revised its vehicle taxation in October 2006. New cars, taken into use in 2006 or after, are taxed according to their $CO_2$ emissions. The tax consists of a base component of SEK 360 for all cars, and a $CO_2$ component of SEK 15/g $CO_2$ per km for cars emitting more than 100 g $CO_2$ per km. For diesel cars, the tax on the $CO_2$ component is multiplied by 3.5 to compensate for the higher particles emissions and the lower energy tax. For cars using alternative fuels, the $CO_2$ component is SEK 10/g $CO_2$ per km. For cars registered before 2006, the annual tax is based on their weight, as under the previous system.

The new tax system has started to reduce average fuel consumption and $CO_2$ emissions from new cars. From 2004 to 2006, average fuel consumption of new cars decreased from 8.3 to 7.7 litres per 100 km, *i.e.* by 7%. With the growing use of biofuels, in 2006, a new car registered in Sweden emitted an average 165 g $CO_2$ per km, 16% less than the 197 g $CO_2$ per km in 2004. $CO_2$ limits for new cars much below that average are likely to be introduced in the EU in the next few years.

Table 5

**Breakdown of Passenger Travel by Mode, 2006**

| *Mode* | *Car* | *Train* | *Bus* | *Airplane* | *Tram, metro* | *Boat* |
|---|---|---|---|---|---|---|
| Share, % | 80.0 | 7.5 | 7.4 | 2.7 | 1.7 | 0.7 |

Source: Statistics Sweden.

Although passenger cars still run predominantly on gasoline, diesel's share is steadily increasing. In 2007, diesel accounted for 34.7% of the 307 000 new passenger cars registered – a strong growth from 19.7 % in 2006 and 9.7 % in 2005. As intended, low-emission cars (emitting less than 140 g $CO_2$ per km) are also becoming more popular. Their share of all new registrations was 11.3% in 2007, up from 6.5% in 2006. Cars emitting less than 120 g $CO_2$ per km made up 5.8% of all new registrations in 2007, against 2.8% in 2006. These low-emission cars were mostly of the E85 ethanol-fuelled type (see Table 6). The new tax system is also contributing to renewing the relatively old vehicle stock – four out of ten cars were registered more than a decade ago. Thus, the new system is also set to reduce exhaust pollution emissions, such as nitrous oxides and particulates.

Table 6

**New Registrations of Low-Emission Passenger Cars* by Fuel Type, 2007**

| *Fuel type* | *E85* | *Gasoline* | *Diesel* | *Hybrid* | *Gas* |
|---|---|---|---|---|---|
| Share, % | 64.9 | 13.7 | 12.1 | 6.2 | 3.1 |

* Cars emitting 120 g $CO_2$ or less per km (equalling max. 4.5 L diesel or 5.2 L gasoline per 100 km).
Source: BIL Sweden.

Freight is mostly transported by lorries. These accounted for 53% tonne-kilometres and 82% of transport weight in 2006. Reflecting considerable long-haul ore transport from Lapland's mines, rail freight accounted for 15% of weight, but 34% of tonne-kilometres. Shipping accounted for the rest.

Freight volumes in Sweden, as in most countries, are closely linked to developments in the overall economy. The government's long-term objective, however, is to decouple road freight transport's $CO_2$ emissions from GDP. Reducing the emissions by 15% from 2005 to 2025 is seen as possible, even after increases in freight transport volumes. The Swedish Road Administration (Vägverket), the government body responsible for measures to cut $CO_2$ emissions from road transport, has set up an ambitious joint project on climate-neutral freight transport with scientists and representatives from oil, car and logistics companies. The project aims at halving $CO_2$ emissions by 2020 and is looking into ways to improve transport, fuel production and vehicles, and to increase the use of biofuels.

Box 1

## Stockholm's Congestion Charge

A congestion charge was introduced in Stockholm on 1 August 2007, with the aim of improving traffic flow in the city and reducing pollution, while also helping to finance investments in the road network in the Stockholm region. The charge applies to cars driving to and from the Stockholm inner city on weekdays (Monday to Friday) from 6:00 to 19:00. There are some exceptions, for example cars running on alternative fuels and all buses are exempt from the charge. The charge was introduced together with additional public transport.

Vehicles are registered automatically at the control points. Each passage costs SEK 10, 15 or 20, depending on the time of day. The maximum daily charge per vehicle is SEK 60. The daily total charge must be paid within 14 days, either by automatic debiting from a bank account, on the Internet, or at several kiosks and supermarkets. To save time, the charge is not paid at the control points. Car owners can find information on their charges on their individual Internet accounts, or by calling the system's customer service. From August to December 2007, crossings ranged from 350 000 to 400 000 per day, and the accrued charges from SEK 70 million to SEK 90 million per month.

The charge has proved to be effective. During the trial period in the first months of 2006, vehicle traffic to and from the inner city was reduced by 20-25% and emission of particulates and $NO_x$ fell by 8-12%. The system's running costs, however, have been relatively high by international comparison. Changes in the billing system, planned for autumn 2008, should lower them.

### Information Dissemination

The SEA is a central provider of information on energy efficiency. It employs various channels and works with a large number of parties to ensure that information reaches its target groups. A major part of its efforts is financing a country-wide network of local energy advisors. In each of Sweden's 292 municipalities, advisors provide free energy consultancy for the general public, small companies and organisations. The advisors, in turn, are supported by 11 regional energy agencies that provide training and co-ordinate information activities. Information is widely available on the SEA web site (http://www.energimyndigheten.se).

In 2006 and 2007, the SEA, the National Board of Housing, Building and Planning, the Swedish Consumer Agency and the Swedish Environmental Protection Agency managed information campaigns on long-term energy efficiency improvements and energy conservation measures, aimed at domestic consumers, and detached house and apartment owners. The campaigns included an information tour around the country and the creation of a web site.

# CRITIQUE

## CLIMATE CHANGE

Environmental protection is one of the key objectives of Sweden's energy policy and fully in line with the IEA's three Es (Energy security, Environmental protection and Economic growth). Climate change is the biggest challenge, and the government has given it priority at home and abroad. Sweden's climate policy is ambitious, and has been successful to date.

Under the EU burden-sharing agreement related to the Kyoto Protocol, Sweden is allowed to increase its GHG emissions by 4% from 1990 to 2008-2012. It is likely to meet this target by a wide margin. This is remarkable, especially because no JI/CDM credits are used. On the other hand, the EU-ETS is becoming a burden on Sweden's energy-intensive export industries, particularly iron and steel where coal is a vital input to the production process. This is because electricity and heat generation in Sweden have the lowest emissions-intensity in the EU and, therefore, has relatively fewer opportunities to reduce emissions in that sector as opposed to process industries that face global competition. Against this background, Sweden's decision to favour export industries in allocating allowances for the 2008-2012 period of the EU-ETS is to be commended for its economic soundness.

International and EU targets for the period after 2012 are being negotiated. Sweden is well advised to prepare a comprehensive climate strategy for that purpose. As reducing $CO_2$ emissions normally comes at a cost, Sweden would benefit from consistently using a cost-effectiveness criterion (SEK/t $CO_2$ avoided) to help prioritise its various policies and measures. One cost-effective way to mitigate emissions would be to resort more to the JI/CDM credits. The country is already involved in such projects and, as suggested by the SEA and the Swedish Environmental Protection Agency, should consider using the Kyoto flexibility mechanisms (JI/CDM) to help mitigate emissions at a lower cost.

In the non-trading sector, transport is the logical choice of strong focus, as it already accounts for more than four-fifths of the emissions, and its emissions are increasing. For road transport, Sweden's policy is to promote biofuels and increased diesel use to replace gasoline. In a country with practically $CO_2$-free

electricity generation, a shift from road to electric rail in both passenger and freight transport should be encouraged.

## ENERGY EFFICIENCY

Sweden's energy intensity is equal to the IEA average. Though it may not seem so, this is in reality an impressive achievement, given that the country has a very cold climate and a very large heavy industry. Sweden has a long tradition of highly effective measures to enhance energy efficiency across sectors. The IEA applauds Sweden for these continuous and successful efforts, particularly because energy efficiency is a cost-effective way to meet the IEA three Es.

Nevertheless, there is room for more efficient energy use in Sweden, just as in all countries. The IEA recommends an in-depth review of the existing economic potential for further improving energy efficiency, including an analysis of the barriers. This would help Sweden to further refine the instruments for enhancing energy efficiency. The IEA also encourages the government to continue the efficient system of local energy advisors.

To improve energy efficiency, the IEA also urges the government to continue its work to make the national and EU policies fully consistent with the 16 energy efficiency policy recommendations the IEA presented to the Group of Eight (G8). These policy measures were endorsed by both G8 leaders and the IEA energy ministers in 2007 (see Box 2).

Box 2

### G8 Energy Efficiency Recommendations

At the Group of Eight* (G8) Summit in 2005 in Gleneagles, Scotland, the G8 countries asked the IEA to assist in developing and implementing energy efficiency policies. Responding to this request, the IEA prepared 16 recommendations, covering appliances, lighting, buildings, transport, industry and cross-sectoral policies, summarised below. The recommendations were subsequently endorsed in 2007 by all IEA member countries, who agreed to take them forward.

*Appliances*

- Limit stand-by power use to 1 watt across all electronic appliances.
- Establish minimum energy efficiency requirements for television set-top boxes and digital television adapters.

- Establish and enforce mandatory energy performance requirements and, where appropriate, energy labelling across the full range of mass-produced equipment.
- Require individual and networked devices to enter low-power modes automatically.

*Lighting*

- Adopt best practice in lighting energy efficiency.
- Phase out the most inefficient incandescent bulbs as soon as commercially and economically viable.

*Buildings*

- Make voluntary energy efficiency requirements for new buildings mandatory and strengthen mandatory requirements such that they aim to minimise total costs over a 30-year lifetime.
- Promote very low energy buildings to ensure they are commonly available on the market by 2020.
- Monitor, collect and analyse information on energy efficiency in existing buildings and on barriers to energy efficiency.

*Transport*

- Implement a fuel-efficient tyre programme.
- Introduce mandatory fuel efficiency standards for cars and vans.
- Adopt international test procedures for measuring tyre rolling resistance and require the fitting of a tyre pressure monitoring system.

*Industry*

- Improve the coverage, reliability and timeliness of industries' energy use data.

*Cross-sectoral*

- Provide adequate resources for countries' energy efficiency policy agencies and publish energy efficiency action plans.
- Encourage investment in energy efficiency by adopting a common energy savings verification protocol, reviewing fiscal incentive programmes and collaborating with the private financial sector.
- Report progress in the implementation of the proposed energy efficiency actions to the IEA.

* The Group of Eight is an international forum for the governments of Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States.

## Buildings

Building codes are a key instrument for promoting energy efficiency. By international comparison, Sweden is a star performer, and its revised standards set a strong example for other countries. Buildings have the longest service life of all energy-using products, spanning decades or even centuries, and they account for close to one-third of all end-use energy. Therefore, strict building codes are a necessity in improving overall energy efficiency. In Sweden, the building sector has the largest potential for energy efficiency improvements. The government has set further energy efficiency targets for 2020 and 2050. The current standards provide a solid basis for more ambitious measures.

In addition to its stringency, other commendable features of the building code are its flexibility and openness to innovation. The code sets a goal for the overall efficiency (energy use per floor area), but leaves it to planners and builders to decide on how to reach this goal. Generally, building codes should require minimising the life-cycle cost of energy use in new buildings over a period of at least 30 years. The government should continue to update regularly the minimum requirements to encourage a move towards zero-net energy or "passive house" energy performance levels.

In the existing buildings, more challenges remain. Retrofitting the existing building stock to reduce energy consumption in some one million apartments built in the 1960s will pose a serious challenge for Swedish energy efficiency policy. The government is now offering grants to support the conversion from electric heating to other heating systems and the installation of energy-efficient windows. It could consider wider retrofitting packages that should be available in time and deployed broadly.

The plan to introduce automated meter reading (AMR) for electricity consumption in the majority of households by 2009 will make Sweden one of the front-runners in this field. This measure should contribute significantly to reducing electricity consumption in households.

## Industry

The Programme for Energy Efficiency in Energy-Intensive Industry is the central industry-specific policy measure to enhance energy efficiency in the highly energy-intensive industry sector. The participating companies represent around half of total electricity used in industry, and have managed to cut their annual electricity use by 1 TWh (3%). The SEA estimates that at an annual cost of around EUR 15 million in tax exemptions, some EUR 110 million of private investment in energy efficiency have been triggered. This can be considered very successful, and the IEA encourages the government to continue the programme.

A key component of the programme is the use of energy management systems at the companies. Whether these systems deliver the expected savings, or even more, depends to a large part on the skills and knowledge of the experts and managers. Therefore, the government should consider ways to underline the need for sufficient know-how at the company level. Furthermore, ways and means to expand the programme to include small to medium-sized firms should be studied. Incentives could be used: one option to consider could be to increase the tax, or the maximum payback time for eligible measures.

### Transport

The transport sector continues to depend on fossil fuels, with 96% of fuels for road transport being gasoline and diesel. As 80% of all personal travel is by car, additional policy incentives are needed to enhance energy efficiency in the sector. More efficient cars are crucial in mitigating climate change and reducing import dependence. The government has emphasised fuel substitution towards more environment-friendly fuels rather than more energy-efficient transportation.

The new tax regime since 2006 is creating greater incentives for customers to purchase more fuel-efficient or biofuels-run vehicles. It is also stimulating faster turnover of the relatively old vehicle stock. Support for "clean cars" is encouraged, but a clearer definition is needed. All this will help reduce emissions of regional air pollutants. The tax regime is flexible and market-based, and can be used as a model for other countries. To complement it, the government should continue to pursue other policies that encourage mode shifting, more efficient driving behaviour and more fuel-efficient vehicles.

A good example is the new congestion charge system in Stockholm. It can serve as a best practice strategy for other metropolitan areas in Sweden as well as in other IEA countries. In order to further propagate the model, complementary concepts of intermodal transport to and from metropolitan areas are needed.

## *RECOMMENDATIONS*

*The government of Sweden should:*

### Climate change

- *Continue efforts to reduce energy-related GHG emissions and prepare for post-Kyoto by developing integrated and co-ordinated energy and GHG scenarios and policies.*

- *Increase the use of cost-effectiveness (SEK/t $CO_2$ avoided) as a criterion for prioritising measures to lower GHG emissions.*
- *Consider more JI/CDM projects as a cost-effective way to meet GHG targets in the long term.*

### Energy efficiency

- *Review the economic potential for improving energy efficiency, identify the barriers, and develop measures to realise this potential.*
- *Continue to engage with the municipalities to further develop high-quality, individual and independent advisory services for energy saving.*

#### *Buildings*

- *Consider increasing support for renovation and refurbishment, for example by designing packages of measures for energy-related retrofitting and by considering strategies for their broad deployment.*
- *Ensure sufficient funding for conversion grants to encourage more efficient space heating systems.*
- *Monitor closely the compliance with the energy efficiency requirements in the building code.*

#### *Industry*

- *Maintain the voluntary Energy Efficiency in Energy-Intensive Industry scheme and consider ways to trigger greater energy efficiency investments in industry, including in SMEs.*

#### *Transport*

- *Encourage models for intermodal connections to and from metropolitan areas.*
- *Monitor and, if needed, increase current efforts to reduce oil use in the transport sector by encouraging more efficient fuel use.*

Security of supply has been one of the core energy policy issues in Sweden as all fossil fuels are imported. The country has reduced its dependence on them to the lowest level in the IEA, at around 35% of TPES. Sweden continues its ambitious plans to improve energy efficiency and increase the use of renewable energy sources, both pivotal for energy security. Over the years, the government has successfully used regulation, taxation, investment grants, but also energy R&D to support its policy goals. Security of electricity supply is dealt with mostly in the Nordic context.

## OIL

Sweden meets its stockholding requirements to both the IEA and the EU by placing minimum stockholding obligations on oil industry participants. Oil companies and large consumers are obliged to hold at least 25% of the total amount of products sold or consumed, on a net basis, during the previous calendar year.

There are three main categories of companies obliged to hold stock: companies selling or importing more than 50 000 $m^3$ (roughly 314 thousand barrels, kb) of refined products annually; power plants consuming more than 5 000 $m^3$ (roughly 32 kb) of oil products annually; and district heating plants or gas turbine plants with more than 5 MW installed capacity.

At the end of 2006, Sweden's overall stockholding equated to nearly 127 days of net imports. This was composed of roughly 70% refined products, mostly in the form of middle distillates. The other 30% was crude oil.

The SEA (or its designated inspectors) is entitled to inspect the stocks held under the obligations, and can also examine the accounts and other documents relating to company stockholding operations. Any company failing to maintain compulsory stocks must pay the state a special storage penalty charge. This penalty charge corresponds to the estimated capital cost of the product for one month, plus a surcharge of 60% for failing to meet the requirement.

Draw-down of compulsory stocks held by companies would take place under an agreement established in October 2003 between the SEA, the Swedish Petroleum Institute and six major oil companies operating in Sweden. The stock draw-down would be set in motion in the event of a peacetime oil crisis, and carried out in a cost-effective manner. Such a stock draw-down would be conducted in co-ordination with the SEA, and under its supervision. The SEA

and individual companies would agree on a time period for the re-establishment of the stocks, which would not exceed three months. Depending on circumstances, a government decision on whether to authorise a stock-draw is expected to take seven to 14 days.

Table 7

**Legal Basis for Oil Security Measures in Sweden**

| *Legislation* | *Powers* |
|---|---|
| The Rationing Act (1978/268);<br>The Oil Crisis Act (1975/197) | **Emergency response organisations**<br>These acts are the legal authority to establishing and operating the National Emergency Sharing Organisation.<br>The Sustainable Energy Management team within the SEA is its core. |
| The Contingency Storage of Oil and Coal Act (1984/1049), as amended in 1995 and in 2002. | **Stockholding**<br>The act obliges the oil industry to hold stocks, corresponding to at least 25% of consumption or sales during the previous calendar year. |
| The Contingency Storage of Oil and Coal Act (1984/1049), as amended in 1995 and in 2002;<br><br>The agreement between the SEA, Swedish Petroleum Institute and six major oil companies. | **Implementation of stock-draw and other emergency measures**<br><br>The act and agreement provide the government with the statutory power to release the contingency stocks held by industry in crisis situations. |

Source: *Oil Supply Security: Emergency Response of IEA Countries 2007*. IEA/OECD Paris, 2007.

## NATURAL GAS

Natural gas is a minor fuel in Sweden, accounting for 1.8% of TPES in 2006. Its use is geographically limited to the western coast of the country. Gas use is set to increase with a new gas-fired CHP plant. Natural gas is supplied through one pipeline from Denmark, but the gas companies have plans for diversifying supply routes, *e.g.* from Norway (see Chapter 5).

The 2005 Natural Gas Act requires the suppliers of natural gas for heating purposes to have a plan for possible supply disruptions. A proprietor of a natural gas pipeline, storage plant or gasification plant shall, to the extent possible, implement the planning measures and those otherwise needed to safeguard the supply of natural gas.

The SEA is responsible for the national strategy for the security of natural gas supply. Enacted by the 2006 Natural Gas Ordinance, the strategy shall contain:

- an objective for natural gas supply in Sweden,
- an assessment of the vulnerability and threat profile, and the method therefor,
- a method for monitoring global developments,
- a description of completed and planned preventive activities,
- a description of completed and planned information and training initiatives,
- a description of how such tasks are to be co-ordinated between several authorities, and
- a national plan with measures to secure national gas supply in an emergency

Sweden has a small-scale gas storage (10 million $Nm^3$), but it has also an agreement to use the transmission pipeline for storage purposes by increasing the pressure (line-pack).

## COAL

As with natural gas, coal is a minor fuel in Sweden, accounting for 4.6% of TPES in 2006. Coal imports are geographically well diversified. Electricity and heat production accounts for around one-third of coal use, but it is facing strong pressure under the EU-ETS. The rest is used in industry, mostly in producing iron and steel.

## ELECTRICITY

Sweden's security of electricity supply needs to be understood in the context of the Nordic electricity market (see Chapter 6). Increasing trade and regional integration resulting from electricity market reform has enabled Sweden to effectively draw on the reserves of other Nordic countries to enhance its security of supply.

Although peak demand in Sweden has remained relatively stable since liberalisation, generating capacity has diminished significantly, leading to a tightening supply-demand balance. According to Nordel's projections for the winter 2007/08, Sweden would have a small deficit in its power balance in

unusually harsh conditions (one out of ten winters). By activating its 300-MW reducible load agreements, however, Sweden would rise to a small capacity surplus. Any deficit could be covered by imports from within the Nordic market area.

Peak load resources are typically needed for only a few hours per year. The Nordic governments have agreed to work towards greater elasticity of demand as a way to secure peak load resources in the Nordic electricity market. Also, the Nordic TSOs in 2007 agreed on harmonised Nordic guidelines for possible peak load arrangements. Sweden's Law on Peak Load Reserve came into effect on 1 July 2003 and expired on 1 March 2008. The law states that Svenska Kraftnät, the TSO, has the responsibility to hold a peak load reserve of up to 2 000 MW, financed by balance providers. The reserve is procured from producers as well as large consumers who agree to make production capacities (or consumption reductions) available during the winter. The parliament has decided to prolong the Law on Peak Load Reserve until March 2011.

Since 2006, distribution companies are obliged to pay compensation to end-users for unplanned power cuts lasting 12 hours or more. Prior to 2006, paying compensation was voluntary. Depending on the duration of the power cut and the level of network charges, compensation per customer can range from a minimum of SEK 900 to a maximum of three years' network charges.

## DISTRICT HEATING

Total installed capacity for district heating in Sweden is estimated at 27 to 39 GW, of which 14 to 26 GW is oil-fired reserve capacity. At the minimum, this is 50% more than the 18 GW peak capacity demand in unusually harsh conditions (a five-day period of cold occurring statistically every 30 years).

The system is also flexible, as some 9 GW can be switched relatively quickly to run on other fuels. Biomass from domestic sources increases security of supply and accounts for almost two-thirds of the fuels used in district heat generation. District heating plants with more than 5 MW installed capacity are required to hold oil stocks equal to at least 25% of the total fuels used.

## CRITIQUE

Sweden relies completely on imports to meet fossil fuel demand. Since the 1970s, it has worked consistently to reduce oil demand, with considerable success. The country now has the lowest share of fossil fuels in its TPES within

the IEA. Sweden's emergency stocks of oil covered 127 days of net imports at the end of 2006, much more than the IEA obligation of 90 days. This is highly commendable and sets a strong example to other countries.

Natural gas supply, though still small, is set to increase in the coming years. Today, natural gas is supplied through one pipeline, but gas companies are planning to diversify supply routes. New supply routes would be very positive for security of supply. To speed up this diversification, the IEA recommends that the government ensure a swift procedure for granting permissions and licences.

In securing electricity supply, co-operating within the Nordic market offers the best system stability for all countries in the market area. This applies to ensuring sufficient transmission capacity and avoiding congestion, and also to maintaining a balance between supply and demand. In particular, meeting peak demand for electricity should be left to the market, as government involvement in setting up emergency generation would reduce prices and discourage private investment, or demand response. Sweden's efforts to work with other Nordic countries on market-based mechanisms that enhance security without unduly distorting the market are to be commended. The government should ensure that any future emergency procurement provisions are clearly established as a short-term, interim policy with a clear termination date. These provisions should be based on common Nordic principles, and be transparent in view of the type and volume of the resources, activation and pricing, financing of the arrangement, and opt-out rules.

## RECOMMENDATIONS

*The government of Sweden should:*

- *Continue to monitor and enforce compliance with security of fuel supply, taking due account of any potential increase in consumption.*
- *Give priority to market-based measures in responding to peak demand for electricity.*

# PART II

# SECTOR ANALYSIS

# OIL

## SUPPLY AND DEMAND

### Supply

Oil continues to be the most important fuel in Sweden. In 2006, oil supply amounted to 14.6 Mtoe, accounting for 29% of TPES. The share has been stable in recent years and remains clearly below the IEA average (40% in 2006).

All oil is imported. In 2006, crude oil imports, 19.3 Mt in total, came from Russia (37%), Denmark (27%), Norway (25%), Venezuela (6%), the United Kingdom (3%) and Iran (1%). But Sweden is a net exporter of oil products. In 2006, total exports amounted to 10.7 Mt and net exports to 3.6 Mt. Products were exported to Denmark (19% of total export volume), the United Kingdom (15%), Norway (13%), the United States (10%), the Netherlands (8%) and to some 25 other countries.

### Demand

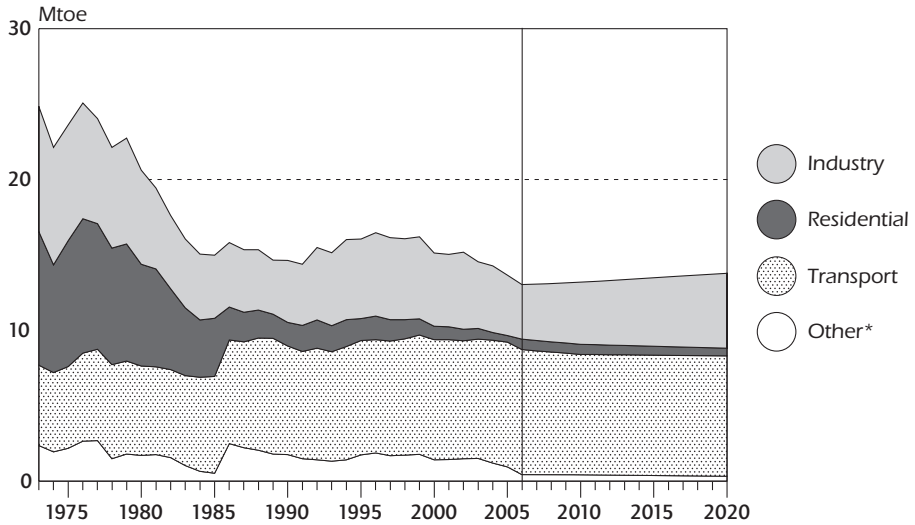
In 2006, oil accounted for 37% of TFC. At 13.0 Mtoe, oil use continued its downward trend since the mid-1990s (see Figure 10). Transport is the largest user (61% of the total in 2006) and it is also the only major sector in which oil consumption is growing, up 20% from 1990.

