# ENERGY POLICIES OF IEA COUNTRIES

# Sweden

## 2019 Review

International Energy Agency
Secure
Sustainable
Together

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# INTERNATIONAL ENERGY AGENCY

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# Foreword

The International Energy Agency (IEA) has been conducting in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development but also encourages exchange of and learning from international best practice and experiences. In short, by seeing what has worked – or not – in the "real world", these reviews help to identify policies that achieve objectives and bring concrete results. Recently, the IEA has moved to modernise the reviews by focusing on some of the key energy challenges in today's rapidly changing energy markets.

Sweden is leading the way towards a low-carbon economy globally, with the lowest share of fossil fuels in its primary energy supply among the IEA member countries, and the second-lowest $CO_2$ emissions per gross domestic product and per capita. In its 2016 Energy Agreement, Sweden has set ambitious long-term energy and climate targets. Now, it needs to turn them into action. The transport sector requires extra attention since it accounts for half of energy-related $CO_2$ emissions in the country. New policies that support low-emission vehicles and biofuels will push the transport sector in the right direction, but the outcome of these must be closely monitored to verify that they are stringent enough to meet the ambitious emission targets.

Smart policies and measures are essential to decarbonise the economy at least cost. Sweden's market-based approach to energy policy, which is focused on creating well-functioning and competitive energy markets, has often proved successful. The challenge going forward is to ensure that markets can deliver the targeted emission reductions while maintaining security of supply during the energy transition. In particular, Sweden needs to make sure that the energy-only power market can deliver a stable electricity supply, while facing higher shares of wind power and a potential nuclear phase-out. This will require a well thought-through market design and further regional collaboration.

Sweden continues its quest for a secure, affordable and environmentally sustainable transformation of its energy sector. Although being one of the leaders in low-carbon energy, the country still faces many challenges going forward. It is my hope that this review will guide Sweden in its energy transition and support its contribution to a cleaner, more sustainable and secure global energy system.

Dr Fatih Birol

Executive Director

International Energy Agency

## ENERGY INSIGHTS



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# 1. Executive summary

In many ways, Sweden is leading the way towards a low-carbon economy. Today, it has the second-lowest carbon dioxide ($CO_2$) emissions per gross domestic product (GDP) among the International Energy Agency (IEA) member countries (after Switzerland) and the second-lowest $CO_2$ emissions per capita (after Mexico). In part, this follows from having the lowest share of fossil fuels in its primary energy supply among IEA members while remaining relatively energy-intensive. Space heating and electricity generation are already practically decarbonised. Another factor is that energy use is generally efficient, largely owing to the wide use of electricity and district heating (DH). Electricity use per capita is one of the highest in the world.

Sweden's energy policy has for decades aimed to establish a sustainable energy system focused on energy efficiency and to switch from fossil fuels to domestic renewable energy. This policy has been very successful. Total primary energy supply (TPES) and total final consumption (TFC) of energy peaked late in the 20th century and have remained stable while the economy and the population have continued to grow. Electricity demand is increasing only slowly. The country is set to continue on the same path by improving energy efficiency and increasing renewable energy use from already high levels. In its energy market policy, the government aims to promote efficient and competitive markets to ensure a reliable energy supply at internationally competitive prices.

## The 2016 Framework Agreement on Energy Policy

Sweden defined its current long-term energy policy goals in the 2016 Framework Agreement on Energy Policy (Energy Agreement). A large majority in the parliament, which represented both the government and the opposition, supported the Agreement. In June 2018, the parliament adopted the government's bill of April 2018, based on the Energy Agreement. Prior to that, on 15 June 2017, the parliament had adopted the Climate Policy Framework, which related to Sweden's new climate goals.

Within the 2016 Energy Agreement, Sweden set the target of a net zero-carbon economy by 2045. To achieve this, Sweden aims for a 100% share of renewables in electricity generation by 2040. This is a target; it is not a deadline for nuclear power, nor does it mean closing nuclear power plants through political decisions. Sweden also aims for a 50% decrease in energy intensity (TPES per GDP) from 2005 to 2030, and a 70% reduction in greenhouse gas (GHG) emissions in the transport sector from 2010 to 2030. A progress report will be prepared every four years.

In the 2017 Climate Policy Framework, Sweden also set targets to reduce GHG emissions in the sectors not in the European Union Emissions Trading System (EU-ETS) by at least 63% by 2030 and at least 75% by 2040, compared with 1990 levels. However, current policies are not sufficient to bring about the long-term goal of decarbonisation, thus there is a need to develop roadmaps, set intermediate targets, and design new policies. The 2016 Energy Agreement focuses on electricity supply and $CO_2$ emissions. These are covered in more detail below.

## Moving to a fully renewables-based electricity system

Sweden has almost fully decarbonised its electricity generation, a feat which is quite unique among the IEA member countries. Since the 1980s, electricity generation has been based on hydropower and nuclear power, representing a combination of stability and flexibility. In recent years, under the support system for renewable electricity, wind power has grown fast. In 2017, fossil fuels provided only 2% of the 160 terawatt-hours (TWh) of electricity generated in Sweden.

Sweden is part of a harmonised and integrated Nordic electricity market with several interconnections with neighbouring countries. Cross-border lines with Norway, Finland and Denmark as well as Poland, Germany and Lithuania (with further extensions planned) enable intensive trade and help to cope with possible capacity shortages.

Sweden has a robust power system with sufficient generating capacity to cover national consumption and significant exports. Nevertheless, as for many countries with ageing nuclear fleets in Europe, Sweden faces potential issues with generation adequacy in the medium term. Nuclear power generates around 40% of the total electricity in the country, but the operators, faced with the costs of post-Fukushima safety upgrades and low prices on the Nordic electricity market, have struggled to remain competitive.

The 2016 Energy Agreement abolished the nuclear capacity tax and endorsed the existing regulation with no forced phase out of the existing nuclear capacity as well as no ban on new nuclear capacity. Six of the current eight nuclear units will make the required large investments to refurbish and implement safety upgrades. These are expected to continue to operate until the early 2040s, with two units (totalling 1.8 gigawatts) scheduled to close. The IEA applauds the decision to abolish the nuclear capacity tax as well as the property tax on hydropower capacity, given the disadvantage with respect to other generating options that taxing these low-carbon electricity sources had put them.

Sweden is not pursuing a politically mandated phase-out of nuclear energy. Political parties also agree that nuclear power will not be subsidised. However, in a liberalised and well-supplied electricity market such as Sweden’s, which supports renewables, there is essentially no room for other new, unsubsidised, low-carbon technologies. To meet the target by 2040, Sweden needs around 60 TWh more of green electricity to maintain today’s level of electricity generation. Sweden should carefully assess the generation and system adequacy of an electricity system based only on renewable energy sources, of which wind and hydropower could provide the majority. The government should also monitor the competitiveness of the existing hydropower capacity, and make sure that its policies and measures do not discourage maintaining the generation of this dispatchable low-carbon source of electricity.

Sweden relies (since 2003) on the electricity certificate system to increase renewable electricity supply to help meet EU-driven renewable energy targets, first to 2010 and then to 2020. The system has delivered the expected volumes and proved relatively cost-efficient, particularly compared to countries that have used feed-in tariffs as the support mechanism. The 2016 Energy Agreement sets a new target for the electricity certificate system to 2030 and gradually increases the volume of new green electricity generated, with 18 TWh anticipated by 2030. As in recent years, most of the new volume is expected to be wind power.

However, as electricity demand in Sweden is growing slowly, the increase in generation under the system has led to an increase in electricity exports. In recent years, Sweden has been a net exporter of electricity (19 TWh in 2017), and the Swedish Energy Agency projects that Sweden will remain a net exporter in the coming decades. The increase of generation under the certificate system has coincided with the increase in electricity exports.

Sweden and the rest of the Nordic countries have indicated a preference for energy-only markets. Wholesale prices in the Nordic market area have remained relatively low in recent years and currently do not signal a need for investments in new capacity, something that decision makers should consider when facing medium- to long-term challenges. The prices of the EU-ETS allowances are expected to rise and encourage low-carbon investment, but it is not clear to what extent this would be reflected in the already low-carbon Nordic electricity market.

The surplus of capacity in Sweden and the availability of low-cost resources from the rest of the Nordic region are almost certainly the primary reasons for the low wholesale prices. This is partly driven by divergent approaches to renewable energy support in the Nordic market area, which has distorted investment patterns throughout the region. As electricity demand in the market is not expected to grow fast, and adding new supply to the market will put pressure on electricity prices, the Nordic governments should consider ways to harmonise their policies on renewable electricity and, more generally, on climate change mitigation. For this reason, the Nordic governments should also co-ordinate their national climate and energy strategies.

Both globally and in Sweden, wind power and other renewable technologies are becoming more market-competitive, which is a positive development. Once these technologies can compete on market terms, the successful support system can be phased out. However, the closing mechanism of the Swedish green certificate system has yet to be decided, and we recommend it be done without undue delay to provide predictability to the market operators.

Critical for electricity supply, Sweden’s transmission system works in a stable way, but it also requires strengthening. Old lines must be replaced, and more transmission capacity is needed from north to south and at the entry points of large cities. Encouragingly, the transmission system operator is working on these issues, and the transmission capacity will be expanded in the next few years.

Practically all the electricity customers in Sweden have a smart meter. This creates many opportunities to continue to develop smart grid systems and further introduce measures to foster a demand-side response in the residential sector. The development of a data hub, a centralised system for electricity use information, will help to realise this potential. The data hub is also a critical element of the regional retail market integration. In general, the efforts to develop a Nordic retail market should be intensified. To create a common balancing market, which is already a work in progress, is an important step in this process.

Turning to nuclear waste management, since the 2013 in-depth review, Sweden has made significant progress on developing the final repository for spent nuclear fuel. If the government grants the construction licence in the near future, the Swedish Nuclear Fuel and Waste Management Company (SKB) expect work to start by 2020 and all the facilities, the final repository and a new encapsulating plant to be operational in 2030. The government and SKB should ensure that sufficient capacity is available in the interim storage facility (Clab) in case the licencing or the construction of the final repository is delayed.

## Leadership in reducing $CO_2$ emissions

Sweden's climate policy is delivering results, largely due to long-term policies to move away from fossil fuels and improve energy efficiency. The new targets to 2045 go beyond its international obligations, a good example for other countries to follow. The net zero-emission target by 2045 requires an 85% reduction in domestic emissions compared to 1990 (excluding land use, land-use change and forestry) and allows alternative measures to cover the rest.

With the adoption of the 2017 Climate Framework, the government should now start to prepare for the Climate Policy Action Plan. This work should include overall strategies, national emission scenarios, and pathways indicating how to reach the targets. To engage other important stakeholders, the government should collaborate with industry, academia and civil society, and create a shared vision towards the long-term targets.

Sweden has historically used both energy and $CO_2$ taxes to stimulate efficient energy consumption and low-carbon energy supply. Sweden introduced the $CO_2$ tax in 1991, which was one of the first of its kind in the world. The public broadly accepts the tax, which has gradually increased to stimulate a sustainable energy transition. Since its introduction, the carbon tax has increased from 0.25 Swedish kronor per kilogramme (SEK 0.25/kg) to SEK 1.15/kg in 2018 (around US dollars 140/tonne). This is the highest level of carbon taxation in the world. Strong $CO_2$ taxation has proved effective to drive decarbonisation across many sectors, and it should be utilised further in combination with other policy tools. Sweden should also regularly review the tax reductions and exemptions that remain for different industries to enable further cost-effective $CO_2$ mitigation.

Transport, the largest emitting sector still to be decarbonised in Sweden, is a focus area of Sweden's climate policy. Sweden has successfully moved away from oil in the residential and commercial sectors and substantially reduced its use in industry. Oil use in transport is the main component of the country's energy-related $CO_2$ emissions.

In 2016, while transport accounted for less than one-quarter of Sweden's TFC, it was responsible for over half of all the energy-related $CO_2$ emissions and a vast majority of the emissions from the non-EU-ETS sectors. The 2016 Energy Agreement includes a 2030 target to reduce emissions from domestic transport by 70% from 2010. To meet the target, the government introduced several policies and measures, the most important of which are the emissions reduction obligation for gasoline and diesel suppliers, and the bonus-malus system for new light-duty vehicles, both from July 2018.

Electrification of the transport sector, which is essential to meet Sweden's climate targets, requires infrastructure development. This includes, but is not limited to, a public charging infrastructure to enable longer trips and increased consumer trust in electric vehicles (EVs). In a deviation from Sweden's usual market-based policy approach, the government also subsidises the purchases of electric buses, electric bikes, scooters and boat engines. Investment subsidies can help speed up EV adoption, but the government should assess its cost-effectiveness and focus its support on investments that would not take place without such support.

Congestion charges and environmental zones are encouraging a modal shift in Stockholm and Gothenburg, the two largest cities. Congestion charges can be expanded to facilitate a transition from the taxation of fuel to the taxation of distances driven since the revenue from fuel taxation declines with increased electric mobility.

Heavy trucks account for one-fifth of the total GHG emissions in transport. Since the bonus-malus system applies only to light-duty vehicles, consideration should be given to expanding it to include heavy-duty vehicles. Furthermore, a shift from road to rail or sea can significantly reduce energy consumption and emissions from freight. The government should continue to support such a shift and prioritise efficient transport modes in future transport infrastructure plans.

Developing new technology is critical to combat climate change. The IEA encourages the government to continue to promote energy research, development and demonstration (RD&D) nationally and internationally, and to collaborate with academia and industry to capture new ideas and trigger technology development. Ideally, public spending on energy RD&D would be increased.

## Targeting energy efficiency

Although Sweden's GDP grew by 16% from 2007 to 2017, energy consumption remained almost flat. The country is on track to meet its target to reduce the energy intensity of the economy by at least 20% from 2008 to 2020. The 2030 target of lowering energy intensity by 50% compared to 2005 is also within reach.

Energy efficiency targets should be ambitious, realistic, understandable and clearly communicated. As the Swedish energy intensity targets are based on primary energy use, the closure of nuclear power plants (NPPs) contributes significantly to reaching them. Furthermore, energy intensity depends on the structure of the economy, and structural changes in energy-intensive industries can have a large impact on a country's performance. The government could therefore complement the targets that are based on TPES with a different metric to better capture energy efficiency improvements in TFC. Furthermore, the energy efficiency targets should be aligned with Sweden's climate targets and supported with actions to ensure that energy efficiency effectively helps reduce emissions.

Sweden has a long history of including energy performance standards in building regulations. Building stock changes only slowly, however, building technology keeps improving, thus buildings remain an important area for energy efficiency improvements. For new buildings, the energy performance requirements should be regularly reviewed. For non-residential buildings, the government should consider introducing additional categories to better capture the potential for cost-efficient measures. It should also introduce a system to measure and evaluate the overall energy performance of buildings before and after both construction and renovation projects are carried out.

A major part of energy consumption in Swedish buildings comes from DH, which supplies 90% of heat to multi-dwelling houses and 77% to non-residential buildings.

Active policy has succeeded in transforming the DH supply from oil dominance in the 1970s to using mostly biomass fuels and waste today. The $CO_2$ taxation is a main driver of this transformation.

In Sweden, DH competes with other heating technologies such as heat pumps. Producing DH at co-generation[1] plants is overall more efficient than producing it at heat-only plants. However, the low wholesale prices of electricity, which are challenging this model across the Nordic market area, have implications for the electricity system. As the share of variable renewable power (mainly wind) in electricity supply increases, the power system would benefit from more, not less, controllable backup power, such as biomass-fuelled co-generation. The government should closely monitor this situation to avoid undesired developments for the available power generation capacity. On the positive side, the technological development of DH systems can benefit both resource efficiency and system integration. Low-temperature heat use in fourth-generation DH networks is a good example.

## Ensuring oil and gas security

Sweden fulfils its IEA and EU obligations to hold emergency stocks of crude oil and/or petroleum products. As oil use is set to decline, meeting these obligations will require gradually diminishing efforts. However, securing stocks of biofuels for transport is an emerging area for which the government needs to define its long-term policies and measures.

Sweden has by far the highest share of biofuels in the transport sector among IEA member countries, and the new emissions reduction obligation will drive further growth. Of the biofuels used today, most is imported biodiesel. Sweden should assess what implications these increasing imports have on the security of supply for transport fuels. To allow for a continuous increase, the government should also consider producing a greater quantity of sustainable biofuels domestically.

Natural gas has limited importance in the Swedish energy system and, in the government's long-term projections, its supply gradually declines as biogas production increases. However, in the south-west of the country, where natural gas is mainly available, it provides around 20% of the TPES. It is mostly imported from the Tyra field in Denmark, which will be closed for maintenance between December 2019 and March 2022. In that period, the Swedish market will depend on natural gas supply from Germany through one route only. The government should monitor to ensure that ample supplies are available to Sweden during the Tyra closure.

[1] Co-generation refers to the combined production of heat and power.

## Key recommendations

***The government of Sweden should:***

- Design policies and measures to meet the targets of the 2016 Energy Agreement. In particular:
  - give preference to technology-neutral policies and market mechanisms, such as carbon pricing, and review existing tax reductions and exemptions
  - minimise the number of policies with the same objective and avoid overlaps
  - closely monitor the outcome of new policies to ensure the targets are reached, specifically in the transport sector
  - set interim milestones.
- Develop a shared vision and pathways to 2045 with academia, industry and civil society to guide the preparation of the Climate Policy Action Plan.
- Continue to develop the Nordic/Baltic electricity market together with the other countries and also co-ordinate the preparations for the national climate policies with them from this perspective.
- Analyse the long-term impact of 100% renewable electricity generation in 2040 on the generation adequacy, system resilience and cost-effectiveness of electricity supply; clarify how to reach that target in a Nordic energy-only electricity market.

# 2. General energy policy

## Key data

(2017)

**TPES**: 49.0 Mtoe (nuclear 34.9%, bioenergy and waste 26.3%, oil 21.2%, hydro 11.4%, coal 3.9%, wind 3.1%, natural gas 1.9%, heat 0.3%, peat 0.3%, electricity export -3.3%), -2% since 2007

**TPES per capita**: 4.8 toe/cap (IEA average: 4.1 toe)

**TPES per unit of GDP**: 108 toe/USD million PPP (IEA average: 106 toe)

**Energy production**: 35.9 Mtoe (nuclear 47.6%, bioenergy and waste 31.8%, hydro 15.6%, wind 4.2%, heat 0.4%, peat 0.3%), +8% since 2007

**Exchange rates**: Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Country overview

The Kingdom of Sweden (hereafter “Sweden”) lies in the north of Europe and borders the countries of Norway and Finland, and the bodies of water of the Baltic Sea, Kattegat and Skagerrak (Figure 2.1). It has an area of 450 000 square kilometres, around two-thirds of which is covered by forests. With 10.2 million inhabitants, the country remains sparsely populated. Most Swedes live in the south, with roughly one-third in the metropolitan areas of Stockholm, Gothenburg 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 combines an open-market economy with a generous welfare state. The gross domestic product (GDP) per capita is some 15% higher than the Organisation for Economic Co-operation and Development (OECD) average, and the overall tax rate, 44% of GDP in 2016, is among the highest within the OECD. Unemployment has decreased over the current decade, standing at 6.7% in 2017. Real GDP has grown rapidly for a developed country: by 4.5% in 2015, 3.2% in 2016, and 2.4% in 2017 (OECD, 2018).

As in all developed economies, services are the largest sector (74% of GDP in 2017). The country’s industry (25% of GDP) is led by exports and has traditionally focused on processing the abundant local forest and mineral resources. Home to several large multinational companies, Sweden’s major export articles include vehicles, machinery, pulp and paper, pharmaceuticals, and oil products. The primary sector (which includes forestry, agriculture and fishing) accounts for 1% of GDP (OECD, 2018).

## Figure 2.1 Map of Sweden


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Notes: Russia = Russian Federation. km = kilometre.

Sweden is a constitutional monarchy in which the king has a representative role only. The single-chamber parliament (the Riksdag) is directly elected by proportional representation. Since October 2014, Sweden has been ruled by a centre-left minority government of the Social Democratic Party and the Green party. Parliamentary elections were held in September 2018 and after four months negotiations the government was re-elected in January 2019, supported by two liberal parties through the so-called *January Agreement*.

Sweden is a unitary state with 21 administrative counties. The development of energy policy rests with the government, supported by several implementing national authorities and active local authorities.

Sweden joined the European Union in 1995, but it decided to stay out of the euro area and maintains the Swedish krona. The European Union sets legal requirements for the Swedish energy policy, particularly the electricity and gas markets, energy efficiency, renewable energy, energy taxation, state aid, environment and greenhouse gas (GHG) emissions.

## Supply and demand

Sweden's energy supply is characterised by high shares of hydropower, nuclear power and bioenergy, which together accounted for 95% of domestic energy production and 73% of the total primary energy supply (TPES)[1] in 2017 (Figure 2.2). Sweden has a large and growing supply of bioenergy, mainly from domestic forest resources. The hydropower, nuclear power and bioenergy production brings Sweden's overall self-sufficiency in energy to over 70%, despite having no domestic fossil fuel production (besides a small supply of peat). Oil is the largest imported energy source and accounted for 84% of the total energy imports to Sweden in 2017 (not including the uranium fuel for the NPPs). Natural gas consumption is very small, mostly limited to process industries and some electricity and heat production.

Ambitious environmental and climate policy has led to a transition of Sweden's energy system, which is mainly visible in energy transformation sectors. Electricity generation is nearly emissions free, thanks to the large production from hydropower and nuclear power, each of which provide about 40% of domestic production, together with wind and bioenergy and waste, which account for most of the rest. In recent years, wind power has grown rapidly and made Sweden a net exporter of electricity. The large district heating (DH) sector is also supplied mainly with low-carbon energy sources, such as biofuels and municipal waste.

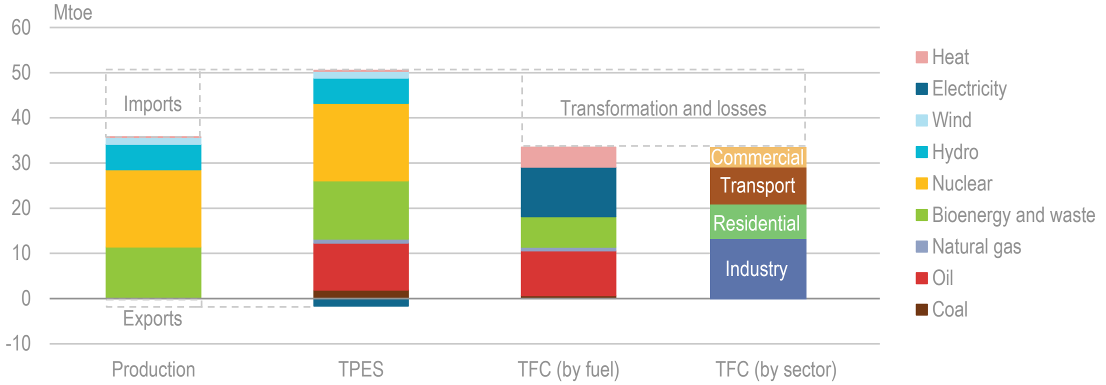
The country has a large energy-intensive industry sector, which accounts for 40% of total final consumption (TFC)[2] (Figure 2.2). The high energy intensity is mainly due to processing of domestic resources like wood and iron ore. Energy use in the pulp and paper industry is particularly high, but the sector is almost self-sufficient, owing to the use

[1] TPES is made up of production + imports – exports – international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use. Nuclear energy supply in TPES includes losses. The primary energy equivalent of nuclear electricity is calculated from the gross electricity generation by assuming a 33% conversion efficiency.