Within the transport sector, diesel use is rising, whereas gasoline use is declining. Reflecting this development, diesel cars' share of all new registrations was close to 30% in early 2007, although diesel cars only made up 6% of Sweden's car fleet. Oil use in transport is facing competition from biofuels (see Chapter 7).

Oil use in industry is fairly stable, down 6% from 1990, and accounts for 28% of the total. Oil use in the other sectors has decreased by 61% since 1990, and accounted for 11% of the total in 2005. The key development here has been the reduction of oil demand for residential heating, down by half since 2000, which can be mostly attributed to government subsidies for converting away from oil heating, but also to the doubling of heating oil prices in the past decade.

Figure 10

**Final Consumption of Oil by Sector, 1973 to 2020**




* includes commercial, public service, agricultural, fishing and other non-specified sectors.
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

# INDUSTRY STRUCTURE

## Refineries

Sweden has four large refineries, with a total crude distillation capacity of 434 thousand barrels per day (kb/d): Nynas Refining AB, Preemraff Lysekil, Preemraff Göteborg, and Shell Refining AB in Göteborg. Nynas is specialised in refining heavy crudes. It is owned 50/50 by Neste Oil of Finland and PDVSA, the Venezuelan national oil company. Preemraff refineries are part of Preem, a privately-owned Saudi oil company.

Responding to market demand for more environment-friendly products, some refineries (*e.g.* Preemraff in Lysekil) are undertaking major investments to produce greater volumes of sulphur-free gasoline and diesel oil. This also reflects legislation from 2002, which called for a gradual transition to sulphur-free transport fuels from 2005-2008. Refining capacity in Sweden is expected to reach 443 kb/d in 2010, an increase of 2% compared to 2006.

## Retail Market

The Swedish oil retail market is fully open to competition. The market is dominated by Preem, Statoil, QK-Q8 and Shell, which together accounted for

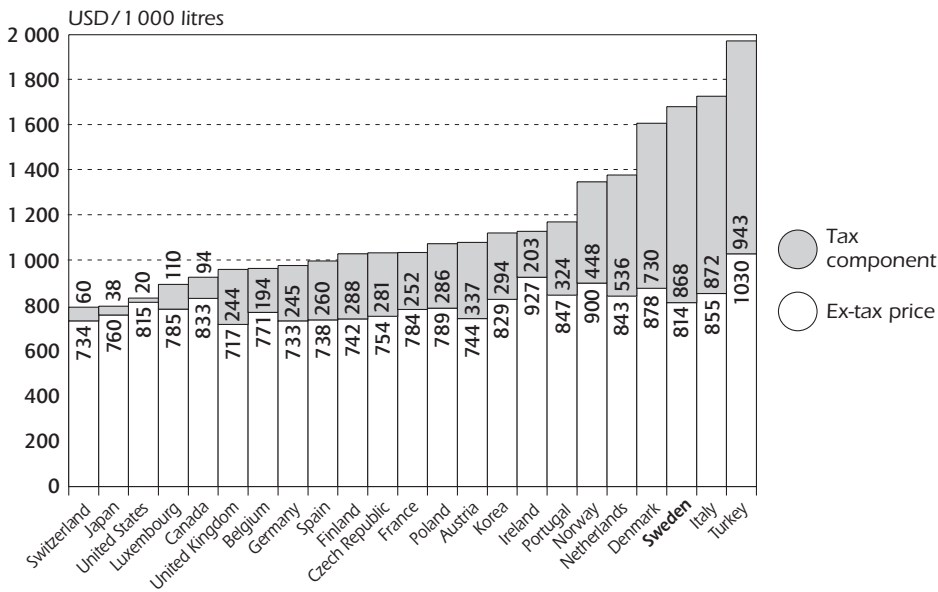
72% of sales volume in 2006. In 2007, Sweden had 3 701 filling stations, operated by 13 different companies. The five largest networks were those of QK-Q8 (899 stations), Statoil (590), Hydro (503), Preem (483) and Shell (378), accounting for 77% of the total. Oil is distributed to consumers and retail outlets by road tankers.

## PRICES AND TAXES

Heating oil is expensive in Sweden. In the fourth quarter of 2007, it was the third-most expensive in a comparison of 23 OECD countries (see Figure 11). Taxes were 52% of the retail price, also third-highest in the OECD comparison. Sweden's long-term policy to reduce oil use for space heating has rested on gradual tax increases, in addition to providing grants for converting to other heating systems. Also, gasoline and diesel prices are higher than the OECD average. Diesel, in particular, is expensive (see Figures 12 and 13).

Figure 11

**OECD Light Fuel Oil Prices and Taxes for Households, Fourth Quarter 2007**

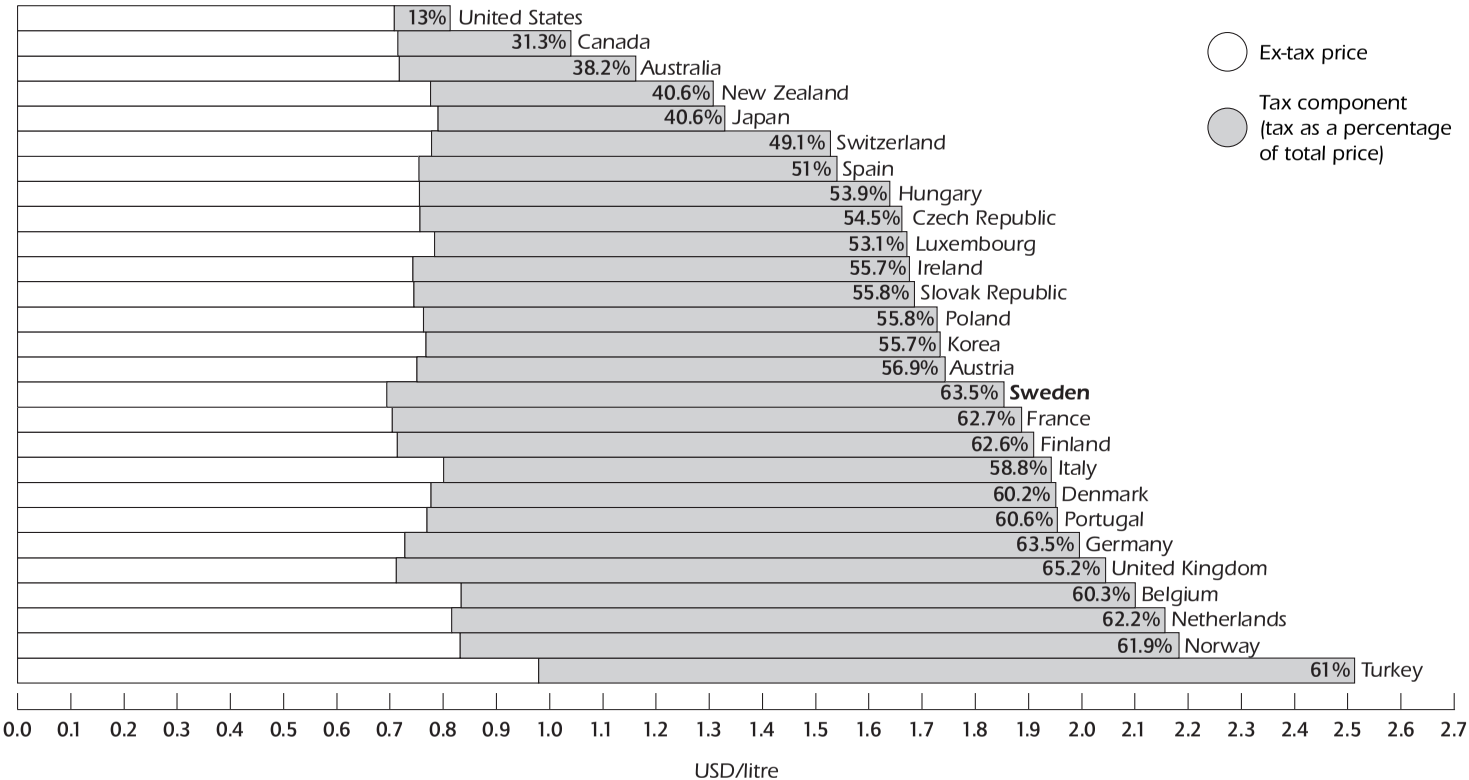



Note: data not available for Australia, Greece, Hungary, Mexico, New Zealand and the Slovak Republic.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2007.

Figure 12

## OECD Unleaded Gasoline Prices and Taxes, Fourth Quarter 2007

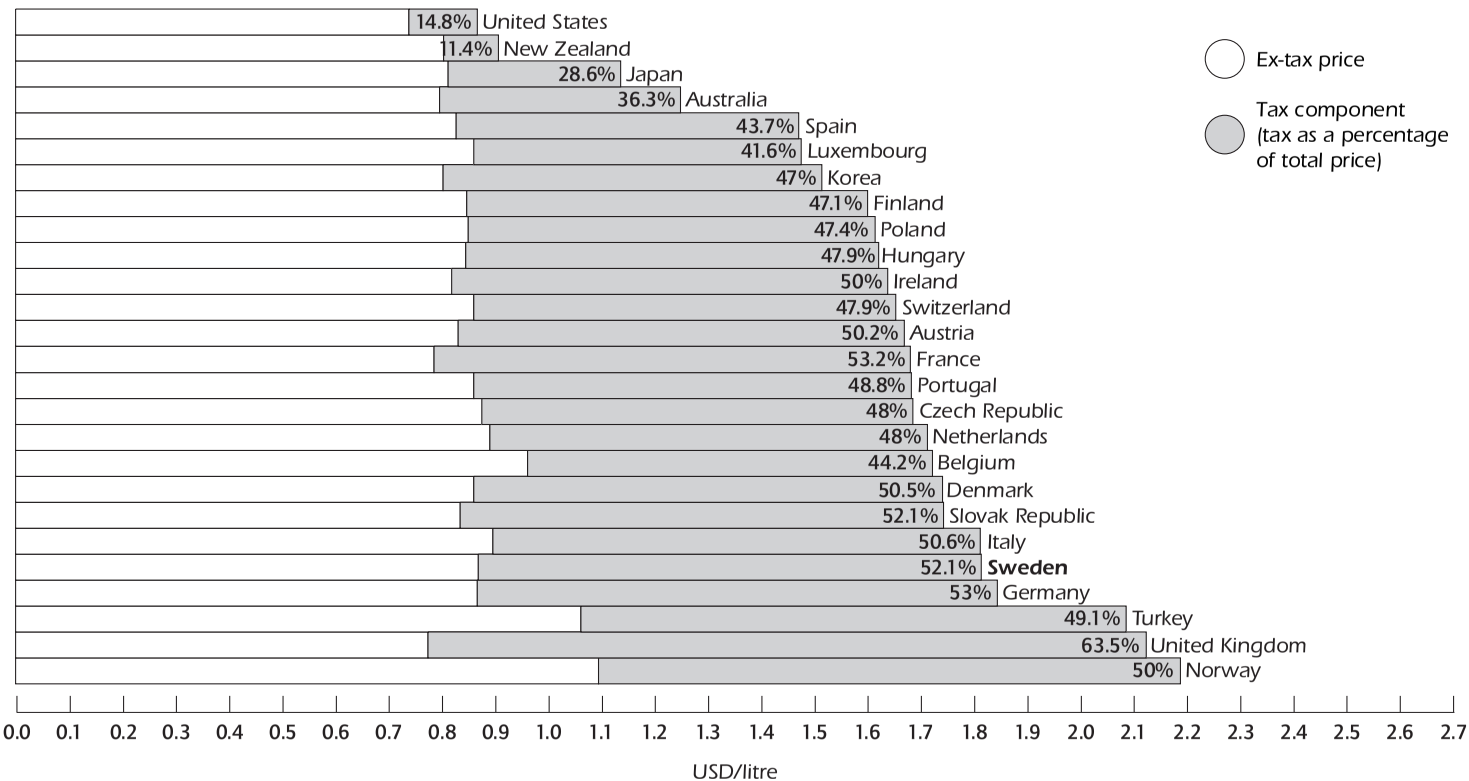



Note: data not available for Greece and Mexico.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2007.

Figure 13

## OECD Automotive Diesel Prices and Taxes, Fourth Quarter 2007




Note: data not available for Canada, Greece and Mexico.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2007

# NATURAL GAS

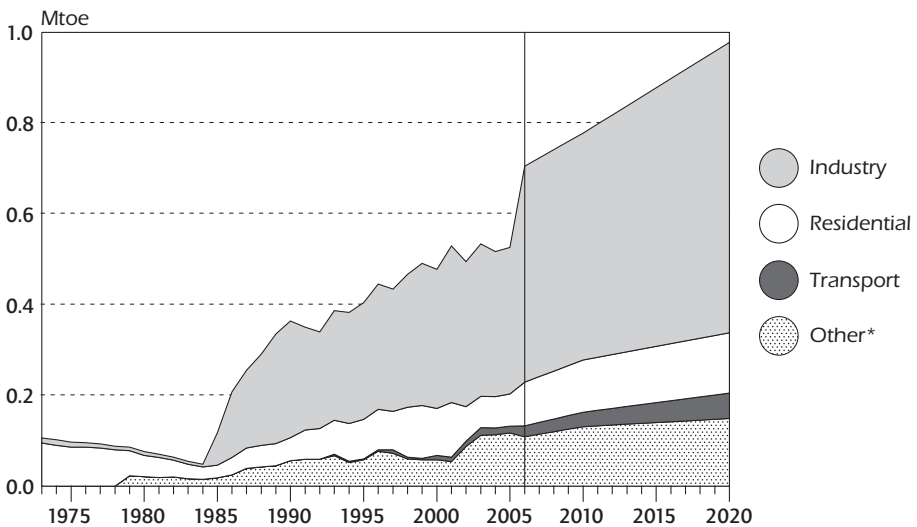
## SUPPLY AND DEMAND

Natural gas plays a minor role in Sweden's energy mix. In 2006, it provided 1.7% of TPES. From 1990 to 2006, use of natural gas increased by half, from 0.6 Mtoe to 0.9 Mtoe. At the same time, its share of TFC almost doubled from 1.1% to 1.9%. However, in areas where natural gas has been introduced, it accounts for some 20% of energy use. In 2005, the largest user was industry (44% of the total), followed by CHP and heat plants (32%), services and households (22%) and transport (2%). Reflecting the use for heating purposes, natural gas use is strongly concentrated in winter months. In 2004-2006, 78% of the total was consumed from October to March.

In the projections until 2020, the government expects gas demand to double from 2006, with CHP capacity for industry accounting for most of the increase (see Figure 14). In late 2006, a 270-MW CHP plant was inaugurated in Göteborg, and there are plans for a 400-MW CHP plant in Malmö, to be commissioned in 2009. Given the small size of the Swedish gas market, constructing more gas-fired capacity would change the demand outlook substantially.

Figure 14

**Final Consumption of Natural Gas by Sector, 1973 to 2020**




* includes commercial, public service, agricultural, fishing and other non-specified sectors.
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

# REGULATORY FRAMEWORK

Sweden's gas market legislation is based on the relevant EU directives and regulations. The Natural Gas Act, which transposes the second EU Gas Market Directive (2003/55/EC) into national law, came into force in July 2005. It sets requirements for further opening of the market; the form and application of transmission tariffs; legal and functional unbundling of network operations; and system responsibilities on the natural gas market.

Supplementing the second Gas Market Directive, Regulation 1775/2005 on conditions for access to the natural gas transmission networks entered into force in all EU member states in July 2006. The regulation concerns the fees and services for third-party access (TPA), balancing rules and mechanisms for the allocation of capacity.

Since July 2005, all customers other than households, 2 600 in total, are eligible to choose their gas supplier. They account for some 95% of gas use in Sweden. Households became eligible to choose their supplier in July 2007.

The Natural Gas Act established the Energy Markets Inspectorate (EMI) as the regulator. Formerly part of the Swedish Energy Agency, the EMI became an independent body in January 2008. The network owners are obliged to provide third-party access (TPA) on objective, non-discriminatory and reasonable terms. Methods for setting the network tariffs are subjected to prior approval by the EMI. The network owners are also required to publish their tariffs. EMI regulates tariff levels *ex post*. In case of non-compliance, the EMI can fine the gas companies, and require them to lower the tariffs and refund customers.

The regulator is mainly funded by a government grant, but the network operators are also obliged to pay a fee to the regulator. The fee is calculated from the amount of gas transmitted and was around 4% of the regulator's budget in 2006. Competition issues related to the supply of natural gas are monitored by the Swedish Competition Authority.

Since 2005, the gas transmission system is operated by the state-owned Svenska Kraftnät, which is also the TSO for the electricity system. Svenska Kraftnät is responsible for the short-term maintenance of balance between the input and extraction of gas in the national gas system. The pipeline owners are responsible for operating and maintaining the gas distribution system.

Constructing transmission and distribution pipelines requires a permit from the government. Applications for permits are submitted to and processed by the EMI. Siting of the pipelines must be in accordance with the environmental law, avoiding pipeline-to-pipeline competition, unnecessary impingement on property rights, and archaeological damage. Public consultations are an elemental part of the siting process.

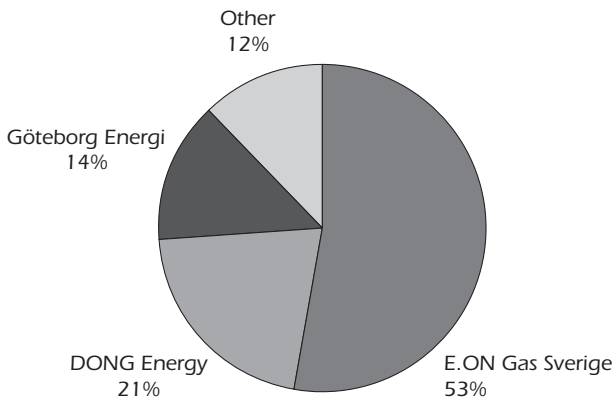
## INDUSTRY STRUCTURE

The gas market is dominated by a small number of vertically integrated companies, and most gas is supplied under long-term contracts. The Swedish transmission network for natural gas is owned by Swedegas and E.ON Gas Sverige AB: Swedegas owns the trunk line and E.ON Gas Sverige AB the branches. Swedegas, the former Nova Naturgas, is owned by E.ON Ruhrgas of Germany (29.6%). Statoil of Norway (29.6%), Fortum of Finland (20.4%) and DONG Energy of Denmark (20.4%). E.ON Gas Sverige, formerly Sydkraft Gas, is owned by E.ON Ruhrgas (55%) and Statkraft of Norway (45%). E.ON Ruhrgas is expecting to purchase Statkraft's stake in E.ON Gas Sverige in the course of 2008.

Two companies import natural gas to Sweden: E.ON Gas Sverige AB purchases its supplies from E.ON Ruhrgas in Germany, whereas DONG Energy supplies gas from Denmark. These two companies also dominate the Swedish retail gas market. In 2006, they accounted for three-quarters of the sales, with E.ON Gas Sverige AB alone selling more than half of all the gas. The other suppliers – Göteborg Energi, Lunds Energi, Varberg Energi and Öresundskraft – are municipal companies with a local customer base (see Figure 15). They also own the network they use for distributing gas. Except for Swedegas and DONG Energy, all natural gas companies are part of energy companies with operations in the electricity and/or district heating market in Sweden. In total, Sweden has 55 000 gas users, of which 2 600 are industrial.

**Figure 15**

**Natural Gas Sales to End-Users by Supplier, 2006**




Source: Country submission.

## INFRASTRUCTURE

The gas grid covers the western coast of Sweden. All natural gas is imported from Denmark through one pipeline and, through Denmark, Sweden is linked to the Central European gas system. In 2006, Sweden had 540 km of transmission and some 3 000 km of distribution grid.

The transmission pipeline between Malmö and Göteborg has an annual capacity of 2 billion cubic metres (bcm), though only half of that capacity is now being used. The capacity could be increased by 30% without substantial cost through additional compressors.

Gas storage in Sweden is limited to one facility with a volume of 10 million $Nm^3$. The facility is owned by E.ON Gas Sverige and it is in commercial use since May 2006. The storage is open to third-party access. For geological and technical reasons, large-scale gas storage is not feasible.

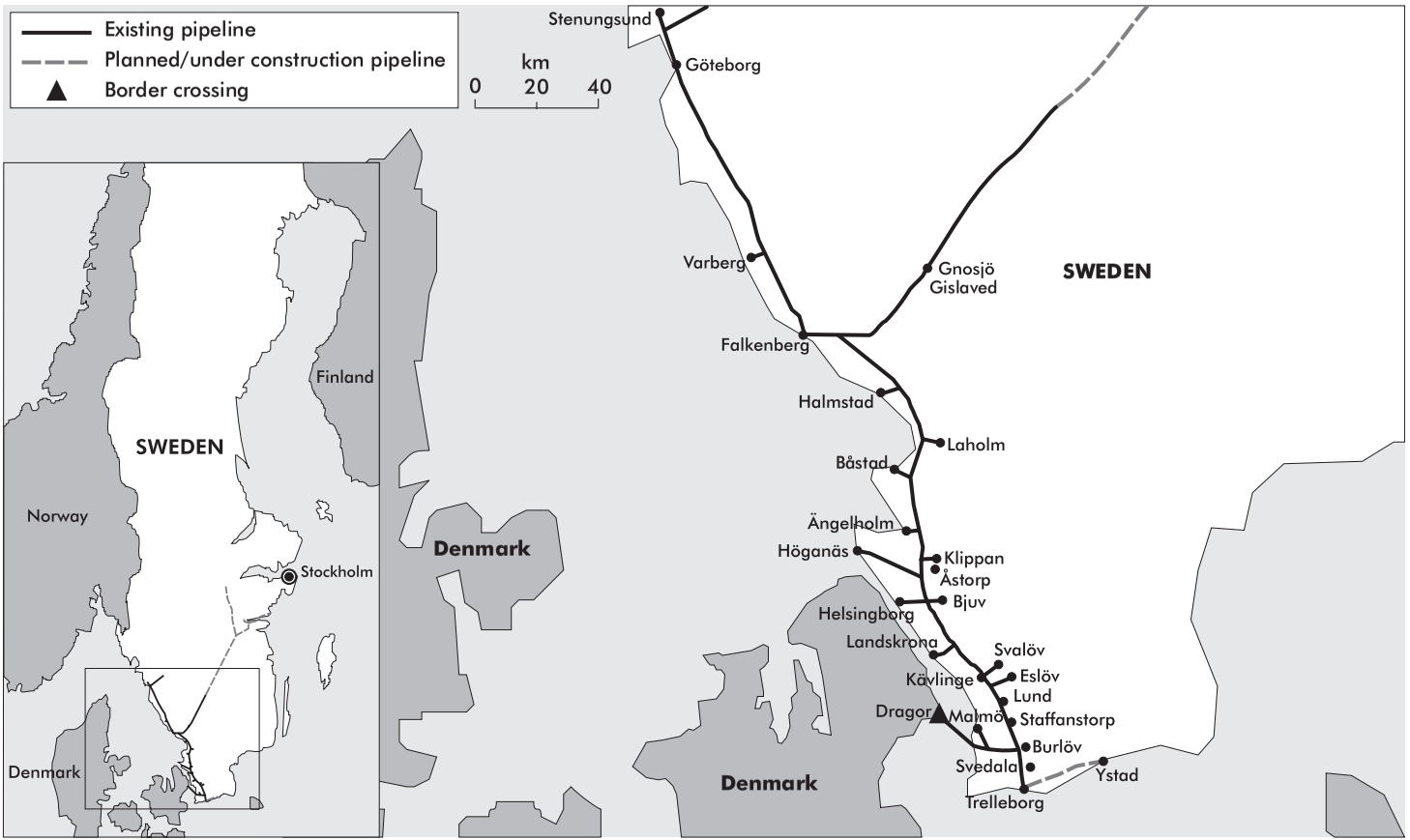
Construction of the natural gas infrastructure is done commercially: the government does not finance or own any part of the natural gas network. Gas companies have several plans to expand the Swedish natural gas system to reach both new customers in Sweden and new supplies from abroad. E.ON Gas Sverige has applied for permits to extend the gas network from Trelleborg to Ystad in the south of the country and towards central Sweden (see the dotted line in Figure 16).

In 2004, the government granted Sydkraft Gas (now E.ON Gas Sverige) a permit for a pipeline between Sweden and Germany, but the final investment decision is yet to be taken. Annual capacity is planned to be 3 bcm at first, but could ultimately rise to 10 bcm. The pipeline would be part of a project to link northern Germany with eastern Denmark and southern Sweden (the Baltic Gas Interconnector). Seven companies from the three countries are involved in the project, including E.ON Sverige, DONG and several municipal utilities.

Plans to connect the Swedish grid to Norwegian gas sources (the Skanled project) are also advancing. The Norwegian Parliament voted in March 2005 to approve building an offshore pipeline from Stavanger to Grenland, south-west of Oslo. Several Swedish stakeholders, including major natural gas consumers, are working to ensure that the pipeline is dimensioned to meet the potential needs in Sweden. The planned capacity in the transport system from Kårstø, close to Stavanger, is 20 mcm/d. Project developers are expected, in early 2008, to submit to EMI an application for a permit to construct the pipeline in Sweden. A final decision regarding the investment is scheduled for

Figure 16

## Map of the Swedish Natural Gas Transmission System




The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the IEA.

Source: *Natural Gas Information 2007*, IEA/OECD Paris, 2007.

late 2009, and the pipeline could be taken into use in 2012, at the earliest. In Sweden, it would primarily serve the petrochemical industry. Eventually, the Skanled project could also connect Denmark and Poland to the Norwegian gas sources.

To introduce natural gas in the Stockholm region, a liquefied natural gas terminal is being considered by Fortum, in co-operation with AGA and Nynas Refining. The terminal would be built in Nynäshamn and have a storage volume of 20 000 $m^3$.

The Nord Stream pipeline, which would run from Russia to Germany offshore through the Baltic Sea, would link Sweden directly to Russian gas resources. The pipeline project is a joint venture of Gazprom, E.ON Ruhrgas, BASF and Gasunie, and E.ON Sverige has expressed interest in building a branch from the pipeline to the east coast of Sweden. The project, however, is facing delays, and it is also opposed by the Swedish government on environmental and safety grounds.

### PRICES AND TAXES

Prices of gas imports are based on long-term contracts and linked to the price of oil. For the past several years, prices for end-users have been steadily rising, reflecting growing demand and higher oil prices (see Table 8). Natural gas prices for industrial users have also increased because of the EU-ETS, which came into effect on 1 January 2005. Information on wholesale prices is not available. Statistics on the breakdown of end-use prices into energy and transport components are being developed.

Natural gas consumption is subjected to an excise tax, which includes both an energy tax component and a $CO_2$ tax component. Tax rate varies according to user category. Natural gas use for electricity generation is exempt from all tax. Industrial customers pay no energy tax and only 21% of the $CO_2$ tax. CHP plants pay the same tax rate as industry for fuels in heat production. The use in vehicles, in turn, is exempt from the energy tax and subject to just over 50% of the $CO_2$ tax.

## COAL

In 2006, coal use in Sweden was 2.4 Mtoe, accounting for 4.7% of the country's TPES. All coal is imported. In 2006, metallurgical coal (2.1 Mt) came from Australia (61%), Russia (16%) and the United States (17%); steam coal (1.0 Mt) was imported mostly from Russia (44%) and other former Soviet Union republics (25%).

Table 8

## End-User Prices for Natural Gas, 1997 to 2007

| | | *Households, 23 260 kWh per year* | *Industry, 11 630 MWh per year Load factor: 250 days, 4500 hours* |
|---|---|---|---|
| | | *Price including tax and VAT (öre/kWh)* | *Price including taxes (öre/kWh)* |
| 1997 | January/July | 38.3 | .. |
| 1998 | January/July | 40.2 | .. |
| 1999 | January/July | 37.5 | .. |
| 2000 | January/July | 40.2 | .. |
| 2001 | January | 51.7 | 29.0 |
| | July | 52.7 | 30.5 |
| 2002 | January | 57.3 | 23.4 |
| | July | 57.3 | 33.2 |
| 2003 | January | 60.5 | 26.0 |
| | July | 57.4 | 23.6 |
| 2004 | January | 64.4 | 24.7 |
| | July | 64.4 | 26.9 |
| 2005 | January | 72.3 | 30.0 |
| | July | 70.5 | 31.8 |
| 2006 | January | 87.0 | 38.8 |
| | July | 89.6 | 40.5 |
| 2007 | January | 86.9 | 37.2 |

Source: Statistics Sweden.

Coal use has been relatively stable in recent years. Roughly half is used in the iron and steel industry and consumption may rise with the planned expansion of iron ore mining in Sweden. The iron and steel producer, SSAB (Svenskt Stål AB or Swedish Steel), is the dominant importer of metallurgical coal and coke, and is the only producer of coke. It has two plants, in Luleå and Oxelösund, that are connected to the municipal district heating network.

Electricity and heat production accounts for around one-third of coal use, with all coal-fired plants being CHP, and the cement industry using less than 10%. Steam coal is used at five CHP plants: in Stockholm, Västerås, Norrköping, Linköping and Uppsala on the eastern side of the country. Since January 2004, coal use for heat generation at CHP plants is exempt from the energy tax and subject to only 21% of the $CO_2$ tax. Electricity generation at CHP plants is fully tax-exempt. Coal use is, however, facing strong pressure under the EU-ETS.

## PEAT

In 2006, peat use was 0.3 Mtoe, accounting for 0.5% of Sweden's TPES. Peat use has been relatively stable since 1990. Roughly three-fourths of peat is produced domestically and the rest is imported from Finland, the Baltic states and Belarus. In 2006, CHP plants accounted for 64% of peat use, heat plants for 34% and condensing power plants for 2%. In all, peat is used in about 30 plants in Sweden.

The government regards peat as something in between biofuels and fossil fuels. Though it is subjected to the sulphur tax, it is exempt from energy and $CO_2$ taxes, and, since April 2004, electricity generated from peat-fired CHP plants is eligible for green electricity certificates. In 2005, this electricity generation amounted to 0.4 TWh, equalling 0.25% of total generation. The government has two main reasons for favouring peat over coal in taxation. First, peat production has some regional importance in Sweden, and, second, co-firing of peat with wood fuels, a common practice at CHP and heat plants, improves plant efficiency by reducing slag formation, sintering, build-up of deposits and corrosion in boilers, something coal could not do.

## CRITIQUE

### OIL

Since the last in-depth review, oil use in Sweden has remained relatively unchanged. Sweden's policy to reduce oil use for space heating has been very successful, and the heating conversion grant system could be an example to other countries. The IEA encourages the government to continue this policy. Oil use in the transport sector is the largest source of $CO_2$ emissions, and these emissions are growing. The government is addressing this issue with a suite of measures, including ambitious plans to promote alternative fuels. Oil use will also be affected by any future EU obligations to reduce $CO_2$ emissions from private cars. As oil remains the most important fuel in Sweden, and as all oil is imported, further reducing dependence on it would help both to secure energy supplies and to mitigate climate change.

## NATURAL GAS

Since the last review, the Swedish gas market has seen some positive developments. For example, a regulator and an independent system operator have been established, but, as in many other countries, the gas market in Sweden remains dominated by a small number of vertically integrated companies, and most gas is supplied under long-term contracts. E.ON Gas Sverige alone accounts for about half the annual sales. The incumbents also own the transmission grid.

So far, competition in the gas market has been characteristically that of gas against other forms of energy. More could be done to increase competition between gas companies. The government should ensure a sufficient level of competition, especially in the light of the growing importance of natural gas to Sweden's energy supply.

The government should ensure effective unbundling of network operations from the utilities' other activities, which is vital for a well-functioning gas market. To increase flexibility in the gas system, especially in light of increasing gas use, the government should also require establishing a secondary market for transmission capacity.

To increase incentives for grid investment, the regulator should monitor the level of the allowed rate of return and adjust it, if necessary. The IEA also encourages the government to consider moving from *ex post* to *ex ante* regulation to reduce long-term uncertainties and, therefore, facilitate investment decisions.

Increasing supply routes is crucial for more competition. All natural gas is imported from Denmark through one pipeline, but the gas companies are planning to diversify the supply routes. Such connections would be very positive for security of supply and competition on the Swedish energy market. To speed up this diversification, the IEA advises the government to ensure a swift procedure for granting permissions and licences.

## COAL

Coal use is dominated by Sweden's large steel industry. The country has ample iron ore resources, and converting them into steel requires coal (mostly in the form of coke) as a process input. The EU-ETS is penalising coal use, thus challenging the competitiveness of Sweden's steel industry. In response to the steel industry's concerns, the government has favoured steel plants in the National Allocation Plan (NAP) of the EU-ETS. This is an essentially sound

approach given that the industry must compete in an international market. However, the government and industry do need to consider how $CO_2$ capture and storage technologies might reduce $CO_2$ emissions from the steel industry in the future.

## PEAT

The government regards peat as something in between biofuels and fossil fuels, and exempts it from both the energy and $CO_2$ taxes. Peat is also eligible for renewable electricity certificates. As peat is primarily a domestic energy source in Sweden, it is understandable that the government prefers to support its use to avoid greater reliance on imported fossil fuels. Peat use, however, does not support Sweden's climate policy goals, especially in light of the projected growth in its use. Therefore, any policy that might further increase demand, particularly for imported peat, should be carefully considered. Although peat use falls within the EU-ETS, the government should also consider adjusting peat taxation to avoid favouring this fuel over alternatives.

# *RECOMMENDATIONS*

*The government of Sweden should:*

- *Continue efforts to reduce dependence on oil, increase the efficiency of oil use and reduce $CO_2$ emissions from its use.*
- *Improve conditions for competition in the natural gas market by ensuring effective unbundling of network operations from the utilities' other activities; establishing a secondary market for gas transmission capacity; considering* ex ante *regulation of network tariffs; and ensuring regulatory flexibility for developing international gas connections.*
- *Balance the environmental burden of peat with a more appropriate peat taxation policy.*

# ELECTRICITY

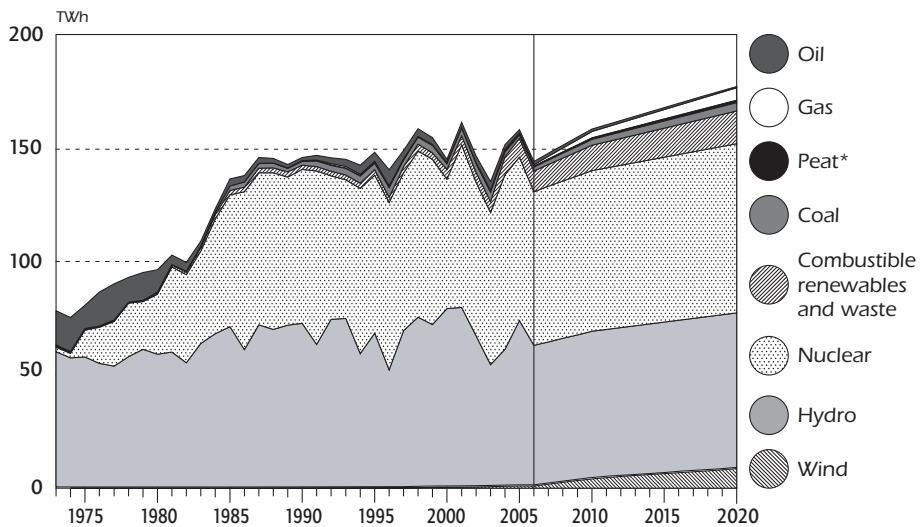
## SUPPLY AND DEMAND

### Supply

Sweden's electricity supply is dominated by hydro and nuclear power, accounting for 90% to 92% of the country's annual electricity generation, with each providing roughly one-half of this. The rest is mostly generated from biomass, although some coal, oil, natural gas and wind power are also used (see Figure 17).

Figure 17

**Electricity Generation by Source, 1973 to 2020**




* negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

In 2006, total generation amounted to 140 TWh (see Table 9). Since 2000, total electricity generation has varied from 135 TWh to 162 TWh. Over the

same period, Sweden's annual hydropower generation has ranged from 54 to 79 TWh. Nuclear power generation ranges typically from 67 to 73 TWh per year. Some 70% of CHP electricity is produced from biomass and waste, and the rest is fossil fuels. Condensing power is fossil-fired reserve capacity and seldom used.

As in all power systems dominated by low-cost hydropower, precipitation levels are a key determinant of production levels and of the production mix in Sweden and in the whole Nordic market. During wet years, Sweden is a net exporter of power, reflecting the relatively low marginal cost of hydro generation. During dry years, however, Sweden becomes a net importer, importing mostly from Denmark and Finland, which can compensate for the reduction in hydro by using coal condensing capacity. Sweden's net electricity trade since liberalisation has generally been closely correlated to water inflows.

Table 9

**Electricity Generation and Net Maximum Capacity, 2006**

| | *Capacity at 31 December 2006, MW* | *Generation in 2006, TWh* |
|---|---|---|
| Nuclear power | 8 965 | 65.0 |
| Other thermal power | 8 094 | 13.2 |
| *– CHP, industry* | *1 229* | *5.5* |
| *– CHP, district heating* | *2 954* | *6.9* |
| *– Condensing power* | *2 298* | *0.8* |
| *– Gas turbines* | *1 613* | *0.01* |
| Hydropower | 16 180 | 61.2 |
| Wind power | 580 | 1.0 |
| **Total** | **33 819** | **140.3** |

Source: *Nordel Annual Statistics 2006.*

## Demand

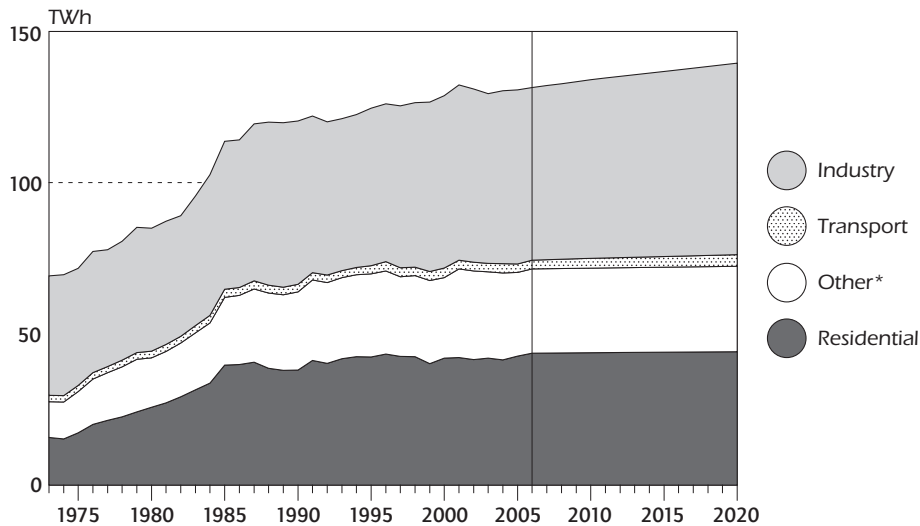
Sweden is an electricity-intensive country. Annual use is almost 16 MWh per citizen, one of the highest in the world. This is explained by the needs of the

large electricity-intensive industry, especially mechanical pulping, widespread use of direct electric heating in detached houses, and traditionally low electricity prices. Electricity consumption has, however, remained relatively stable over the last years. Consumption varies from year to year mostly because of changes in temperature and in the business cycle of the heavy industry. The cold climate and high proportion of electrically heated residences also make Swedish electricity demand peak in winter. The highest hourly peak is usually around three times higher than the hourly minimum. In 2006, the maximum load occurred on 3 January, hour 18 (26 385 MW).

In 2006, the breakdown of electricity end-use by sector was industry 44%; residential 33%; services 20%; transport 2%; and agriculture, forestry and fishing 1%. In the projections until 2020, the government expects demand in industry to grow at a rate of 0.7% per year, and in transport at 1.9% per year. Demand in the other sectors is projected to remain stable (see Figure 18).

Figure 18

**Final Consumption of Electricity by Sector, 1973 to 2020**




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

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007 and country submission.

Net maximum generating capacity, as measured on 31 December 2006, was 33.8 GW (see Table 9), slightly up from 2005, but below pre-liberalisation

levels of the early 1990s. Available production capacity[4], as estimated by Nordel, was 28.6 GW in 2006. In recent years, new capacity has mostly come in the form of biomass-fired CHP, based on favourable taxation. In 2006-2009, decided and planned capacity increases would amount to almost 3 GW, of which wind would account for 1.25 GW, nuclear 0.6 GW and other thermal (biomass and gas) 0.9 GW. Renewable electricity is boosted by taxation, EU-ETS and the electricity certificate system (see Chapter 7). At the nuclear power plants, uprates are expected to raise capacity in total by around 1.2 GW in the next few years.

## REGULATION AND MARKET DESIGN

Since the major reforms in the mid-1990s, Sweden has been one of the front-runners in electricity market liberalisation. The Swedish electricity market is fully liberalised. All customers are free to choose their own supplier; Svenska Kraftnät, the TSO, owns the transmission grid and is unbundled from the other parts of the industry; grid access for third parties is guaranteed; and a regulator, the EMI, is in place to oversee market operations. Distribution assets, however, are typically owned by the generators.

More than in the national context, the Swedish electricity system should be seen as part of the regional Nordic electricity market, which also comprises Denmark, Finland and Norway. The Nordic market, in many ways a model as an integrated regional market, is based on common rules and principles, which are endorsed by the Nordic governments and form a basis for close co-operation between regulators (NordREG), and between TSOs (Nordel).

In the Nordic electricity market, most electricity wholesale takes place at the Nord Pool, the Nordic electricity exchange. In 2007, physical spot market trading on Nord Pool amounted to 292 TWh, representing 69% of total consumption in the four Nordic countries, up from 61% in 2006. The remaining 31% was traded bilaterally. Trade on the Nord Pool spot market has increased every year since liberalisation, and Nord Pool is Europe's largest power exchange in terms of both physical and financial contract volumes. Nord Pool's main markets are listed in Box 3.

4. Refers to production capacity for the market at peak on a cold winter day (statistically occurring once a decade). For more information, see www.nordel.org.

Box 3

## Overview of Nord Pool Markets

Nord Pool operates four markets for electricity: Elspot, Elbas, Eltermin and Eloptions.

**Elspot** is the market for physical trading of electricity for delivery the following day. The price is determined on the basis of the total quantity of electricity the participants announce that they will be buying and selling. Prices for sales and purchases are determined hourly throughout the next day. The system price is the market-clearing price for the aggregate supply and demand curves, assuming there is no congestion in the system. Elspot determines the system price (the so-called reference price) both for the financial market and for the rest of the power market. Area prices are established taking into account congestion in the Nordic transmission system.

**Elbas** is a continuous physical market for balance purposes, namely trade in electricity up to two hours before delivery. This market is only available to Swedish, Finnish and Danish participants, and is not used by the Norwegian system operator. In Sweden and Finland, Elbas is a supplement to Elspot. The administration for the Elbas market is in Helsinki. Liquidity in this market is very low.

**Eltermin** is a financial market for price hedging and risk management when buying and selling electric power. The market currently consists of futures contracts, forward contracts and contracts for difference. Participants can hedge purchases and sales for up to five years. The difference between these contract types lies in the form of settlement during the contract's trading period. For futures, the value of each participant's contract is calculated daily, on the basis of the difference between the price set in the contract and the system price. Forward contracts do not have cash settlements prior to the beginning of the delivery period. Contracts for difference provide opportunities for adjusting and hedging portfolios in terms of differentials between the system price and the various area prices in Elspot.

**Eloptions** is part of Nord Pool's financial market and is an instrument for risk management and for forecasting future income and costs related to trade in power contracts. Trade in power options gives the right to buy and sell an underlying instrument for a specific underlying period. The power options offered by the power exchange are standardised and thus have clearly defined conditions. The market was established in October 1999.

Nord Pool also operates markets for exchange-traded and over-the-counter carbon credits, and offers credit clearing services.

Source: *Energy Policies of IEA Countries – Norway 2005 Review*, IEA/OECD Paris, 2005.

Electricity generation is dispatched according to a single market-clearing price. Capacity bids into the Nord Pool market and, transmission constraints permitting, the lowest-priced capacity is dispatched every hour until total demand is met. The price of the last unit taken – the so-called marginal supplier – sets the price for all generation during that hour.

In addition to the common wholesale exhange, the Nordic power system includes common grid planning, *i.e.* criteria for transmission system planning, rules for system operation, and minimum technical requirements for connecting power plants to the grid. It also comprises implicit auctions of cross-border capacity between the Nordic countries, co-ordinated planning of outages in the transmission grid, and continuous exchange of real-time operational data to ensure that the Nordic power system is operated as a single regional market.

Retail markets for electricity remain national, but the Nordic governments have set 2010 as the target year for establishing a common Nordic retail market, with free choice of supplier. The Nordic energy regulators are now working on harmonising the data exchange and metering systems to form a common Nordic balance settlement system. The Nordic TSOs, in turn, have agreed on harmonised principles for balance management.

## INDUSTRY STRUCTURE

### Generation

Power generation in Sweden continues to be dominated by a few companies. In 2006, the three largest electricity companies, Vattenfall, Fortum and E.ON Sweden, generated 86% of all electricity. Vattenfall accounted for 45% of the total, E.ON Sweden for 21% and Fortum for 19%. The Swedish wholesale market is part of the Nordic electricity market, and Vattenfall is also the largest producer in the Nordic context, with 18% of total generation, followed by Fortum at 12%. The market share of the four largest electricity generators in the Nordic region was over 50% in 2006.

The biggest companies are owned by the Nordic governments. Vattenfall is wholly owned by the Swedish government, while Fortum is 50.8% owned by the Finnish government. The Norwegian government-owned generator Statkraft holds 44.6% of E.ON Sweden, but is expected to sell its share to the majority-shareholder E.ON of Germany during the first half of 2008.

Increasing market concentration in Sweden has raised concerns about the potential for abuse of market power, although evidence of actual abuse has not been found. In 2007, the Swedish Competition Authority suggested government measures to improve competition in the electricity market. First, joint ownership of power plants should be reduced. In recent years, the three

largest generators have reduced joint ownership of hydropower capacity, but for nuclear capacity, it is still the norm (see Table 16 in Chapter 8). Joint ownership should be fully dissolved and the reactors divided among the owners. Alternatively, the plants could be made more independent of their owners. Second, the government should reduce the restrictions on investments in electricity production, and facilitate market entry.

### Distribution

More than five million customers are connected to the Swedish electricity network. In 2006, they were supplied by some 130 companies, down from more than 220 in 1996, when the market was opened for competition. Most of the distributing companies are owned by municipalities. In 2006, the three largest electricity retailers had a market share of more than 50%, up from some 30% in 1996. Vattenfall accounted for 21% of retail sales, and both E.ON Sweden and Fortum for 17%. Each of them has more than 800 000 customers, whereas the smallest network companies have less than 1 000 customers.

## NETWORK INFRASTRUCTURE AND OPERATION

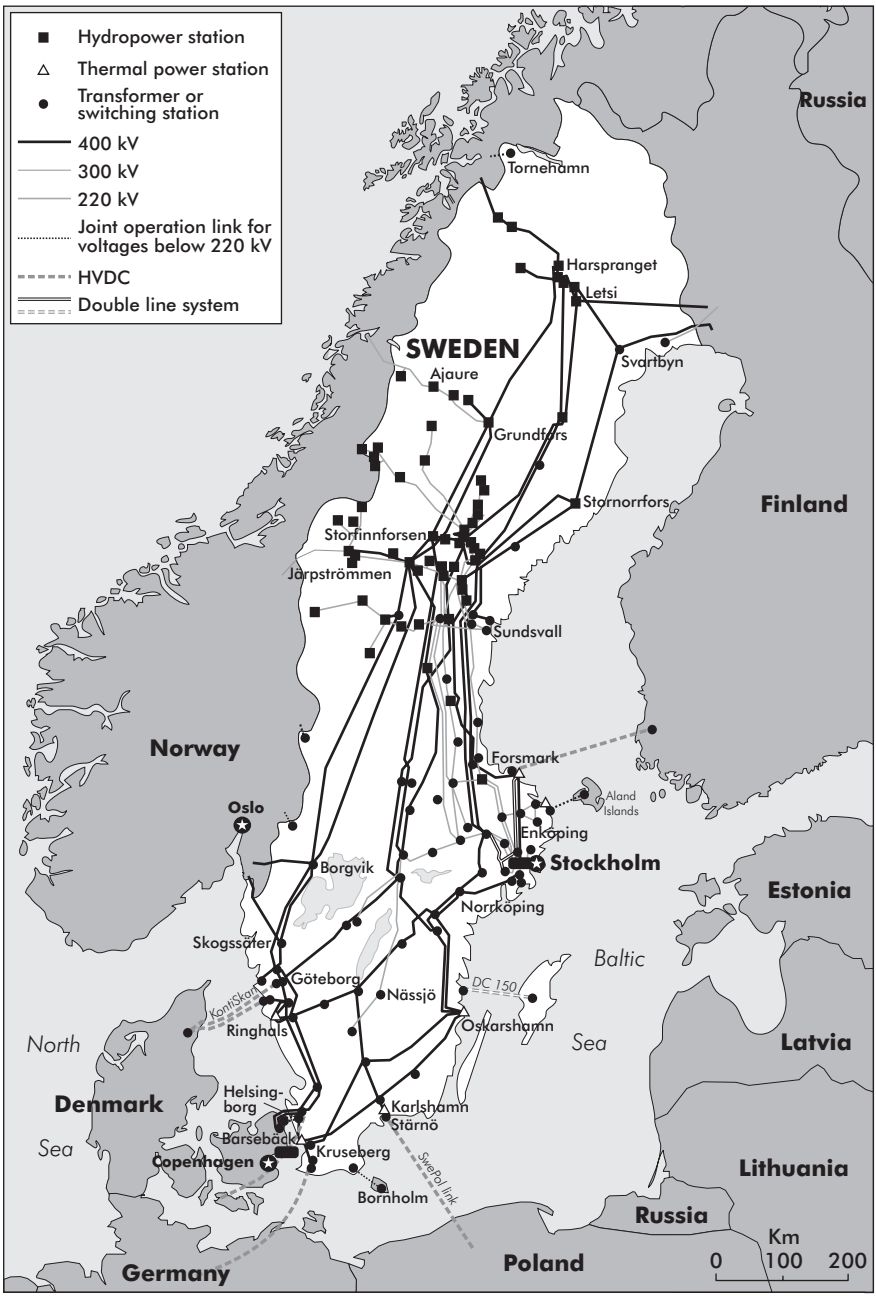
At the end of 2006, Sweden's high-voltage transmission network consisted of 11 100 km of 400-kV lines, and 4 600 km of 220-kV lines. The network has been constructed to facilitate the flow of power from the major hydroelectric generating centres in the north to the main consumption centres in the south (see Figure 19). The national grid is owned by the TSO, Svenska Kraftnät, which is wholly owned by the Swedish government and unbundled from other activities in the electricity sector.

The regional transmission network typically consists of 70-kV to 130-kV lines. It transports electricity from the national transmission grid to local distribution networks and directly to some larger electricity users. There are 13 regional networks, most of which are owned by the large generators.

Network tariffs for transmission and distribution of electricity are regulated by the EMI. It reviews the network tariffs *ex post*. For monitoring it uses a so-called Performance Assessment Model, which has been criticised by many distribution companies. Companies whose tariffs have been inspected and that have been asked to pay back part of the revenue have systematically appealed to the court against EMI decisions. As required by the second EU Electricity Market Directive, Sweden is now taking measures to change tariff regulation to be *ex ante*.

Figure 19

## Map of the Swedish High-Voltage Electricity Grid




The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the IEA.

Source: Nordel.

## Cross-Border Capacity and Trade

Sweden is well connected to the other countries in the Nordic market area (see Table 10). It also has interconnectors to Poland and Germany. Owing to its central geographical position, reducing congestion in Sweden facilitates electricity flows in the whole Nordic market area.