[2] TFC is the final consumption of energy (electricity, heat, and fuels, such as natural gas and oil products) by end users, not including the transformation sector (e.g. power generation and refining).

of its by-products and waste wood for heat and power generation. Transport is the second-largest energy consumer. It is also the only sector that remains largely dependent on fossil fuels and in which energy demand has increased in recent years.

**Figure 2.2 Overview of energy production, TPES and TFC by fuel and sector, 2017**




Domestic bioenergy, nuclear power and hydropower dominate the energy supply. Sweden is relatively independent of energy imports, except for oil.

Note: TPES does not include oil supplied to international bunkers.
Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

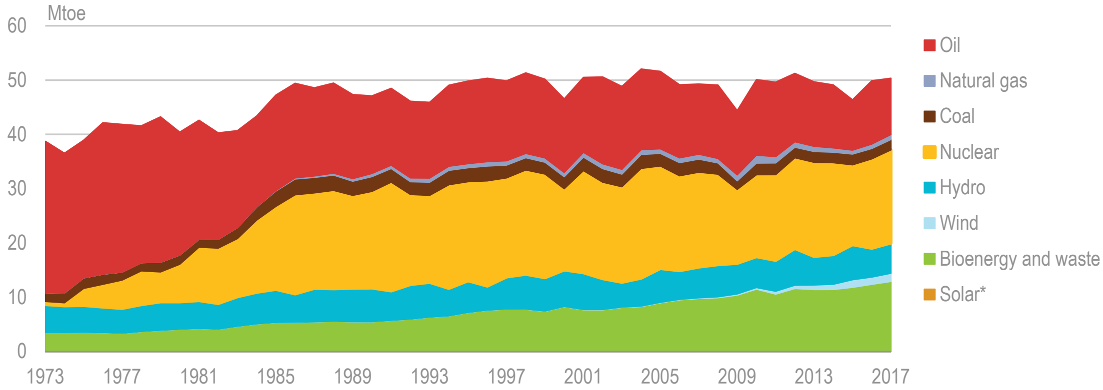
## *Primary energy supply*

Since the introduction of nuclear power between 1973 and 1986, TPES has remained at around 50 million tonnes of oil equivalent (Mtoe) (Figure 2.3). However, the energy mix has changed, with a large shift from oil towards solid and liquid biofuels and, in recent years, also the growth in wind power (which is more visible in a comparison of electricity sources). From 2007 to 2017, the supply of biomass-based fuels and waste increased by 24% across sectors such as heat and power generation, the pulp and paper industry, and the residential and transport sectors. Over the same decade, oil supply declined by 20%, replaced mainly by biofuels in the transport sector and biomass in residential heating.

Nuclear power remains a large source of primary energy in Sweden despite a 6% decline in the past decade. However, the share of nuclear in TPES includes losses in power generation, which is not the case for hydropower or wind power (see footnote 1). Two nuclear reactors were closed in recent years, and two more are scheduled to close by 2020. In contrast, renewable energy continues to gain ground in electricity generation. Wind power in particular has increased significantly in recent years, supported by the electricity certificate system (Chapter 7).

In 2017, the share of fossil fuels in Sweden's TPES was 30%, by far the lowest among International Energy Agency (IEA) member countries (Figure 2.4). Today, coal (4% of the TPES) is mostly used in the steel and cement industry, whereas natural gas (1.4% of the TPES) is mainly supplied through a network that only covers the southwest of the country. The share of nuclear power in TPES is the second highest after France and the share of biomass-based fuels and waste is the third highest after Denmark and Finland.

## Figure 2.3 TPES by source, 1973-2017



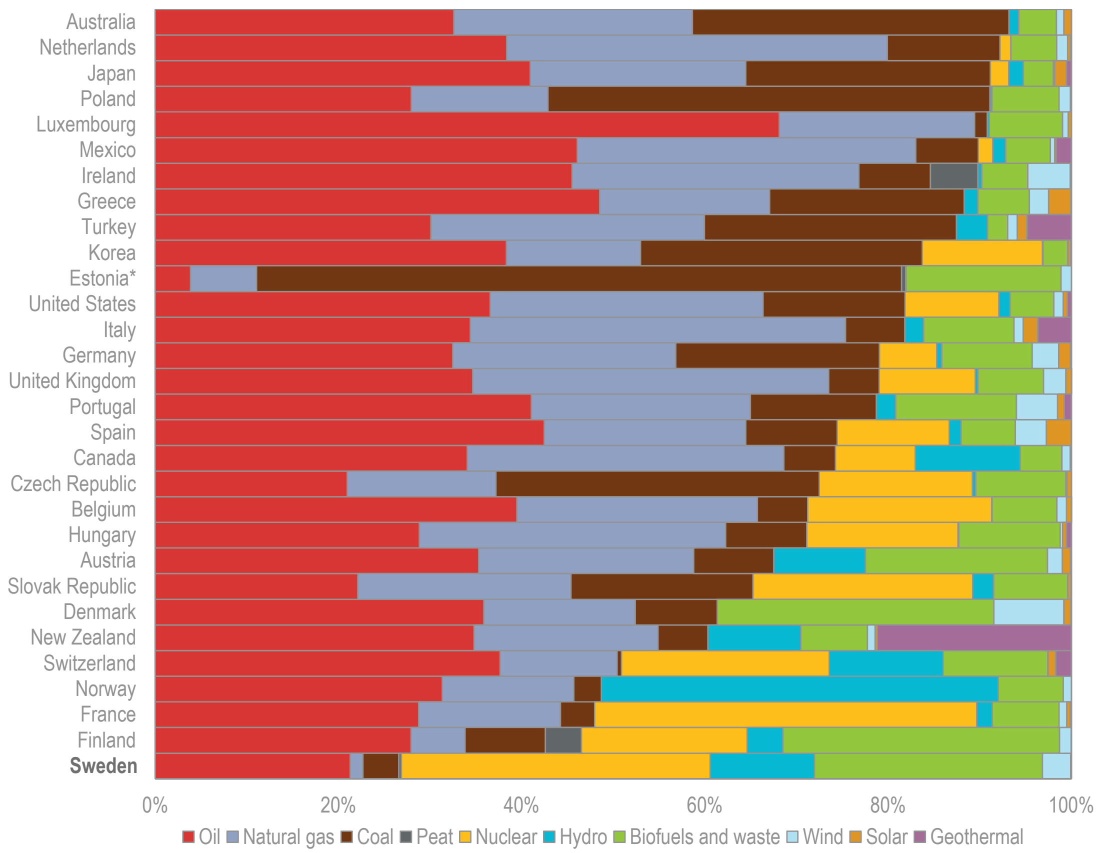

Bioenergy and waste supply increased rapidly in recent decades and, in 2015, it overtook oil as the second-largest primary energy source after nuclear power.

* Negligible.

Notes: *Nuclear* supply includes thermal losses. Electricity imports and exports are not included.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

## Figure 2.4 Breakdown of TPES by source in IEA member countries, 2017




Of the IEA member countries, Sweden has the lowest share of fossil fuels in TPES thanks to a large supply of nuclear power, bioenergy and hydropower.

* Estonia's coal is represented by oil shale.

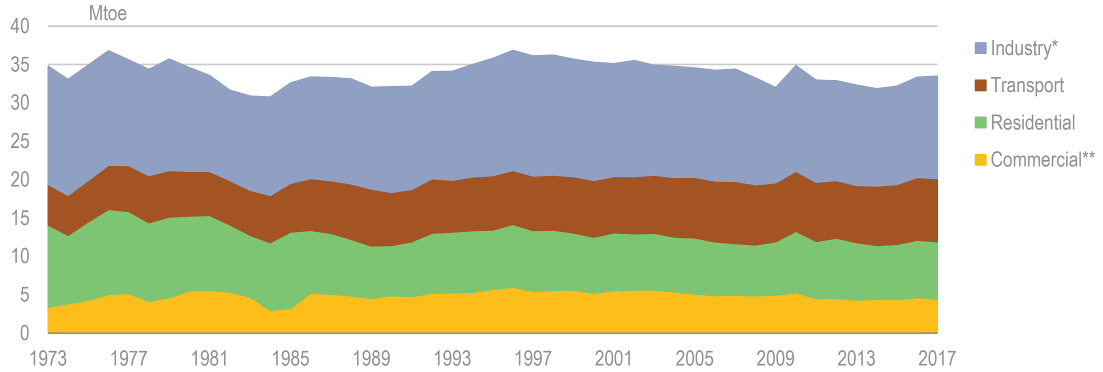
Note: Data are provisional.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

## Energy consumption is relatively stable

Since peaking at 36.8 Mtoe in 1996, TFC declined slowly to around 33 Mtoe in the past decade. In 2017, TFC was 33.5 Mtoe, 3% less than in 2007, but 5% more than in 2014. Although energy consumption is mostly stable, it varies somewhat year-on-year according to temperature and business cycle. Examples are the drop in industrial energy demand after the financial crisis in 2008 and the peak in residential energy demand during the cold winter of 2010 (Figure 2.5). Electricity is the largest source of TFC, at one-third in 2017, followed by oil, biomass-based fuels and waste, and DH (Figure 2.6).

### Figure 2.5 TFC by sector, 1973-2017



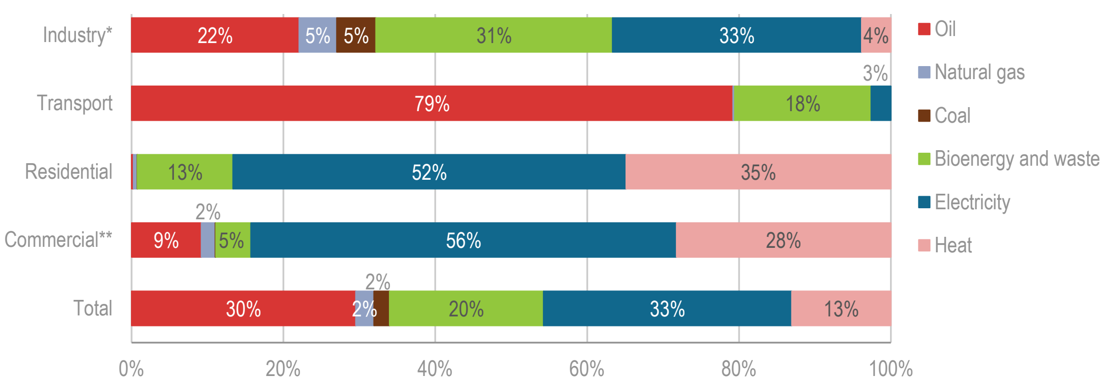

Industry is the largest energy consumer, at around 40% of TFC, of which nearly half goes to pulp and paper production.

* *Industry* includes non-energy consumption.

** *Commercial* includes commercial and public services, agriculture and forestry.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

### Figure 2.6 TFC by source and sector, 2017




Electricity, DH and biofuels are the largest energy sources in all the sectors except for transport, where oil still dominates despite a recent increase in biofuels.

* *Industry* includes non-energy consumption.

** *Commercial* includes commercial and public services, agriculture and forestry.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

Industry is the largest energy consumer, at 40% of TFC. In 2017, the total industry energy consumption was 13.4 Mtoe. Pulp and paper is by far the largest industrial subsector, at 42% of the total industrial consumption in 2017. Over the last two decades, the industrial energy use has decreased from nearly 16 Mtoe to around 13 Mtoe. This is mainly due to structural changes within some industrial branches, e.g. a switch from mechanical pulp production to chemical pulp, and to more energy-efficient manufacture processes. In recent years, industrial energy use has been rather stable.

In the residential and commercial sectors, electricity accounts for more than half of the total consumption, not least because of the use of heat pumps and electric heating in buildings. DH is the other main source for heat and in residential energy consumption it is among the highest of all IEA members. The share of natural gas in the residential sector is, however, the second-lowest of the IEA members after Norway.

As in most countries, the transport sector stands out with its high dependence on oil products. In 2017, diesel fuel accounted for 50% of the energy consumption in road transport and gasoline for another 31%. However, in recent years, biofuels have increased rapidly in the transport sector, and Sweden has the highest share of renewable transport fuels of the IEA members. Hydrogenated vegetable oil, a type of biodiesel, accounts for the largest share of biofuels in the Swedish transport sector.

## Main institutions

The **Ministry of the Environment and Energy (MEE)** is responsible for energy policy. Within the Ministry, this task has been delegated to a relatively small (25 people) Division for Energy, as most policy implementation is delegated to governmental agencies.

The Division for Climate in the Ministry is responsible for Sweden's participation in global climate change negotiations and the European Union's work on fulfilling its commitments under the Kyoto Protocol. In addition, this Division is responsible for emissions trading, project-based mechanisms and other climate policy instruments, as well as air-quality issues. The Division for Chemicals works on issues that relate to the environment and health, and to products and their lifecycles. This includes nuclear safety, radiation protection and the management of radioactive waste. The Ministry also co-ordinates and governs the national work on the environmental objectives system.

The **Swedish Energy Agency (SEA)**, under the MEE, is a government agency in charge of implementing most of the energy policy. It is responsible for the energy projections and forecasts, provides energy statistics and policy analysis, administers the electricity certificate system, implements the sustainability criteria for biofuels, etc. It also oversees the implementation of energy efficiency measures and of publicly funded energy research, development and demonstration.

The **Swedish Energy Markets Inspectorate** is the national regulator for the electricity, natural gas and DH markets. It works to improve the functioning and efficiency of these markets.

The **Swedish National Grid** (*Svenska kraftnät*) is the transmission system operator. It owns and operates the national high-voltage electricity grid and is responsible for the electricity system's short-term balance.

The **Swedish Competition Authority** works to safeguard and increase competition in Sweden. In addition to applying the Competition Act, it proposes changes to rules and suggests other measures to eliminate obstacles to effective competition. It also builds up and disseminates knowledge on competition issues.

The **National Board of Housing, Building and Planning** is the national agency for planning, management of land and water resources, urban development, building and housing. It is responsible for promoting the efficient use of energy in buildings, notably the reduction of electricity use for residential heating and the implementation of the building regulations.

The **Swedish Environmental Protection Agency** has responsibility for Sweden's regular climate reporting to the United Nations Framework Convention on Climate Change and the European Union. It regularly prepares projections and prepares reports related to climate change, GHG emissions and climate policies and measures. It does this work in collaboration with the responsible sectoral authorities.

The **Swedish Radiation Safety Authority** works proactively and preventively on nuclear safety, radiation protection and nuclear non-proliferation to protect the people and the environment from the harmful effects of radiation.

The **Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning** (FORMAS) promotes and supports basic research and need-driven research in the areas of the environment, agricultural sciences and spatial planning.

**Vinnova, the Swedish Governmental Agency for Innovation Systems**, integrates research and development in technology, transport and working life. Its task is to promote sustainable growth and competitiveness.

More information about the key institutions in individual sectors of energy policy is given in the subsequent chapters of this report.

## Policy

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

Sweden has historically used both an energy and a carbon dioxide ($CO_2$) tax to stimulate efficient energy consumption and a low-carbon energy supply. The Swedish $CO_2$ tax was introduced in 1991 as one of the first in Europe. The tax is broadly accepted among the general public and is gradually increased to stimulate a sustainable energy transition.

### *2016 Energy Agreement*

In March 2015, the government appointed a Parliamentary Committee (Energy Policy Commission) to review energy policy and to propose a broad agreement on energy policy with a focus on the conditions for electricity supply after 2025-30.

In June 2016, the Framework Agreement on Energy Policy (Energy Agreement) was reached between five parties that represent a majority in the parliament: the Swedish

Social Democratic Party, the Moderate Party, the Swedish Green Party, the Centre Party and the Christian Democrats. In June 2018, the parliament adopted the government's bill of April 2018 based on the Energy Agreement.

The 2016 Energy Agreement states that Sweden's energy policy should combine ecological sustainability, competitiveness and security of supply. These are also the fundamental objectives of energy policy of the IEA and the European Union.

Regarding electricity, the Agreement states that Sweden must have a robust electricity network with a high security of supply and low environmental impact and offer electricity at competitive prices. This starting point should provide a long-term perspective and clarity for actors in the market and help generate jobs and investment in Sweden. The energy policy is based on the fact that Sweden is closely linked to its neighbours in northern Europe and aims to find joint solutions to challenges in the common electricity market.

The 2016 Energy Agreement also sets out new targets:

- By 2045, Sweden is to have no net emissions of GHGs into the atmosphere and should thereafter achieve negative emissions.
- By 2040, electricity generation is to be 100% renewable. This is a target, not a deadline for banning nuclear power, and nor does it mean closing nuclear power plants (NPPs) through political decisions.
- By 2030, Sweden's primary energy use per GDP is to be 50% more efficient than in 2005.

As part of the 2016 Energy Agreement, the electricity certificate system was prolonged from 2020 to 2030 and expanded to deliver an additional 18 terawatt hours (TWh) of renewable electricity in that period. The system, in operation since 2003, has delivered as expected and helped Sweden increase the share of renewable sources in electricity supply in a predictable way. The current target is a deployment of 28.4 TWh of new RES for electricity in the common Swedish–Norwegian electricity certificate system by 2020 compared to 2011.

A progress report on the implementation of the 2016 Energy Agreement will be prepared every four years. The report will serve to suggest areas of further work to reach the targets.

In addition to the targets from the 2016 Energy Agreement, the following 2020 targets, dating from 2009 and based on the European Union's 20/20/20 targets, apply:

- at least 50% of renewable energy in the gross final consumption of energy
- at least 10% of renewable energy in the transport sector
- 20% more efficient use of energy compared to 2008.

## *2017 Climate Policy Framework*

Regarding climate targets, in June 2017 the parliament adopted a national Climate Policy Framework. This includes the Energy Agreement target on no net emissions of GHG by 2045. Furthermore, the climate framework sets targets to reduce GHG emissions in non-European Union Emissions Trading System (EU-ETS) sectors by at least 63% in 2030 and by at least 75% in 2040 from 1990 values. It also includes a new 2030 target for the transport sector to reduce GHG emissions by 70% from 2010 to 2030. This is more realistic than the previous vision of a fossil-fuel-free transport fleet in 2030.

With the current policies, the total GHG emissions are projected to be 30% below the 1990 level by 2020 and 36% below it by 2030. Current policies are thus not sufficient to reach the long-term goal of decarbonisation, which highlights the need to develop roadmaps, set intermediate targets and design new policy initiatives.

### *2019 January Agreement*

In January 2019, four parties in the Swedish parliament came to an agreement that led to the re-election of the government with the Social Democrats and Green Party. The January Agreement contained a list of 73 policy statements across different areas, which the new government has agreed to follow. The list includes actions on increasing the environmental taxation and a commitment to stop selling new cars that run on fossil gasoline or diesel after 2030. The January Agreement states further actions towards an expanded system for increasing the share of biofuels in the transport sector. This includes biofuels for aviation, increasing investments in production and distribution of biogas, and other infrastructure for fossil-free charging of vehicles. Moreover, during the Swedish Statement of Government Policy on 21 January 2019, the Government stated the commitment to the 2016 Energy Agreement and to the 2017 Climate Policy Framework.

## Long-term scenarios

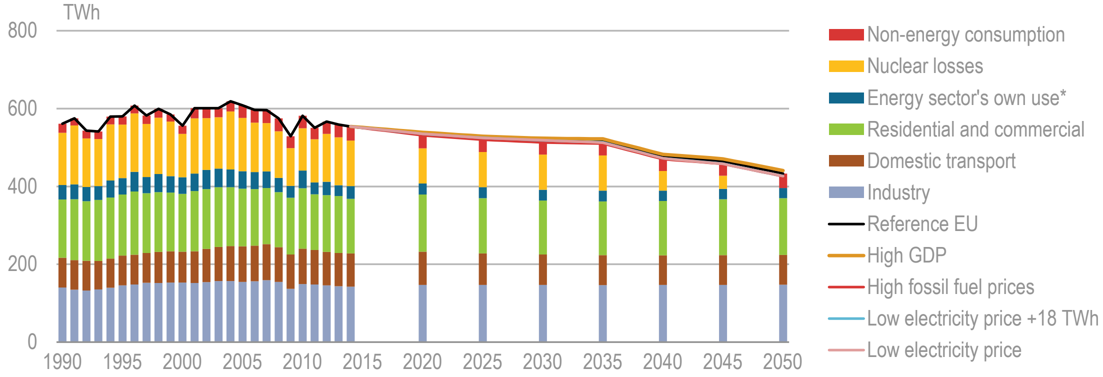
The SEA is tasked with developing energy scenarios and its latest long-term one dates from 2016. The reference scenario, the high GDP scenario and the high fossil prices scenario are all based on the European Commission's assumptions on future prices of fossil fuels and EU-ETS allowances. In addition, the SEA also prepared two scenarios on low electricity prices: the lower electricity price scenario and the lower electricity prices + 18 TWh scenario, which takes into account the extension and expansion of the electricity certificate system to 2030. The two low-price scenarios include lower prices for coal and natural gas as well as a lower price for EU-ETS allowances than the European Commission's assumptions. All the scenarios are based on the policies and measures that were valid in Sweden on 30 June 2016, that is, no assumptions were made on possible future policies.

### *Demand*

In all scenarios, total demand (which here includes both the transformation sector and the final-use sectors) declines towards 2050 to 426-441 TWh (36.6-37.9 Mtoe) (Figure 2.7).

The highest demand is in the high GDP scenario and the lowest is in the high fossil prices scenario in which consumption is subdued by the high prices. However, the differences between the scenarios are small. Total demand declines mainly because of the closures of NPPs, which have high energy-conversion losses that are counted here as part of demand.

**Figure 2.7 Energy demand by sector, 1990-2014 and scenarios to 2050**




The SEA projects Sweden's energy demand to decrease from the current level of around 550 TWh (47 Mtoe) by around 20% by 2050.

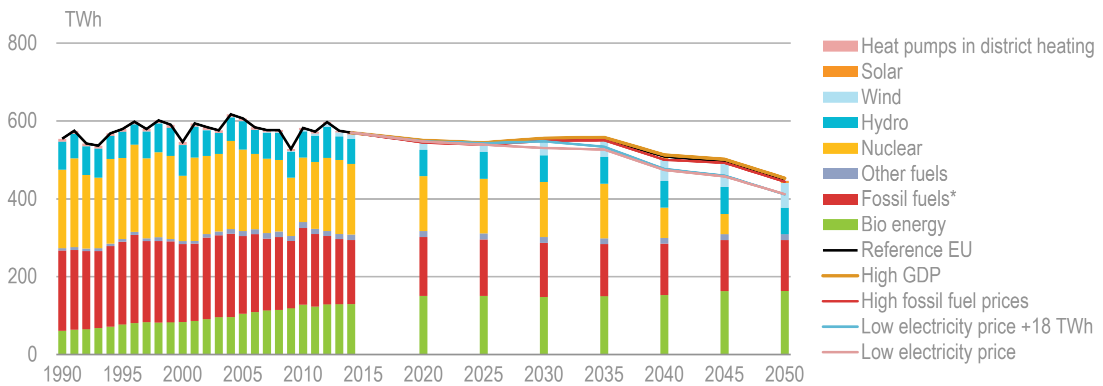
*Energy sectors own energy use, including transformation and distribution losses (excluding nuclear)
Source: SEA.

## *Supply*

As with demand, total energy supply also declines in all scenarios to 2050 (Figure 2.8), to 411-453 TWh (35.3-39.0 Mtoe), excluding the net electricity trade. The highest supply is in the high GDP scenario (here, net electricity exports are high), and the lowest is in the lower electricity prices + 18 TWh scenario since electricity generation is subdued by the low electricity prices and net imports are needed.

Hydropower and nuclear power are the same in all the scenarios, and the decline in supply is caused by reactor closures: the four oldest nuclear reactors are taken out of service by 2020, and the other six reactors are in operation for 60 years to 2040-45. The supply of biofuels and wind power increases in all the scenarios but at a different pace, whereas the supply of fossil fuels decreases.