In the Nordic market, transmission network planning is shared by the TSOs under Nordel, which has identified the following three projects for strengthening the Swedish electricity network:

- the Southern Link between central and southern Sweden (by 2012)
- the Fennoskan 2 Link between Finland and Sweden (800 MW, by 2011)
- the Nea-Järpströmmen Link between Norway and Sweden (750 MW, by 2009).

There are also plans for a 700-1 000 MW transmission line between Sweden and Lithuania (the SwedLit cable). The line could be operational by 2015, thus connecting the Baltic states to the Nordic power grid.

Cross-border capacity in the Nordic market is allocated through implicit auctions at the Nord Pool. Capacity in the merchant line connections between Sweden-Germany (Baltic Cable) and Sweden-Poland (SwePol Link) is allocated mainly bilaterally, but any excess transmission capacity is available to the market.

Table 10

**Electricity Trade and Net Transfer Capacities between Sweden and its Neighbours**

| *Country* | *NTC in winter 2007/08, MW* | | *Electricity trade in 2007, TWh* | | |
|---|---|---|---|---|---|
| | *To Sweden* | *From Sweden* | *From Sweden* | *To Sweden* | *Net exports* |
| Denmark | 2 440 | 1 980 | 4 705 | 2 127 | 2 577 |
| Finland | 1 600 | 2 000 | 3 087 | 2 565 | 523 |
| Norway | 3 450 | 3 000 | 2 880 | 10 199 | – 7 318 |
| Germany | 600 | 600 | 1 852 | 930 | 922 |
| Poland | 600 | 600 | 2 211 | 230 | 1 981 |
| **Total** | **8 690** | **8 180** | **14 735** | **16 050** | **– 1 315** |

Note: Net transfer capacity = total transfer capacity - transmission reliability margin.

Sources: ETSO, available from http://www.etso-net.org/NTC_Info/map/e_default.asp; Svenska Kraftnät, available from http://www.svk.se/web/Page.aspx?id=5794.

### Congestion Management

Congestion within the Nordic region is handled through market splitting. The Nordic market can be split into several market areas, with Sweden forming one. If congestion arises within Sweden, the TSO manages it by using domestic counter-trade and balancing power, but also by restricting exports from the deficit areas.

Counter-trading involves Svenska Kraftnät purchasing more expensive generating capacity on the consumption side of a network constraint and cancelling generating capacity on the other side, with the objective of allowing all market participant transactions to proceed without being affected, as if there were no physical constraints. The costs are borne by Svenska Kraftnät, which provides a financial signal for it to pursue investments to alleviate congestion.

In 2005, the EMI stated that Svenska Kraftnät and the other Nordic TSOs are extensively managing internal congestion through reductions of trading capacities to neighbouring countries. With relatively low costs for counter-trade, the current regime helps to keep the transmission grid tariff for Swedish consumers at a low level. In the short term, reduced export also means that the price of electricity will be lower in Sweden. On the other hand, moving internal congestion to the national borders reduces the efficiency of the price formation on the Nordic market, and can lead to considerable price spikes in neighbouring countries.

## PRICES

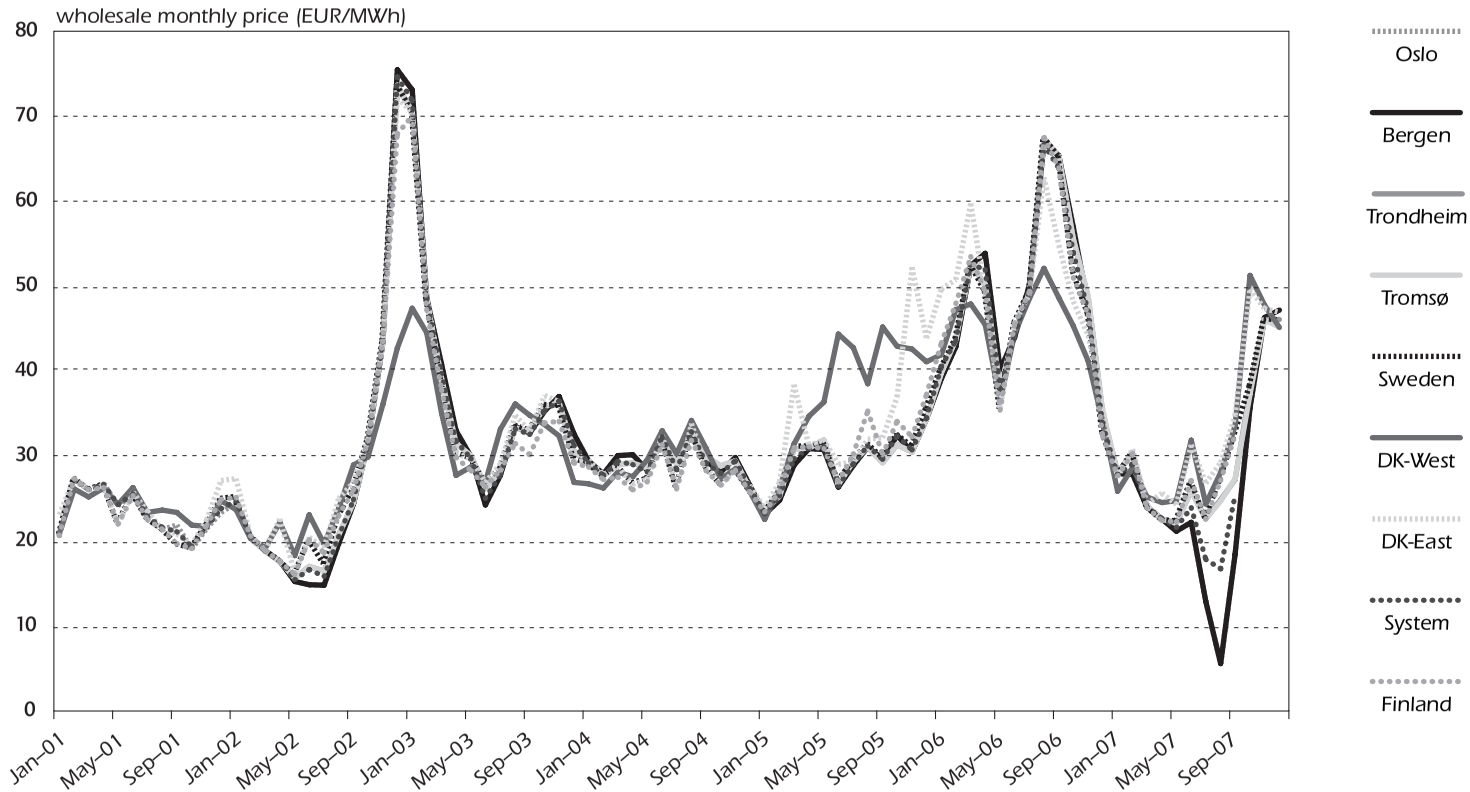
### Wholesale Prices

Wholesale electricity prices in Sweden and other Nordic countries depend strongly on the availability of hydropower, the cheapest and most abundant source for large-scale generation. In a normal year, hydropower generation amounts to 205 TWh, but it can range from 150 to 250 TWh. In wet years, such as 2000, wholesale prices are relatively low. In dry years, such as 2002-2003 and 2006, more expensive thermal power, especially coal-fired condensing power in Denmark and Finland, is generated to compensate for low hydropower production in Norway and Sweden. Imports from Russia are also increased.

Wholesale prices have been driven higher in recent years by more expensive fossil fuels, and, since 2005, by the EU-ETS. Although the bulk of electricity in the market is generated by hydro and nuclear power, the price of $CO_2$ allowances needed for fossil-fired generation is reflected in the wholesale prices, because coal-fired power is normally the price-setting marginal production mode. This mechanism has generated so-called windfall profits for the owners of plants not emitting $CO_2$.

Figure 20

## Average Monthly Wholesale Prices at Nord Pool, 2001 to 2007




Source: Nord Pool.

The whole Nordic market area has the same wholesale price, when there are no bottlenecks. This was the case in 2006 for 33% of the time. When transmission is constrained, the market is split into several price areas. Owing to its ample cross-border capacity, Sweden most of the time forms a price area at least with eastern Denmark and/or Finland. By international comparison, the Nord Pool spot and financial markets are very liquid and prices are lower than in continental Europe.

## Retail Prices

Although data for international comparison are not readily available, retail prices in Sweden are traditionally low compared to other IEA countries. Since 2005, they have, however, increased steadily (see Table 11), mostly because of the same factors that affect the wholesale prices – more expensive fossil fuels and the EU-ETS.

Table 11

**Electricity Prices for Selected Groups of End-Users, SEK/kWh**

| | *Industry, 350 MWh/year* | *Detached house, 20 MWh/year* | *Detached house, 5 MWh/year* |
|---|---|---|---|
| 1 January 2002 | 0.438 | 0.879 | 1.113 |
| 1 January 2003 | 0.599 | 1.114 | 1.354 |
| 1 January 2004 | 0.624 | 1.179 | 1.436 |
| 1 January 2005 | 0.552 | 1.099 | 1.359 |
| 1 January 2006 | 0.613 | 1.174 | 1.439 |
| 1 January 2007* | 0.821 | 1.444 | 1.713 |

* Includes the price of electricity certificate, average price of which was SEK 0.027 per kWh.
Source: Swedish Energy Agency: *Energy in Sweden 2007*.

## Customer Switching

In 2006, 401 000 customers switched supplier in Sweden, where household customers accounted for 85%. Since the market reform in 1996, around 55% of the customers have switched supplier or renegotiated their contract, a high rate by international comparison; 63% of the customers who live in a detached house have switched supplier or renegotiated the contract, while only 42% of apartment dwellers have done so, reflecting the lower potential savings.

The EMI believes that the large price differences that exist between standard agreement prices and variable prices signal that competition on the retail market needs to be further strengthened. Potentially implying weaker competition on the Swedish retail market, estimated trading margins (difference between wholesale and retail prices) for retail electricity traders are considerably higher in Sweden than in Norway.

## DISTRICT HEATING

### SUPPLY AND DEMAND

District heating has increased strongly since 1990, supplying about 47 TWh of heat in 2006, or about half the end-use heating in Sweden. It is the most common form of heat supply in every town and city with a population of more than 10 000, and it is also used for industrial purposes. Measured by floor area, 77% of apartments and 59% of commercial premises are heated with district heating.

Total energy supply to the district heating sector in 2006 was over 55 TWh. Today, biomass accounts for almost two-thirds of the fuels used (see Figure 25 in Chapter 7). About 40% of the heat is produced at CHP plants. Owing to advanced technology and high load factors, losses from conversion and heat distribution amount to about 14%, which is low by international comparison.

### MARKET STRUCTURE

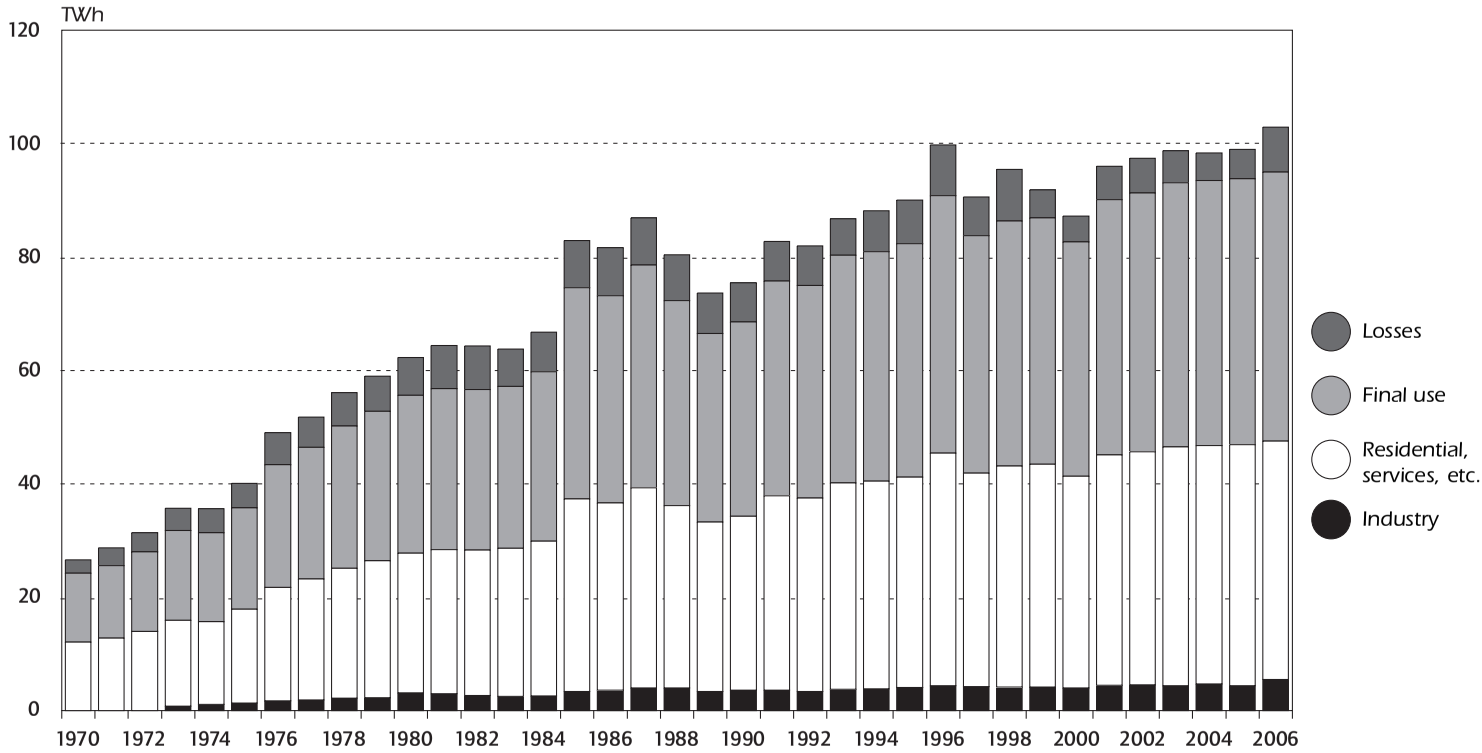
Sweden has some 220 heat-producing companies, although several have the same main owners. Since deregulation of the electricity market, there has been a concentration of ownership in the sector as the larger energy companies have bought up municipal energy companies, including their district heating activities. Municipality-owned companies supply about 60% of all district heat. Large electricity companies, such as Vattenfall, Fortum and E.ON Sweden, own the district heating systems in Stockholm, Malmö, Uppsala, Norrköping and Örebro.

### REGULATION

At present, the district heating sector remains largely unregulated, but the government is planning to increase transparency in the industry to stimulate competition and greater efficiency. Since July 2005, an amendment to the Electricity Act requires companies in the district heating business to separate the accounting of district heating activities from their other activities. This reform should work towards reducing cross-subsidies. Concessions for constructing district heating distribution mains are no longer required since 2006, therefore helping district heating networks to expand.

Figure 21

## Use of District Heating by Sector, 1970 to 2006




Source: Swedish Energy Agency.

More reforms were proposed by the District Heating Commission, a government body established in 2003 to protect and strengthen the position of customers. In its in-depth review of the district heating market in June 2005, it recommended, for example, to separate legally and functionally district heating from electricity market activities; to publish key performance indicators; and to establish a district heating panel for negotiations and resolution of conflicts. A government bill including many of these proposals is now being drafted and expected to be presented to the parliament in 2008.

## PRICES

Prices of district heat have generally been increasing faster than inflation in recent years, and they also differ widely across the country. In 2006, the cost of district heat, on average, was 17% more than in 2000. This is partly explained by increases in the prices of competing sources of heat. The average price in 2006 was SEK 0.65 per kWh. This compares well with prices for other sources of heat: in 2005, retail prices for electric heating were around SEK 1.30/kWh, for oil SEK 1.00/kWh, for heat pumps SEK 0.70/kWh, and for pellet burners less than SEK 0.60/kWh.

Although the lowest price in the country was only half the highest one (SEK 0.41 vs. 0.82 per kWh), in two-thirds of the municipalities, prices were in the SEK 0.56 to 0.72 per kWh range. According to the industry, prices differ across municipalities because of differences in fuel supply, customer base, plant type, etc. The previous government, however, considered competition to be ineffective.

# CRITIQUE

## ELECTRICITY

As part of the Nordic electricity system, Sweden continues to be one of the forerunners in electricity market liberalisation, and committed to a competitive market with limited government interference. The network regulator is transparent and fully independent from the government. The power grid is open to all competitors, and the TSO is fully unbundled. Network tariffs are regulated *ex post*, but the government is working to change the regulation to *ex ante*. All this deserves commendation.

Although the Nordic electricity market functions very well by international standards, Sweden and the other Nordic countries continue to develop it. Currently, they are studying options to set up a regional independent system operator.

Sweden's location in the centre of the Nordic electricity flows sets high requirements for the functioning of its transmission grid. Through Nordel, the TSOs have identified five priority projects for the whole region, to be commissioned by 2012. Three of them are in Sweden. Nordel is currently looking into further investment priorities from the perspective of Nordic socio-economic benefits. The TSOs have agreed upon a Nordic Grid Code, which is a sound basis for operating and developing the regional transmission system. The IEA commends Sweden's continued and positive role in this successful process.

Cross-border connections to link the Nordic market to the south and east are being built and more are planned. Recently, the Nordic market has become more closely integrated with other parts of Europe through the Estlink and NordNed cables. Market coupling with Germany is to take effect in June 2008, when Nord Pool and EEX start a day-ahead trade. Market coupling between the Nordic and other markets is an important step towards a larger regional electricity market, and towards greater flexibility for the electricity sector.

Population and electricity consumption are concentrated in the south of Sweden. The south is dependent on electricity transmission from the north, and at times the north-south transmission system becomes congested. This affects both Sweden and the wider Nordic market.

Sweden constitutes a single price area in the Nordic system, but stronger market signals could help companies build power plants closer to where the electricity is used and give signals to demand to locate closer to existing supply, thus improving the economic efficiency and overall functioning of the Nordic electricity system. The need to restrict imports and exports would thus also be reduced. For that purpose, the IEA encourages the government to introduce stronger locational price signals in Sweden by dividing the country into price areas that are relevant when taking physical conditions into account, including transmission and generating capacity, and competition.

Plans to form a common Nordic retail market by 2010 are progressing. A single retail market will increase competition and, thus, bring benefits to end-users. The IEA welcomes these plans and encourages the government to continue its work towards realising them by 2010.

Electricity use is becoming more efficient, but investment in new capacity will still be needed to maintain security of supply and competitive prices for end-users. New investment is challenged by the uncertainties over the sector's future regulatory framework, most notably the future form of the EU-ETS, which is an EU-wide issue, and even more so, the future of nuclear power, which is a national issue. Taking into account its energy policy goals of economic efficiency, security of supply and climate change mitigation, the government should strive for a stable long-term regulatory framework for capacity investment.

While greater capacity and transmission are an important means of providing security of supply, it is often less expensive and more sustainable to do this through enhanced demand-side participation in the market. As for all countries, the IEA encourages Sweden to maximise the ability of customers to respond to price and invest in energy efficiency. One means of responding to price is through customer switching, which is already on a very high level. The country is also among the leaders in automated meter-reading, thus empowering customers to respond to price changes.

Obtaining a permit for building power plants in Sweden often takes several years. The main reason is appeals to courts. The industry sees this as a major hindrance for building new electricity capacity, including from renewable sources. It is, obviously, necessary to consider environmental impacts and local acceptance when building power plants. However, it is important that this process does not unnecessarily delay the project development process.

Competition needs constant vigilance in all electricity markets, including Sweden, where market concentration is increasing through mergers and acquisitions. The three largest electricity generators in the country accounted for 86% of the market in 2006. In the Nordic market, the three largest producers had a 43% share. Even though the Nordic market is integrated, bottlenecks in the transmission networks split the market into two or more areas more than half of the time. Competition could be promoted, for example by facilitating new entrants to the market, reducing joint ownership of power plants and further increasing integration with neighbouring countries. The process for obtaining permits should not favour incumbents. Plans to improve the transmission system in the Nordic market and to increase cross-border connections to other markets are encouraging. The regulator, however, should closely monitor the competitive conditions on a German-Nordic electricity market, because two of the three biggest producers in Germany (E.ON and Vattenfall) are also two of the four biggest producers in the Nordic countries.

## DISTRICT HEATING

Sweden has a well-developed district heating sector. In existing buildings, district heating faces little competition from other heating forms, and in many cases, shifting away from district heating would not be environmentally beneficial either. As heat distribution is a natural monopoly that is not regulated in Sweden, incumbents are tempted to take advantage of their position. Regulation is needed to change this. It should be *ex ante* to ensure predictability and give the correct incentives to efficient operation and investments. One way to ensure this is by benchmarking similar firms and rewarding the most efficient ones. Third-party access should be considered to the extent that it is possible and beneficial.

# RECOMMENDATIONS

*The government of Sweden should:*

***Electricity***

- *Continue to harmonise and improve the Nordic wholesale electricity market, focusing particularly on transmission grid investment and congestion management; consider increased co-operation with neighbouring markets, preferably through market coupling.*
- *Continue efforts to establish a Nordic retail electricity market.*
- *Increase efforts to promote competition both in Sweden and in the Nordic area by, among others, lowering barriers for new entrants and considering the positive implications of reducing joint- and cross-ownership of power plants.*

***District heating***

- *Ensure cost-reflective consumer prices and provide incentives for efficient operation and investment by regulating the district heating sector, preferably* ex ante.

# OVERVIEW

## SUPPLY

In 2006, Sweden's supply of renewable energy amounted to 14.5 Mtoe, accounting for 28% of TPES, the third-highest share within the IEA countries (see Figure 22). Biomass contributed 18% to TPES and hydropower 10%. Hydropower production varies annually according to seasonal rainfall, whereas biomass supply is closely linked to the business cycle of the forest industry and has grown constantly since 2001 (see Figure 23). Other forms of renewable energy, including wind power, solar and organic wastes from renewable materials, accounted for only 0.2% of TPES and are barely visible in Figure 23.

Sweden remains a world leader in bioenergy utilisation, mainly using woody biomass feedstocks from the forest industry sector. Within all IEA member countries, total biomass feedstock arising from both forest and agricultural residues, as a share of TPES, is second only after Finland. Both countries have a well-developed forest products industry, good road systems to transport the high volumes of biomass, and wide use of district heating systems. Bioenergy is discussed in more detail in the following section.

## MEASURES TO PROMOTE RENEWABLE ENERGY

Sweden has a wide range of support measures for renewable energy uptake. Taxation, especially the $CO_2$ tax, has long been a key instrument (see Chapter 2). Direct financial support measures, partly or entirely for renewable energy, are listed in Table 12. Electricity certificates and bioenergy-related measures are discussed in more detail below.

# BIOENERGY[5]

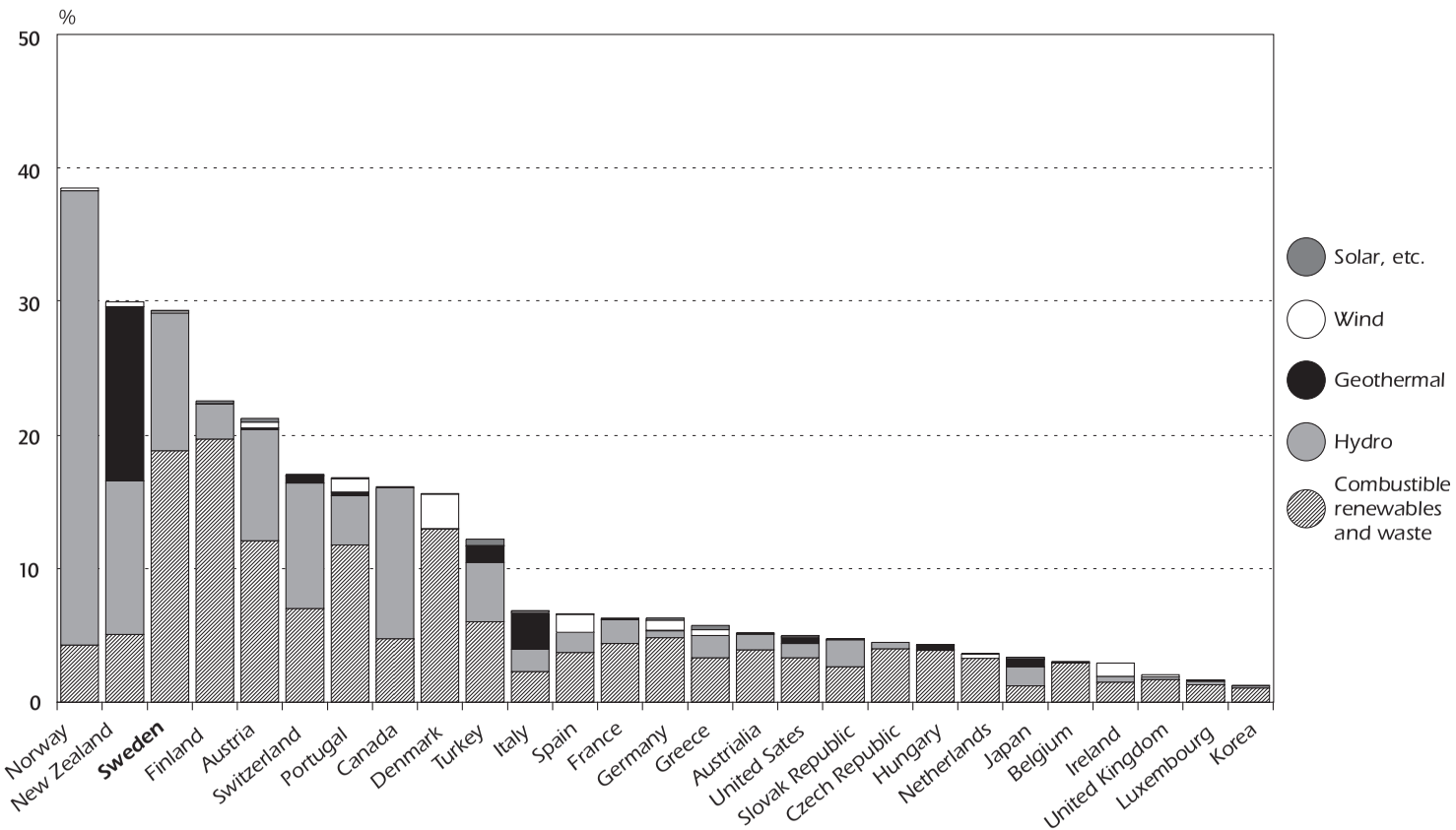
## SUPPLY

Biomass is a traditional and increasingly important energy source in Sweden. Its contribution to TPES grew from 12% in 1990 to 18% in 2006. Government policies, especially $CO_2$ taxation on fossil fuels first imposed in 1990, have

5. Bioenergy comprises solid biomass, liquid biomass, biogas, and industrial and municipal waste from renewable sources.

Figure 22

## Renewable Energy as a Percentage of Total Primary Energy Supply in IEA Countries, 2006*

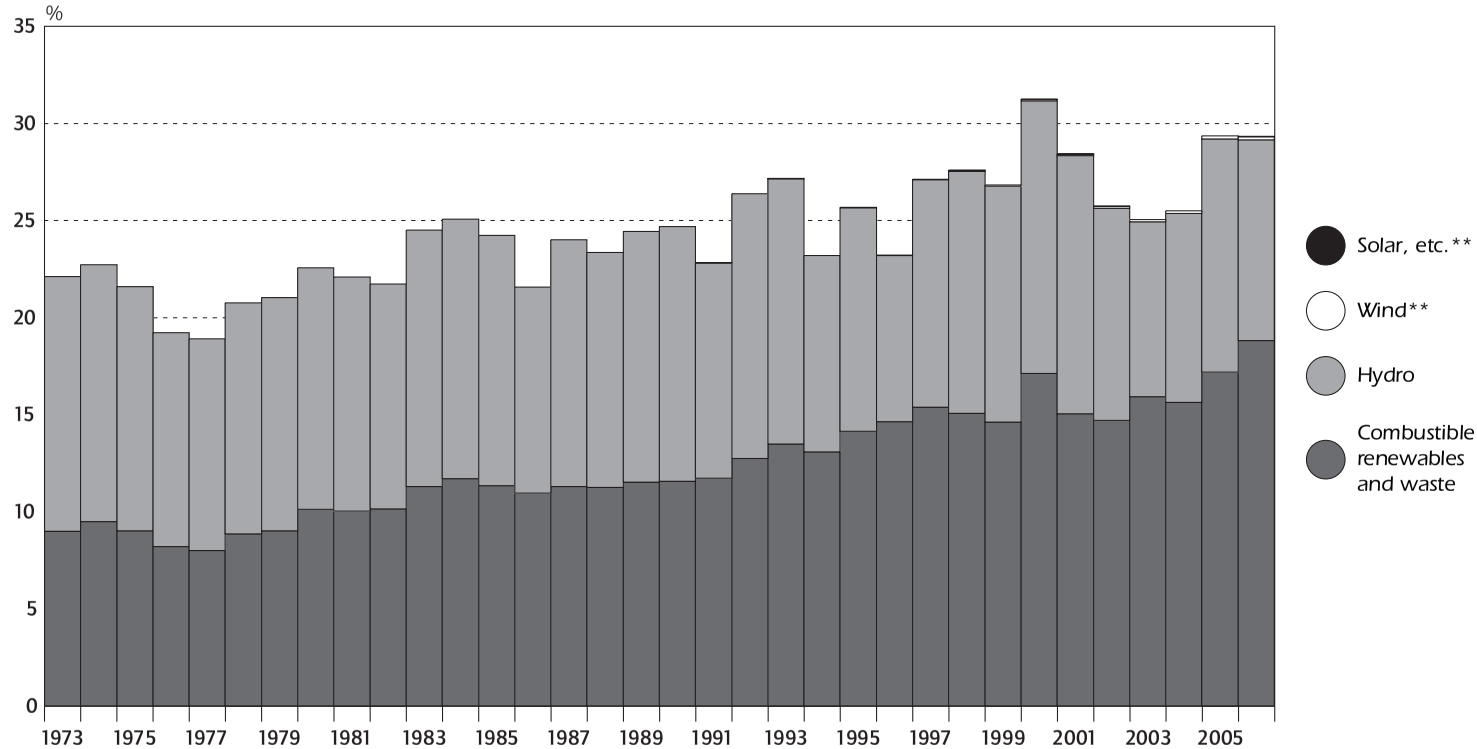



* estimates. ** excludes industrial and non-renewable municipal waste.

Source: *Renewables Information*, IEA/OECD Paris, 2007.

Figure 23

## Renewable Energy as a Percentage of Total Primary Energy Supply in Sweden, 1973 to 2006*




* 2006 provisional.

** negligible.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2007.

Table 12

## Financial Measures to Support Renewable Energy

| *Measure* | *Sector* | *Begun in* | *Expires in* | *Budget, SEK million* |
|---|---|---|---|---|
| Electricity certificates | Energy | 2003 | 2030 | See section on Other Forms of Renewable Energy |
| Support for technology development and market introduction of wind power | Energy | 2003 | 2012 | 700 |
| Support for conversion from oil and direct electric heating | Residential /buildings | 2006 | Until 2010 (2007 for conversion from oil) | 2 000 |
| Investment grants for solar heating | Residential /buildings | 2000 | 2010 | Around 100 |
| Investment grants for solar power | Residential /buildings | 2005 | 2008 | 150 |
| Investment grants for small-scale biomass-fired heating systems and energy-efficient windows | Residential /buildings | 2004 | 2008 | 250 |
| Support for solar heating in commercial buildings | Residential /buildings | 2006 | 2010 | 50 |
| Climate Investment Programme (KLIMP) | Cross-cutting | 2003 | 2008 | 2 000 |

Source: Country submission.

strongly contributed to this increase. Growth is also explained by capacity increases in the forest industry, the main provider of woody biomass. In 2005, total biomass use amounted to 8.5 Mtoe of which woody biomass accounted for 93% of the total, municipal organic waste for 3.5%, agriculture-based biomass for liquid biofuels for 2.8%, and biogas for 0.4%.

Use of briquettes and pellets for heating in industry and households doubled between 2000 and 2006, and reached over 1% of TPES. About 20% of pellets were imported in 2006, though the data are uncertain as reliable statistics of pellet use are not collected.

The Swedish Energy Agency expects biomass use to continue to grow and reach around 11 Mtoe by 2025, the bulk users being the pulp and paper industry, power generation and district heating. The SEA also expects municipal waste from renewable sources to more than triple over this period and reach almost 2 Mtoe, to be used mainly for district heating.

Accurate assessment of biomass use is not possible with current data collection methods, particularly for distributed heating systems. Methods to improve data collection, including the survey of users, are being reviewed and, once refined, the methodology could be of interest to other countries.

Future growth of bioenergy in Sweden is supported in several ways. The country has large forest biomass resources, a mature bioenergy heat market, high forest industry utilisation, local engagement by municipalities, long-term policies for fossil fuel substitution, investment subsidies and tax incentives, and investments in RD&D relating to biomass production and supply, bioenergy conversion and biofuels[6] for transport.

Sweden has the potential to increase the volumes of domestic biomass supply. Forest-based resources are set to continue to be used primarily as raw materials for wood products, bringing more employment and value added than if used directly for energy. Possible increases in the forest industry capacity, however, also produce residues that would thus imply a larger future bioenergy supply. Nevertheless, there is growing interest in extracting more of the branch and top residues from the forest by integrated harvesting rather than leaving them in the forest as at present.

There are also plans to increase the production of energy crops. Energy plantations have been well researched for nearly two decades and *Salix* and vegetative grasses (such as *Phalaris arundinacea,* reed canary grass) appear to have significant potential. Commercial yields of *Salix* were originally disappointing, but with further breeding and better management, an average yield today may reach 8 to 10 tonnes of dry matter per hectare (ha). Over 15 000 ha of *Salix* have been planted to date, and technical advances have been made in planting, managing and harvesting the crop. The total area of commercial crop production has, however, declined in recent years, but could be revived given appropriate policies. If similar yields can be reached with vegetative grasses, then they would have the advantage of allowing farmers to use conventional sowing, mowing and baling machinery and avoid costly development of new equipment.

6. In this report the term "biomass" includes all sources of organic feedstocks used for energy, whereas liquid or gaseous forms of biomass used for transport fuels are termed "biofuels".

Agriculture currently provides around 0.2 Mtoe per year of biomass for energy purposes from a range of crops currently grown on approximately 70 000 ha of arable land (see Table 13). The Commission on Bioenergy in Agriculture estimates that agriculture could contribute an additional 1.2 to 2.5 Mtoe per year, mainly by increasing the planted area of *Salix* as well as by utilising more animal manure and green crops for biogas.

Biogas supply, currently at 0.1 Mtoe per year, could possibly be increased to 1.2 Mtoe per year, mainly from using purpose-grown green crop feedstocks. A further 2.1 Mtoe per year of gas could be provided from wood gasification but is subject to competing arable land use. To provide additional incentive, biogas methane injection into the natural gas grid has been permitted, where technically possible, since 2005, and if the gas quality is acceptable.

Table 13

**Bioenergy Crops in Sweden, 2006**

| *Crop* | *Use* | *Area (ha)* |
|---|---|---|
| Wheat | Ethanol | 25 000 |
| Oats | Heat | 5 000 |
| Cereal straw | Heat | Co-product |
| Oil-seed rape | Biodiesel | 25 000 |
| Salix (willow) | Heat | 14 000 |
| Reed canary grass | Heat | 600 |
| Pasture (fodder grass) | Biogas | 300 |

Source: Report of the Commission on Bioenergy from Agriculture (SOU 2007:36).

## DEMAND

Nearly half of the total biomass resource is used by industry, around 40% in district heating and CHP plants, roughly 10% in the residential sector, and 2% for road transport. To meet the growing demand, liquid biofuels and pellets are imported.

### Industry

Pulp- and saw-mills account for 99% of bioenergy use in industry, and bioenergy provides a major share of their energy needs at around 5 Mtoe per year. Using wood residues for energy is also an economical way of solving an otherwise major waste disposal problem.

Forest industry by-products, including black liquor, bark and sawdust, are already largely utilised to provide some two-thirds of total biomass used in industry (see Figure 24). Black liquor residual products from pulping have a high lignin content and are currently used on site by most pulp-mills to provide heat in recovery boilers as a means of chemical recovery and waste disposal.

## District Heating and CHP

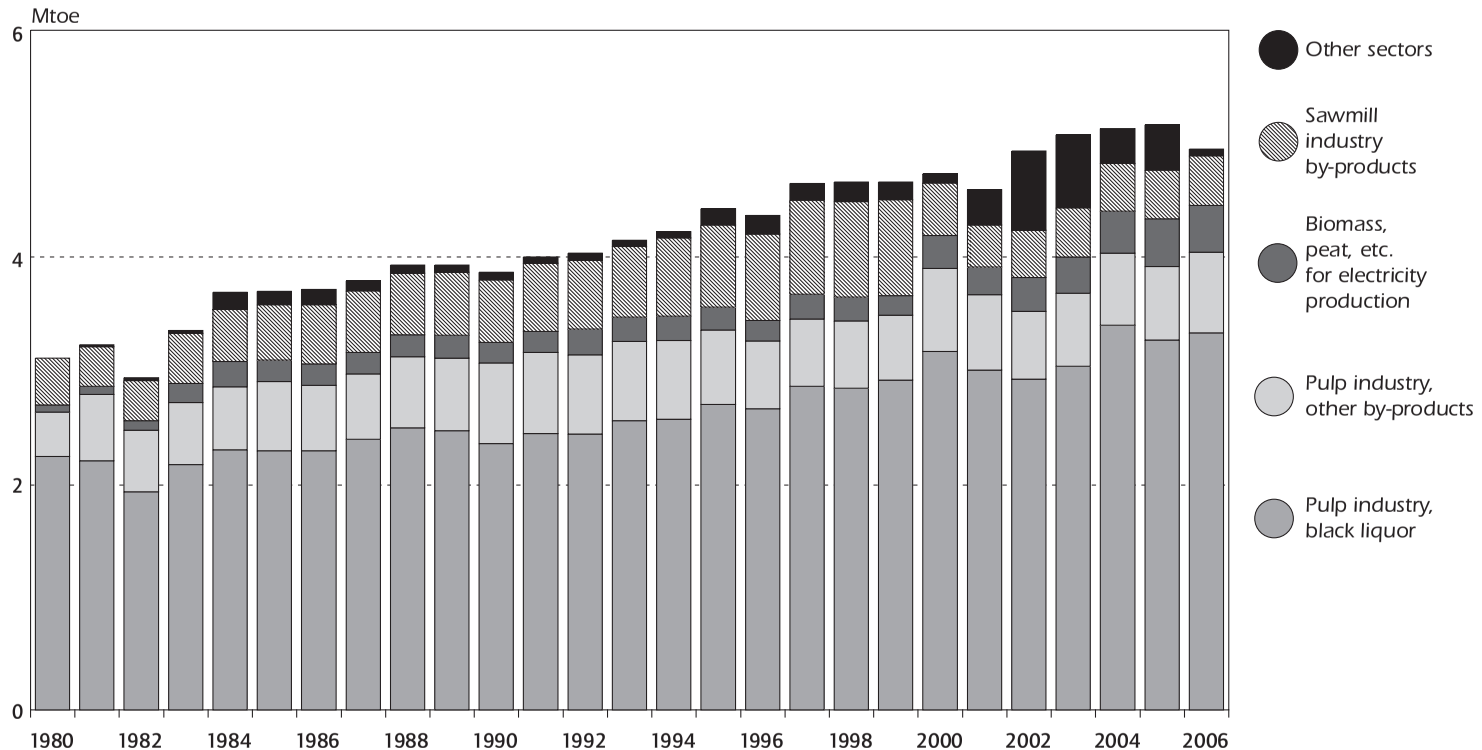
Sweden uses district heating for roughly half of its heating needs, and biomass has become the most important fuel for producing this heat (see Figure 25). In 2006, biomass, including waste, provided 62% of the 55 TWh of energy used to supply district heat, up from 2% in the early 1970s. The fuel mix used in heat plants has changed considerably since 1980 when oil provided 100% of the fuel. A switch from oil essentially to biomass resulted mainly from the favourable $CO_2$ and energy tax system. Owing to the high share of biomass in the fuel mix, the Swedish district heating plants have low average $CO_2$ emissions per unit of heat generated, at around 80 g $CO_2$ per kWh.

By 2025, SEA expects woody biomass to provide 36% of the fuel for district heating with a further 27% coming from municipal solid waste (MSW) biomass (with natural gas at 7% and oil and electric boilers virtually phased out). The MSW biomass contribution of around 0.33 Mtoe in 1990 doubled by 2005. Since 2005, the disposal of organic combustible waste in landfills was banned, which will increase the share combusted for district heating.

At present, CHP plants account for some 60% of heat production in Sweden and biomass accounts for around 30% of the total fuel in CHP plants. The overall efficiency across all plants (fuel energy consumed for generating all the heat and electrical energy produced, including electricity for auxiliary units) was 88% in 2005. From 1 January 2004, a reduction of the previous 100% of $CO_2$ tax and 50% of electricity tax on all fuels used for CHP production to just 21% of the $CO_2$ tax aimed to encourage increased production from existing CHP plants as well as greater investment in new plants. Over time, investment costs have tended to decrease from approximately EUR 3 000 per kW for early plant designs to EUR 1 750 per kW thanks to learning experience, though recently constructed plants have a wide cost range between EUR 1 400 and EUR 3 000 per kW because of site-specific variations. Electricity generation costs are typically EUR 0.06 to 0.09 per kWh, of which 60% is for purchasing the biomass fuel, 30% for capital investment, and 10% for operating and maintaining the plant.

Figure 24

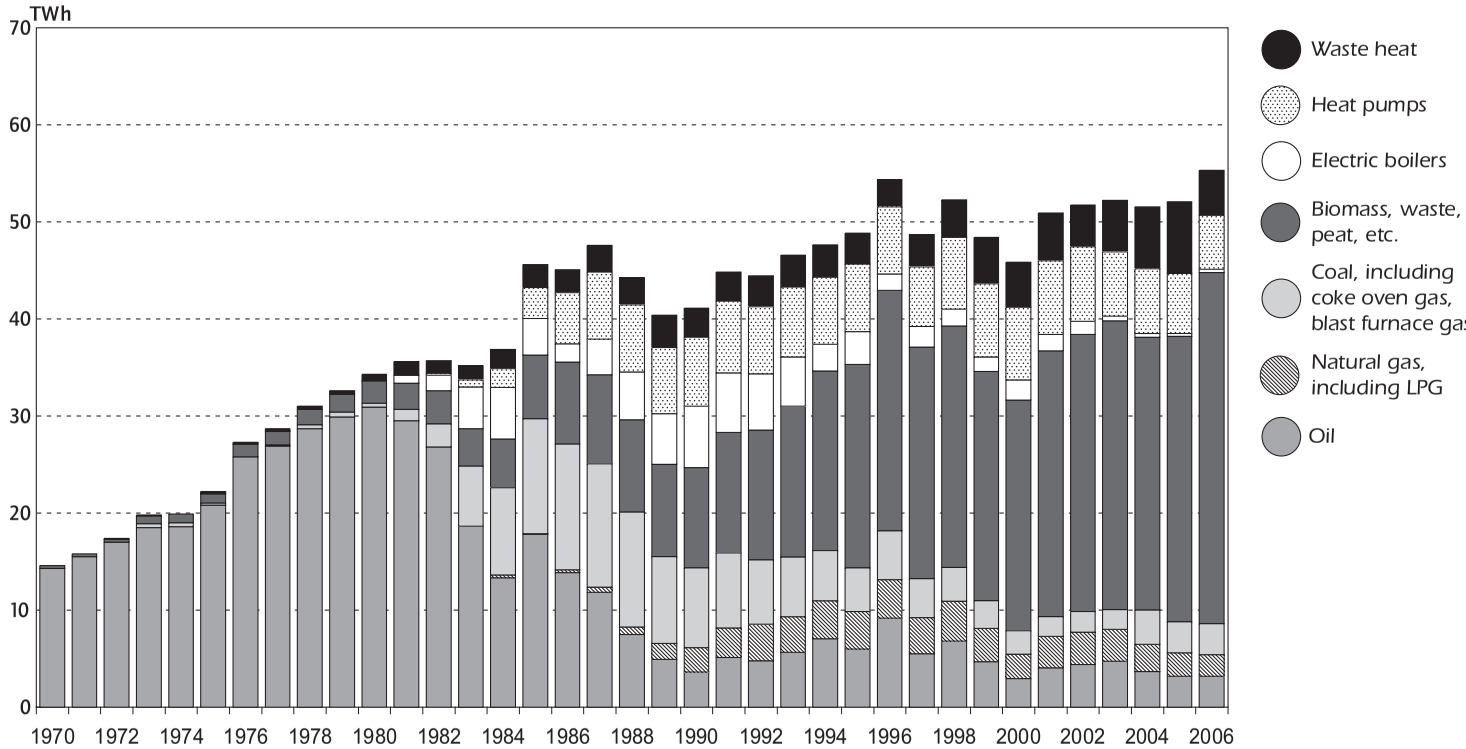
## Bioenergy Use in Industry, 1980 to 2006




Source: Swedish Energy Agency.

Figure 25

## Energy Input for District Heating, 1970 to 2006




* 2006 provisional.

Source: Swedish Energy Agency.

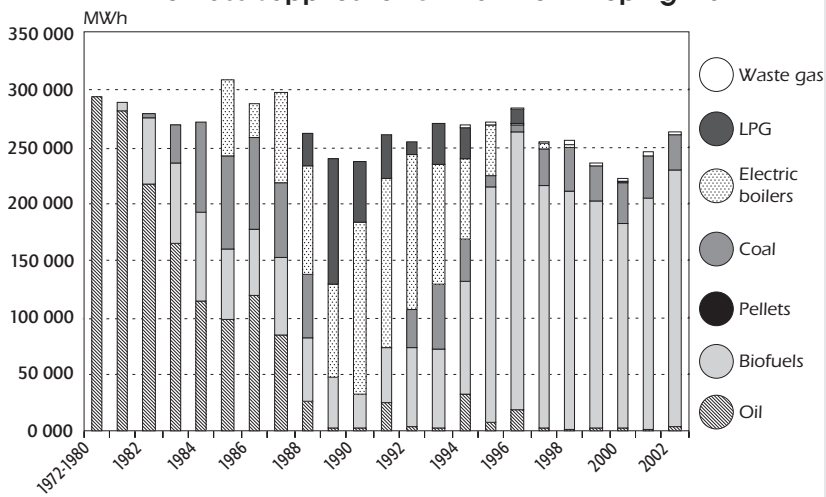
Box 4

# Biomass-Fired CHP Plant in Enköping

One example of a typical CHP plant is in Enköping. This plant generates annually around 95 GWh of electricity and 200 GWh of heat from over 1 petajoule (PJ) of biomass energy. The fuel mix has changed significantly over the past two decades (see Figure 26). When electricity prices are low, the flue gas condenser is operated and efficiencies can reach close to 100%. When electricity prices are high, however, the flue gas condenser is not operated in order to give more power output and then only about 90% efficiency is achieved. The plant owners have an incentive to encourage their customers to waste heat in order to run the plant harder and so to produce more profit-making electricity.

Figure 26

**Biomass Supplies for CHP at the Enköping Plant**

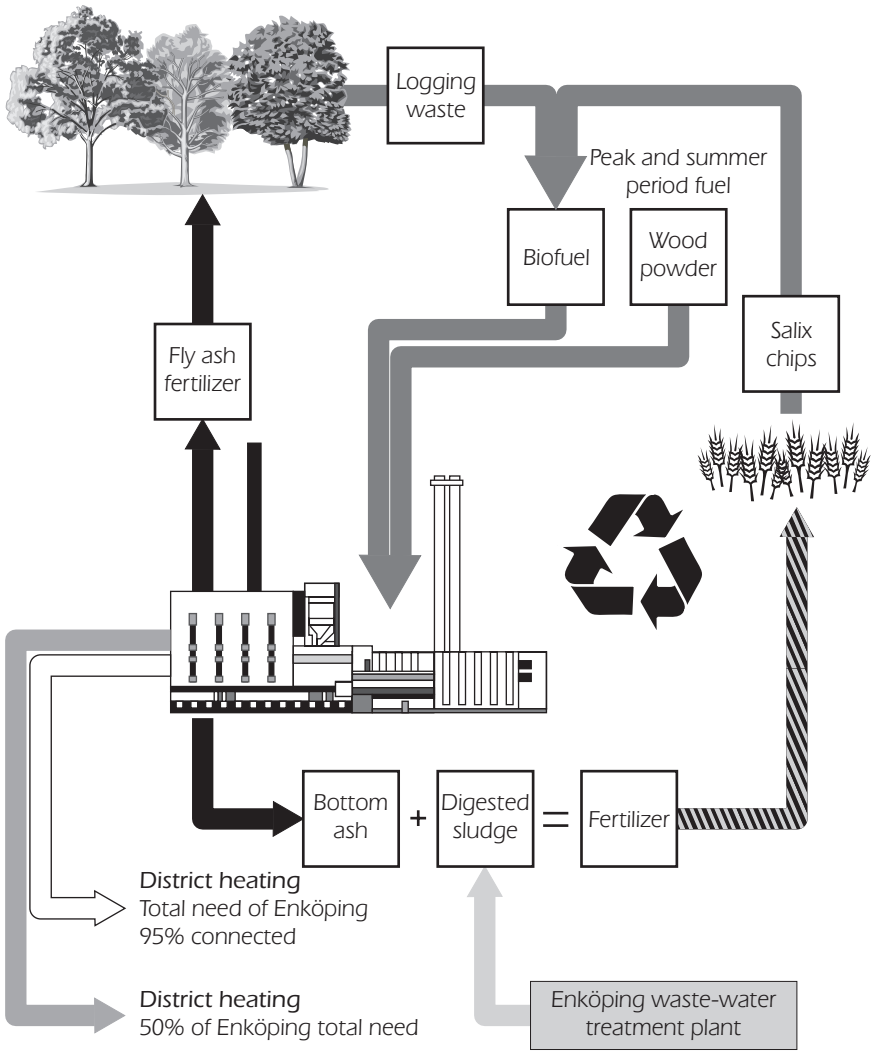



Source: ENA Energi, Enköping.

The ENA Energi plant in Enköping is unusual in that the fuel mix also includes *Salix* grown on adjacent land in combination with waste-water treatment on land from the local sewage treatment plant (see Figure 27). Having a range of biomass fuels available gives more fuel security to a bioenergy plant of this type. Also, nutrients are returned to the land in the form of fly and bottom ash.

Figure 27

**System Cycle for the CHP Plant at Enköping**




Source: ENA Energi, Enköping.

Most district heating comes from standard boilers and steam turbines so that, overall, the sector has a relatively low power-to-heat (alpha) ratio. Therefore, there is potential to expand the co-generation production to provide more power. Biomass-fuelled CHP units usually have a low alpha ratio of <0.3. However, with a combined-cycle system when low heat-value steam is superheated, the alpha ratio can rise to >0.5 (alpha ratios for gas-fired units can be even higher).

## Households

Direct space heating with bioenergy consumed about 1 Mtoe in 2005, mainly in the form of firewood logs, but also wood chips, pellets and briquettes. Traditionally, this form of space heating is typical to rural areas, but through pellet use, it has gained in popularity in single houses, including in the more urban areas. Pellet use increased seven times from 2000 to 2005 by which time over 80 000 houses had a pellet burner installed. In 2006, households paid an average SEK 50/kWh for pellets, which was slightly more than half the price for heating oil and only 40% of the price of electricity.

The government is supporting the installation of low-emission direct space-heating systems. Since 2006, a 30% rebate on installation costs has been offered to households switching from oil or gas heating to either biomass, solar thermal or heat pumps, and also to those making a connection to district heating.