**Figure 2.8 Energy supply by source, 1990-2014 and scenarios to 2050**




Energy supply is projected to decrease with falling demand, and, for Sweden to reach its climate targets, fossil fuels will need to be replaced.

* Includes coal and coal products, oil products and natural gas.
Source: SEA.

# Assessment

Since the in-depth review in 2013, Sweden has made significant progress in its long-term ambition of becoming one of the world's first fossil-free welfare nations. Continuous efforts in developing and implementing energy and climate-related policies – such as stringent $CO_2$ and energy taxation since the early 1990s, the promotion of RES, and a strong focus on research and innovation in sustainable energy systems – places Sweden at the forefront of IEA member countries in the energy transition. Sweden is also rightfully proud of its technology-neutral policies such as $CO_2$ taxation that enable efficient and market-based development. The IEA applauds this approach and advises Sweden to divert from this principle only if energy and climate policy goals cannot be met otherwise.

The 2016 Energy Agreement, approved by parliament in June 2018, sets long-term targets for Sweden's energy sector. The agreement was supported by around 70% of the parliament, which represents political parties from both the government and the opposition. Its work builds on energy policy targets from 2009, which have been expanded beyond the year 2020. Sweden aims for a 100% share of renewables in electricity generation by 2040 and for a 50% decrease in energy intensity (primary energy supply per GDP) from 2005 to 2030. This contributes to the target of a net-zero carbon economy by 2045. Sweden also aims to reduce GHG emissions in the transport sector by at least 70% from 2010 to 2030. A progress report will be prepared every four years.

In June 2017, the parliament also introduced a climate policy framework that included targets to reduce GHG emissions from 1990 levels in non-EU-ETS sectors by at least 63% by 2030 and by at least 75% by 2040. Current policies are not sufficient to achieve this long-term goal of decarbonisation, which illustrates the need to develop roadmaps, set intermediate targets and design new policies.

The Energy Agreement sets clear long-term goals, and the IEA advises that these be complemented by shorter-term milestones in order to steer policy development and implementation and to clarify different timeframes for different targets. The government should identify pathways to reach the targets and translate these pathways into more concrete actions. This should be done without delay and in broad consultation with stakeholders.

Sweden has been able to increase gradually the use of RES, supported by dedicated policy measures and favourable natural conditions. Currently, more than half of final energy consumption is covered by RES. Sweden is thus comfortably fulfilling its goals for 2020. Sweden is also a front runner in the deployment of RES in transport. The successful growth in RES is mainly attributed to stringent taxation on energy and $CO_2$ emissions, and to the promotion of RES through the electricity certificate system. As part of the Energy Agreement, the certificate system has been extended to 2030 and, by that year, it will deliver 18 TWh more generation annually than in 2020.

Sweden has historically used both energy and $CO_2$ taxation to stimulate efficient energy consumption and a low-carbon energy supply. The Swedish $CO_2$ tax was introduced in 1991 as one of the first in Europe. The tax is broadly accepted among the general public and is increased gradually to stimulate a sustainable energy transition. In recent years, Sweden has also abolished most of the tax expenditures to simplify the overall system. Further increases in the carbon price would help to achieve carbon objectives efficiently.

It is important to clarify the overall role of pricing mechanisms in achieving the long-term goals of the 2016 Energy Agreement.

The transport sector is broadly regarded as a challenge to decarbonisation, and Sweden leads in tackling this challenge. Although Sweden has the lowest share of fossil fuels in transport among IEA member countries, fossil fuels still constitute around 82%; the remainder consists of biofuels and some electricity. In the 2016 Energy Agreement, Sweden set a target to decrease emissions from the transport sector by 70% over the period from 2010 to 2030.

Sweden has a robust power system with sufficient generating capacity to cover national consumption and significant exports. Nevertheless, as for many countries with ageing nuclear fleets in Europe, Sweden is facing potential issues with generation adequacy in the medium term. The uncertain future role of nuclear power, which currently generates around 40% of its electricity, is at the core of this problem. The 2016 Energy Agreement clarified the future role of nuclear power as it found agreement to abolish the nuclear capacity tax and decided against a forced phase-out of existing nuclear plants or a ban on new nuclear capacity.

Sweden is not pursuing a politically decided phase-out of nuclear energy. It is also agreed among political parties that nuclear power will not be subsidised. However, on such a liberalised and well-supplied electricity market as Sweden's where renewables are supported, there is essentially no room for other new, unsubsidised, low-carbon technologies. To achieve 100% renewable electricity by 2040, around 60 TWh more of green electricity is needed to maintain today's level of electricity generation. Sweden should carefully assess the generation and system adequacy of an electricity system based only on RES, of which wind and hydropower would provide the majority.

Sweden can undoubtedly be considered as a front runner in a transition towards a zero-emission welfare state. Where some countries lack specific policies, Sweden has multiple dedicated policies and measures, such as the climate-related policies in the transport sector. Pursuing multiple policies and targets at the same time entails a challenge to focus on the overall target (the reduction of GHG emissions) while maintaining cost-effectiveness. Sweden should carefully address this challenge in order to minimise these risks.

## Recommendations

***The government of Sweden should:***

- ☐ Carefully translate targets of the 2016 Energy Agreement into policies and measures. In doing this, it should:
  - > identify possible pathways to reach the targets, using new and already existing analysis on a co-ordinated basis across all the relevant bodies
  - > give preference to technology-neutral policies and market mechanisms such as carbon pricing
  - > minimise the number of policies with the same objective and avoid overlap

  - operationalise the targets of the 2016 Energy Agreement by setting interim milestones
  - monitor the progress and periodically assess whether the targets are achievable within the specified timeframes in a stable and secure way.

- Carefully co-ordinate the implementation of the 2016 Energy Agreement across all the relevant bodies, namely the dedicated councils, relevant ministries and agencies, municipalities, and regions, which will lead to an efficient integration of energy and climate policies.
- Assess the cost-effectiveness of energy policies and measures with the climate impact across sectors and prioritise them accordingly.
- Analyse long-term scenarios of electricity system development with a view to achieving the ambitious targets of the 2016 Energy Agreement and a focus on ensuring the security of supply and cost-effectiveness.

### References

IEA (International Energy Agency) (2019 forthcoming), *World Energy Balances 2019 preliminary edition* (database), OECD/IEA, Paris, www.iea.org/statistics/.

IEA (2018), *World Energy Balances 2018* (database), OECD/IEA, Paris, www.iea.org/statistics/.

OECD (Organisation for Economic Co-operation and Development) (2018), *Country Statistical Profile: Sweden 2018*, www.oecd-ilibrary.org/docserver/csp-swe-table-2018-2-en.pdf?expires=1536333189&id=id&accname=guest&checksum=48204D9521086021DB916C8ADBE2EF40.

# 3. Energy, climate change and transport

## Key data

(2017)

**GHG emissions without LULUCF**:* 52.7 $MtCO_2$-eq, -26% since 1990

**GHG emissions with LULUCF**:* 8.9 $MtCO_2$-eq, -76% since 1990

**Energy-related $CO_2$ emissions**:

**$CO_2$ intensity per GDP**:** 82.8 $gCO_2$/USD (IEA average 237 $gCO_2$/USD in 2016)

**$CO_2$ emissions from fuel combustion**: 37.6 $MtCO_2$, -28% since 1990

**$CO_2$ emissions by fuel**: oil 69.3%, coal 18.2%, natural gas 4.0%, other 8.5%

**$CO_2$ emissions by sector**: transport 52.5%, power and heat generation 18.8%, industry 17.2%, other energy industries 7.2%, commercial 3.8%, residential 0.4%

**Final energy consumption in transport**: 8.2 Mtoe (oil 79.2%, biofuels 18.0%, electricity 2.6%, natural gas 0.2%), +1% since 2007

**Exchange rates**: Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

* Land use, land-use change, and forestry. Source: SEPA (2018a).

** In USD 2010 PPP.

## Overview

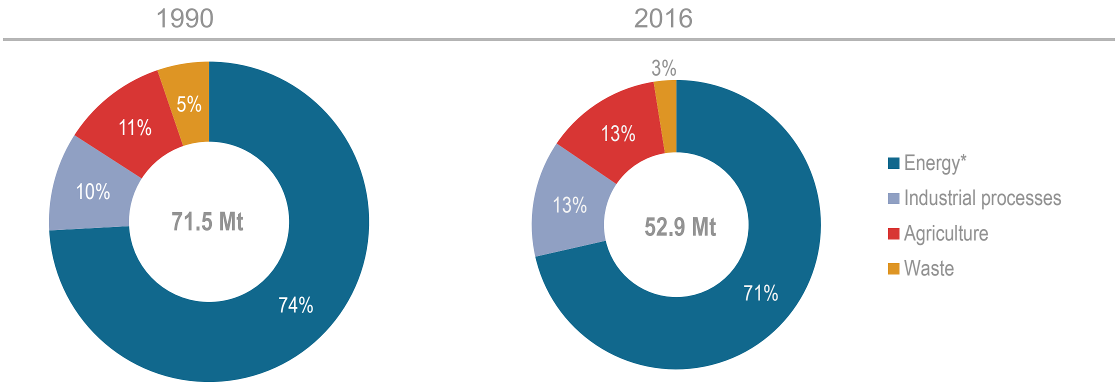
Sweden has managed to reduce its total greenhouse gas (GHG) emissions in recent decades, while maintaining strong economic growth. In 2017, Sweden's GHG emissions were 21% lower than in 2005 and 26% lower than in 1990 (without land use, land-use change, and forestry [LULUCF]). Energy-related carbon dioxide ($CO_2$) emissions represent the largest share of total GHG emissions. As a result of the decarbonisation of energy systems in Sweden, energy-related emissions have declined faster than the overall GHG emissions, and their share in total emissions decreased from 74% in 1990 to 71% in 2016 (Figure 3.1). Sweden's $CO_2$ tax has been an important driver for reducing emissions in the energy sector.

In 2017, the government decided on a new climate framework that stipulates national emission targets and a new climate law that obliges the government to take these targets into account when introducing policies. The long-term target is that Sweden should have zero-net emissions by 2045. With the climate framework in place, Sweden now needs to develop pathways to reach this ambitious target.

The transport sector accounts for over half of total energy-related emissions, and the reduction in transport emissions has been slow compared to that in other sectors. As part of the climate framework, the government set the target to reduce transport emissions by at least 70% from 2010 to 2030. To achieve this very ambitious target, the government introduced several policies to support new low-emission vehicles as well as to introduce more biofuels in the fuel mix.

One major development in the transport sector is the growth in electric vehicles (EVs). Sweden has one of the highest shares of EVs in new car sales globally, which requires new infrastructure to support continued growth.

**Figure 3.1 GHG emissions by sector, 1990 and 2016**




From 1990 to 2016, total GHG emissions were reduced by 26%, with the largest decline in energy-related emissions.

* *Energy* includes emissions from transport and stationary combustion in different sectors.
Source: SEPA (2018a), *National Inventory Report Sweden 2018*, https://unfccc.int/documents/65685.

# Energy-related $CO_2$ emissions

The following sections focus on energy-related $CO_2$ emissions, which account for the majority of GHG emissions.

## *$CO_2$ emissions by sector and fuel*

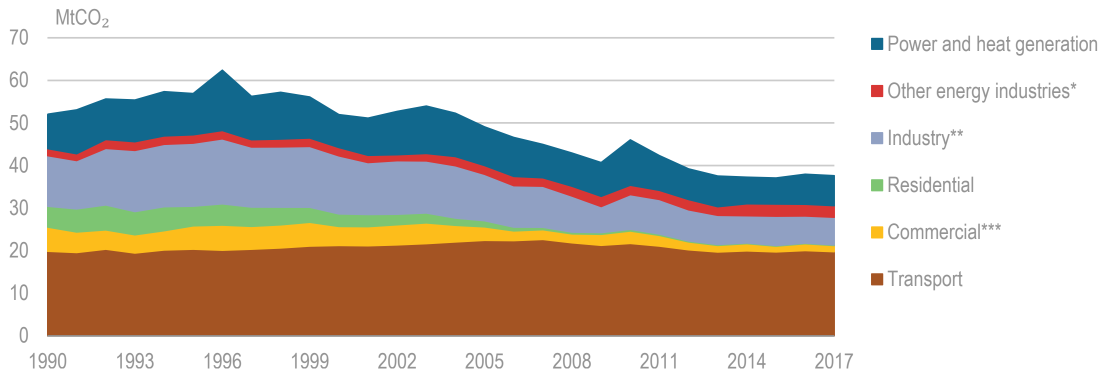
Sweden's energy-related $CO_2$ emissions fell rapidly in the late 1970s as oil use in electricity generation, industry and space heating was replaced with electricity from new nuclear power plants. In the following decades, emissions were relatively stable as declines in the residential and commercial sectors offset increases in transport. Since the early 2000s, emissions have declined across all the sectors, notably in industry, through the decreased use of fuel oil in pulp and paper industries (Figure 3.2). However, the decline has stalled in recent years, and emissions have remained stable since 2013.

In 2017, Sweden's energy-related $CO_2$ emissions were 38 million tonnes (Mt). The transport sector emitted 20 Mt, over half of the total emissions. Most of the rest were from heat and power generation, which accounted for 19% of the total emissions; manufacturing industry with 17%; and oil refineries with 7%. The commercial and residential sectors together represented just over 4% of the total emissions. This does not include indirect emissions from consumption of electricity and district heating.

Transport emissions have remained flat in the last five years as increased energy demand partly offset the gains from rapid growth in biofuels. Emissions from industry and from power and heat have fallen slightly in recent years, as a result of switching to higher shares of renewable energy. Sweden's $CO_2$ intensity in heat and power generation is the second lowest in the International Energy Agency (IEA) after Norway.

The dominance of transport emissions is reflected also in the share of emissions by fuel type (Figure 3.3). In 2017, oil accounted for 69% of the total $CO_2$ emissions, followed by coal at 18%. However, emissions from oil decreased by 19% from 2007 and those from coal by 24%. Emissions from non-renewable waste in heat and power generation, however, has increased significantly. Natural gas accounts for only a few percentage points of total emissions and has declined in recent decades.

### Figure 3.2 Energy-related $CO_2$ emissions by sector, 1990-2017




Sweden has reduced its energy-related $CO_2$ emissions across most sectors, but less so in the transport sector, which accounted for over half of total emissions in 2016.

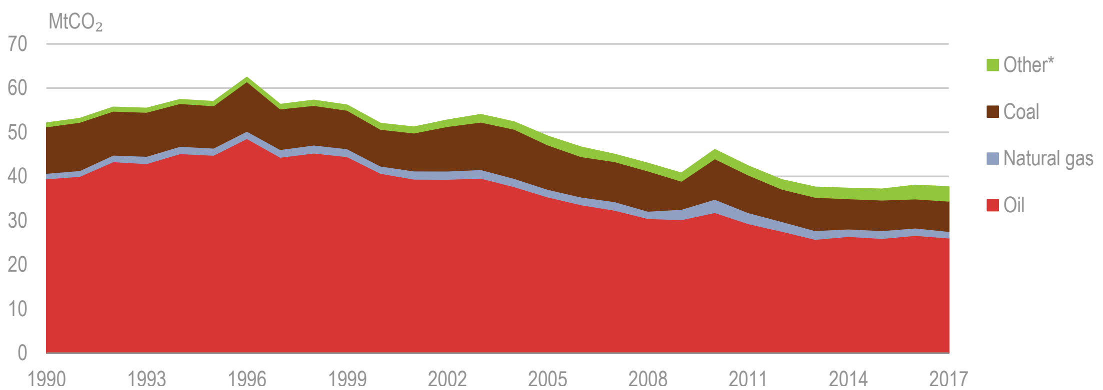
* *Other energy* includes emissions from oil refineries and coke ovens.

** *Industry* includes $CO_2$ emissions from combustion at construction and manufacturing industries. Emissions related to industry processes other than combustion are not included.

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

Source: IEA (2019a forthcoming), $CO_2$ Emissions from Fuel Combustion 2019 preliminary, www.iea.org/statistics/.

### Figure 3.3 Energy-related $CO_2$ emissions by source, 1990-2017




Oil emits most energy-related $CO_2$, as it dominates emissions from transport and industry.

* *Other* includes emissions from peat and non-renewable waste combustion.

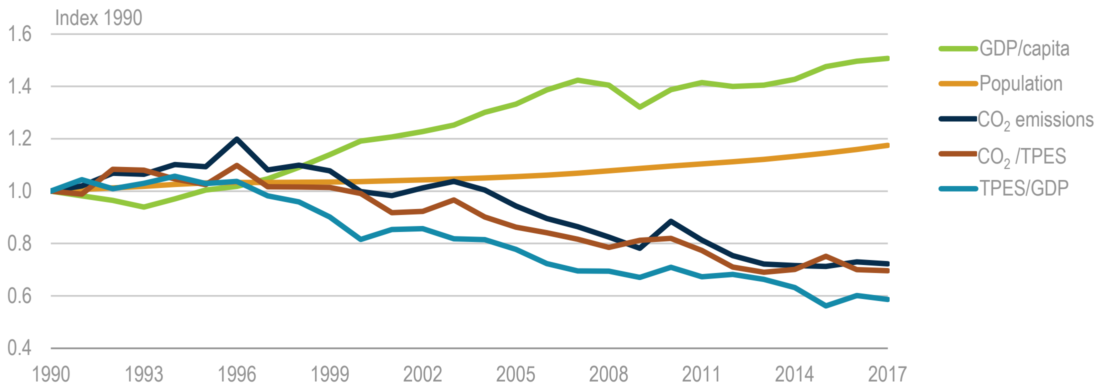
Source: IEA (2019a forthcoming), *$CO_2$ Emissions from Fuel Combustion 2019*, preliminary, www.iea.org/statistics/.

## $CO_2$ drivers and carbon intensity

Total $CO_2$ emissions in a country are related to the size of the population, economic development, energy intensity of the economy, and carbon intensity of the energy supply, as per the equation: $CO_2$ = population × GDP/capita × TPES/GDP × $CO_2$/TPES (GDP = gross domestic product, TPES = total primary energy supply).

Between 1990 and 2017, Sweden's GDP per capita increased by 51% and the population grew by 18%. Yet, Sweden managed to reduce its $CO_2$ emissions by 28%, owing to a 41% drop in energy intensity of the economy and a 30% drop in the carbon intensity of the energy supply (Figure 3.4).

### Figure 3.4 Energy-related $CO_2$ emissions and main drivers, 1990-2017

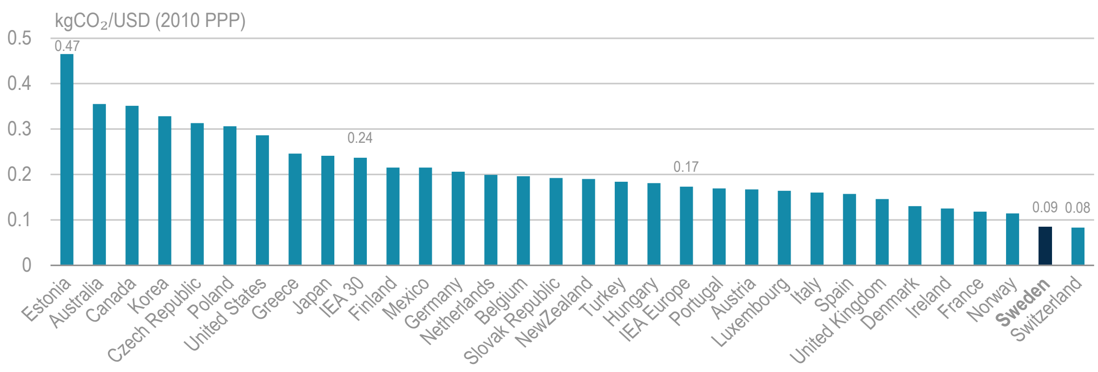



Despite large economic growth per capita, Sweden has managed to reduce its energy-related $CO_2$ emissions significantly.

Note: Real GDP in 2010 USD prices and purchasing power parity (PPP).
Source: IEA (2019a forthcoming), *$CO_2$ Emissions from Fuel Combustion 2019* preliminary, www.iea.org/statistics/.

In 2016, Sweden's carbon intensity was 85 grammes of carbon dioxide ($gCO_2$) per US dollar (USD) (2010 prices and PPP), the second lowest in the IEA after Switzerland (Figure 3.5). Sweden's carbon intensity was half the IEA Europe average of 173 $gCO_2$ per USD and much below the IEA average of 237 $gCO_2$ per USD. In terms of $CO_2$ emissions per capita, Sweden again ranks the second-lowest in the IEA, after Mexico.

### Figure 3.5 $CO_2$ intensity in IEA member countries, 2016




Sweden has the second-lowest $CO_2$ intensity in the IEA, after Switzerland.

Source: IEA (2019a forthcoming), *$CO_2$ Emissions from Fuel Combustion 2019* preliminary, www.iea.org/statistics/.

# Climate policy framework

## The EU climate framework

Sweden's climate change policy and measures to 2020 and 2030 are guided by EU legislation. Through the 2020 climate package and the 2030 climate framework, the European Union decided to reduce GHG emissions by 20% from 1990 to 2020 and by at least 40% from 1990 to 2030. Specific targets exist for the Emission Trading System (ETS) and the non-ETS sector.

The ETS is a cap-and-trade system for large power and heat plants [at least 20 megawatts thermal ($MW_{th}$)] and heavy industry. It covers around 45% of the European Union's total emissions. By law, the ETS sector must reduce emissions by 43% from 2005 to 2030 (EC, 2018a). This is an EU-wide target, without national sub-targets. The ETS sector emissions are thus mainly subject to the EU policy framework.

The non-ETS sector includes transport, residential and commercial sectors, non-ETS industry, agriculture, and waste management. The EU-level targets for GHG reductions in the non-ETS sectors are 10% from 2005 to 2020 and 30% from 2005 to 2030. Although the EU-ETS target applies to the European Union as a whole, the EU-level target for the non-ETS sector is translated into member states' national GHG emissions targets. The Swedish reduction targets are 17% by 2020 and 40% by 2030, compared to 2005 values (EC, 2018b). The EU regulation allows countries to use flexibility mechanisms to some extent, which include trading emission allowances between sectors and EU member states.

For 2050, the European Union has a climate roadmap, which states that the European Union should cut its domestic emissions to 80% below 1990 levels. The EU climate framework forms the basis for the collective commitment of EU countries under the 2015 Paris Agreement to reduce GHG emissions to at least 40% below 1990 levels by 2030.

## Sweden's new National Climate Framework

In 2017, the Swedish Parliament adopted the Climate Framework (Bill 2016/17:146) that contains three parts:

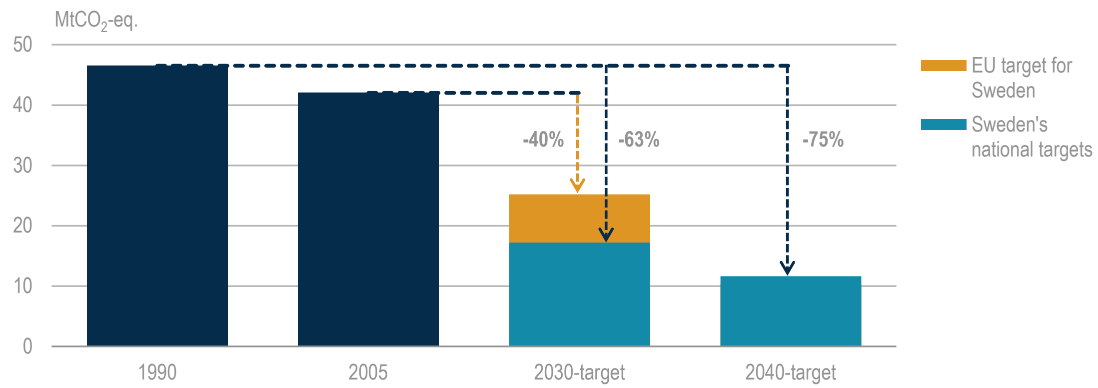
- National climate targets
- Climate Act
- Climate policy council.

### The climate targets

Sweden has set the target to have net-zero GHG emissions by 2045, followed by negative emissions. By zero-net emissions, Sweden aims to reduce domestic emissions by at least 85% from 1990 (excluding LULUCF). The remaining 15% could come from other measures, such as carbon capture and storage and emission reductions that occur outside Sweden undertaken via international projects or mechanisms. The 2045 target is more ambitious and due five years earlier than the EU roadmap target.

To achieve the 2045 target, Sweden has set sub-targets for 2030 and 2040. For the non-ETS emissions, Sweden's target is at least a 63% reduction from 1990 to 2030 and at least a 75% reduction from 1990 to 2040. Compared to 2005, this corresponds to reductions of 59% by 2030 and 72% by 2040 (Figure 3.6). The national target is thus more ambitious than the Swedish EU target of a 40% reduction by 2030. As a separate target, emissions from transport should be reduced by 70% from 2010 to 2030 (see Figure 3.9 below).

**Figure 3.6 Sweden's non-ETS GHG emissions and targets, 1990-2040**




Sweden has set more ambitious targets for non-ETS emission reductions by 2030 and 2040 than those imposed by the European Union.

Note: $MtCO_2$-eq = million tonnes of carbon dioxide equivalent.

Sources: SEPA (2018b), *Utsläpp av Växthusgaser i Icke-Handlande Sektorn* (*Emissions of Greenhouse Gases in the Non-Trading Sector*), www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser-utslapp-i-icke-handlande-sektorn/; EC (2018b), *Effort Sharing 2021-2030: Targets and Flexibilities*, https://ec.europa.eu/clima/policies/effort/proposal_en.

## *The Climate Act*

In January 2018, the parliament adopted the Climate Act (2017:720), which states four main points of Sweden's climate policy:

- Climate policy must be based on the climate goals.
- The government must present a climate report every year in its Budget Bill.
- Every four years, the government must draw up a Climate Policy Action Plan to describe how the climate goals are to be achieved.
- Climate policy goals and budget policy goals must be mutually consistent.

## *The Climate Policy Council*

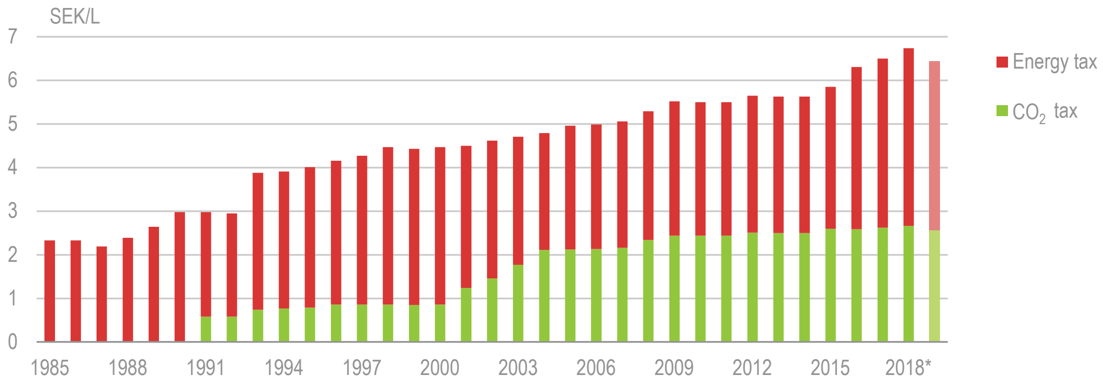
The third pillar of the Climate Framework is the Climate Policy Council, established in January 2018. It has eight members from different academic institutions, appointed by the government for a three-year period. Their task is to support the government by providing an annual independent assessment of how the overall policy is compatible with the climate targets. The Climate Policy Council can provide recommendations, but not legally binding instructions.

## Taxation on energy and $CO_2$

Sweden has a long history of energy taxation. Initially it was a fiscal tax to increase the state revenue, but it has become increasingly used to meet environmental objectives. In 1991, as one of the first countries in the world to do so, Sweden introduced a $CO_2$ tax on fossil fuels to complement the energy taxation. The energy and $CO_2$ taxations are fundamental for Sweden's climate policy and for the transition towards lower emissions across sectors.

The energy and $CO_2$ taxes work together to form a total tax level on fuel consumption. When the $CO_2$ tax was introduced, the energy tax on most fuels, e.g. gasoline, was reduced to avoid a sudden price spike for the consumer (Figure 3.7). Between 2000 and 2004, the government introduced a green tax reform programme and increased the $CO_2$ tax significantly, but reduced energy taxes to moderate the total tax increase. From 1994, the $CO_2$ tax was adjusted annually with inflation, and, from 2017, the government introduced an additional 2% annual increase to let taxes increase in line with economic growth (FORES, 2018). In the past four years, the total energy and $CO_2$ tax level was increased by 20%, mostly from higher energy taxes. On 1 July 2018, the energy and $CO_2$ taxes for gasoline and diesel were reduced as part of the introduction of the emission reduction obligation system (see Table 3.2 below).

**Figure 3.7 Energy and $CO_2$ taxes on gasoline, 1985-2018**




Since the introduction of the $CO_2$ tax in 1991, fossil fuel taxes have been more focused on emissions, and the tax level has increased rapidly in recent years.

* The new tax levels from July 2018 are indicated with the lighter coloured bars.

Note: SEK/L = Swedish kronor per litre.

Source: Swedish Tax Agency (2018a), *Skattesatser på Bränslen och El under 2018* (*Tax Levels for Fuels and Electricity 2018*), www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/skattesatserochvaxelkurser.4.77dbcb041438070e0395e96.html.

The Swedish $CO_2$ tax is by far the highest in the world at USD 140 per tonne of $CO_2$-equivalent ($tCO_2$-eq) in 2017 (World Bank, 2017). Switzerland has the second-highest, at USD 87/$tCO_2$-eq, followed by Liechtenstein, Finland, Norway, France and Denmark. With the exception of Finland, countries with the highest $CO_2$ taxation in the world have the lowest carbon-intensive economies (Figure 3.5).

Energy and $CO_2$ taxation in Sweden works across the sectors and increases the price for both transport and heating fuels. However, certain sectors receive tax reductions to help industries remain internationally competitive and avoid carbon leakage. These exemptions have been gradually limited. In 2018, the $CO_2$ tax reductions for heating fuels used in industries outside the European Emissions Trading System (EU-ETS) and the agriculture sector were removed completely. Reductions remain on the energy tax, and industry within the EU-ETS is exempted from the $CO_2$ tax (Table 3.1).

Among industries, diesel consumption in mining and for agriculture receives large tax reductions. Furthermore, a lower energy tax is levied on heat in all co-generation plants and, if part of the EU-ETS, a lower $CO_2$ tax is also applied. Other heat production within the EU-ETS also receives a certain $CO_2$ tax reduction. Solid and liquid biomass fuels used in heat generation are also exempt from both energy tax and $CO_2$ taxation, as are high-blend biofuels used for transport.

The $CO_2$ tax is considered to have contributed to reducing emissions in the residential and commercial sectors, and to slowing down the emission growth in transport (OECD, 2014). Furthermore, the $CO_2$ tax has greatly influenced the relative competitiveness of biofuels in district heating (DH) systems.

**Table 3.1 Reductions in energy and $CO_2$ taxation by sector, 2018**

| Sector | Energy tax reduction | $CO_2$ tax reduction |
|---|---|---|
| Manufacturing industries (heating) | 70% | - |
| Agriculture and forestry* (heating) | 70% | - |
| Mining industry | 89% (diesel), 70% (oil) | 40% (diesel), 0% (oil) |
| Co-generation – electricity** | 100% | 100% |
| Co-generation – heat, within EU-ETS** | 70% | 89% |
| Co-generation – heat, outside EU-ETS** | 70% | 0% |

* For diesel used in agriculture, forestry and aquaculture, the $CO_2$ tax is reduced by SEK 1.7/L.

** Only valid for co-generation plants with an efficiency of at least 15% electricity generated per fuel energy content.

Source: Swedish Tax Agency (2018b), *Verksamheter med Lägre Skatt* (*Sectors with Lower Taxation*), www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/verksamhetermedlagreskatt.4.15532c7b1442f256baebb93.html.

## *Climate investment support programme – Climate Leap*

In 2015, the Swedish government introduced Climate Leap (*Klimatklivet*), a subsidy programme to support local and regional infrastructure investments that reduce GHG emissions. The programme is administered by the Swedish Environmental Protection Agency (SEPA), which supports projects with the largest emissions reductions per invested SEK. The programme is thus intended to be technology neutral.

As of May 2018, Climate Leap has provided a total of SEK 3.2 billion (USD 0.37 billion) in funding for 1 900 projects, with a total project cost of SEK 7.2 billion. On average, Climate Leap provides 44% of the project cost. EV-charging stations account for most of the projects supported, whereas energy conversion projects and biogas production plants have received the largest total funding (SEPA, 2018c).

SEPA estimates that projects supported so far will save a total of 0.88 $MtCO_2$ per year during an average lifetime of 16 years (SEPA, 2018c). In 2018, the programme was extended so that SEPA can allocate funding for projects until 2023. The government has allocated SEK 1.5 billion for 2018, SEK 2 billion for 2019, and SEK 3 billion for 2020 (SEPA, 2018d).

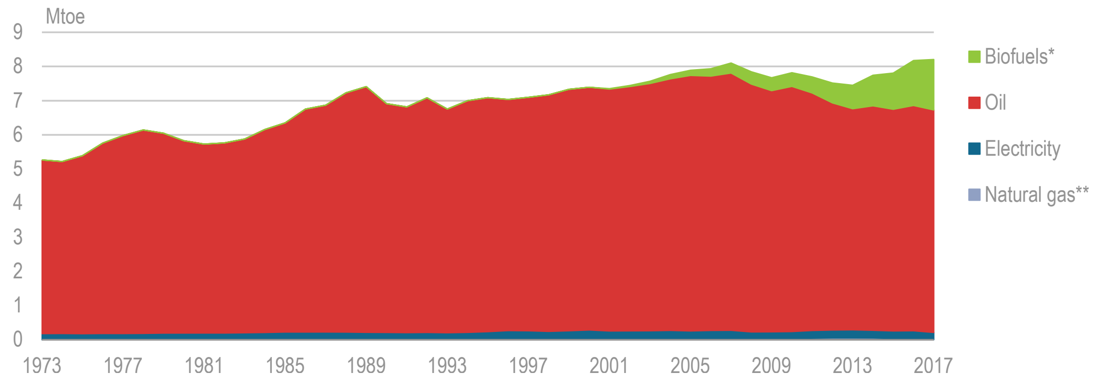
# Transport emissions and policies

Transport is the most important sector to be decarbonised in Sweden. In 2017, it accounted for less than one-quarter of the total final consumption (TFC) of energy, but over half of energy-related $CO_2$ emissions (Figure 3.2). Furthermore, a large share of the remaining energy-related emissions is from combustion in large heat and power plants and industries, which are included in the EU-ETS and regulated on the EU level. Among energy-related emissions outside of the EU-ETS, transport accounts for the vast majority. Transport emissions are therefore an important focus area for the Swedish government and are discussed in more detail in this review.

## *Energy consumption in transport*

In recent years, biofuels have rapidly increased and become a significant energy source in the sector (Figure 3.8). In 2017, biofuels accounted for 18% of the TFC in transport[1] (17% liquid biofuels and 1% biogas), after a fivefold increase in ten years. This is by far the highest share among IEA member countries, over twice as high as in Norway, in second place. Sweden has already reached its 2020 target of 10% renewable energy in the transport sector by a large margin. As a result of the rapid growth in biofuels, oil consumption in the Swedish transport sector declined by 12% in 2006-16, despite a 3% increase in the overall transport energy demand.

**Figure 3.8 TFC in transport, 1973-2017**




Biofuels have increased rapidly and are replacing oil in the transport sector. In 2017, biofuels accounted for 18% of the energy demand in the sector.

* *Biofuels* includes liquid biofuels and biogas.

** Negligible.

Note: Mtoe = million tonnes of oil equivalent.

Source: IEA (2019b forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

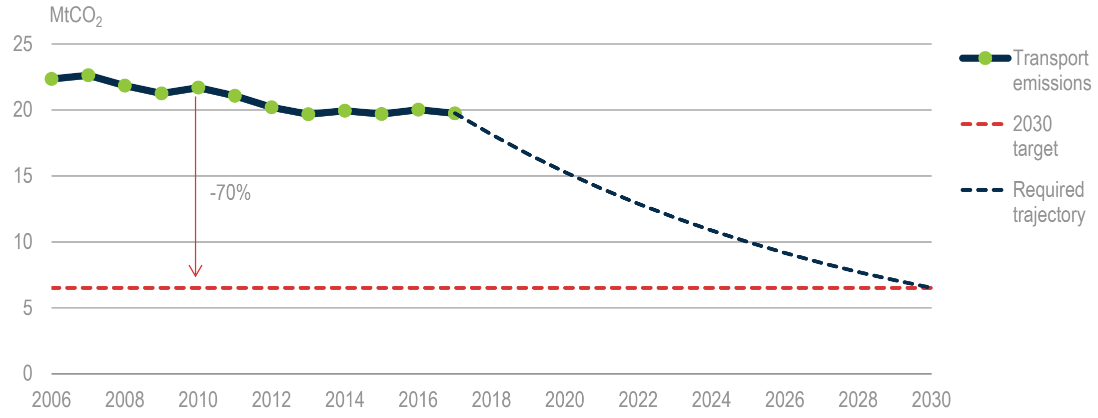
The growth in biofuels was initially bioethanol, supported by the "Pump Act" that obligates large filling stations to offer at least one pump with a biofuel option (Box 3.1). In recent years, biodiesel has become the main biofuel in road transport through a rapid growth in hydrogenated vegetable oil (HVO). Unlike bioethanol, which requires specific car engines, HVO can replace normal diesel without any modifications to the car or the infrastructure.

[1] Not including double counting methods used in the European Union Renewable Energy Directive.

The decrease in oil consumption has reduced $CO_2$ emissions in the transport sector. From 2010 to 2017, emissions fell by 9%, from 21.7 $MtCO_2$ to 19.7 $MtCO_2$. However, despite the positive trend, Sweden is not on a path to meet its ambitious 2030 target to reduce emissions in the sector by 70% in the period from 2010 to 2030 (Figure 3.9).

Domestic biofuel production has not kept up with the growth in consumption. In 2017, biodiesel imports accounted for 75% of all liquid biofuels used in transport. This has implications for the long-term security of supply for energy in the sector (Chapter 9).

**Figure 3.9 Transport emissions 2006-17 and target for 2030**



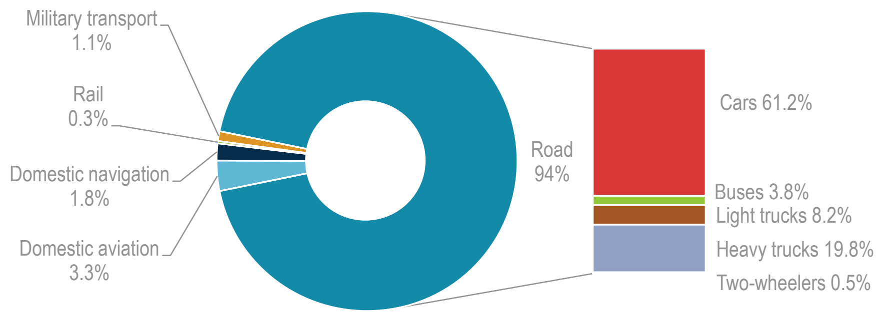

The recent increase in biofuels has reduced $CO_2$ emissions from the transport sector, but Sweden is not yet on a path to meet its 2030 target.

Source: IEA (2019a forthcoming), *$CO_2$ Emissions from Fuel Combustion 2019*, preliminary edition, www.iea.org/statistics/.

## *Policies introduced to reduce emissions from road transport*

Road transport dominates the TFC and $CO_2$ emissions in the transport sector. In 2016, road transport accounted for 94% of the total transport GHG emissions, of which cars represented the largest share, followed by heavy trucks (Figure 3.10).

**Figure 3.10 Breakdown of GHG emissions from transport by subsector, 2016**




Road transport accounts for 94% of the domestic transport emissions, and cars represent the largest share of this.

Source: SCB (2018a), *Emissions of Greenhouse Gases from Domestic Transport by Greenhouse Gas and Mode of Transport. Year 1990-2016*, www.statistikdatabasen.scb.se/pxweb/en/ssd/START__MI__MI0107/MI0107InTransp/?rxid=41602454-af45-48f1-9e6d-e31227ac940d.

In 2017, the government introduced several policies to reduce GHG emissions from the transport sector, with the main focus on light-duty vehicles (cars and light trucks). The most important new policies are an emission-reduction obligation to increase the share of biofuels and a bonus-malus system to incentivise purchases of low-emission vehicles. Both were introduced in July 2018. Furthermore, in the January Agreement from 2019, the government has set the objective to ban sales of new fossil fuel cars by 2030.

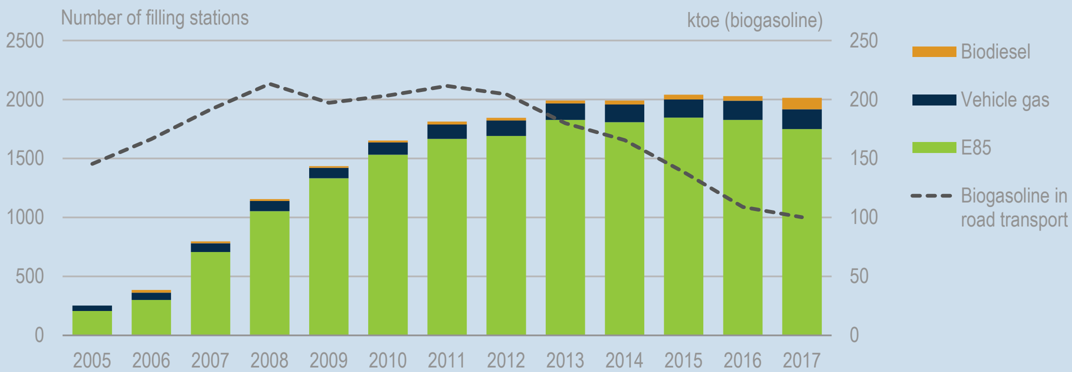
### Box 3.1 The Swedish Pump Act

In December 2005, the parliament adopted the Pump Act (2005:1248), which obliged all large filling stations to supply at least one renewable fuel. The objective was to improve the availability of renewable fuels and thereby remove a major obstacle to reducing $CO_2$ emissions in the transport sector.

By not promoting any specific fuel, the Pump Act was intended to be technology neutral. In practice, the act has resulted mostly in installations of pumps that provide ethanol (E85), which has been the cheapest option for the station owner. By the end of 2017, there were 1 749 filling stations for E85, which represented 87% of the total biofuel filling stations (Figure 3.9). The rapid growth in HVO consumption is not represented by an increase in biodiesel filling stations since the HVO is mostly blended into regular diesel fuel.

The Pump Act succeeded in increasing the availability of biofuels at Swedish filling stations. However, this does not guarantee that consumers use renewable fuels. Ethanol cars can drive on either E85 or regular gasoline, and consumption of biogasoline has declined in recent years despite the high availability of E85 fuelling stations (Figure 3.11). Fulfilling the obligation in the Pump Act has also led to extra costs for the station owner.

#### Figure 3.11 Filling stations for renewable transport fuels, 2005-17




The Pump Act successfully increased the number of biofuel filling stations in Sweden, but not a guaranteed growth in biofuel consumption.

Note: ktoe = kilotonnes of oil equivalent.

Sources: SPBI (2018a), "*Försäljningsställen med Förnybara Drivmedel*" [Filling Stations with Renewable Fuels], http://spbi.se/statistik/forsaljningsstallen/forsaljningsstallen-med-fornybara-drivmedel/; Swedish Parliament (2009), *The Act on the Obligation to Supply Renewable Fuels – A Follow-Up Report*, www.riksdagen.se/globalassets/06.-utskotten--eu-namnden/trafikutskottet/tu-uppfoljning/summary-a-follow-up-of-the-act-on-the-obligation-to-supply-renewable-fuels.pdf; IEA (2019b forthcoming), *World Energy Balances 2019 preliminary edition* (database), www.iea.org/statistics/.

### *Emission reduction obligation*

From July 2018, suppliers of gasoline and diesel are obliged to reduce $CO_2$ emissions through increased biofuel blending. The indicative target is to reduce the total GHG emissions from the use of diesel and gasoline in vehicles by at least 40% by 2030, which equals a share of biofuels of about 50%.

The emission reductions from diesel and gasoline vehicles that are required to reach the 2030 target depends on other changes to the transport sector, such as how fast the EV market grows. Therefore, the exact quota levels up to 2030 are not decided. Initially, the blending obligation is a 19.3% reduction of emissions by blending biodiesel in diesel fuel and a 2.6% reduction of emissions by blending ethanol (or other biofuel) in gasoline, which, in volumes, roughly equals 25% biodiesel in diesel and 5% ethanol in gasoline.[2]

Since the introduction of the emission-reduction obligation scheme, biofuels that are blended with gasoline and diesel are levied with the same energy and $CO_2$ tax per litre as the fossil parts of the fuels. To avoid rapid increases in consumer prices due to the reform, the emission reduction obligation is complemented by reduced energy and $CO_2$ taxes on fossil fuels (Table 3.2). These tax reductions should compensate for the increased costs of supplying more biofuels in the fuel mix.

**Table 3.2 Energy and $CO_2$ taxes by fuel, January and July 2018 (SEK/L)**

| Fuel | January 2018 | | July 2018 | | Change | |
|---|---|---|---|---|---|---|
| | Energy tax | $CO_2$ tax | Energy tax | $CO_2$ tax | Energy tax | $CO_2$ tax |
| Gasoline | 4.08 | 2.66 | 3.87 | 2.57 | -0.31 | -0.09 |
| Diesel | 2.65 | 3.29 | 2.34 | 2.19 | -0.31 | -1.10 |

Sources: Swedish Tax Agency (2018a), *Skattesatser på Bränslen och El under 2018* [Tax Levels for Fuels and Electricity 2018], www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/skattesatserochvaxelkurser.4.77dbcb041438070e0395e96.html; Swedish Tax Agency (2018b *Verksamheter med Lägre Skatt* (*Sectors with Lower Taxation*), www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/nyheter/2018/nyheter/nyaskattesatsernaforbensinochdieselfranden1juli2018.5.41f1c61d16193087d7fd1f3.html.

### *The bonus-malus system ("feebate") within light-vehicle taxation*

Sweden has used vehicle taxation to promote low-emission vehicles for many years, and the government considers it an important complement to fuel taxation. Cars of model year 2006 or later and other light-duty vehicles from 2010 or later are subject to carbon-based vehicle taxation. Other vehicles are subject to weight-based vehicle taxation.