## Transport

Total demand for transport fuels in Sweden almost doubled between 1970 and 2007, as has been the case in many other countries. In 2006, diesel and gasoline accounted for 96% of this total. Half of the remaining 4% (around 0.22 Mtoe) was from ethanol sold as a 5% blend in 95 octane gasoline (E5); ethanol in E85 blends (0.4%); ethanol-fuelled buses (0.2%); rapeseed oil methyl ester biodiesel in blends with diesel (0.5%); compressed natural gas (0.3%); and biogas in dedicated vehicles (0.3%). Ethanol use in blends with gasoline has been growing over the past five years, and in 2005, around 285 million litres were consumed.

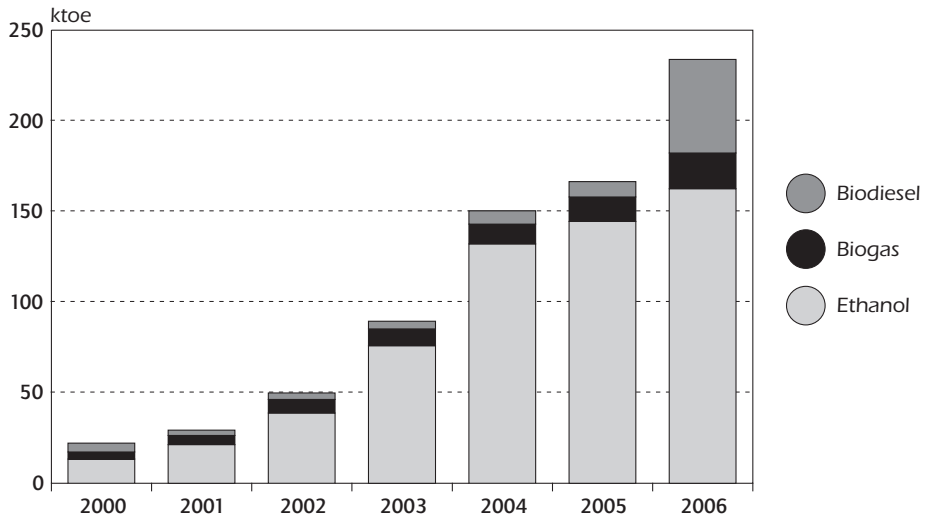
As in all EU member states, since 2003, Sweden has a non-binding target of 5.75% biofuels of transport fuels in 2010, and, as can be seen in Figure 28, biofuels use has grown in the previous few years. An increase to 10% by 2020 is under debate within the EU. The use of biofuels in transport is driven by security of fuel supply and GHG emissions reduction, although the latter can be at a very high cost in terms of SEK/t $CO_2$-eq avoided.

A government commission was established at the end of 2004. It proposed various measures for supporting the uptake of biofuels:

- A vehicle tax on new cars based on $CO_2$ emission rather than weight was introduced in 2006 but vehicles are exempt if they can run on biofuels. Tax exemptions for 10 years in accordance with the EU Mineral Oil Directive depend on the amount of ethanol in the blend.
- Since April 2006, service stations are selling more than 3 000 $m^3$ of gasoline and diesel per year. Over 2 400 stations out of a total of 3 700 will be required to supply at least one biofuel by 2009.

Figure 28

**Final Energy Use of Biofuels in Transport, 2000 to 2006**




Source: Swedish government statistics and the Swedish Gas Association.

A SEK 50 million government grant was budgeted in 2006 to help meet the costs of infrastructure and other costs for biofuels other than ethanol.

- All 95 octane gasoline was to be blended with E5.
- The permissible admixture proportion of biodiesel in class 1 diesel fuel was increased from 2% to 5% (B5) from 2006.
- Blends of E85 for dedicated flex-fuel vehicles (FFV) were made available.

The first Ford Focus FFV was introduced in 2001 and now Volvo and Saab FFVs are also available. Around 600 service stations sell E85. Sales of ethanol FFVs have increased thanks to several measures: exemptions from the congestion charge in Stockholm and free parking; a SEK 10 000 subsidy when purchasing a new "clean car[7]"; and a lower vehicle tax. In addition, rising oil prices have resulted in improving the competitiveness of biofuels and technical developments have decreased their production costs, although competition with the food market for some of the feedstocks has caused recent increases.

7. A definition was adopted in 2006. Currently 17% of vehicles (approximately 50 000) sold in the Stockholm region are registered as clean cars, with the City Council aiming for 35% by 2010.

Sweden has two bioethanol plants. In Norrköping, around 55 million litres per year are produced from cereals, and at a pilot plant in Örnsköldsvik, 18 million litres are produced using various forest material feedstocks supplied from an adjacent pulp mill. Volvo, Saab and Scania are all actively participating in biofuel development. A range of vehicles, including 400 Stockholm buses, 40 dump trucks and 14 models of cars are running successfully. Nearly three-quarters of the total ethanol demand is currently imported following a change of custom duties in early 2006 that added SEK 1.50 per litre to the price to help stimulate the local industry. The effect was that supplies from Brazil were replaced by less efficiently produced supplies from southern Europe. More Swedish ethanol plants are planned.

Around 12 000 vehicles (2% of the total fleet) run on gaseous fuels, with a quarter of these using biogas methane that is available from some 30 filling stations. Biogas produced from sewage treatment plants in Stockholm is currently available at 11 service stations and used by several dedicated vehicle fleets for 35 dump trucks and 52 buses. Around five million $Nm^3$ of biogas was purchased in 2006. Following agreements between the Stockholm public transport company and the biogas distributor, a number of taxis and company cars now consume biogas. Eight models of dual-fuel cars are now available for purchase.

Forest and automobile industries show great interest in second-generation biofuels for both ligno-cellulosic conversion to ethanol and gasification of several forms of biomass, including MSW, to produce synthesis gas (mainly CO and $H_2$) from which methane, methanol, DME (dimethylether) or Fischer-Tropsch diesel can be formulated. The potential to convert black liquor material to biofuels is under investigation at a pressurised, oxygen-blown demonstration plant in Piteå.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

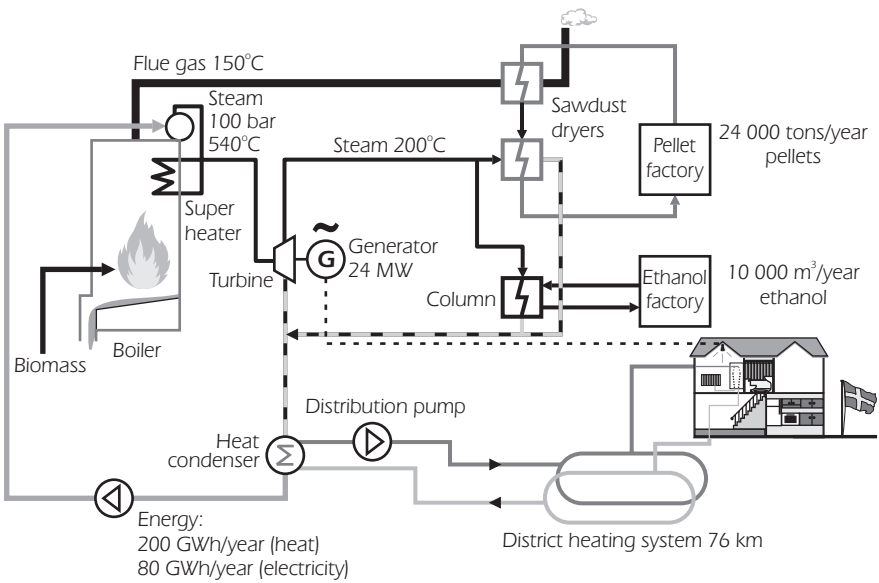
The government's energy R&D policy has a strong focus on bioenergy. In addition, the forest industry is evaluating the potential for second-generation biofuels. Strong international links exist through the IEA Bioenergy Programme, the EU Bioenergy Technology Platform and also informally through the hosting of international bioenergy conferences by the Swedish Bioenergy Trade Association (SVEBIO).

Bioenergy features across all six thematic research areas as identified by the Swedish Energy Agency (see Chapter 9). Research topics receiving government support include energy crop production, sustainable management of production systems, related biotechnology, genomic markers for water and fungal resistance and characteristics of the biomass, supply chains, forest soil

carbon and soil organisms, stump harvesting, and advanced conversion technologies, including combined CHP, pellet production and ethanol plants (see Figure 29).

Figure 29

**Process Chart of a CHP Plant with Pellet Production and Ethanol Processing**




Source: ENA Energi, Enköping.

The major share of RD&D investment relates to transport biofuels. Some SEK 200 million (25% of total energy R&D budget) goes towards the transport sector annually. Projects include adapting energy-efficient engines to run on biofuels and developing novel production processes of second generation in pilot-scale plants. The 1993 to 1997 ethanol R&D programme of EUR 5 million led to the Ethanol from Wood R&D programme which received EUR 22 million from 1998 to 2004 and to the pilot plant in Örnsköldsvik, operating since May 2004, to look at more efficient biofuel production processes. In addition, DME production for use in heavy vehicles is being evaluated in association with vehicle manufacturers, in particular Volvo.

Three pilot plants are being financed by the SEA:

- The demonstration biomass pressurised gasification plant at Värnamo is being rebuilt to produce synthetic gas from woody biomass as a feedstock for biofuel production with EU funding support.
- A pilot ethanol production plant at Örnsköldsvik using ligno-cellulosic feedstock has been operating since 2004 to provide relevant knowledge for possible future scale-up.
- Black liquor gasification has been operating successfully at Piteå for two years with promising results.

## OTHER FORMS OF RENEWABLE ENERGY

### ELECTRICITY

Sweden derives almost half of its electricity supply from domestic renewable sources. The share varies strongly together with fluctuations in hydropower supply, which is the largest component. In 2003-2006, renewable electricity on average accounted for 47% of total power generation, but ranged from 43% to 51%. In 2006, renewable electricity generation amounted to 70 TWh, of which hydropower accounted for 88%, bioenergy for 10%, wind for 1.4%, and industrial and municipal solid waste for 0.6%.

Under the EU Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources, Sweden has a non-binding target of reaching 60% of its electricity consumption from renewable sources by 2010. The necessary increases in production will have to come from sources other than large-scale hydropower, because many of the remaining rivers with potential for additional capacity are protected.

In force since May 2003, and revised in 2006, the electricity certificate system is the main instrument for promoting renewable electricity in Sweden. Under this system, all Swedish electricity generators using eligible technology receive a certificate for each MWh of electricity generated. Eligible technologies are solar, wind, small hydro (up to 1.5 MW) and bioenergy, as well as peat in CHP plants. The system was set up to increase the use of renewable electricity by 17 TWh from 2002 to 2016. During the first three years under the system, renewable electricity production increased by 5 TWh, leaving an increase of 12 TWh to be achieved between 2007 and 2016. To provide long-term stability for investors, the policy will continue until 2030.

Suppliers of electricity are required to obtain electricity certificates equivalent to a predetermined percentage of the total electricity they supply. The size of this quota obligation changes from year to year, increasing the demand for renewable electricity and certificates (see Figure 30). Suppliers may obtain the

certificates needed through generation from their own eligible plants, or they can purchase certificates from other companies which generate electricity using eligible technologies in excess of their obligation. The obligation applies also to autoproducers of electricity, though not to electricity-intensive industries.

To avoid extensive subsidies to generators, power plants are entitled to earn certificates for a maximum of 15 years. The quota obligation will decrease after 2012, and by 2014 all plants built before May 2003 will lose their eligibility for certificates. Hydropower plants built before 2003 will not be entitled to earn certificates after 2010. Svenska Kraftnät, the TSO, is responsible for issuing the certificates, on the basis of metered values from eligible generation. It also maintains the certificate register, with individual accounts for each supplier. The SEA, in turn, approves and checks plants eligible for the certificates and decides on penalties in the rare cases of non-compliance. Helped by the penalty of 150% of the price of the certificate, compliance was 99.9% both in 2005 and 2006. The average price of certificates was SEK 191 in 2006, down from SEK 216 in 2005.

Table 14

**Renewable Electricity Generation in the Electricity Certificate System, 2003 to 2006**

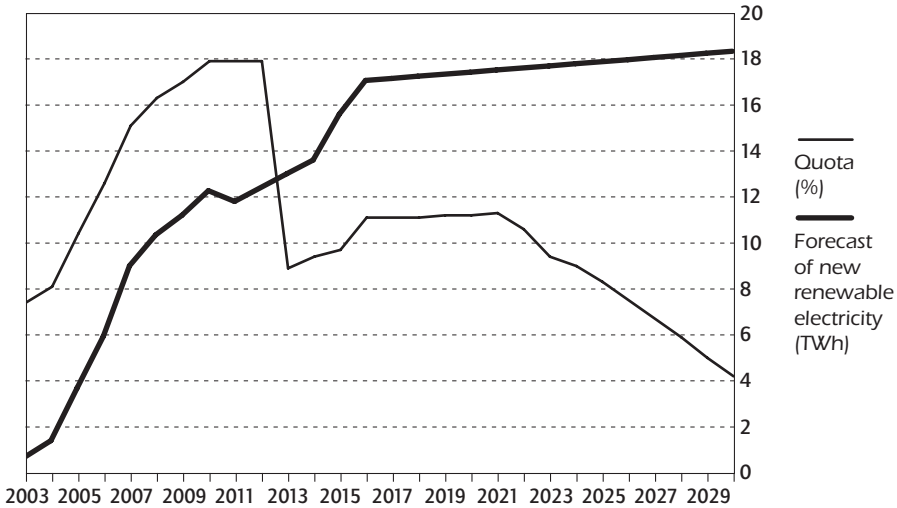
| | *Generation, TWh* | | | | *Capacity, MW* |
|---|---|---|---|---|---|
| | *2003* | *2004* | *2005* | *2006* | *At 1 January 2007* |
| Bioenergy | 4.2 | 8.2 | 8.6 | 9.1 | 3 643 |
| Hydro | 1.0 | 2.0 | 1.8 | 2.0 | 540 |
| Wind | 0.5 | 0.9 | 0.9 | 1.0 | 583 |
| Solar | 0.000004 | 0.000006 | 0.000005 | 0.00002 | 0.036 |
| **Total** | **5.6** | **11.0** | **11.3** | **12.2** | **4 765** |
| Certificate price, SEK | 200 | 231 | 216 | 191 | 195 (year 2007) |
| Revenues to generators, SEK million | 701 | 1 809 | 2 186 | 2 387 | |
| Costs to consumers, SEK/MWh | 24 | 30 | 33 | 34 | |

Note: The system was launched in May 2003. Bioenergy includes electricity from peat that was 0.5 TWh in 2004, 0.6 TWh in 2005 and 0.6 TWh in 2006.

Source: Country submission; SEA: *The electricity certificate system 2007*; https://elcertifikat.svk.se.

Figure 30

**Quota Obligations and Forecast New Renewable Electricity Generation, 2003 to 2030**




Source: Swedish Energy Agency.

The price of certificates is determined by supply and demand, and can vary from one transaction to another. Trading occurs either bilaterally between buyers and sellers, or through brokers. Markets exist for both spot and forward contracts. The cost of certificates is included in the electricity price as charged to end-users. In January 2006, the certificate cost equalled 2% of the total electricity bill of a typical household with electric heating.

In addition to receiving certificates, wind power is subsidised in the form of an energy tax reduction (known as the "environmental bonus") which, in 2006, amounted to SEK 65/MWh for onshore generation and SEK 150/MWh for offshore generation. By 2009, the subsidy for onshore wind is to be gradually phased out, and that for offshore wind, to be reduced to SEK 120/MWh.

The government aims at increasing wind power production to 10 TWh per year by 2015. To support this goal, Sweden's municipalities are obliged to consider sites for wind energy plants in their planning decisions and 49 areas in 13 counties, mostly in southern Sweden, have been identified as particularly suitable. Since 2007, municipalities can apply for financial support from the government for this evaluation. The government is now also looking into ways to increase incentives for better grid connection of small-scale wind power producers.

## SOLAR HEATING

Solar heating is subsidised through two schemes. First, permanent residences and non-commercial buildings receive a subsidy of SEK 2.5/kWh per year. The maximum annual subsidy is SEK 7 500 for one-family houses, and SEK 5 000 for individual apartments. The grant is also limited to a maximum of SEK 250 000 per property. Second, since 1 July 2006, commercial buildings are also eligible for the SEK 2.5/kWh subsidy. The subsidy is granted on the total annual energy production. The maximum grant is 30% of the total costs for material and labour, and it is paid out as a tax refund. The subsidies for solar heating are in force until 2010, with a total budget of some SEK 150 million.

# CRITIQUE

Sweden is one of the leading IEA countries in the use of renewable energy, ranking third in terms of its renewables supply share. Renewable energy makes up 28% of primary energy supply and about half of electricity generation. As IEA countries are working to enhance their reliance on renewable resources, both for environmental and security of supply reasons, Sweden has an enviable starting point.

## BIOENERGY

The government is planning to further increase bioenergy use, supported by both economic and environmental potential for more production. This, however, brings several challenges. As biomass is a limited resource, decisions based on further analysis are needed on its most effective use in order to gain the greatest economic returns and environmental benefits. The source of biomass feedstock should be carefully assessed and whether or not it is sustainably produced. Although the technical potential for increased biomass supply from forests, agriculture, food processing and organic wastes is uncertain, the use of biomass could probably be increased if properly mobilised. Additional solid or liquid bioenergy carriers could be imported, or produced locally from forest thinnings, short rotation forests and other energy crops.

Additional biomass production for energy purposes from crops grown to that effect, however, would intensify competition for land and water use with food, forest and fibre crops. Recommendations for producing biomass more sustainably are needed. The issue is complex and requires careful assessment using full life-cycle analyses for both indigenous and imported biomass. It is, therefore, encouraging that the Swedish government, in association with industry, is already funding research in this area. In order to solve

environmental problems and not create them, an extensive list of topics need to be addressed, including land use competition, deforestation, GHG balances, soil carbon, especially of organic peaty soils, acidification, eutrophication, water quality and demand, stump removal and use, agrochemical and fertilizer inputs, nitrogen management, nutrient recycling (including returning wood ash to the land to avoid soil acidification), biodiversity, landscape, and plant breeding (including genetic modification). In addition, all benefits have to be considered, such as the social impacts of employment, reduced local air pollution, improved health, incentives for international trade, and sustainable development opportunities.

More detailed analysis of the optimum use of biomass for different purposes is recommended. Competition for biomass resources to reach specified energy targets could disrupt the supply for other products and affect GDP and employment. Therefore, a full assessment of the optimum use of the resource is needed, also employing economic, environmental and policy effectiveness indicators, such as toe/ha, SEK/toe, $CO_2$ emissions/km travelled, and investment costs in terms of SEK/t $CO_2$ avoided.

Bioenergy deployment is currently driven mainly by economic benefits, security of supply and climate change mitigation. However, other policies relating to forestry, agriculture and transport are not always supportive of enhanced bioenergy implementation. Increased communication between relevant government officials could prove valuable. This has been undertaken previously but there appears to be further opportunity to improve the understanding of how the various policies might blend, support one another or conflict.

The time taken to gain consent from local municipalities for the development of a bioenergy project, and indeed for other renewable energy projects, is seen to be unacceptable by developers. Any means of streamlining the process would be welcome.

Statistics on bioenergy use are difficult to produce accurately, particularly because of the dispersed nature of non-commercial heat supplies and the lack of metering. More analysis is needed and methods should be developed to incorporate surveys of heat users to improve the statistics for better policy analysis. In this regard, Sweden is undertaking such an initiative that could prove to be of interest to other countries. Once completed, the framework and lessons learned should be widely disseminated.

The Swedish bioenergy market is for the large part mature. Conversion of various biomass feedstocks in existing district heating plants provides around half the total heat supply. Many such plants have already been converted to more efficient CHP plants and there is limited further potential to do more. However, the government should continue to encourage tapping that potential. Biomass fuels have been encouraged by

exemptions from energy and $CO_2$ taxes and by eligibility for the renewable electricity certificates. These have strongly increased investments in bioenergy CHP plants. The government should monitor the adequacy of the current support levels, and adjust them, if needed, to encourage displacing more natural gas and coal in plants close to where a biomass resource is available.

Increasing the use of biofuels for transport may not provide the same climate and efficiency benefits of the biomass that Sweden is already using in the heat and power sector. With present-day methods, a relatively large quantity of energy is required for the production of liquid biodiesel and bioethanol such that current processes are not likely to become very energy-efficient in the near future. Additional biofuels targets, either national or imposed by the EU, should therefore be based on a life-cycle analysis of first- and second-generation biofuels, their costs and benefits, especially for climate change mitigation, and weigh them against those of other forms of renewable energy use.

Car users could be encouraged to switch to biofuel blends where fuel supplies can be reliably made from sustainably produced biomass. Raising the ethanol blend to 10% (E10) in all gasoline fuels is worth considering as a possible cheaper option than subsidising dedicated ethanol and methane-fuelled vehicles. This again would need full comparative life-cycle analyses to be undertaken and would require the support of vehicle engine manufacturers and vehicle importers before permitting the E10 blend to be used. Similarly, agreeing to B5 blends for biodiesel uptake is a start, but higher blends could be technically possible.

The definition of "clean vehicles" should be clarified, preferably at an international level. Since vehicles often travel across borders, standardisation of fuels is required. A standard for E85 fuels could be useful and criteria for sustainable production of biofuels should be prepared in collaboration with other governments.

Hybrid vehicles running on biofuels should be evaluated and the business opportunities discussed with Swedish engine and vehicle manufacturers.

## OTHER FORMS OF RENEWABLE ENERGY

Since May 2003, generating renewable electricity is supported by the electricity certificate system based on a quota and tradable certificates. The aim is to increase annual production of renewable electricity by 17 TWh from 2002 to 2016. This is an ambitious, but realistic, goal. The system has many features that deserve credit. Running until 2030, it has a sufficiently long and predictable time-frame. To encourage new capacity construction, plants are phased out of the system at the latest after 15 years. The quota obligation is

allocated to the electricity suppliers, and trading in electricity certificates is well developed. Most importantly, the system is market-based, encourages cost-effective investment and is delivering as planned. All this is well worth praise. The IEA can recommend Sweden's electricity certificate system as a model for other countries.

The government, however, may have to adjust the well-functioning electricity certificate system to respond to EU developments. EU-wide certificate trading could emerge in the coming years, possibly reducing (or increasing) incentives to invest in renewable electricity in Sweden. Under all development scenarios, the government should ensure that electricity market conditions are stable enough to encourage investment in new generating capacity, renewable or not.

Wind energy is additionally subsidised to generate 10 TWh more per year by 2015, a tenfold increase from 2006. The IEA considers it positive that the subsidies are gradually decreasing and, for onshore wind power, entirely phased out by 2009. The government also offers investment grants to solar power and heating in the residential/building sector, with fairly good response for electricity but less so for heating. For geographical reasons, the total solar potential is limited, notably in Sweden's northern parts. The effectiveness of these subsectoral renewable electricity policies should be monitored and revised, if needed.

## RECOMMENDATIONS

*The government of Sweden should:*

***Bioenergy***

- *Evaluate the optimum use of both indigenous and imported biomass supplies for heat, electricity, CHP, biofuels, biomaterials and biochemicals in terms of economic, environmental and social benefits.*
- *Increase international collaboration to assess the sustainable production of biomass.*
- *Review the collection and analysis of statistics to provide more accurate data on current and future biomass resource demands.*
- *Review current policies supporting the production and importation of first-generation biofuels and use life-cycle analyses to assess their contribution to greenhouse gas mitigation, and the costs per tonne of $CO_2$ avoided.*
- *Encourage the use of ethanol, biodiesel and biogas where technically feasible, economical and positive for greenhouse gas mitigation.*

*Other forms of renewable energy*

- *Maintain the electricity certificate system and monitor the cost-effectiveness of other support schemes for renewable electricity, adjusting them, if needed, to reflect changes in the framework conditions for investing in new generating capacity.*

## OVERVIEW

Sweden has ten nuclear units – six boiling-water reactors (BWR) and four pressurised-water reactors (PWR) – in operation at three sites: Forsmark, Oskarshamn and Ringhals (see Table 15). In 2006, the country's nuclear fleet of 9 $GW_e$ generated 65 TWh of electricity, 46% of total electricity generation. Following a political decision, the Barsebäck 1 unit was shut down permanently in 1999 and the Barsebäck 2 unit in 2005.

Table 15

**Nuclear Power Plants in Operation in Sweden, 31 December 2007**

| *Name* | *Type* | *Net capacity, $MW_e$* | *Commissioning date* | *Electricity generation in 2006, TWh* | *Availability factor in 2006 (%)* |
|---|---|---|---|---|---|
| Forsmark 1 | BWR | 995 | 1980 | 6.7 | 76.5 |
| Forsmark 2 | BWR | 951 | 1981 | 6.0 | 72.9 |
| Forsmark 3 | BWR | 1 190 | 1985 | 9.6 | 94.3 |
| Oskarshamn 1 | BWR | 467 | 1972 | 2.1 | 51.3 |
| Oskarshamn 2 | BWR | 602 | 1975 | 4.1 | 79.7 |
| Oskarshamn 3 | BWR | 1 153 | 1985 | 9.5 | 96.2 |
| Ringhals 1 | PWR | 850 | 1976 | 6.5 | 89.7 |
| Ringhals 2 | PWR | 870 | 1975 | 6.8 | 91.5 |
| Ringhals 3 | PWR | 920 | 1981 | 6.6 | 81.5 |
| Ringhals 4 | PWR | 915 | 1983 | 7.1 | 91.0 |
| **TOTAL** | | **8 913** | | **65.0** | **82.7** |

Source: Nuclear Energy Agency.

In 2006, the average availability factor for the Swedish nuclear power plants (NPPs) was 82.7%, equal to the world average. This, however, was nearly 9% less than in 2004, reflecting the sensitivity of single-year availability factors to specific events such as reloads, maintenance, and temporary shut-downs for safety purposes. Historically, the technical performance of the Swedish NPPs has been robust.

All the nuclear units have been or will be uprated. Consequently, the total installed nuclear capacity is at present only around 10% lower than in the mid-1980s, although two units have been shut down since then. Further uprates are planned at the three nuclear sites in 2008-2011. They would increase installed nuclear capacity by more than 10%.

Swedish NPPs are owned by a mix of public and private partners. Vattenfall AB owns 51% of the nuclear capacity, E.ON Sweden 29% and Fortum 19% (see Table 16). Mellansvensk Kraftgrupp, which has a stake in the Forsmark NPP, is owned by Fortum (87%), Skellefteå Kraft (7.7%) and E.ON Sweden (5.3%).

Table 16

**Ownership of the Swedish Nuclear Power Plants, 2007**

| *Nuclear power plant* | *Ownership* |
|---|---|
| Forsmark | Vattenfall AB (66%), E.ON Sweden (8.5%), Mellansvensk Kraftgrupp AB (25.5%) |
| Oskarshamn | E.ON Sweden (54.5%), Fortum (45.5%) |
| Ringhals | Vattenfall AB (70.4%), E.ON Sweden (29.6%) |

Source: Company annual reports.

Uranium production ended in Sweden by the end of the 1970s and Swedish utilities import uranium and enrichment services. A fuel fabrication plant, processing imported enriched uranium and producing fuel assemblies, has been in service since 1971 at Västerås. The plant is owned and operated by Westinghouse Atom AB, and supplies fuel to Swedish and foreign utilities, while some Swedish utilities buy part of their fuel from foreign companies.

The future of nuclear energy in Sweden has remained a political issue since 1980, when the Swedish voters opted by referendum for a delayed phase-out of nuclear energy and the parliament set 2010 as the date for completion of the phase-out. The parliament also stated that closing down nuclear units should not reduce employment or the welfare of society; neither should it increase the use of oil and gas; and renewable energy sources should be available.

In 1997, the parliament removed the 2010 deadline for a complete phase-out. The 1998 Act on the Phasing-out of Nuclear Power allows the government to decide on closing down an NPP at a certain point in time, provided losses incurred by the owner are compensated by the state. The current government,

in office since October 2006, has declared it will not decide on phasing out any nuclear reactors, nor will it permit building new ones. Uprates, however, will be possible.

## REGULATORY BODIES AND NUCLEAR SAFETY

Two governmental authorities have a regulatory and supervisory role in connection with safety and radiation protection, the Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion – SKI) and the Swedish Radiation Protection Institute (Statens Strålskyddsinstitut – SSI). The main law governing nuclear energy in Sweden is the 1984 Act on Nuclear Activities, amended and supplemented in 1987, 1992, 1995 and 1999.

The SKI is the regulatory body in charge of licensing nuclear facilities and safety controls. It is financed through fees paid by the owners/operators of nuclear facilities, and it reports to the Ministry of the Environment. The SSI participates in inspections of nuclear installations. The government has decided to merge SKI and SSI into a single authority with responsibility for nuclear safety, radiation protection and radioactive waste management. The merger will take place on 1 July 2008.

The Swedish nuclear reactors are licensed to operate as long as the safety authority considers that they are safe. However, irrespective of safety, technical and economic issues, the lifetime of nuclear power plants is limited in principle by the phase-out policy.

The Swedish nuclear reactors are generally functioning very safely. This has also been the case since the previous review, with one major exception. On 25 July 2006 an external electrical fault triggered a short-circuit of the switchgear at Forsmark 1. Two of the four backup diesel generators did not start up as expected, but the safety systems to keep the incident under control – *i.e.* the automatic shut-down and cooling of the reactor – functioned systematically. What occurred at Forsmark was categorised as a Level 2 or "Incident" on the IAEA International Nuclear Event Scale, that is, to be taken seriously but "without consequences to people or to the surrounding environment". Following the incident, the SKI ordered a precautionary and temporary shut-down of three other units (Forsmark 2 and Oskarshamn 1 and 2) pending a thorough investigation.

Nuclear R&D activities, devoted mainly to safety and radioactive waste management, are carried out by the SKI and the industry in co-operation with universities and national laboratories. Sweden is involved in international R&D projects mainly through the International Atomic Energy Agency, Euratom and the OECD Nuclear Energy Agency. In addition, it has formal bi- or multilateral co-operation agreements with many countries, including Canada, Finland, France, Japan and the United States.

## DECOMMISSIONING AND WASTE DISPOSAL

Low- and intermediate-level radioactive waste from reactor and fuel-cycle operations is disposed of in a final repository (SFR-1) located close to the Forsmark nuclear power plant. SFR was built and is owned by Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company, SKB) which is jointly owned by the Swedish utilities operating nuclear facilities. The repository has been in operation since 1988 and it has the capacity to receive operational and decommissioning waste from all Swedish nuclear facilities.

For the back-end of the fuel cycle, Sweden has chosen the direct disposal option, *i.e.* irradiated spent fuel downloaded from reactors is not reprocessed but stored for an interim period for cooling before its final disposal. High-level waste is stored in a central interim storage (CLAB) situated at the Oskarshamn NPP. Also built and operated by the SKB, the CLAB is dimensioned to receive the spent fuel from all Swedish nuclear units during a period of 50 years until final disposal in a deep geological repository. The CLAB's waste strorage capacity was recently increased from 5 000 tonnes to 8 000 tonnes. The SKB conducts R&D on spent fuel conditioning and final disposal. The process to choose the repository site is under way. Östhammar, close to Forsmark, and Oskarshamn are being investigated as possible locations. These investigations are planned to be completed in 2008, and the final repository is expected to be commissioned within a decade.

Generators of nuclear electricity are responsible for the costs of radioactive waste management and disposal, and decommissioning of facilities. The nuclear power utilities collect a fee on each unit of nuclear electricity generated and contribute to a fund – the Nuclear Waste Fund – placed under regulatory supervision. The fund must cover all expenses for the management and disposal of spent fuel, dismantling and decommissioning of facilities and R&D undertaken by the SKB.

## CRITIQUE

Almost three decades after the 1980 decision to phase out nuclear energy, this remains a key component of Swedish energy policy. It continues to strongly support security of supply and climate change mitigation – major energy policy goals of the country.

The phase-out decision has proved hard to implement. Since 1980, two reactors have been permanently shut down and, under the present government, further closures are not in sight. The conditions set for the phase-out are that it should have no negative impact on employment and the welfare of society, and should not result in an increase in oil and gas

consumption. But phase-out would be challenging even without these conditions. At present, nearly 95% of electricity is generated by hydro and nuclear power plants, and in the post-Kyoto period, targets for reducing GHG emissions are likely to be tighter than today. Against this background, it is hard to see how phasing out nuclear energy could serve Sweden in reaching broader energy policy goals. Furthermore, recent public opinion surveys show that a majority of the population is not in favour of a phase-out.

The lack of a firm political decision about the future of nuclear power in Sweden discourages investment in large electricity generating capacity, and thus decreases security of electricity supply. For the time being, the operators of NPPs are planning to continue their programmes to upgrade and uprate existing plants. Extending the operational life of the plants is a cost-effective way to continue using nuclear energy, but the decision on how to renew the fleet of ageing reactors, whether by new units or alternative forms of power supply, cannot be postponed forever. Therefore, the government should intensify its efforts to clarify the role of nuclear power in the Swedish energy mix, both concerning existing plants in the short and mid term, and concerning the scope for new nuclear reactors in the long term.

Operating a fleet of ten nuclear units requires adequate education and training programmes to ensure that highly-qualified staff are available to the utilities and the safety authority for running and decommissioning the plants and for managing and disposing of radioactive waste. Also, R&D programmes, especially in the field of safety, radiation protection and waste management, are needed for the continued operation of nuclear power plants and their eventual decommissioning and dismantling.

In spite of the uncertainties about the future of nuclear energy in Sweden, the utilities and the SKI have ensured the safe and reliable operation of existing nuclear units. Sweden's NPPs have very good safety records, even after the Forsmark incident in 2006. The incident, however, underlined the need to carefully and continuously monitor nuclear safety. It is positive that, in response to this event, the SKI has taken measures to strengthen safety. To ensure safe and secure nuclear operations, the government should maintain the strong and independent safety authority.

Sweden is among the first countries to be in the process of choosing the site for spent nuclear fuel and other high-level radioactive waste. Establishing a final disposal site will also help ensure long-term acceptance for nuclear power. Commendably, the final repository is expected to be commissioned within a decade. The government should ensure that the process proceeds efficiently without unnecessary delays.

## RECOMMENDATIONS

*The government of Sweden should:*

- *Clarify its position on the role of nuclear energy in the medium and long term in order to provide the industry with a clear and stable framework for investing in new generating capacity.*
- *Maintain a strong and independent safety authority to ensure that nuclear power plants in operation enjoy excellent safety and reliability performance.*
- *Ensure that R&D, education and training programmes in the field of nuclear energy provide human capacity for the safe operation of existing nuclear power plants during their entire lifetime.*
- *Pursue the timely commissioning of a spent fuel repository.*

# PART III

# ENERGY TECHNOLOGY

## POLICY

Sweden's policy on energy R&D aims at building the scientific and technological basis for a transition to a sustainable energy system, and at supporting the development and commercialisation of new energy technologies and services that have the potential for reducing both $CO_2$ emissions and dependence on fossil fuels.

The current National Energy Research Programme was approved by the parliament in June 2006 (*Energy Research and Development Towards Future Energy Systems*, 2005/06:127). Compared to the previous energy research programme (1998-2004), the current programme concentrates on fewer thematic areas and has a stronger focus on facilitating new technologies to the market. It also places more importance on priority-setting for approving proposals for programmes and individual projects. Energy R&D concentrates on areas in which Sweden has the greatest potential, and the results are required to find implementation in industry and society as a whole. Collaboration with industry and other intended users of the results is emphasised. The current programme has no fixed end-date and will be evaluated once every four years.

The National Energy Research Programme focuses on the following six areas:

- **Energy System Studies:** analysis of energy policy measures.
- **Buildings as Energy Systems:** energy- and resource-efficient construction and maintenance; passive houses.
- **Transport:** second-generation biofuels, mainly ethanol from forest industry and gasification of biomass, including three pilot and demonstration plants (see Chapter 7); energy-efficient combustion engines adapted to alternative fuels.
- **Energy-Intensive Industry:** reducing energy losses and using biofuels more efficiently; process integration.
- **Electricity Generation and Distribution:** more efficient power system; hydro and wind power generation; contributing to the creation of a Swedish solar cell industry.
- **Bioenergy, including CHP:** stronger resource base for a sustainable production of bioenergy; increasing energy efficiency through effective processes, mainly from climate-neutral fuels (see Chapter 7).

Within each area, research is organised into specific programmes, the number of which can vary depending on identified research needs. In 2006, some 40 programmes were running. In addition to them, several individual projects were also conducted.

For each thematic area, an energy technology platform is established to support the Swedish Energy Agency. Individual platforms have around 15 members, both in-house staff and experts from key stakeholders, mainly from industry and academia. The platforms are responsible for strategic energy R&D planning within their thematic area; they develop scenarios, roadmaps, energy outlooks and analysis. In its work, each platform is supported by a senior advisory board.

Programme areas and individual projects are prioritised according to three criteria. First, they should have the potential to reduce $CO_2$ emissions, improve energy efficiency and/or increase security of energy supply. Second, Sweden should have, or needs to improve, knowledge and competence in the prioritised area. Third, good conditions should exist for industrial and commercial application of the results.

For evaluating progress, the SEA uses several indicators, such as the number of doctorates and publications or the number of patents, venture capital investments, spin-off companies, and new products on the market. The programmes are also regularly peer-reviewed.

## INSTITUTIONS

Since January 2005, the SEA manages the National Energy Research Programme and is also responsible for all funding of non-nuclear activities. In managing the programme, it has an obligation to co-operate with three other government bodies, namely the Swedish Research Council (Vetenskapsrådet), the Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) and the Swedish Agency for Innovation Systems (VINNOVA). Before 2005, these three agencies managed their own energy R&D programmes and budgets.

The Energy Research and Development Board (EUN) is the ultimate decision-making body for the National Energy Research Programme. It is responsible for decisions on SEA's funding for energy R&D. It decides on participating in external programmes; large internal programmes and large individual projects. It can delegate decisions on some programmes or projects to the Director-General of the SEA. The EUN is appointed by the Swedish government.

In addition to government-financed energy R&D, a number of private companies and organisations are active in this area. Among them are Elforsk, which is owned by Swedish electricity suppliers and network operators. Other private R&D actors in the energy field include ABB, Vattenfall, the Swedish Steel Producers' Association (Jernkontoret), Scania and Volvo.

Energy R&D institutions include the "competence centres" at three universities. These were established by the Swedish National Board for Industrial and Technical Development (NUTEK) in 1995 to conduct interdisciplinary applied research in areas relevant to industry's long-term goals. There are currently six energy-related competence centres, focusing on combustion engines; high-temperature corrosion; catalysis (at Chalmers Institute of Technology); electric power technology; internal combustion engines (at the Royal Institute of Technology); and combustion processes (at Lund University). The centres are all co-financed by the SEA, various industrial alliances and the university itself, each one contributing about one-third of the budget.

## FUNDING

In 2006, public spending on energy R&D amounted to SEK 802 million (EUR 87 million). Per capita, this was close to the IEA average (see Figures 32 and 33). It was used to fund close to 700 projects. The current national energy research programme has an average funding of some SEK 815 million per year from 2006 to 2010, comparable to the levels of the previous programme (1998–2004).

Overall funding from the public sector is by and large matched by industry (see Table 17). The estimated funding for 2008 is SEK 850 million from the SEA and SEK 820 million from the private sector, and for 2009, SEK 870 million from the SEA and SEK 850 million from the private sector. The large drop in funding from 2004 to 2005 resulted from a delay in deciding on the continuation after the previous energy R&D programme expired.

By research area, energy efficiency and renewable energy receive the largest share, roughly one-third each of the total public funding in 2006-2007. In 2006, the largest recipients of public R&D funding were the universities and institutes of technology (55%), research institutes and trade organisations (22%), industry (19%), and international co-operation and other recipients (4%). Energy research at universities and institutes of technology is often entirely funded by the government. In line with the EU state aid rules, the share of public funding in all R&D funding decreases along the innovation chain towards market entry for the product or service.

Table 17

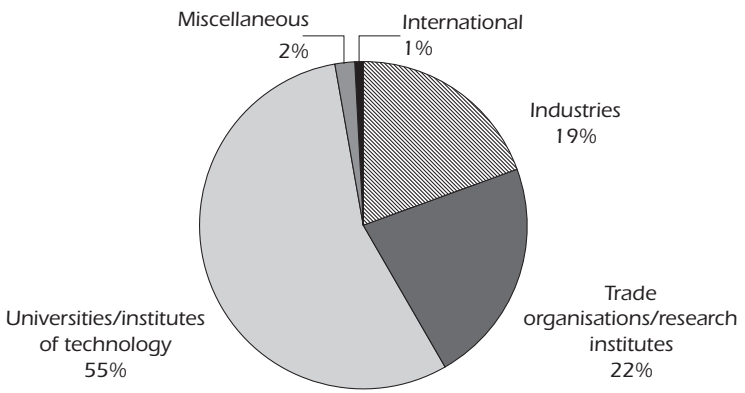
## Government Energy R&D Budget, 2005 to 2007

| *Funding area* | *2005* | | *2006* | | *2007** | |
|---|---|---|---|---|---|---|
| | *SEK million* | *%* | *SEK million* | *%* | *SEK million* | *%* |
| **Energy efficiency/conservation** | **178** | **33** | **257** | **32** | **278** | **33** |
| *I.1 Industry* | *67* | *12* | *125* | *16* | *130* | *16* |
| *I.2 Residential and commercial* | *17* | *3* | *39* | *5* | *42* | *5* |
| *I.3 Transport* | *82* | *15* | *72* | *9* | *81* | *10* |
| *I.4 Other (heat pumps, district heating, etc.)* | *12* | *2* | *22* | *3* | *25* | *3* |
| **Renewable energy sources** | **126** | **23** | **304** | **38** | **284** | **34** |
| *III.1 Solar energy* | *6* | *1* | *28* | *3* | *22* | *3* |
| *III.2 Wind energy* | *2* | *0* | *24* | *3* | *20* | *2* |
| *III.3 Ocean energy* | *5* | *1* | *7* | *1* | *6* | *1* |
| *III.4 Bioenergy* | *108* | *20* | *231* | *29* | *219* | *26* |
| *III.5 Geothermal energy* | | | | | | |
| *III.6.2 Small hydropower (< 10 MW)* | *5* | *1* | *10* | *1* | *12* | *1* |
| *III.7 Other renewables* | | | *4* | *1* | *5* | *1* |
| **Nuclear fission and fusion** | **50** | **9** | **50** | **6** | **50** | **6** |
| **Hydrogen and fuel cells** | **22** | **4** | **19** | **2** | **15** | **2** |
| **Other power and storage technologies** | **61** | **11** | **58** | **7** | **69** | **8** |
| **Other cross-cutting technologies** | **99** | **18** | **113** | **14** | **134** | **16** |
| **TOTAL** | **537** | **100** | **802** | **100** | **830** | **100** |
| **Funding from the private sector** | **421** | | **770** | | **800** | |

* Estimates. Source: Country submission.

Figure 31

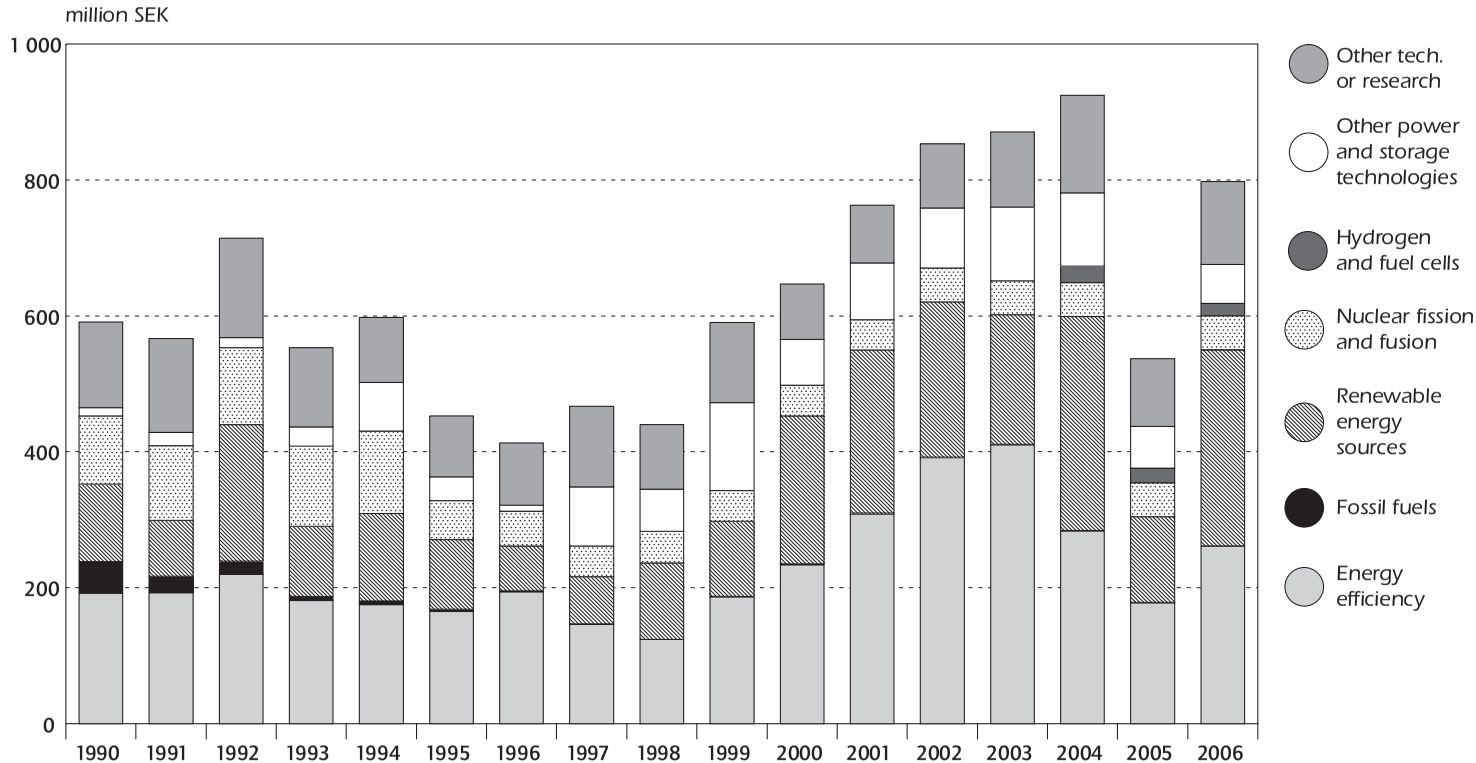
## Recipients of Public Funding for Energy R&D, 2006




Source: Swedish Energy Agency.

Figure 32

## Public Funding of Energy R&D by Sector, 1990 to 2006*

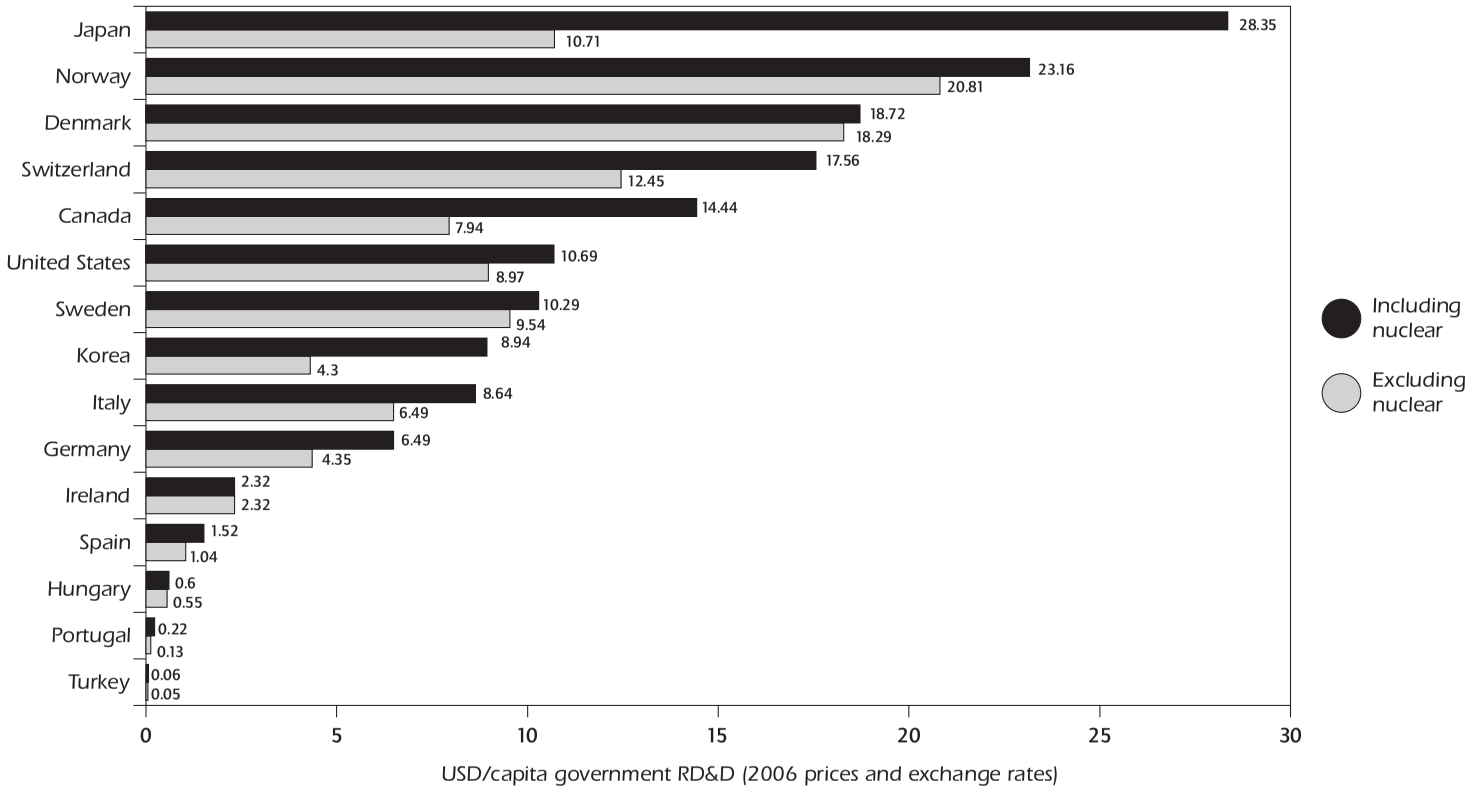



* 2006 = estimates.

Source: Country submission.

Figure 33

## Government Spending on Energy R&D per Capita in IEA Countries, 2006*




* estimates.

Note: data not available for Australia, Austria, Belgium, the Czech Republic, Finland, France, Greece, Luxembourg, the Netherlands, New Zealand and the United Kingdom.

Sources: Country submissions and *National Accounts of OECD Countries*, OECD Paris, 2007.

## INTERNATIONAL COLLABORATION

Swedish energy research is closely tied to the international energy research community. Sweden participates in multilateral co-operation with the IEA, the EU and the Nordic countries. It also has bilateral R&D agreements with several countries and regions, such as China and the United States.

Sweden is a member of 25 IEA implementing agreements, particularly those related to energy efficiency and renewable energy. Sweden is also active in the Nordic Energy Research Programme, which for the current programme period, 2007-2010, focuses on integrating energy markets, renewable energy, more efficient use of energy, hydrogen society and climate change.

Within the EU, the SEA participates in four ERA-NETs (European Research Area Networks): bioenergy, hydrogen, solar cells, and innovative energy research. Another Swedish public research funding organisation, Formas, participates in the ERA-NET on Buildings. ERA-NETs are networks of national science and technology funding organisations in Europe. They identify common priorities and co-ordinate national activities within the European research area (ERA), and their co-operation is funded from the EU Framework Programme.

Also within the EU, Sweden participates in several energy-focused technology platforms. The European Technology Platforms bring together stakeholders in industry-led efforts to define medium- to long-term research and technological development. Covering the whole economic value chain, they aim to better align EU research priorities with industry's needs.