In the carbon-based system, the annual vehicle tax consists of a basic rate of SEK 360 plus a part based on $CO_2$ emissions. The $CO_2$ part of the vehicle tax is SEK 22 for each gramme of $CO_2$ emitted above 111 grammes of carbon dioxide per kilometre ($gCO_2/km$) a vehicle emits at mixed driving. For diesel cars, this sum is multiplied by 2.37 (fuel factor) to compensate for a lower energy tax on diesel than on gasoline. Diesel cars registered for the first time in 2008 or later pay an additional SEK 250 (cars registered

[2] The reduction levels are set as a reduction of GHG emissions compared to using fossil gasoline or diesel, not as specific volumes of biofuels. The fuel supplier can choose between blending in larger volumes of a biofuel with low emission reductions or smaller volumes of a biofuel with large emission reductions.

before 2008 pay SEK 500). For vehicles that can be powered by ethanol or gas other than liquefied petroleum gases (LPGs), the $CO_2$ part of the tax is SEK 11 per gramme emitted above 111 $gCO_2$/km.

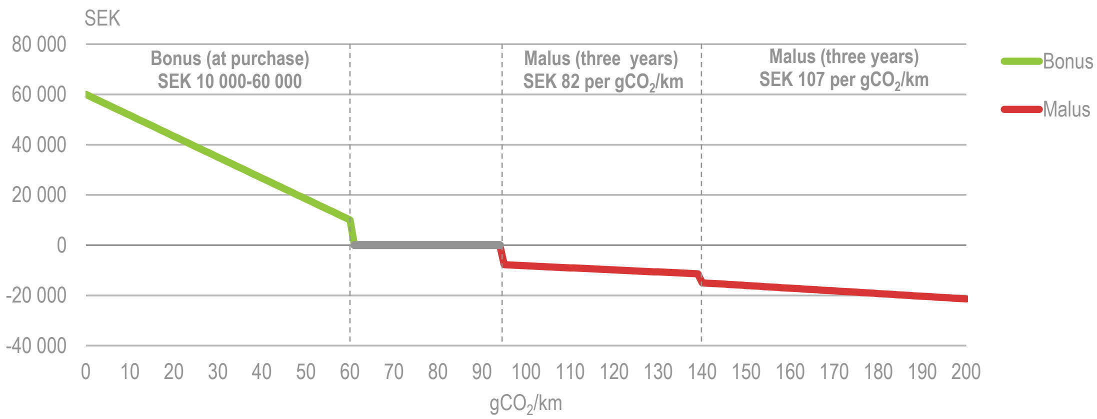
In July 2018, the government introduced a bonus-malus system (sometimes referred to as a “feebate”) for new light-duty vehicles. Vehicles with low $CO_2$ emissions qualify for a bonus at purchase, whereas vehicles with high emissions are taxed at a higher rate for the first three years. The system is replacing the previous five-year exemption from annual vehicle tax and the super-green car rebate for low-emission vehicles. “New vehicles” refers to vehicles of model year 2018 or later that have become subject to taxation for the first time on 1 July 2018 or later. Light-duty vehicles are passenger cars (class I and II), and buses and trucks with a maximum weight of 3 500 kilogrammes. The system does not cover motor cycles.

Vehicles with low emissions of $CO_2$ qualify for a bonus at purchase. Vehicles that emit zero $CO_2$, such as pure EVs, qualify for the maximum bonus of SEK 60 000. Vehicles that emit a maximum of 60 $gCO_2$ qualify for the minimum bonus of SEK 10 000. Vehicles using gas qualify for a bonus of SEK 10 000 (Figure 3.12).

Vehicles with high emissions of $CO_2$ are subject to an increase in vehicle tax (malus) during the first three years. For gasoline and diesel vehicles, the increased $CO_2$ amount is SEK 82 per $gCO_2$/km at mixed driving above 95 grammes and SEK 107 per $gCO_2$/km above 140 grammes (Figure 3.12). From year four and beyond, the $CO_2$ tax is back at SEK 22 per $gCO_2$/km above 111 grammes.

Vehicles that can be powered by ethanol or gas other than LPG are not subject to increased taxation, which means that these vehicles have a $CO_2$ tax of SEK 11 per $gCO_2$/km above 111 grammes, for all the years they are in service. The vehicle tax for diesel-powered vehicles in the bonus-malus system is adjusted by converting the current fuel factor into a fuel surcharge.

**Figure 3.12 Subsidies and fees in the bonus-malus system per emission level**



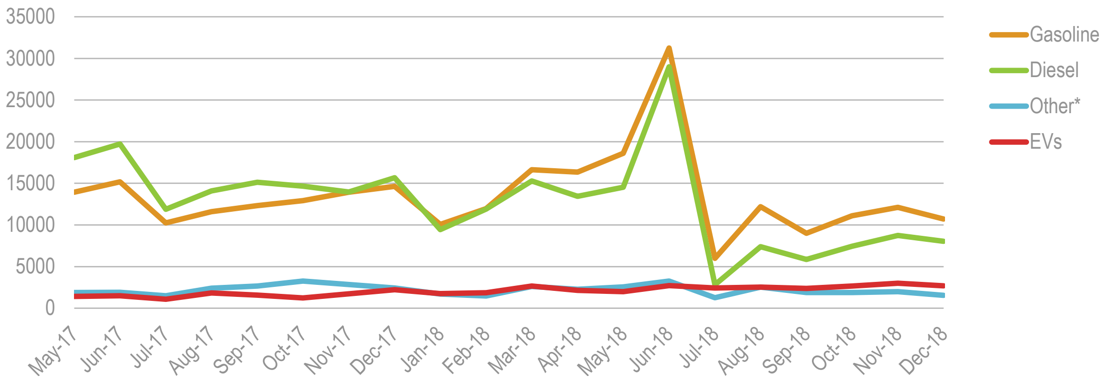

The bonus-malus system provides a purchase subsidy for vehicles with low emissions and an increased $CO_2$ fee for high-emission vehicles.

Note: The malus fee is calculated as the total additional vehicle taxation under three years.

Source: Analysis based on STA (2018), *Bonus-Malus System för Personbilar, Lätta Lastbilar och Lätta Bussar* (*Bonus-Malus System for Cars, Light Trucks and Light Buses*), www.transportstyrelsen.se/bonusmalus.

A short-term effect of the bonus-malus system is visible in recent sales figures for Swedish cars. In June 2018, the month before the policy was implemented, the sales of gasoline and diesel cars roughly doubled (Figure 3.13). After the introduction of the new taxation, overall car sales plummeted in July. Electric vehicles (EVs), supported by the bonus system, are on an increasing trend; EV sales in the fourth quarter 2018 were 60% above the same period 2017. However, it is yet premature to evaluate the long-term effects of the bonus-malus system on the Swedish vehicle fleet.

**Figure 3.13 Monthly car registrations per engine type, May 2017 to Dec 2018**




The new bonus-malus system strongly impacted new car sales in the months before and after the introduction.

* *Others* includes biofuel vehicles and hybrids other than plug-in hybrids.

Source: Bil Sweden (2018), *Nyregistreringar* (*New Car Registrations*), www.bilsweden.se/statistik/nyregistreringar.

## National transport infrastructure plan 2018-29

Every four years, Sweden updates its national transport infrastructure plan for the next twelve years. In June 2018, the government presented the new infrastructure plan for the years 2018-29. The total budget is SEK 622.5 billion, around 20% more than in the previous plan for the period 2014-25. The allocated state budget is complemented with an additional SEK 90 billion collected from congestion taxes, railway fees and sponsors (Ministry for Enterprise and Innovation, 2018).

Maintenance of the existing infrastructure receives nearly half of the state transport budget: 26% for road maintenance and 20% for railways. The rest of the budget is for developing new transport systems, which includes high-speed railways. Furthermore, as part of the plan, the Swedish Transport Administration (STA) provides SEK 1 billion per year to the Urban Environment Agreements for investments in public transport and cycling infrastructures at the regional and local level. The budget also includes SEK 8 billion for research and development.

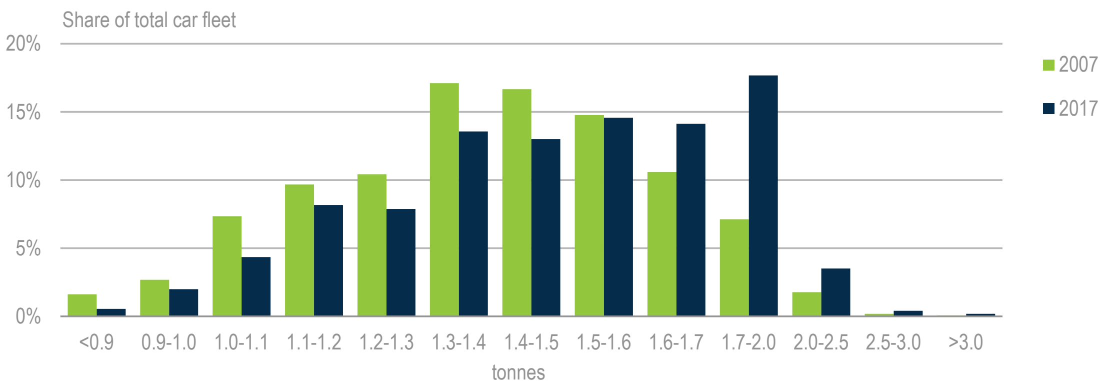
## Energy efficiency in transport

Increased energy efficiency can provide emission reductions in the transport sector and complement the effects from fuel switching. A modal shift from cars to public transportation is one way to improve the overall energy efficiency in transport. Sweden supports investments in the public transport and cycling infrastructure at the regional and local level through the Urban Environment Agreements. For 2018-20, the government also allocated SEK 150 million to stimulate the transfer of freight transport by road to transport by shipping in an Ecobonus system.

Congestion charges and regulations can also encourage a modal shift. The cities of Stockholm and Gothenburg introduced congestion fees in the city centres, which give an economic incentive to switch from cars to alternative transportation. Furthermore, in a decision taken in 2018, the government permits cities to introduce environmental zones in city centres from 2020. This can restrict the use of cars and trucks with high emissions, especially diesel vehicles, in cities.

Besides a modal shift, cars are also becoming more fuel-efficient, thanks to stricter emission requirements set by the EU fuel economy standards. However, improvements in vehicle efficiency are partly offset by an increase of heavy cars in the vehicle fleet (Figure 3.14). In 2017, 22% of cars weighed above 1.7 tonnes, compared to 9% in 2007. Current vehicle taxation, based on the vehicle's $CO_2$ emissions per kilometre driven, and fuel taxation provide incentives to buy cars that are more fuel-efficient. Despite this, the Swedish consumers seem to prefer heavier vehicles.

**Figure 3.14 Car fleet by weight, 2007 and 2017**




Swedish consumers buy increasingly heavier cars, which partly offsets the energy efficiency improvements and emission reductions of new cars.

Source: SCB (2018b), *Registered Vehicles*, www.scb.se/en/finding-statistics/statistics-by-subject-area/transport-and-communications/road-traffic/registered-vehicles/.

# Electromobility

Sweden has a largely decarbonised electricity system, with more than 97% of power generation from renewable energy sources and nuclear (Chapter 7). Electrification of the vehicle fleet is therefore an important step to reach the 2030 target for emission reductions in the transport sector, as well as the long-term climate target for 2045.

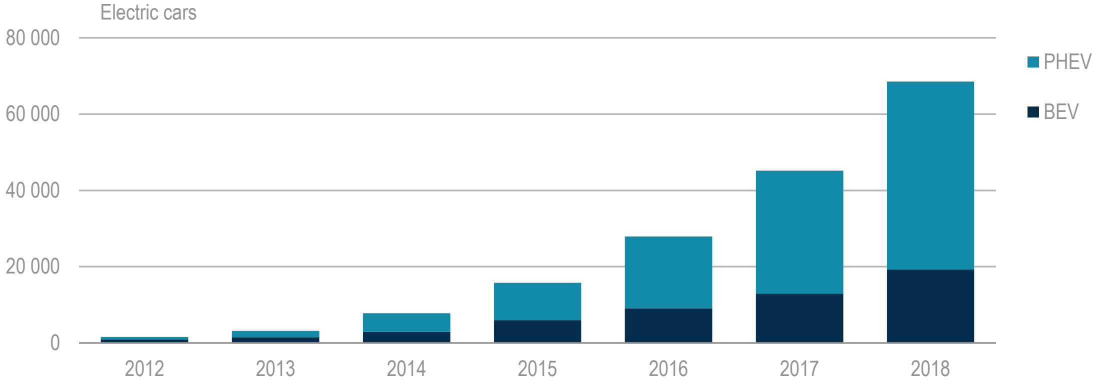
## *EV market*

The sales of EVs in Sweden increased from around 1 000 vehicles in 2012 to over 23 000 in 2018. Sweden has the third highest market share for EVs in the world after Norway and Iceland (IEA, 2018c). In 2018, EVs accounted for around 8% of all new car sales in Sweden (Bil Sweden, 2018), and the EV fleet totalled close to 70 000 vehicles (Figure 3.15). Plug-in hybrid vehicles (PHEV) account for 72% of all EVs and the rest is BEVs, including electric light trucks.

EV sales were previously supported through the Super-Green Car Premium for low-emission vehicles. It provided a subsidy of SEK 40 000 for BEVs and SEK 20 000 for PHEVs. As of July 2018, the premium was replaced by the bonus-malus system, which provides a stronger incentive, with up to SEK 60 000 for BEV purchases.

Sweden has not set any specific targets for growth in EVs. However, based on the current trend and the climate target for the transport sector, EV sales are expected to continue to increase significantly, and could reach around 1.5 million electric cars by 2030 (IEA, 2018). That would represent close to a third of the total car fleet in 2017 (Bil Sweden, 2018) and significantly contribute to the emission reduction target. However, reaching 70% emission reductions will require further measures.

**Figure 3.15 The Swedish EV fleet, 2012-18**




The EV fleet has grown rapidly to nearly 70 000 by the end of 2018, of which 72% were plug-in hybrid vehicles.

Source: Power Circle (2019), *Elbilsstatistik*, www.elbilsstatistik.se/elbilsstatistik.

## *EV infrastructure and charging*

Most EVs are charged overnight when parked at home or when parked at the office, using charging in a normal power outlet (up to 3.7 kW charging speed) or with a charging box (<22 kW). In 2018, the government introduced a subsidy for home chargers, with a total annual budget of SEK 90 million during 2018-20. The subsidy covers up to 50% of the cost of installing home charging equipment, up to SEK 10 000.

To enable long trips with EVs, a public charging infrastructure with faster charging is required. In 2017, Sweden had around 4 000 public chargers, or just above 12 EVs per charger (IEA, 2018c). This is close to the ten EVs per public charger recommended in the EU directive on alternative fuels infrastructures. The government has not defined a target or strategy for the deployment of EV chargers. However, investment support is provided for the public charging infrastructure through the Climate Leap programme.

As of May 2018, 1 200 EV charger projects had received funding through the Climate Leap programme, with a total support of SEK 287 million (SEPA, 2018c). Funding was provided to different actors, which included municipalities, housing associations, energy companies and other commercial actors, such as hotels. The largest power companies are also investing in public EV charges on a commercial basis without support, mostly along the main transport routes.

### *Other types of electrified transport*

In 2018, the government introduced an Electric Vehicle Premium to promote commuting with electric two-wheel vehicles. The support covers up to 25% – or maximum of SEK 10 000 – of the price when buying an electric bike, scooter or motorcycle. In April 2018, the government proposed to provide the premium also to electric boat engines. The total budget for the premium is SEK 395 million per year for 2018-20. As of 4 September 2018, 85% of the budget for 2018 had been used (SEPA, 2018e).

Since 2016, regional public transport agencies may apply for an electric bus premium for buses used in public transportation. The size of the premium depends on the number of passengers and on whether the bus runs on electricity only or is a hybrid. The government allocated a budget of SEK 350 million for 2016-19.

Sweden is also active in research, development and demonstration (RD&D) of future transport solutions, including pilot projects on electrified roads (Box 3.2). On an electrified road, EVs can be charged while driving, which also enables heavy EVs, e.g. trucks, to cover long distances without stopping to charge.

**Box 3.2 Electric roads in Sweden**

The STA, the Swedish Energy Agency and Vinnova (Sweden's innovation agency) established a programme to test and demonstrate electrified roads, and initiated two demonstration projects:

- In 2016, the world first electrified road for commercial traffic was opened in Gävleborg. Electric lines above the road allow electric trucks to charge using a pole on the roof.
- In 2018, a new electrified road outside Arlanda airport was opened. This road uses charging via lines in the road, which could also allow regular cars to charge.

In 2017, the STA presented a roadmap to develop electric roads. This includes a further one or two demonstration projects to test other technologies, e.g. inductive charging. The next stage is a larger pilot project to test a complete concept, which includes payment methods, etc. on a number of roads of 20-30 kilometres. After the pilot project, the STA will develop a long-term plan for electric roads in Sweden.

Source: STA (2017), *Nationell Färdplan för Elvägar* (*National Roadmap For Electric Roads*), www.trafikverket.se/contentassets/b1c845c023e04a3fb61280d072e832cc/nationell-fardplan-for-elvagar_slutlig.pdf.

## Assessment

From 1990 to 2016, Sweden's GHG emissions (excluding LULUCF) decreased by 25% to 54 Mt $CO_2$-eq. The government expects emissions to continue to decline. However, in recent years, the reductions in energy-related emissions have stalled, which indicates a change in the decreasing trend. Since 2013, emissions have increased slightly, mainly in heat and power generation, oil refineries and coke ovens. Energy-related $CO_2$ emissions account for nearly three-quarters of the total GHG emissions and the transport sector accounts for around half of the energy-related $CO_2$ emissions.

In 2017, the government decided on a new climate framework that contained a Climate Law, emission targets and a Climate Policy Council. The Climate Law states that the policy of the government shall be based on the overall climate target and the Climate Policy Council will assess the government's climate policy against the climate goals and advise the government. The climate framework was developed in a broad political agreement, which enables long-term stability in the work towards the targets.

In the new framework, Sweden's goal is to have zero-net emissions by 2045, with intermediate targets for non-EU-ETS emissions to be at least 63% lower by 2030 than in 1990, and at least 75% lower by 2040. With these ambitious targets, which go beyond its international obligations, Sweden sets an example for other countries to follow. The zero net-emission target requires an 85% reduction in domestic emissions compared to 1990 (excluding LULUCF) and allows alternative measures to cover the rest.

Following the adoption of the climate framework, the government should now start preparing for the Climate Policy Action Plan. This work should include overall strategies and national emission scenarios and pathways for how to reach the targets. To engage other important stakeholders, the government should collaborate with industry, academia and civil society and create a shared vision towards the long-term targets.

## Strong $CO_2$ taxation drives de-carbonisation

Sweden was one of the first countries to introduce a $CO_2$ tax on fuels, and it has the highest level of $CO_2$ taxation in the world. Since its introduction in 1991, the $CO_2$ tax has increased from 0.25 SEK/kg to 1.15 SEK/kg in 2018 (around USD 140/tonne). It has provided economic incentives for Sweden's energy transformation from fossil fuels to alternative energy sources across sectors such as households, heat and power generation, and transport. However, some sectors benefit from tax exemptions, which may lead to missed opportunities for cost-effective emission reductions.

Sweden sets an example for how to combine high $CO_2$ taxation with steady economic growth. The IEA applauds this and encourages the government to continue to use effective carbon pricing and to review the remaining tax reductions, e.g. for the mining industry. Tax exemptions can have the effect that some cheap abatement options are missed. All tax exemptions that are not necessary for avoiding carbon leakage should be gradually phased out.

Taxation alone will not be enough to drive investments in renewable energy and other new technologies at the rate necessary to reach the climate targets. The Climate Leap investment programme provides a good complement to taxation in supporting investments that lead to emission reductions. To ensure the cost-efficiency of the programme, the government should regularly monitor how the funding is used and assess the climate impact of the subsidised investments.

## Transport emissions in focus for new targets and policy

Decarbonisation of the transport sector is crucial if Sweden is to meet its climate objectives. In 2017, transport accounted for less than one-quarter of Sweden's final energy consumption, but for over half of energy-related $CO_2$ emissions. The government has now set the ambitious target to reduce emissions from domestic transport by 70% from 2010 to 2030. The proposed ban on sales of new fossil fuel cars after 2030 will further drive emissions reductions in the longer term.

Sweden has already reached its 2020 target of 10% renewable energy in the transport sector thanks to a rapid increase in biofuels, supported by energy and $CO_2$ tax exemptions. However, the country is not yet on track to meet the 2030 target, and the government has introduced several additional policies and measures to tackle transport emissions further. The most important new policies are the Emission Reduction Obligation system and the bonus-malus system for new light-duty vehicles, both introduced in July 2018.

Initial results show that the increase of the vehicle tax had an immediate impact on car sales in Sweden, with falling sales in gasoline and diesel cars. However, the government needs to monitor the long-term effect on the vehicle fleet transition and review the policy design to ensure its effectiveness and avoid any unintended negative effects.

The Emission Reduction Obligation will ensure further growth in biofuels. It is more effective than the Pump Act, which imposed costs for filling stations without guaranteeing an increased uptake of renewable fuels. The government should closely monitor the fuel prices and growth in biofuels, and continue to align the emission reduction requirements with other policies, including taxation and the bonus-malus system.

The government also subsidises the purchases of electric buses, electric bikes, scooters and boat engines. Such investment support can be useful to speed up the transition towards a sustainable transport sector, but deviates from Sweden's usual market-based policy approach. The government should closely monitor the results of the new policies to ensure that emissions are reduced in a cost-effective manner. Furthermore, electrified transport can provide multiple benefits, such as lower particle emissions and noise levels, which should be taken into account.

## *Electric vehicles require new infrastructure*

Electrification of transport suits well with the largely decarbonised electricity production in Sweden. In 2017, EVs accounted for 6.3% of new car sales, one of the highest shares in the world. Further growth of the EV market requires a new infrastructure of chargers. Most EV charging is done at home, and the government has introduced an investment subsidy to support home charger installations.

To enable longer trips and to increase consumer trust in EVs, a public charging infrastructure is also required. Investments in public chargers are supported by the Climate Leap fund, and the number of public charging points is growing. These investment subsidies could help accelerate EV adoption, but the government should assess the cost-effectiveness and focus the support on investments that would not take place without the support.

Utilities and other companies are investing in public EV chargers to offer charging as a new business. Market-based investments tend to focus on commercially attractive areas in cities and along main routes. To reach rural areas as well, municipalities and other public actors play an important role. Regional co-ordination and state oversight are needed to ensure that investments in EV infrastructure are sufficient and have a broad reach. Furthermore, as the number of EVs grows, charging will have an impact on the electricity distribution system. This increases the importance of co-ordinating the infrastructure together with stakeholders on the electricity market, e.g. distribution system operators.

## *Sweden should keep a broad approach to transport policy*

New trends in the transport sector include vehicle sharing, automation and electrification. It is important to understand what these trends mean for the transport sector as a whole and utilise the new possibilities that emerge. To reduce emissions significantly from the transport sector, policies must be broad and influence the vehicles, the fuels and the consumer behaviour. The government should aim to both reduce energy demand in transport and support cleaner transport solutions and innovations.

Public transportation and modal shifts help reduce energy demand in transport. The government should continue to support public transportation and the cycling infrastructure, and more attention should be given to solutions that improve the connection between public transportation and other transport modes. Environmental zones and congestion charges also provide incentives for modal shifts in cities. In addition, congestion charging can be expanded to facilitate a transition from the taxation of fuel to the taxation of distances driven, as the revenue from fuel taxation declines with the increase in electric mobility.

Heavy trucks used for freight account for one-fifth of total GHG emissions in transport. The bonus-malus system only affects light-duty vehicles; an expansion to include heavy-duty vehicles also should be considered. Furthermore, a shift from road to rail or sea can significantly reduce energy consumption and emissions from freight. The government should continue to support such a shift and prioritise efficient transport modes in future transport infrastructure plans.