## CRITIQUE

Sweden has an ambitious energy R&D policy, which comprehensively covers the whole innovation system: basic research, application-oriented RD&D, pilot and demonstration projects. The current National Energy Research Programme, launched in 2006, is in many ways an improvement from its predecessor. It has a clearer focus; it emphasises commercialisation and deployment of results; stakeholders are better involved; funding is continuous; and the programme is evaluated regularly. In another development, delegating to the SEA the overall responsibility for energy R&D policy, including funding, helps to co-ordinate public-sector efforts in a field so often fragmented among various agencies and institutions. With these improvements, Sweden has set a solid basis for a more successful energy R&D policy.

Consistent long-term policy is crucial in a sector where lead times for new products can be more than a decade. This is why close co-operation with industry is needed and encouraged, something in which Sweden is already

performing well. Nevertheless, the private sector should be encouraged to participate more at the universities, with a focus on technology transfer and commercialisation of products. The competence centres provide a good example of such work.

The current National Energy Research Programme is reviewed and evaluated every four years. To ensure consistency with its long-term energy policy goals, such as radically reducing $CO_2$ emissions per capita by 2050, the government could consider establishing quantitative targets for the six programme areas. In the forthcoming first evaluation of the current programme, the government could also review the criteria for allocating public resources over the six focus areas, and revise the sectoral allocations, if needed.

Sweden's energy R&D efforts are now more strongly focused on commercialisation of results. Successful commercialisation calls for policies and measures on the demand side, and for aligning energy R&D policy with general innovation and entrepreneurial policies. The government is using grants and taxation to stimulate demand for new energy technologies. Public procurement and also the technology procurement programme have the potential to stimulate demand for new technologies. To reap the full benefits from energy R&D spending, the government should also pay more attention to the general framework conditions conducive to innovation, such as reducing the administrative burden, encouraging entrepreneurship and improving access to finance.

Sweden's focus on international research co-operation is to be commended. Developing technologies is becoming increasingly complex, so pooling resources in international activities makes sense, especially for small countries. Sweden's active participation in the international research networks is to be praised and future participation encouraged.

## RECOMMENDATIONS

*The government of Sweden should:*

- *Consider establishing quantitative targets for energy R&D to support its consistency with the general energy policy goals.*
- *Continue to emphasise commercialisation of near-market technologies by, for example, considering and fine-tuning policies and measures to stimulate demand.*
- *Continue to actively participate in international collaboration.*

# PART IV

# ANNEXES

# ORGANISATION OF THE REVIEW

## REVIEW CRITERIA

The *Shared Goals* of the IEA, which were adopted by the IEA ministers at their 4 June 1993 meeting held in Paris, provide the evaluation criteria for the in-depth reviews conducted by the Agency. The *Shared Goals* are set out in Annex B.

## REVIEW TEAM

The in-depth review team visited Sweden from 15 to 19 October 2007. The team met with government officials, energy suppliers, interest groups and various other organisations. The team is grateful for the openness, co-operation and hospitality of the many people it met; they greatly contributed to a successful and productive review. In particular, the team wishes to thank the staff of the Ministry of Enterprise, Energy and Communications, and of the Swedish Energy Agency for their professionalism in preparing and guiding the review.

The members of the team were:

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**Mr. Miika Tommila**
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Miika Tommila managed the review and drafted the report with the exception of the section on bioenergy in Chapter 7, drafted by Ralph Sims, and the chapter on nuclear energy, drafted by Evelyne Bertel. Monica Petit and Bertrand Sadin prepared the figures. Marilyn Ferris and Viviane Consoli provided editorial assistance.

## ORGANISATIONS VISITED

- BIL Sweden
- Chemrec AB
- City of Stockholm
- Committee on Energy Efficiency and Services
- Confederation of Swedish Enterprise
- Elforsk AB
- ENA Energi AB
- Energy Markets Inspectorate
- Ministry of Finance
- Ministry of the Environment
- Ministry of Enterprise, Energy and Communications
- Royal Institute of Technology
- Skellefteåkraft
- SVEBIO
- Svenska Kraftnät
- SwedEnergy
- Swedish Competition Authority
- Swedish District Heating Association
- Swedish Energy Agency
- Swedish Gas Association
- Swedish Nuclear Power Inspectorate
- Swedish Petroleum Institute
- Swedish Plastics and Chemicals Federation
- Swedish Property Federation
- Swedish Road Administration
- Swedish University of Agricultural Sciences
- Södra
- Vattenfall

# ENERGY BALANCES AND KEY STATISTICAL DATA

Unit: Mtoe

## SUPPLY

| | | 1973 | 1990 | 2005 | 2006 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|---|
| **TOTAL PRODUCTION** | | **9.3** | **29.7** | **34.7** | **32.8** | **35.8** | **39.6** | **..** |
| Coal | | 0.0 | 0.0 | – | – | – | – | .. |
| Peat | | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | .. | |
| Oil | | – | 0.0 | – | – | – | – | .. |
| Gas | | – | – | – | – | – | – | .. |
| Comb. Renewables & Waste[1] | | 3.5 | 5.5 | 9.0 | 9.5 | 10.7 | 12.9 | .. |
| Nuclear | | 0.6 | 17.8 | 18.9 | 17.5 | 18.6 | 19.5 | .. |
| Hydro | | 5.1 | 6.2 | 6.3 | 5.3 | 5.6 | 5.9 | .. |
| Wind | | – | 0.0 | 0.1 | 0.1 | 0.4 | 0.7 | .. |
| Geothermal | | – | – | – | – | – | – | .. |
| Solar/Other[2] | | – | 0.0 | 0.3 | 0.3 | 0.3 | 0.3 | .. |
| **TOTAL NET IMPORTS[3]** | | **29.2** | **17.7** | **18.3** | **17.8** | **20.5** | **24.5** | **..** |
| Coal | Exports | 0.0 | 0.0 | 0.0 | 0.0 | – | – | .. |
| | Imports | 1.7 | 2.6 | 2.5 | 2.3 | 2.7 | 3.1 | .. |
| | Net Imports | 1.7 | 2.6 | 2.5 | 2.3 | 2.7 | 3.1 | .. |
| Oil | Exports | 1.4 | 8.6 | 10.5 | 11.2 | .. | .. | .. |
| | Imports | 30.0 | 23.9 | 28.0 | 27.3 | 18.7 | 21.6 | .. |
| | Bunkers | 1.1 | 0.7 | 1.9 | 2.1 | 2.2 | 2.2 | .. |
| | Net Imports | 27.5 | 14.6 | 15.6 | 14.0 | 16.5 | 19.4 | .. |
| Gas | Exports | – | – | – | – | – | – | .. |
| | Imports | – | 0.6 | 0.8 | 0.9 | 1.3 | 1.9 | .. |
| | Net Imports | – | 0.6 | 0.8 | 0.9 | 1.3 | 1.9 | .. |
| Electricity | Exports | 0.4 | 1.3 | 1.9 | 1.0 | – | – | .. |
| | Imports | 0.5 | 1.1 | 1.3 | 1.5 | – | – | .. |
| | Net Imports | 0.1 | –0.2 | -0.6 | 0.5 | – | – | .. |
| **TOTAL STOCK CHANGES** | | **0.5** | **0.2** | **–0.8** | **0.8** | **–** | **–** | **..** |
| **TOTAL SUPPLY (TPES)** | | **39.0** | **47.6** | **52.2** | **51.3** | **56.3** | **64.1** | **..** |
| Coal | | 1.6 | 2.7 | 2.3 | 2.4 | 2.7 | 3.1 | .. |
| Peat | | – | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | .. |
| Oil | | 28.0 | 14.7 | 14.9 | 14.6 | 16.5 | 19.4 | .. |
| Gas | | – | 0.6 | 0.8 | 0.9 | 1.3 | 1.9 | .. |
| Comb. Renewables & Waste[1] | | 3.5 | 5.5 | 9.0 | 9.5 | 10.7 | 12.9 | .. |
| Nuclear | | 0.6 | 17.8 | 18.9 | 17.5 | 18.6 | 19.5 | .. |
| Hydro | | 5.1 | 6.2 | 6.3 | 5.3 | 5.6 | 5.9 | .. |
| Wind | | – | 0.0 | 0.1 | 0.1 | 0.4 | 0.7 | .. |
| Geothermal | | – | – | – | – | – | – | .. |
| Solar/Other[2] | | – | 0.0 | 0.3 | 0.3 | 0.3 | 0.3 | .. |
| Electricity Trade[4] | | 0.1 | –0.2 | -0.6 | 0.5 | – | – | .. |
| ***Shares (%)*** | | | | | | | | |
| *Coal* | | *4.2* | *5.7* | *4.4* | *4.7* | *4.8* | *4.9* | .. |
| *Peat* | | *–* | *0.5* | *0.6* | *0.5* | *0.5* | *0.5* | .. |
| *Oil* | | *71.9* | *30.8* | *28.6* | *28.5* | *29.3* | *30.2* | .. |
| *Gas* | | *–* | *1.2* | *1.6* | *1.7* | *2.4* | *3.0* | .. |
| *Comb. Renewables & Waste* | | *9.1* | *11.6* | *17.2* | *18.4* | *19.1* | *20.1* | .. |
| *Nuclear* | | *1.4* | *37.4* | *36.1* | *34.0* | *32.9* | *30.5* | .. |
| *Hydro* | | *13.2* | *13.1* | *12.0* | *10.3* | *9.9* | *9.2* | .. |
| *Wind* | | *–* | *–* | *0.2* | *0.2* | *0.6* | *1.2* | .. |
| *Geothermal* | | *–* | *–* | *–* | *–* | *–* | *–* | .. |
| *Solar/Other* | | *–* | *–* | *0.6* | *0.6* | *0.6* | *0.4* | .. |
| *Electricity Trade* | | *0.2* | *–0.3* | *–1.2* | *1.0* | *–* | *–* | .. |

0 is negligible. - is nil. .. is not available. Forecasts for 2030 are not available.

Unit: Mtoe

## DEMAND

### FINAL CONSUMPTION BY SECTOR

| | 1973 | 1990 | 2005 | 2006 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|
| **TFC** | **34.9** | **32.5** | **35.2** | **35.0** | **37.4** | **41.4** | **..** |
| Coal | 0.9 | 1.0 | 0.9 | 0.8 | 1.3 | 1.9 | .. |
| Peat | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .. |
| Oil | 24.5 | 14.4 | 13.6 | 13.0 | 13.2 | 13.8 | .. |
| Gas | 0.1 | 0.4 | 0.5 | 0.7 | 0.8 | 1.0 | .. |
| Comb. Renewables & Waste[1] | 3.5 | 4.6 | 4.7 | 5.1 | 6.5 | 8.1 | .. |
| Geothermal | – | – | – | – | – | – | .. |
| Solar/Other | – | 0.0 | 0.0 | 0.0 | – | – | .. |
| Electricity | 6.0 | 10.4 | 11.2 | 11.2 | 11.5 | 12.0 | .. |
| Heat | – | 1.7 | 4.2 | 4.2 | 4.1 | 4.6 | .. |
| ***Shares (%)*** | | | | | | | |
| *Coal* | *2.7* | *3.2* | *2.6* | *2.3* | *3.4* | *4.6* | .. |
| *Peat* | – | – | – | – | – | – | .. |
| *Oil* | *70.1* | *44.3* | *38.6* | *37.2* | *35.2* | *33.3* | .. |
| *Gas* | *0.3* | *1.1* | *1.5* | *1.9* | *2.1* | *2.4* | .. |
| *Comb. Renewables & Waste* | *9.9* | *14.3* | *13.4* | *14.4* | *17.5* | *19.5* | .. |
| *Geothermal* | – | – | – | – | – | – | .. |
| *Solar/Other* | – | – | – | – | – | – | .. |
| *Electricity* | *17.0* | *31.9* | *32.0* | *32.2* | *30.8* | *29.0* | .. |
| *Heat* | - | *5.2* | *11.9* | *11.9* | *11.0* | *11.1* | .. |
| **TOTAL INDUSTRY[5]** | **15.4** | **13.8** | **14.3** | **14.5** | **16.6** | **19.7** | **..** |
| Coal | 0.9 | 1.0 | 0.9 | 0.8 | 1.3 | 1.9 | .. |
| Peat | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .. |
| Oil | 8.2 | 4.1 | 4.1 | 4.0 | 4.1 | 5.0 | .. |
| Gas | 0.0 | 0.3 | 0.3 | 0.5 | 0.5 | 0.6 | .. |
| Comb. Renewables & Waste[1] | 2.9 | 3.7 | 3.6 | 3.9 | 5.1 | 6.2 | .. |
| Geothermal | – | – | – | – | – | – | .. |
| Solar/Other | – | – | – | – | – | – | .. |
| Electricity | 3.4 | 4.6 | 5.0 | 4.9 | 5.1 | 5.4 | .. |
| Heat | – | 0.2 | 0.4 | 0.4 | 0.5 | 0.5 | .. |
| ***Shares (%)*** | | | | | | | |
| *Coal* | *5.7* | *7.2* | *6.4* | *5.5* | *7.7* | *9.6* | .. |
| *Peat* | – | – | – | – | – | *0.1* | .. |
| *Oil* | *53.2* | *29.4* | *28.9* | *27.7* | *24.8* | *25.2* | .. |
| *Gas* | *0.1* | *1.9* | *2.4* | *3.1* | *3.0* | *3.2* | .. |
| *Comb. Renewables & Waste* | *19.0* | *26.6* | *24.9* | *27.0* | *30.9* | *31.7* | .. |
| *Geothermal* | – | – | – | – | – | – | .. |
| *Solar/Other* | – | – | – | – | – | – | .. |
| *Electricity* | *22.0* | *33.7* | *34.7* | *33.9* | *30.6* | *27.6* | .. |
| *Heat* | – | *1.2* | *2.7* | *2.7* | *2.9* | *2.6* | .. |
| **TRANSPORT** | **5.4** | **7.3** | **8.5** | **8.6** | **8.5** | **8.9** | **..** |
| **TOTAL OTHER SECTORS[6]** | **14.1** | **11.4** | **12.4** | **11.9** | **12.4** | **12.7** | **..** |
| Coal | 0.0 | 0.0 | – | – | – | – | .. |
| Peat | – | – | – | – | – | – | .. |
| Oil | 11.1 | 3.3 | 1.4 | 0.9 | 1.1 | 0.8 | .. |
| Gas | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 | .. |
| Comb. Renewables & Waste[1] | 0.5 | 1.0 | 1.0 | 0.9 | 1.2 | 1.3 | .. |
| Geothermal | – | – | – | – | – | – | .. |
| Solar/Other | – | 0.0 | 0.0 | 0.0 | – | – | .. |
| Electricity | 2.4 | 5.5 | 6.0 | 6.1 | 6.2 | 6.2 | .. |
| Heat | – | 1.5 | 3.8 | 3.8 | 3.6 | 4.1 | .. |
| ***Shares (%)*** | | | | | | | |
| *Coal* | *0.3* | *0.4* | – | – | – | – | .. |
| *Peat* | – | – | – | – | – | – | .. |
| *Oil* | *78.5* | *28.6* | *10.9* | *7.5* | *8.8* | *6.7* | .. |
| *Gas* | *0.7* | *0.9* | *1.5* | *1.5* | *2.0* | *2.2* | .. |
| *Comb. Renewables & Waste* | *3.7* | *8.4* | *8.2* | *8.0* | *9.9* | *9.9* | .. |
| *Geothermal* | – | – | – | – | – | – | .. |
| *Solar/Other* | – | – | – | *0.1* | – | – | .. |
| *Electricity* | *16.8* | *48.1* | *48.7* | *51.1* | *49.9* | *49.0* | .. |
| *Heat* | – | *13.5* | *30.6* | *31.9* | *29.5* | *32.3* | .. |

Unit: Mtoe

## DEMAND

### ENERGY TRANSFORMATION AND LOSSES

| | 1973 | 1990 | 2005 | 2006 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|
| **ELECTRICITY GENERATION**[7] | | | | | | | |
| **INPUT (Mtoe)** | **8,2** | **26.7** | **31.0** | **28.8** | **30.5** | **33.4** | .. |
| **OUTPUT (Mtoe)** | **6.7** | **12.6** | **13.6** | **12.3** | **13.6** | **15.3** | .. |
| (TWh gross) | 78.1 | 146.0 | 158.4 | 143.3 | 158.7 | 177.5 | .. |
| *Output Shares (%)* | | | | | | | |
| *Coal* | *0.6* | *1.1* | *0.9* | *1.1* | *1.6* | *2.1* | .. |
| *Peat* | – | – | *0.3* | *0.3* | *0.5* | *0.6* | .. |
| *Oil* | *19.4* | *0.9* | *0.9* | *1.2* | *0.7* | *0.3* | .. |
| *Gas* | - | *0.3* | *0.4* | *0.4* | *1.8* | *3.2* | .. |
| *Comb. Renewables & Waste* | *0.5* | *1.4* | *5.3* | *6.5* | *7.1* | *8.1* | .. |
| *Nuclear* | *2.7* | *46.7* | *45.7* | *46.7* | *44.9* | *42.2* | .. |
| *Hydro* | *76.7* | *49.7* | *46.0* | *43.1* | *40.8* | *38.6* | .. |
| *Wind* | – | – | *0.6* | *0.7* | *2.7* | *4.9* | .. |
| *Geothermal* | – | – | – | – | – | – | .. |
| *Solar/Other* | – | – | – | – | – | – | .. |
| **TOTAL LOSSES** | **3.4** | **15.8** | **17.8** | **17.3** | **17.4** | **19.5** | .. |
| of which: | | | | | | | |
| Electricity and Heat Generation[8] | 1.5 | 12.3 | 13.5 | 12.6 | 13.2 | 14.5 | .. |
| Other Transformation | 1.0 | 0.7 | 1.7 | 2.2 | 1.7 | 2.2 | .. |
| Own Use and Losses[9] | 1.0 | 2.8 | 2.5 | 2.5 | 2.5 | 2.9 | .. |
| **Statistical Differences** | **0.6** | **–0.7** | **–0.7** | **–1.0** | **1.5** | **3.3** | .. |

### INDICATORS

| | 1973 | 1990 | 2005 | 2006 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|
| GDP (billion 2000 USD) | 143.30 | 201.30 | 278.60 | 290.00 | 311.33 | 388.15 | .. |
| Population (millions) | 8.14 | 8.56 | 9.03 | 9.08 | 9.30 | 9.70 | .. |
| TPES/GDP[10] | 0.27 | 0.24 | 0.19 | 0.18 | 0.18 | 0.17 | .. |
| Energy Production/TPES | 0.24 | 0.62 | 0.66 | 0.64 | 0.64 | 0.62 | .. |
| Per Capita TPES[11] | 4.79 | 5.56 | 5.78 | 5.65 | 6.06 | 6.61 | .. |
| Oil Supply/GDP[10] | 0.20 | 0.07 | 0.05 | 0.05 | 0.05 | 0.05 | .. |
| TFC/GDP[10] | 0.24 | 0.16 | 0.13 | 0.12 | 0.12 | 0.11 | .. |
| Per Capita TFC[11] | 4.30 | 3.80 | 3.90 | 3.85 | 4.03 | 4.26 | .. |
| Energy-related $CO_2$ Emissions (Mt $CO_2$)[12] | 84.0 | 52.8 | 50.4 | 48.3 | 54.9 | 64.8 | .. |
| $CO_2$ Emissions from Bunkers (Mt $CO_2$) | 3.9 | 3.2 | 8.0 | 8.5 | 9.1 | 9.7 | .. |

### GROWTH RATES (% per year)

| | 73–79 | 79–90 | 90–05 | 04–06 | 06–10 | 10–20 | 20–30 |
|---|---|---|---|---|---|---|---|
| TPES | 1.9 | 0.8 | 0.6 | –1.7 | 2.4 | 1.3 | .. |
| Coal | 1.6 | 3.9 | –1.1 | 4.3 | 2.7 | 1.5 | .. |
| Peat | – | – | 1.7 | –12.3 | 0.3 | 0.8 | .. |
| Oil | –0.6 | –5.4 | 0.1 | –1.9 | 3.0 | 1.6 | .. |
| Gas | – | – | 2.6 | 4.8 | 11.1 | 3.8 | .. |
| Comb. Renewables & Waste | 1.8 | 3.1 | 3.3 | 5.6 | 3.2 | 1.9 | .. |
| Nuclear | 46.7 | 11.3 | 0.4 | –7.5 | 1.5 | 0.5 | .. |
| Hydro | 0.3 | 1.6 | 0.0 | –15.2 | 1.2 | 0.6 | .. |
| Wind | – | – | 33.9 | 6.3 | 44.0 | 7.4 | .. |
| Geothermal | – | – | – | – | – | – | .. |
| Solar/Other | – | – | 35.9 | –3.3 | 2.1 | –1.8 | .. |
| TFC | 0.5 | –0.9 | 0.5 | –0.5 | 1.7 | 1.0 | .. |
| Electricity Consumption | 3.5 | 3.2 | 0.6 | 0.1 | 0.6 | 0.4 | .. |
| Energy Production | 8.0 | 6.6 | 1.0 | –5.4 | 2.2 | 1.0 | .. |
| Net Oil Imports | 0.4 | –5.8 | 0.4 | –9.8 | 4.1 | 1.6 | .. |
| GDP | 1.8 | 2.2 | 2.2 | 4.1 | 1.8 | 2.2 | .. |
| Growth in the TPES/GDP Ratio | 0.1 | –1.3 | –1.5 | –5.3 | 0.6 | –0.9 | .. |
| Growth in the TFC/GDP Ratio | –1.3 | –3.0 | –1.6 | –4.0 | -0.2 | –1.1 | .. |

Please note: Rounding may cause totals to differ from the sum of the elements.

# FOOTNOTES TO ENERGY BALANCES AND KEY STATISTICAL DATA

1. Combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste 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, gas and electricity, total net imports also include peat, combustible renewables and waste, and trade of heat.
4. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
5. Industry includes non-energy use.
6. Other Sectors includes residential, commercial, public services, agriculture, forestry, fishing and other non-specified sectors.
7. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
8. 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 33% for nuclear and 100% for hydro and photovoltaic.
9. 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.
10. Toe per thousand US dollars at 2000 prices and exchange rates.
11. Toe per person.
12. "Energy-related $CO_2$ emissions" have been estimated using the IPCC Tier I Sectoral Approach. 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 2005 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.

## INTERNATIONAL ENERGY AGENCY "SHARED GOALS"

The 27 member countries* of the International Energy Agency (IEA) seek to create the conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and 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 they 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 hydropower, 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** is 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 where practicable have regard to the "polluter pays principle".

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 members wish to retain and improve

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic (since November 2007), Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

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 encourage 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 their 4 June 1993 meeting in Paris.)

## GLOSSARY AND LIST OF ABBREVIATIONS

In this report, abbreviations are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention and abbreviated subsequently, this glossary provides a quick and central reference for many of the abbreviations used.

| | |
|---|---|
| AMR | automated meter-reading |
| bcm | billion cubic metres |
| BWR | boiling-water reactor |
| CDM | clean development mechanism |
| CHP | combined production of heat and power; sometimes, when referring to industrial CHP, the term "co-generation" is used |
| $CO_2$ | carbon dioxide |
| $CO_2$-eq | carbon dioxide equivalent |
| DME | dimethyl ether |
| EMI | Energy Markets Inspectorate |
| ERA | European Research Area |
| EU | European Union |
| EU-ETS | EU Emissions Trading Scheme |
| EUN | Energy Research and Development Board |
| FFV | flex-fuel vehicle |

| | |
|---|---|
| G8 | Group of Eight (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States) |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GW | gigawatt, or 1 watt x $10^9$ |
| ha | hectare |
| JI | joint implementation |
| kV | kilovolt, or 1 volt x $10^3$ |
| kWh | kilowatt-hour = kilowatt x 1 hour, or 1 watt x 1 hour x $10^3$ |
| L | litre |
| LNG | liquefied natural gas |
| LPG | liquefied petroleum gas; refers to propane, butane and their isomers, which are gases at atmospheric pressure and normal temperature |
| mcm | million cubic metres |
| MSW | municipal solid waste |
| Mt | million tonnes |
| Mtoe | million tonnes of oil equivalent; see toe |
| MW | megawatt of electricity, or 1 Watt x $10^6$ |
| MWh | megawatt-hour = megawatt x 1 hour, or 1 watt x 1 hour x $10^6$ |
| NAP | National Allocation Plan |
| $Nm^3$ | normal cubic metre |
| $NO_x$ | oxides of nitrogen |
| NPP | nuclear power plant |

| | |
|---|---|
| PJ | petajoule, or 1 joule x $10^{15}$ |
| PPP | purchasing power parity: the rate of currency conversion that equalises the purchasing power of different currencies, *i.e.* estimates the differences in price levels between different countries |
| PWR | pressurised-water reactor |
| R&D | research and development, especially in energy technology; may include the demonstration and dissemination phases as well |
| SEA | Swedish Energy Agency |
| SICLIP | Swedish International Climate Investment Programme |
| SKI | Swedish Nuclear Power Inspectorate |
| $SO_2$ | sulphur dioxide |
| SSI | Swedish Radiation Protection Inspectorate |
| t | tonne |
| TFC | total final consumption of energy; the difference between TPES and TFC consists of net energy losses in the production of electricity and synthetic gas, refinery use and other energy sector uses and losses |
| toe | tonne of oil equivalent, defined as $10^7$ kcal |
| TPA | third-party access |
| TPES | total primary energy supply |
| TSO | transmission system operator |
| TW | terawatt, or 1 watt x $10^{12}$ |
| TWh | terawatt x 1 hour, or 1 watt x 1 hour x $10^{12}$ |
| UNFCCC | United Nations Framework Convention on Climate Change. |
| VAT | value-added tax |

IEA PUBLICATIONS, 9, rue de la Fédération, 75739 PARIS CEDEX 15
PRINTED IN FRANCE BY STEDI MEDIA
(61 2008 17 1P1) ISBN : 978-92-64-04333-6 - 2008