Energy efficiency should be promoted to complement emissions reductions. Heavier cars use more fuel and produce more noise and particle emissions, which is a particular issue in cities. The current tax regime for vehicles and fuels incentivises buying cars that are more fuel-efficient. Nevertheless, the Swedish car fleet is getting heavier, and the government could consider further measures to stop this trend.

Innovation is a central component in effectively addressing the long-term climate change challenge. Sweden is already active in many RD&D projects for sustainable transport, which include electrified roads. The allocated budget in the National Infrastructure Plan is a good step, but further resources may be required. The government should continue to incentivise RD&D and collaborate with academia and industry to capture new ideas and benefit from technology development.

# Recommendations

***The government of Sweden should:***

- ☐ Develop a shared vision and pathways to 2045 with academia, industry and civil society to guide the preparation of the Climate Policy Action Plan.
- ☐ Continue to use $CO_2$ taxes as a proven, accepted way to limit $CO_2$ emissions, and consider removing the remaining tax exemptions.
- ☐ To decarbonise the transport sector:

- Monitor progress on all new transport-related policies, and adjust these where needed to ensure a cost-effective transformation in line with the 2030 target.
- Together with regions and municipalities, develop a strategy to charge-infrastructure deployment that supports a continued rapid growth in the EV market without compromising the stability of the electricity system.
- Maintain a broad perspective on the transport sector and continue to support public transportation and other alternatives to private cars, e.g. bicycle routes and a modal shift, as well as innovative RD&D projects.
- Consider promoting energy-efficient passenger cars further through taxation, in co-ordination with the increased $CO_2$ tax under the bonus-malus system.
- Continue to support a shift in freight transport from trucks to alternatives with lower emissions, e.g. trains and shipping.

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# 4. Energy efficiency

## Key data

(2017)

**Total final consumption (TFC)**: 33.5 Mtoe (electricity 32.7%, oil 29.5%, bioenergy and waste 20.3%, heat 13.1%, natural gas 2.4%, coal 2.1%), -2.6% since 2007

**Consumption by sector**: industry 39.9%, transport 24.5%, residential 22.4%, commercial 13.1%

**Energy consumption (TFC) per capita**: 3.3 toe (IEA average 2.9 toe), -11.4% since 2007

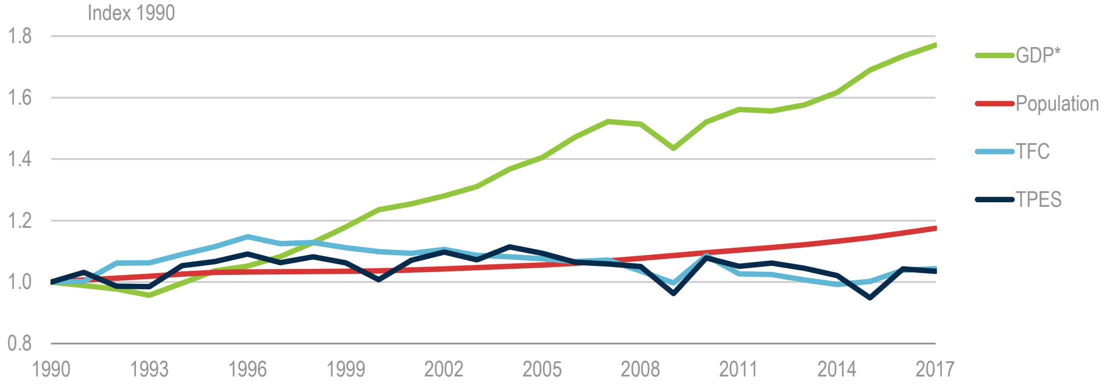
**Energy intensity (TFC/GDP)**: 73.7 toe/USD million PPP (IEA average 76.3 toe/USD million), -16.3% since 2007

**Exchange rates:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Overview

Energy efficiency has been high on the policy agenda in Sweden for many years, with targets on reducing the energy intensity of the country. In recent decades, the total final consumption (TFC) increased only marginally, despite a significant growth in the gross domestic product (GDP) and population (Figure 4.1). Further improvements are possible, and Sweden is now developing strategies for energy efficiency across sectors.

### Figure 4.1 Energy demand and drivers, 1990-2017




Sweden's energy consumption has increased only marginally since 1990, despite a population growth of 18% and a GDP growth of 77%.

* GDP in US dollar (USD) 2010 prices.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

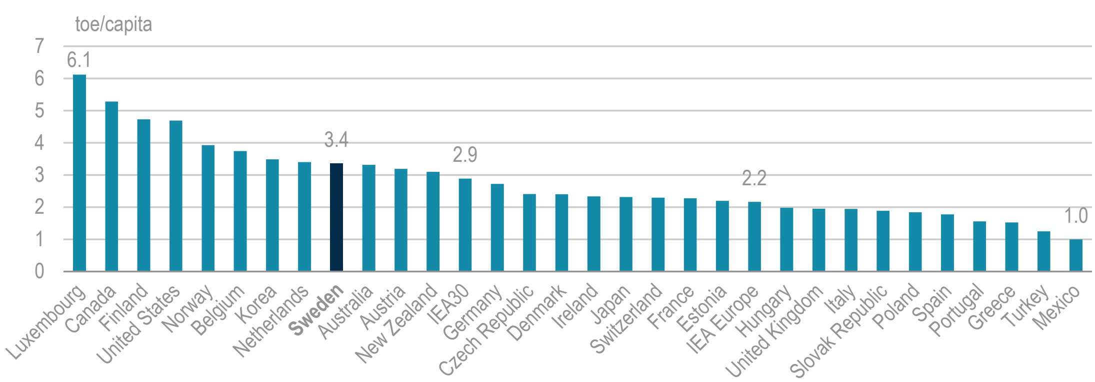
## Energy intensity per capita and GDP

Sweden is large by area and has cold winters, which result in a high energy demand for transport and heating. Furthermore, the industry sector, such as pulp and paper and metals industries, is the main energy consumer. This contributes to a relatively large energy consumption per capita. In 2016, Sweden had the ninth-highest TFC per capita among the International Energy Agency (IEA) member countries, 16% above the IEA average (Figure 4.2).

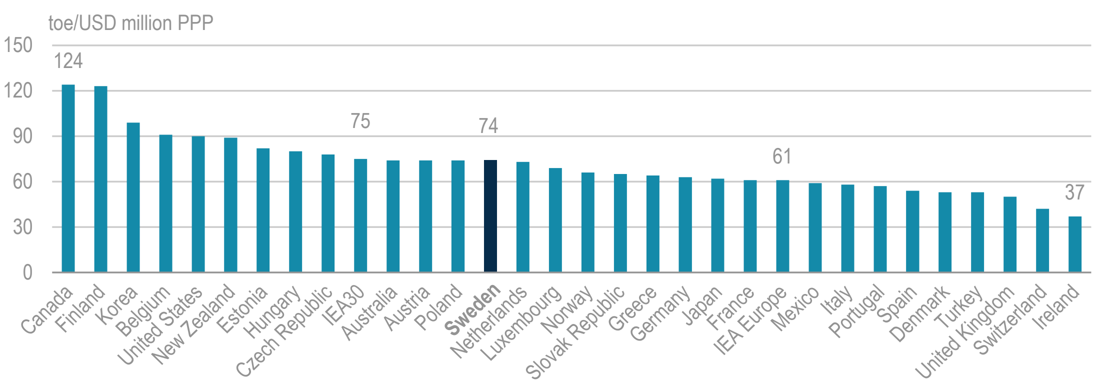
In terms of the energy intensity of the economy, Sweden is closer to the middle in the comparison, with a TFC/GDP that is 10% above the median but 1% below the IEA average. From 2006 to 2016, Sweden's energy intensity decreased by 17% (Figure 4.3). It follows a similar trend to that of the IEA average as well as of the neighbouring Nordic countries. Sweden's energy intensity is higher than Denmark's and Norway's, but lower than Finland's.

### Figure 4.2 Energy intensity in IEA member countries, 2016

Energy consumption per capita (TFC/CAP)




Energy consumption per GDP (TFC/GDP)

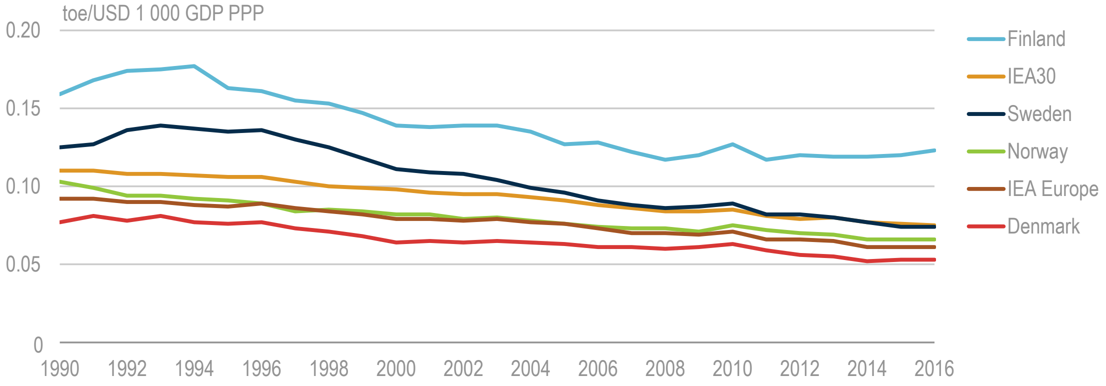



With a cold climate and large industries, Sweden has relatively high energy consumption per capita, but ranks close to median in terms of energy intensity of the economy.

Notes: toe = tonnes of oil equivalent. PPP = purchasing power parity.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

**Figure 4.3 Energy intensity in selected IEA member countries, 1990-2016**




Sweden has reduced its energy intensity on a similar trend as the IEA average in recent decades, and ranks between its Nordic neighbours.

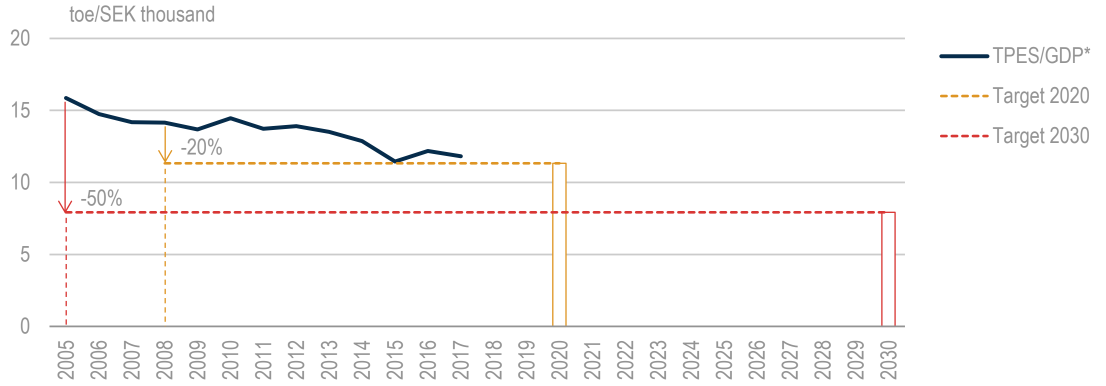
Note: Energy intensity as TFC/GDP PPP.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

## *Energy intensity target*

As part of its contribution to the EU 2020 targets, Sweden is to improve its energy efficiency by 20% from 2008 to 2020. The target is expressed in terms of total primary energy supply (TPES) in relation to GDP. As of 2016, energy intensity had been reduced by 15%, and the government considers the 2020 target to be within reach without additional measures.

In the energy framework agreement from 2016, Sweden set a target for 2030 to reduce its energy intensity (measured again in TPES/GDP) by 50% compared to 2005. Changing the base year from 2008 to 2005 is in line with EU targets. From 2005 to 2016, the energy intensity declined by 24% (Figure 4.4).

**Figure 4.4 Energy intensity (TPES/GDP) 2005-17 and targets for 2020 and 2030**




Sweden is on track to meet its 2020 target of a 20% lower energy intensity compared to 2008, but additional savings are also required to meet the 2030 target.

* GDP in SEK 2010 prices.
Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

The energy intensity target of Sweden is expressed in terms of TPES per GDP, which includes thermal losses in nuclear power generation. This means that when nuclear power is replaced by electricity generation without thermal losses, e.g. wind power, the TPES declines regardless of whether the final energy consumption remains the same. Nuclear shutdowns will thus help meet the energy intensity target. Since 2005, three Swedish nuclear reactors have been taken out of operation (in 2005, 2015 and 2017) and two more closures are planned in 2019 and 2020 (see Chapter 8).

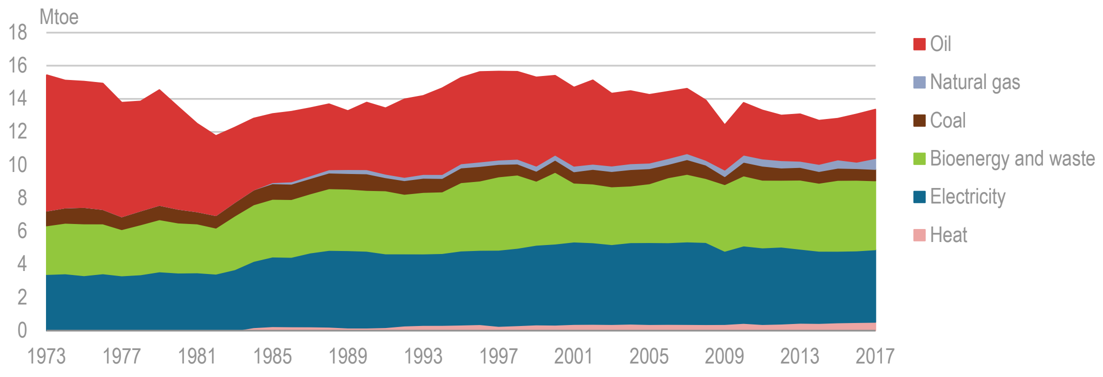
## Energy consumption by sector

In 2017, the TFC in Sweden was 33.5 million tonnes of oil equivalent (Mtoe), down 3% since 2007. Industry is the largest energy consumer in Sweden, followed by transport[1] and the residential and commercial sectors.

### *Industry sector consumption*

The industry sector accounted for 40% of TFC in Sweden in 2017. Thanks to energy efficiency improvements, energy consumption has slowly declined over the past two decades, despite an increased value added in the industry sector. From 2007 to 2017, industry's energy use fell by 9% (Figure 4.5). However, it has increased slightly since 2014.

**Figure 4.5 TFC in industry by source, 1973-2017**




Energy demand in industry has decreased by 9% in the past decade, mainly driven by a decline in oil consumption in the paper, metals and minerals industries.

Note: Includes non-energy consumption.

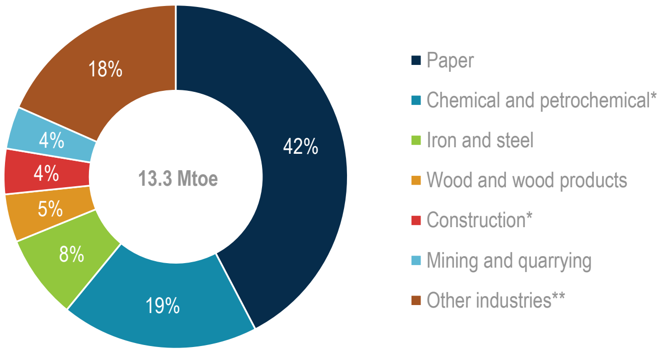
Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

Biofuels and electricity each account for around one-third of the energy consumption in industry. The rest is oil products and small volumes of coal, natural gas and district heating (DH). Oil consumption has declined in recent decades, partly replaced by biofuels. From 2007 to 2017, oil consumption dropped by 25%, whereas biofuels increased by 2%.

[1] The transport sector's energy use and emissions are addressed in Chapter 3. This chapter focuses on the industry, residential and commercial sectors.

Sweden has large forest resources that supply a major export-oriented industry sector. Pulp and paper production accounts for 42% of the total industry energy consumption (Figure 4.6). Two-thirds of energy use in the pulp and paper industry is wood fuels (mainly residues and black liquor from chemical pulping) and the rest is mainly electricity in mechanical pulping. Other large industries are chemicals, metals, wood products, construction and mining. From 2007 to 2017, energy consumption increased in mining by 41% and chemicals (+7%), but decreased in steel (-22%) and paper (-9%) industries.

**Figure 4.6 Energy consumption in manufacturing industry by sector, 2017**




The paper industry uses more than half of all energy in industry, and two-thirds of its energy use is by-product biofuels from its processes.

* Consumption in chemical and petrochemical industries and in construction includes non-energy use.

** *Other industries* includes food and tobacco, non-metallic minerals, non-ferrous metals, machinery, transport equipment, textile and leather, and non-specified industry consumption.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

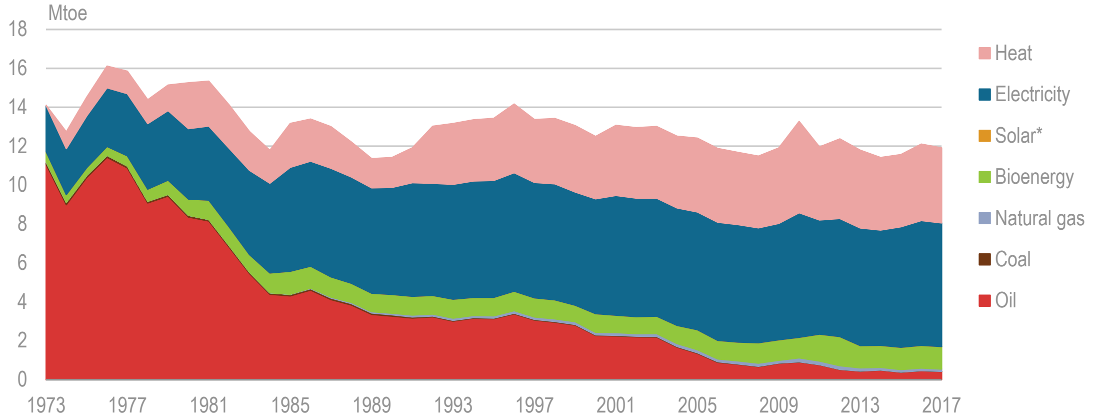
## *Residential and commercial consumption*

In 2017, the residential and commercial sectors together accounted for 36% of TFC (residential 22% and commercial 13%). Energy use has been around 12 Mtoe per year since the mid-1980s, with annual variations from 11 Mtoe to 14 Mtoe that result mainly from weather conditions. The growth in the number of buildings and services has been offset by the improved energy efficiency in buildings and heating systems, which has stabilised total consumption (Figure 4.7).

Electricity accounted for over half of the total energy consumption in the residential and commercial sectors in 2017, used for both heating and household, and service applications. DH is the main source of heat and in 2017 accounted for one-third of the total energy consumption in the sectors (Chapter 5). The remaining consumption is mainly biofuels plus small volumes of heating oil and natural gas. There has been a long-term fuel shift from heating oil to more renewable heat sources. From 2007 to 2017, the use of oil nearly halved, whereas the use of bioenergy increased by 20%.

In the residential sector, space and water heating accounts for 70% of the total energy consumption. The rest is consumed by household appliances, lighting and cooking (IEA, 2018). Space heating has become significantly more energy efficient in recent decades thanks to better technology, e.g. heat pumps, and to stricter energy performance standards for buildings. From 2000 to 2016, the energy intensity of space heating (energy per floor area) was reduced by 43% (Figure 4.8). The total energy intensity per dwelling fell by 14%.

**Figure 4.7 TFC in residential and commercial sectors by source, 1973-2017**



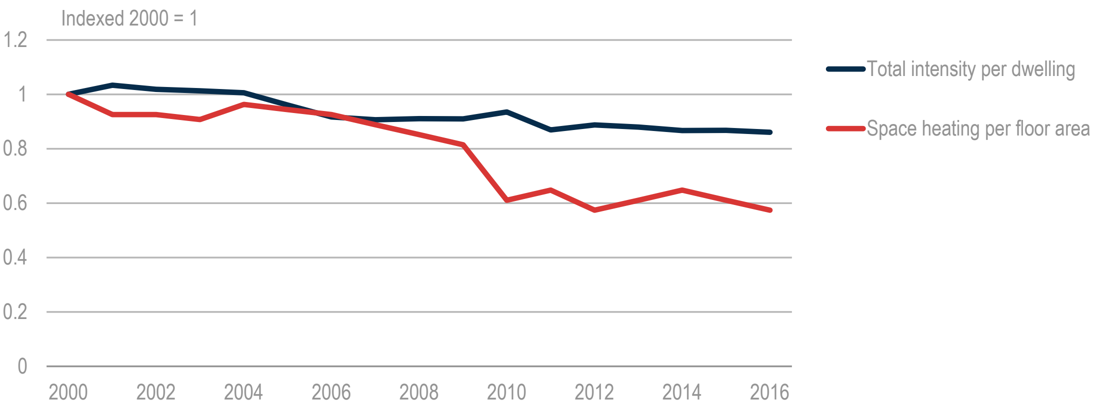

Electricity, DH and biofuels have replaced oil heating in the residential and commercial sectors, and fossil fuels account for only 5% of energy consumption.

* Negligible.

Note: The commercial sector includes commercial and public services, agriculture, forestry and fishing.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

**Figure 4.8 Residential energy intensity, 2000-16**




More efficient heating technologies and stricter energy performance standards have helped reduce energy intensity for space heating.

Source: IEA (2018), *Energy Efficiency Indicators Highlights 2018*, https://webstore.iea.org/download/direct/2407?fileName=Energy_Efficiency_Indicators_2018_Highlights.pdf.

# Regulatory framework

As a member of the European Union, Sweden transposes EU directives into national legislation. Directives on energy efficiency are the Energy Efficiency Directive (EED), the Energy Performance of Buildings Directive (EPBD), the Ecodesign Directive and the Energy Labelling Directive (ELD). Furthermore, the European Union Emissions Trading System (EU-ETS), which forces large heat and power plants and heavy industry to limit their $CO_2$ emissions, can help increase energy efficiency in those sectors. This section briefly presents the EU regulations, after which the Swedish policies and measures are discussed.

## The Energy Efficiency Directive

The 2012 EED (2012/27/EU) establishes a set of binding measures to help the European Union reach its 2020 energy efficiency target. The target is defined as a 20% reduction of energy consumption (in primary and final energy) compared to the business-as-usual projections (EPRS, 2015). In a number of articles, the EED requires EU member countries to:

- Article 3: Set energy efficiency targets, based on primary or final energy consumption, primary or final energy savings, or energy intensity.
- Articles 4 and 5: Present national building renovation strategies and measures for improving energy efficiency in public buildings.
- Article 6: Ensure that central governments purchase only products, services and buildings with high energy efficiency performance.
- Article 7: Require energy companies to save at least 1.5% of annual energy sales to final consumers, or implement other measures that achieve the same savings, such as improving the efficiency of heating systems and thermal performance of buildings.
- Article 8: Require large companies to regularly audit their energy consumption to identify ways to reduce it. National incentives should support energy audits also for small and medium-sized enterprises.

A recast of the EED is expected to come into force by early 2019. It will include a binding target of 32.5% energy savings compared to a reference case, with a clause for an upwards revision by 2023. It will also extend the annual energy-saving obligation beyond 2020 (EC, 2018).

## Other EU directives on energy efficiency

The EPBD (2010/31/EU) requires all new buildings to be nearly zero energy from the end of 2020. New public buildings must be nearly zero energy from the end of 2018. In accordance with the directive, EU countries have to draw up national plans to increase the number of nearly zero-energy buildings. A recast of the 2010 EPBD came into force in 2018 [Directive (EU) 2018/844]. It aims to accelerate the cost-effective renovation of buildings and decarbonise the national building stocks by 2050. For this, EU member countries will have to adopt stronger long-term renovation strategies.

Other important EU Directives are the Ecodesign Directive (2009/125/EC) and the ELD (2010/30/EU), which from 2017 is being gradually replaced by a new regulation [(EU) 2017/1369]. The Ecodesign Directive aims to improve the energy efficiency throughout the life cycle of products that have an impact on energy consumption, such as household appliances and building components. Based on the directive, EU regulations set product-specific standards. The ELD expands the mandatory labelling requirement from household appliances to cover commercial and industrial appliances as well as energy-related appliances.

## National institutions

The national energy efficiency policy is decided by the government and implemented by the National Board for Housing, Building and Planning (NBHBP) and the Swedish Energy Agency (SEA).

The government has set energy efficiency targets for 2020 and 2030. It decides on energy and $CO_2$ taxation, which are fundamental to improve Sweden's energy efficiency across all sectors. To implement the energy savings target of EED Article 7, Sweden has opted for alternative measures, most importantly the energy and $CO_2$ taxation.

The SEA is responsible for developing strategies to improve energy efficiency on a sectoral level. It also regulates and evaluates energy audits for industries in accordance with the EED. The NBHBP defines building energy performance standards and ensures the implementation of the EPBD in Sweden.

## National policies and measures

In 2017, the government instructed the SEA to develop sectoral strategies for energy efficiency to reach the 2030 target for energy intensity as well as contribute to other energy and climate targets. The agency discussed these with stakeholders and defined five sectors for such strategies: industry, buildings, consumption (including public procurement), transport (Chapter 3) and the electricity system (Chapter 7) (SEA, 2018a).

Next, in 2018-19, the SEA together with stakeholders will develop strategies for the defined sectors. The strategies should contain specific targets and action plans, and possible suggestions for new policies. Finally, from 2020 on, measures should be introduced based on the strategies. The agency will prepare a progress report to the government on an annual basis.

### *Policies for energy efficiency in buildings*

The Swedish housing stock contains around 4.6 million dwellings, of which 54% are in multi-dwelling buildings and the rest mostly detached houses. Nearly half of the housing stock was built from 1951 to 1980 (Figure 4.9). Old buildings hold a large potential for further energy efficiency improvements. To tap into this, the government has introduced both financial support systems and information campaigns.

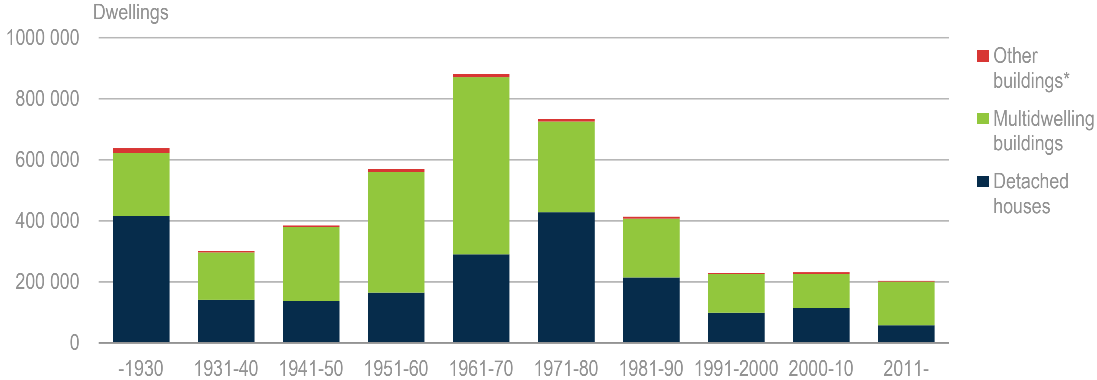
### *Performance standards for new buildings*

Energy performance standards apply to new buildings and, in certain cases, to renovation. The Swedish building performance requirements are set by the NBHBP, and include maximum allowed values for primary energy consumption, installed electric heating capacity, air leakage and thermal transmittance (the so-called U-value) of the building envelope. The standards also include a geographical factor for each municipality that allows buildings in colder areas to have a higher energy consumption.

To satisfy the near-zero energy requirements of the EU EPBD, the NBHBP introduced new energy performance standards in April 2017. Importantly, energy consumption is now calculated in primary energy, instead of purchased energy. Energy consumption in new buildings is converted by using specific primary energy factors. The primary energy factor is 1.6 for electricity and 1.0 for DH, biofuels and fossil fuels (NBHBP, 2018). This discourages the use of direct electrical heating in new buildings. However, electricity can still be used for heating when installing heat pumps that are more energy efficient.

The energy performance standards set different requirements for single-family houses, multifamily dwellings and non-residential buildings. The annual primary energy consumption is limited to 90 kilowatt hours per square metre (kWh/m$^2$) for detached single-family houses, 85 kWh/m$^2$ for multifamily dwellings and 80 kWh/m$^2$ for non-residential buildings. The limit varies according to the primary energy factor of the energy source and the geographical factor. The non-residential buildings category includes all types of public and commercial buildings.

**Figure 4.9 Number of dwellings by type and period of construction**




The Swedish housing stock grew rapidly in the three decades from 1951 to 1980, and less than 10% of the dwellings are from 2000 onward.

* *Other buildings* are partly residential and partly commercial (around 80 000).

Notes: Excludes dwellings for which information on the age is missing (around 29 000). Data from 2017.

Source: SCB (2018), *Number of Dwellings by Region, Type of Building and Period of Construction*, www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104/BO0104T02/?rxid=18bd8f1c-23b5-4556-8336-b63f43afcaa9.

## *Support for the increased energy efficiency of rental houses*

Since October 2016, the government has supported investment to stimulate renovation and greater energy efficiency of rental housing in areas with socio-economic challenges. The government allocated SEK 800 million for the aid in 2016 and has proposed SEK 1 billion annually for 2017-20.

The aid consists of two parts that relate to renovation and energy efficiency measures. Support is only provided to projects that achieve at least a 20% improved energy performance and provide renovations that improve the quality of the building. The energy efficiency improvements need to be reported in an energy review. The aid for energy efficiency measures is up to 5% of the total renovation cost and goes to the property owner. The renovation aid provides 20% of the cost of renovation, which goes directly to the tenants through a rent reduction over a seven-year period.

## *Tax reduction for renovations*

Since 2008, owners of houses or apartments have been able to make tax reductions for the labour cost of repairing, maintaining, rebuilding and enlarging the dwelling. These measures can help improve energy efficiency, but that is not a requirement. In 2016, the tax reduction was lowered from 50% to 30% of labour costs. The maximum amount of aid is SEK 50 000 per person and year, deducted from the income tax.

## *Increased competence in energy-efficient building techniques*

The SEA organises several training programmes to increase energy efficiency in buildings. *Energilyftet* ("the Energy Lift") offers training for engineers, architects and other construction-sector experts to learn about low-energy buildings and Sweden's energy targets. Other training is offered for property developers, teachers and construction workers. The training programmes are set up together with NBHBP and stakeholders from business and public services.

### *Policies for energy efficiency in industry*

Under the EED Article 8, large enterprises in all EU member countries must conduct energy audits every four years, starting from December 2015. This was established in Sweden through the 2014 law on Energy Auditing of Large Companies (2014:266). The law affects around 1 500 Swedish enterprises. The first audit should be done in the four-year period 2016-19. The SEA administers the process and is currently assessing results of the first round of audits (SEA, 2018b).

In 2018, the government introduced *Energisteget* ("the Energy Step"), a programme to support implementing energy efficiency measures. Large companies that have carried out energy audits in accordance with the EED requirements may apply for financial support to invest in energy efficiency measures. The total budget for the programme is SEK 125 million for the years 2018-20.

In 2010, the government introduced a fund to support energy audits also in small and medium-sized enterprises (SMEs). Companies may apply for support of up to 50% of the cost for the audit, at most SEK 50 000. The audit should include energy mapping, proposals for energy efficiency measures and an energy plan. The SEA also guides SMEs in performing energy audits and energy-saving measures. In 2015, the agency initiated a network project for SMEs to support them in introducing energy management principles and in sharing learning experiences and best practice.

### *Public procurement for energy efficiency*

Public bodies at the local, regional and state levels can use public procurement practices to encourage the purchase of energy-efficient goods and services. Sweden has a long history of setting energy and environmental requirements for public procurement. The Swedish National Agency for Public Procurement has developed sustainability criteria for the procurement of products, buildings and services.

## Assessment

### *Sweden is on track to meet its energy intensity targets*

Although Sweden's GDP has grown by 18% from 2008 to 2017, its energy consumption has remained almost flat. The country is on track to meet its target to reduce the energy intensity of the economy by at least 20% from 2008 to 2020. The 2030 target of a 50% lower energy intensity compared to 2005 is also within reach, although further improvements are required.

Energy efficiency targets should be ambitious, realistic, understandable and clearly communicated. As both the Swedish energy intensity targets are based on primary energy use, the closure of nuclear power plants contributes significantly to reaching them. Furthermore, energy intensity depends on the structure of the economy, and structural changes in energy-intensive industries can have a large impact on a country's performance. The government could therefore complement the adopted targets with a different metric to better capture improvements in energy efficiency in the final consumption. Furthermore, the energy efficiency targets should be aligned with Sweden's climate targets and backed up with actions to ensure that energy efficiency effectively helps reduce emissions.

Taxing energy consumption and carbon emissions is a cost-effective way to provide price signals to energy consumers to save energy and steer the economy in a sustainable direction. Together with the EU-ETS, energy and $CO_2$ taxation has stimulated companies, municipalities and individuals to invest in more sustainable energy solutions, which include energy efficiency. Sweden also uses its taxation to satisfy the requirements in EED Article 7. The government should regularly assess the contribution of taxation on energy efficiency improvements and ensure it is sufficient to incentivise energy efficiency further to fulfil the energy savings requirements for 2030.

## *Sectoral strategies should align with the intensity target*

With the 2016 Energy Agreement adopted, which includes the 2030 target for energy intensity, Sweden now needs concrete action plans on how to reach the target. The SEA has begun the work to determine the energy efficiency pathways and strategies for individual end-use sectors. The work should clarify the potential for energy efficiency contributions from each of the five identified sectors, while bearing in mind cross-sectoral effects and overlap.

The IEA welcomes the ongoing work with sectoral strategies for energy efficiency and encourages the government to monitor the progress and ensure that the sector contributions can add up to achieving the 2030 target. Furthermore, the strategies need to be aligned with Sweden's climate objectives. Many measures taken today are long-term ones and may have lock-in effects for greenhouse gas (GHG) emissions.

## *Buildings remain an important area for energy efficiency*

Energy use in buildings remains significant in Sweden and the energy performance requirements for new buildings should be regularly reviewed. The variations in the energy consumption of different non-residential buildings can be substantial, which is not captured in the building code today. Despite some benefits of simplicity, placing all the non-residential buildings under one single building category in the energy performance requirements can lead to efficiency losses. The government should consider introducing additional categories to capture better the potential for cost-efficient measures.

In addition to the energy performance requirements, Sweden recognises the need for further incentives for renovations of the building stock. The recently established support for the renovation of residential buildings in areas with socio-economic challenges is a good step, but it is yet to deliver significant results. Improved energy efficiencies in buildings can also provide multiple benefits, e.g. in terms of better indoor air quality and comfort. Such benefits of energy efficiency measures, and the connection between renovation and energy efficiency, should be utilised further. As an example, the government could consider adapting its tax deduction policy to focus funding on renovations that also provide energy efficiency improvements.

The enforcement of building energy efficiency requirements is also an area that requires continuous attention. This is especially true where the state provides financial support.

The government should ensure a system in which energy performance is measured and evaluated before and after construction and renovation projects are carried out.

# Recommendations

***The government of Sweden should:***

- ☐ Consider complementing the energy intensity target with a metric that focuses on efficiency improvements in final energy consumption.
- ☐ Regularly assess how energy and $CO_2$ taxation contributes to energy efficiency.
- ☐ Ensure that the sectoral energy efficiency contributions add up to achieving the general energy efficiency target set for 2030, bearing in mind possible lock-ins for GHG reduction.
- ☐ When reviewing energy performance requirements for buildings, consider breaking up the non-residential buildings category into several subcategories to capture additional cost-efficient measures.
- ☐ Ensure the effective enforcement of building energy efficiency standards, including renovated buildings.

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# 5. Heat and district heating

## Key data

(2016)

**Energy consumption for space heat and hot water in buildings:** 6.9 Mtoe / 80.5 TWh (district heating 57.6%, electricity 25.9%, biofuels and waste 14.2%, oil 1.3%, natural gas 1.0%), -0.3% since 2006

**District heating production by fuel:** 5.3 Mtoe / 62.0 TWh (biofuels and waste 76.2%, industrial surplus heat 7.8%, heat pumps 7.2%, coal and peat 3.0%, natural gas 3.0%, oil 2.3%, electric boilers 0.5%), +5.6% since 2006

**Exchange rates:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

Sources: SEA (2018); IEA (2018a).

## Overview

Space and water heating in buildings account for two-thirds of the total energy consumption in the residential sector as well as a major share in commercial and public buildings. District heating (DH) is a crucial component of heating in Sweden as it supplies 90% of heat demand in multifamily buildings and nearly 60% of total building heat demand. A fuel transition from oil and coal to solid biomass fuels in DH production has helped decarbonise Sweden's energy system. Most DH is produced in co-generation[1] systems, so the DH sector also contributes to the country's electricity supply.

Municipal waste is also an important fuel in DH, and incineration with energy recovery is well developed as a waste treatment method. However, the available volumes of waste as a fuel might decline as recycling is being promoted over incineration. Similarly, the demand for biofuels could increase in other sectors, e.g. for chemical industries and transport. Other alternative low-carbon heat sources, such as industrial waste heat, can thus have a larger role in DH supply. These heat sources typically come with lower temperatures than those used in today's DH systems.

As urbanisation continues to increase the population that lives in cities and uses DH, the energy efficiency in buildings also continues to improve. As a result, future demand for DH is expected to be stable or decrease slightly. DH companies adapt to competition from other technologies, e.g. heat pumps, by accommodating more waste heat and low-temperature heat sources, as well as increase flexibility by integrating heat and electricity systems. At the same time, however, low electricity prices are challenging the

[1] *Co-generation* refers to the combined production of heat and power.

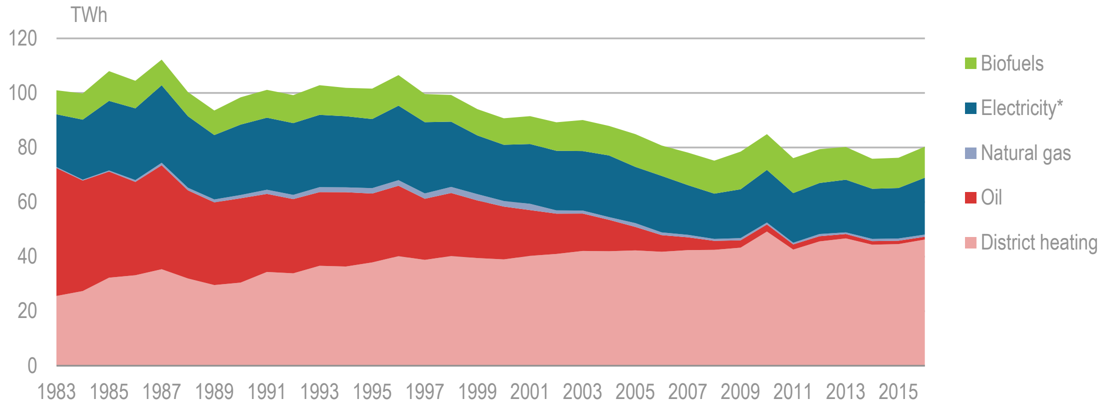
DH market development. More research and development in new DH systems and technology can support modernisation of the infrastructure and maintain DH as an important part of Sweden's energy system.

## Supply and demand

### *Heat sources in buildings*

In recent decades, the Swedish heating sector has gone through a large transformation. In the 1970s, fuel oil dominated energy consumption in the residential sector. After the oil crises of 1973 and 1979, Sweden started to use more electric heating, available through the build-out of nuclear power, as well as DH. In the early 1980s, fuel oil still accounted for nearly half of the total heat consumption in buildings, but DH was steadily growing (Figure 5.1). In 2016, DH accounted for nearly 60% of the heat demand in buildings, up from around 50% a decade earlier. DH supplied 90% of the heating in multifamily buildings, 77% of non-residential buildings and 17% of detached one- and two-dwelling houses (Figure 5.2).

**Figure 5.1 Energy consumption for heating in buildings by fuel, 1983-2016**




DH has increased significantly and, together with heat pumps, it has replaced nearly all oil heating in buildings.

* *Electric heating* includes electric boilers and heat pumps.

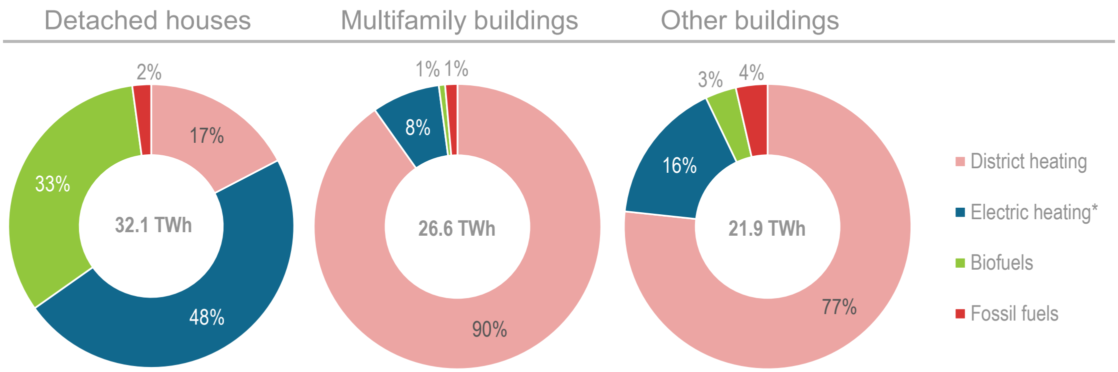
Note: Energy for space heating and water heating.

Source: SEA (2018), *Energy in Sweden, Facts and Figures 2018*, www.energimyndigheten.se/statistik/energilaget/?currentTab=1#mainheading.

In 2016, electricity accounted for around one-quarter of the total heat demand, a relatively stable share for the past three decades. However, many houses have replaced electric boilers with heat pumps to increase the efficiency of electric heating. For over a decade, around 100 000 heat pumps have been installed annually (Figure 5.3). Approximately half of these are air-to-air heat pumps that use outdoor air to produce warm air in the building. Ground-source heat pumps account for around one-third of the total. Heat pumps have primarily replaced direct electric heating and oil boilers in detached houses not connected to DH. Electricity (including heat pumps) accounts for nearly half of total heating demand in detached houses (Figure 5.2).

Solid biomass fuels (wood and pellets) account for 14% of the total heat demand in buildings and one-third of heating in detached houses. The use of such biomass fuels has been relatively stable for decades, with peak demand during the cold winters of 2009 and 2010. Natural gas supplies only a small share of buildings in a few cities, and oil is used only marginally in the remaining fuel oil boilers because it is considerably more expensive than other alternatives. Previously, conversion from fuel oil heating and direct electric heating was supported through specific subsidy schemes (Box 5.1).

**Figure 5.2 Energy consumption for heating by fuel and building type, 2016**



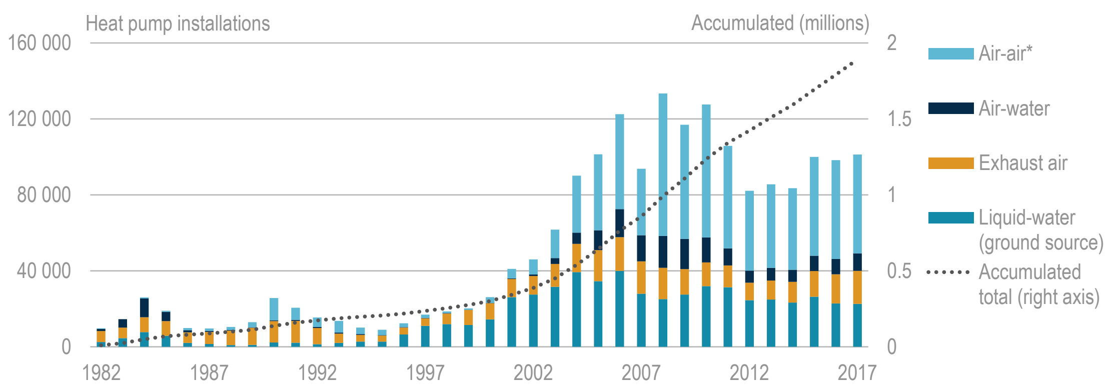

DH dominates in multifamily buildings, whereas electricity and biofuels are the main heat sources in detached houses.

* *Electric heating* includes electric boilers and heat pumps.

Note: Energy for space heating and water heating.

Source: SEA (2018), *Energy in Sweden, Facts and Figures 2018*, www.energimyndigheten.se/statistik/energilaget/?currentTab=1#mainheading.

**Figure 5.3 Heat pump installations in Sweden, 1982-2017**




Heat pump installations increased rapidly in the early 2000s, and they have remained at high levels owing to investment support schemes and low electricity prices.

* Air-air heat pump data are estimated and uncertain.

Source: SKVP (2018), *Värmepumpsförsäljning* (*Heat Pump Sales*), https://skvp.se/aktuellt-o-opinion/statistik/varmepumpsforsaljning.

**Box 5.1 Support schemes for the conversion of oil and electric heating, 2006-10**

In 2006, the government introduced two conversion support schemes to increase the use of more efficient, low-carbon heating alternatives. One scheme supported conversion from oil heaters (Act 2005-1256) and the other conversion from direct electric heating (Act 2005-1255). The schemes allowed house owners to apply for investment support of up to 30% of the total cost when converting to DH, ground source heat pumps, or efficient biofuel boilers. Both schemes were supposed to run for five years until the end of 2010, but the oil conversion scheme was closed by 2007 because it had run out of budget owing to the many applications. In evaluations of the schemes, they were considered to have accelerated the conversion from oil and electric heating. However, their economic efficiency was regarded as questionable because many investments took place without the support schemes, but were driven by the high taxes on fuel oil and electricity.

Sources: Boverket (2008) ), *Mindre Olja, Bättre Miljö – men till vilket Pris* [Less Oil, Better Environment – but at what Price], www.boverket.se/globalassets/publikationer/dokument/2008/mindre_olja_-battre_miljo.pdf; Boverket (2011), *Utvärdering av Stödet för Konvertering från Direktverkande Elvärme i Bostadshus* [Review of the Support for Conversion from Direct Electric Heating in Houses], www.boverket.se/globalassets/publikationer/dokument/2011/utvardering-av-stodet-for-konvertering-fran-direktverkande-elvarme.pdf.

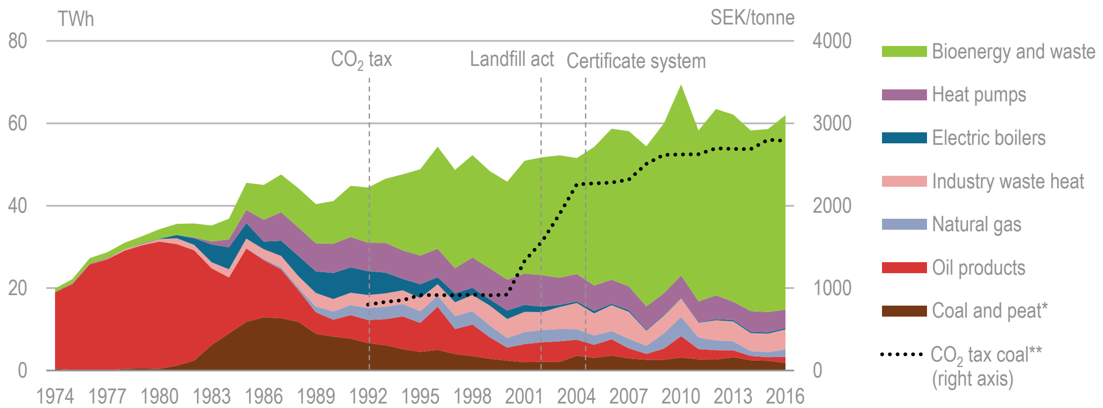
## DH supply

Initially, DH was supplied by oil, but after the oil crises in the 1970s, the fuels shifted to first coal and later to biomass and waste fuels, driven largely by policy decisions. In 1991, the government introduced $CO_2$ taxation as a main policy tool to encourage low-carbon fuels in energy conversion. The $CO_2$ tax was increased rapidly in 2000-04 and more slowly thereafter (Figure 5.4). Facilities included in the European Union Emissions Trading System were initially exempt from $CO_2$ taxation, but to accelerate a fuel switch and replace the remaining fossil fuels in DH, in 2018 the $CO_2$ tax was expanded to cover those plants also.

In 2016, biomass and waste fuels accounted for around two-thirds of total DH generation (Figure 5.4). The largest share of biofuels and waste was primary solid biofuels (such as wood chips), which accounted for over half of total DH generation in 2016. Sweden has a large wood-processing industry sector, with wood fuels as a by-product, and the forest outtake can increase further (Börjesson, 2016). The use of biofuels in DH has also been supported indirectly through the green electricity certificate system, introduced in 2003, which provides incentives for the co-generation of heat and power from renewable energy sources (Chapter 7).

Municipal waste has become an attractive fuel in DH, especially since 2001, when the landfilling of organic and burnable non-toxic household waste was banned. In 2016, waste accounted for 24% of total DH generation, of which roughly half was renewable waste. Nearly half of the total household waste is incinerated, and the rest is recycled through material recycling or biological treatment (Figure 5.5). Less than 1% of the household waste is put on a landfill. Besides the domestic waste incineration, Sweden imports waste to burn at waste-to-energy plants, mostly from Norway and the United Kingdom.

### Figure 5.4 DH production by fuel, 1974-2016




Since the introduction of the $CO_2$ tax, the landfill act and the green certificate system, biofuels and waste have become the dominant energy sources in DH.

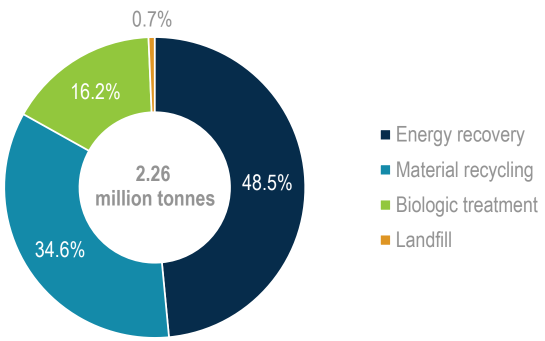
* *Coal* includes coke oven and blast furnace gases.

** The $CO_2$ tax levels are per tonne of coal, but the tax has been increased at the same rate for natural gas and oil.

Notes: *Biofuels and waste* includes the category o*ther fuels* from the statistics, assumed to be non-renewable waste. TWh = terawatt hours.

Sources: SEA (2018), *Energy in Sweden, Facts and Figures 2018*; STA (2018), *Skattesatser på Bränslen och El under 2018* [Tax Levels for Fuels and Electricity 2018], www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/skattesatserochvaxelkurser.4.77dbcb041438070e0395e96.html.

### Figure 5.5 Breakdown of municipal waste by treatment method, 2016




Incineration for heat and power generation, the most common treatment for municipal waste, will probably decline as recycling increases.

Note: *Energy recovery* refers to waste incineration.

Source: AS (2018), *Aktuell Avfallsstatistik* [Current Waste Statistics] www.avfallsverige.se/kunskapsbanken/avfallsstatistik/.

Most of remaining DH is supplied by industrial waste heat and heat pumps, both of which have been relatively stable in DH production. Industrial waste heat, which, together with waste incineration, often has the lowest operational cost in DH generation, is prioritised as the base load in DH systems. Heat pumps are used when electricity prices are low enough to support power-to-heat generation on a large scale.

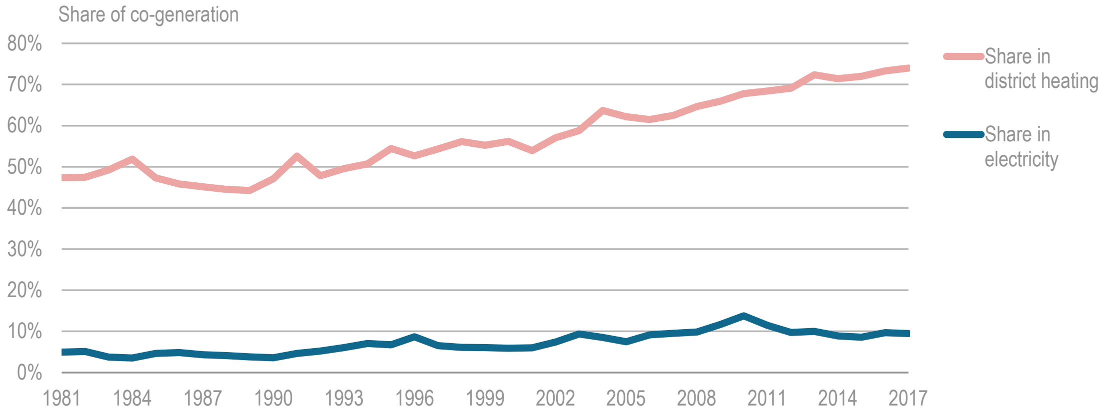
With the growth in biofuels and waste heat, Swedish DH production is largely decarbonised. In 2016, fossil fuels accounted for 8%, shared between natural gas, coal, oil and some peat. The share of fossil fuels is declining further. Natural gas is used in a few heat and power plants in cities connected to the gas transmission grid in the southwest of the country, mainly in Malmö and Gothenburg. Coal is used mostly for peak generation in a few remaining heat and power plants, plus as base load in Värtaverket in Stockholm, which the owner has decided to phase out by 2022. Oil boilers mainly supply peak load in some DH systems, and, in some places, bio-oil has replaced fossil fuel oil.

## Co-generation in DH

Co-generation of heat and electricity enables a more efficient use of energy resources compared to separate production in power plants and heat boilers. Furthermore, co-generation contributes to a stable power supply. The electricity certificate system, which was introduced in 2003, encourages co-generation rather than heat-only boilers when burning biofuels.

In 2016, co-generation accounted for 73% of the total DH generation and 10% of the total electricity generation in Sweden (Figure 5.6). For DH generation, this corresponds to a large increase, from 57% in 2002 when the certificate system had not yet been introduced. Until 2010, the share of co-generation in power generation also increased. In recent years, however, the rapid increase in wind power has led to a lower share of co-generation in the total power generation.

**Figure 5.6 Share of co-generation in DH and electricity generation, 1980-2017**



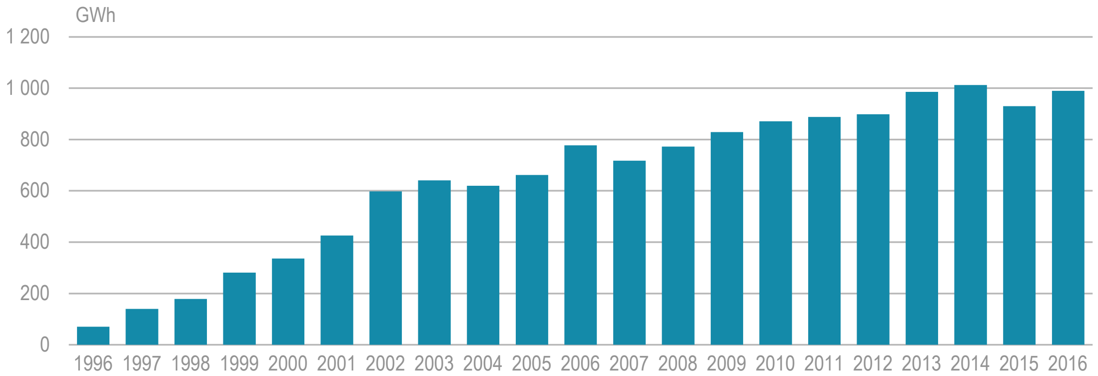

The share of co-generation in DH has increased in recent decades, supported by the electricity certificate system since 2003.

Note: The lines refer to the share of total production of DH and electricity that comes from co-generation plants (which can be operated in different ways, e.g. to maximise electricity generation or for pure heat generation).
Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

## District cooling

District cooling (DC), used in some of the larger cities in Sweden, is mainly supplied to industries, offices and commercial buildings and public services, e.g. shopping malls and hospitals. Stockholm has the largest DC network, which accounts for close to half of the total DC supply in Sweden, supplied by efficient heat pumps in connection with DH production. In 2016, DC supply amounted to around 1 TWh (Figure 5.7). Nearly all DC networks were installed in the past two decades, but the growth has stalled in recent years.

**Figure 5.7 District cooling supply, 1996-2016**




District cooling has increased significantly in the past two decades, but in recent years growth has stalled.

Note: GWh = gigawatt hours.
Source: SEA (2018), *Energy in Sweden, Facts and Figures 2018*, www.energimyndigheten.se/statistik/energilaget/?currentTab=1#mainheading.

# DH markets and regulation

## *The liberalised DH market*

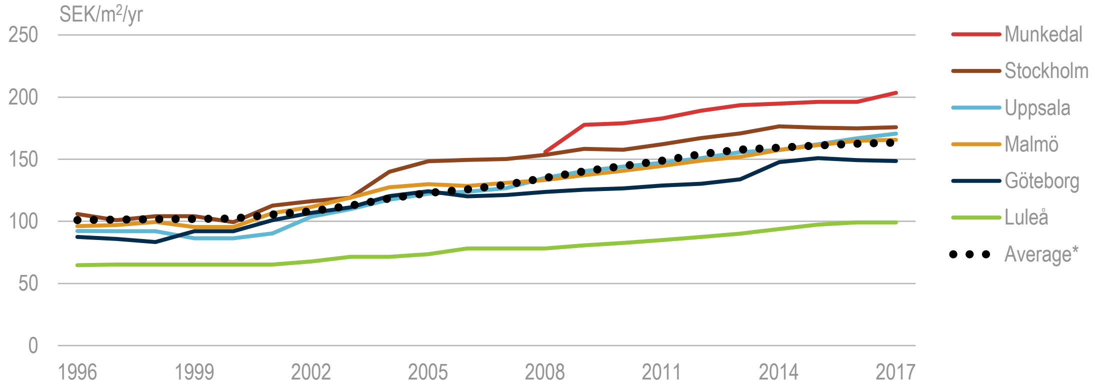
DH was introduced in Sweden in 1948, and it expanded widely in the following decades. Initially, all the DH systems were owned and operated by municipalities, and the heat was sold at a price based on the cost of production. In 1996, the DH market was liberalised together with deregulation of the power market. Since then, DH systems have been operated as a business by public or private companies. Municipalities still own 65% of Sweden's around 200 DH companies, while the rest are private or state-owned. The large DH network in Stockholm is owned 50% by the city and 50% by the company Fortum.

A DH network is a natural monopoly, similar to electricity or gas distribution grids. To avoid the misuse of a monopoly position, many countries regulate DH prices. Sweden has chosen a different approach, in which DH is considered to compete against other heating technologies on an integrated heat market. Since the liberalisation in 1996, DH companies are free to set any DH price and customers are free to switch to alternative heat sources. A similar free-market approach is used in Finland, whereas the other Nordic countries and most others use price regulation of some sort. Heat pumps, which benefit from low electricity prices, are the main alternative to DH in the Swedish heat market.

## *DH prices*

There are no official national statistics of DH prices. However, in 1996, the major Swedish housing associations formed the Nils Holgersson Group, which publishes yearly price statistics from each municipality. The data show that DH prices increased significantly in the early 2000s, but stabilised somewhat in recent years. Furthermore, the statistics show that DH prices vary significantly across networks. A customer connected to the most expensive system pays more than twice as much for DH as does a similar customer in the cheapest system. The price difference is mainly based on the cost of production. A DH system supplied by waste heat from local industries can often offer lower prices, which is the case in, e.g. the cheapest system in Luleå. Small DH systems using expensive fuels, such as wood pellets and oil, tend to have higher prices, e.g. in the DH system in Munkedal (Figure 5.8).

**Figure 5.8 Average DH prices (nominal) in selected municipalities, 1996-2017**




DH prices vary significantly across networks, depending mainly on the production costs, where, e.g. industrial surplus heat leads to lower prices.

* The average is calculated as an average of all available DH prices, not weighted by delivered heat per system.
Note: Average prices for the heating of one square metre during one year in nominal values (SEK/m²/yr).
Source: Nils Holgersson Group (2018), *Fjärrvärme – Historik* [District Heating – Historic Data], http://nilsholgersson.nu/rapporter/rapporthistorik/fjarrvarme-historik/.

Large price differences between different DH systems indicate that DH companies are not operating on a fully integrated heat market, and that they have considerable market power (Åberg et al., 2016). If DH companies were competing with other heating technologies on a fully integrated heat market, DH prices would be set more in relation to other prices, e.g. the electricity price, which reflects the competitiveness for heat pumps. Price variations between Sweden's electricity price regions are insignificant compared to the price differences between different DH markets, which indeed indicates some market power of the DH companies.

## The "Price Dialogue"

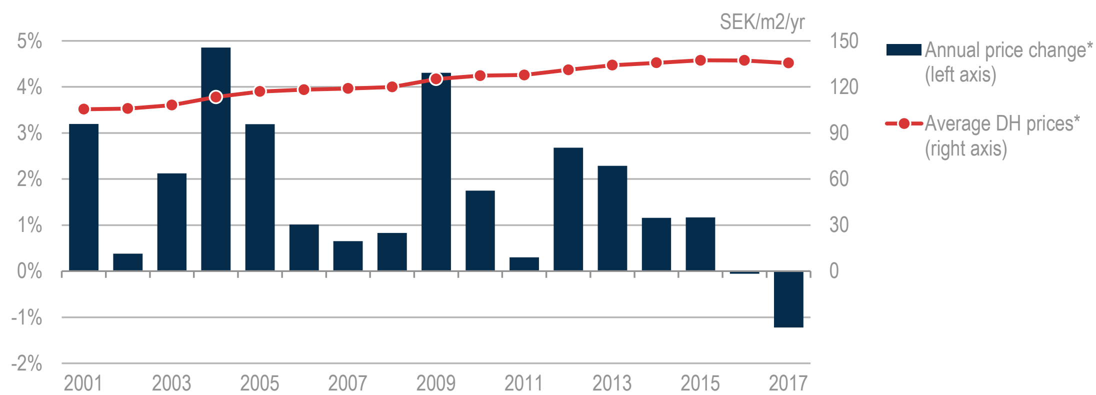
Some years after the liberalisation of the DH market in 1996, the DH prices increased at a fast rate (Figure 5.8), which led to political pressure to strengthen consumer protection. One way to increase competition on the market and thereby improve the situation for the consumers would be to introduce mandatory third-party access (TPA). However, the technical conditions for accessing a DH system can vary locally from one network to another, which complicates TPA regulation. After several studies on the issue, the government concluded that mandatory TPA would not be a feasible solution for strengthening consumers' protection while maintaining flexibility for the producer.

In 2008, the government adopted the District Heating Act (2008:263), which confirms the liberalised nature of the heat market. The act requires producers to increase the transparency of their pricing. Following this, in 2011 the main producers (energy companies) and consumers (housing organisations) jointly established the non-profit organisation Prisdialogen (the Price Dialogue) to assess changes in DH prices and improve transparency and consumer confidence. Prisdialogen is organised by *Riksbyggen* (an association of building unions and local housing associations), SABO (the Swedish Association of Public Housing Companies) and Swedenergy (an industry association for energy companies).

The voluntary process, which builds on dialogue between local producers and consumers, has resulted in a written agreement between the parties (a local DH company and customers) on the principle for coming price adjustments. In 2017, such local agreements covered 72% of total DH supply in Sweden. In 2016, the Swedish Energy Markets Inspectorate (SEMI) evaluated the Prisdialog process, concluding that the process was a success and that it had strengthened consumer protection and provided transparency into the pricing mechanisms.

Data on the price development before and after 2011 also show a positive trend for DH consumers. In the period 2001-10, DH prices increased on average by 2.2% per year (in real prices). In the period 2011-17 following the introduction of Prisdialogen, the annual growth in DH prices averaged 0.9%, with price reductions (in real prices) in the past two years (Figure 5.9).

**Figure 5.9 DH price development and annual price changes, 2001-17**




DH prices have stabilised and declined slightly in recent years (in real prices), after a significant increase in prices following the market liberalisation.

* Average of listed prices for heating of one square metre during one year in Nils Holgersson (2018) corrected by consumer price index (2001 prices).

Source: IEA analysis based on Nils Holgersson Group (2018) *Fjärrvärme – Historik* [District Heating – Historic Data], http://nilsholgersson.nu/rapporter/rapporthistorik/fjarrvarme-historik/.

# Market development

## *Future heat demand*

In the past two decades, energy demand for heating in buildings has fallen from around 100 TWh to around 80 TWh (Figure 5.1). Energy efficiency in new buildings is continuously improving, thanks to stricter national energy performance standards and EU directives as well as to regulation on near-zero-energy buildings and building components. Energy performance in existing buildings has also improved through refurbishments, but a large potential remains for further energy efficiency improvements. Improved energy efficiency in existing and new buildings is likely to reduce the total heating demand further (Sköldberg and Rydén, 2014).

In areas with DH, the increasing energy efficiency is somewhat balanced by a trend towards more people living in cities with DH. To maintain their competitiveness, DH companies have adapted their business models. Traditionally, DH prices were the same throughout the year, with a fixed fee and a variable fee per kilowatt-hour consumed. However, heat demand varies significantly with the outdoor temperature, which leads to variations in production costs for the DH suppliers. To better reflect these cost variations, many DH companies are now introducing seasonal variable fees with differentiated DH prices for the summer, winter and spring/autumn. With differentiated seasonal prices, DH companies can promote energy efficiency improvements to reduce expensive winter demand, which also benefits DH suppliers.

DH companies also find new markets by expanding DH networks to new areas or by delivering DH for new purposes, e.g. in household appliances, such as washing machines, and thereby substituting electricity with DH. In addition, DC can increase and DH can be used to produce cooling in so-called absorption/adsorption chillers (refrigerators that use heat instead of electricity to drive the cooling process.). With heat pumps, DH and DC can be produced in an efficient and integrated process. DH and DC can also be produced together with electricity in so-called tri-generation, which is done, e.g. in the DH systems in Stockholm and in Helsinki, Finland.

## *Future fuel supply*

The European Commission has assessed the role of waste-to-energy as part of the Circular Economy Package. They point out that some EU member states are excessively reliant on the incineration of municipal waste at high rates that are inconsistent with the more ambitious recycling targets (EC, 2017). In 2017, a government-appointed committee assessed introducing a tax on waste incineration (SOU 2017:83). The assessment concluded that such a tax would not have the intended effect to promote more recycling, and that regulation should focus on measures that encourage consumers to increase recycling. The government has not yet decided whether to introduce a tax on incineration.

In addition, a biomass-based fuel supply in DH can be challenged through increased competition from both the energy and industrial sectors. However, there is still a potential to increase the total outtake of biomass from the Swedish forests and agriculture, and different sectors' consumption could be complementary rather than competitive (Börjesson, 2016). However, access to cheap available domestic biofuels for DH cannot be guaranteed (Ericsson and Werner, 2016).

## *4GDH*

4GDH can provide for a more efficient use of the available heat sources, especially industrial waste heat. Compared to the existing DH systems, a 4GDH system can reduce the supply temperature to around 50°C and the return temperature to around 20°C. This enables the use of more industrial waste heat to replace fuel-based heat, but requires a new infrastructure in the DH systems to deliver low-temperature heat to energy-efficient buildings, as well as new business models.

In Stockholm, the DH network owner Stockholm Exergi introduced a concept of open district heating in which data centres, supermarkets and other businesses can be paid for supplying excess heat to the city's DH grid (Stockholm Exergi, 2018). More such initiatives could increase the use of industrial waste heat in DH supply, but may require new infrastructure in line with 4GDH development.

### *Integration of heat and power systems*

Heat and electricity systems are integrated in several ways, e.g. in co-generation of electricity and heat, or when DH is produced with electric boilers or heat pumps. Heat can also be stored more easily than electricity, and thermal storages are used to improve the system balancing of variable power generation. By utilising co-generation, heat pumps and thermal storages, a DH supplier can respond to price signals on the electricity market. In times of high electricity prices, DH production can be adjusted to maximise the power generation and thermal storage used to cover heat demand, and in times of excess power, DH suppliers can utilise more heat pumps.

In the current market environment of low electricity prices, the co-generation business faces both a declining profitability and increased competition from heat pumps. This can cause problems for the electricity system, as peak demand for electricity and heat often coincide. A decline in co-generation capacity would also reduce the flexibility of the power system at the same time as non-controllable wind power generation is increasing. An improved system integration of heat and electricity can provide benefits to both sectors.

## Assessment

### *Biomass and waste has decarbonised district heating*

District heating has become a crucial part of energy consumption in Swedish buildings. It supplies 90% of heat to multi-dwelling houses and 77% to non-residential buildings. Active policy has transformed the DH supply over recent decades, from oil dominance in the 1970s to using mostly biofuels and waste today. The $CO_2$ taxation, introduced in 1991, is the main driver of this transformation towards a renewable and secure energy system.

Sweden’s aim to decarbonise other sectors, such as transport and industry, can lead to increased competition for the available biomass resources. However, there are still untapped resources of forest residues and further potential for energy efficiency improvements, as well as new DH supply technologies that may balance an increased demand for biomass feedstocks.

Waste incineration has grown rapidly in DH systems, driven by DH development and the 2001 Landfill Act. Sweden also imports waste, mainly from Norway and the United Kingdom. As these countries are developing more domestic energy-from-waste solutions, competition for such waste could increase. Furthermore, the EU waste hierarchy prioritises waste reduction and material recycling over incineration, which led the government to assess the potential introduction of a waste incineration tax. The government has yet to decide on the tax or other policy measures to promote a higher degree of material recycling.

### *The price dialogue brings more transparency on the market*

The DH market was deregulated together with the electricity market in 1996. Unlike in the electricity and gas markets, DH network owners and operators are not regulated, despite the networks being natural monopolies. TPA has been investigated several times but is not deemed suitable for Swedish DH networks. Instead of regulation, DH is competing with other technologies on a free heat market, and customers are free to change from DH to, e.g. heat pumps. Large price differences exist between different DH networks, but improvements have been made to increase price transparency.

In 2011, major stakeholders formed the Price Dialogue system (*Prisdialogen*) to improve the relation and communication between the suppliers and customers. It now includes over 70% of all DH customers. By increasing transparency in price setting, Prisdialogen has managed to strengthen the trust of customers in DH suppliers. It is a good example of self-regulation in a market in which many other countries use complicated regulatory frameworks. The Price Dialogue system deserves praise, and the government should encourage further expansion to incorporate more DH companies.

### *District heating is facing changing market conditions*

Increased energy efficiency in buildings has stalled DH market growth in recent years. So far, DH suppliers have managed to compensate for lower heat demand by adding new customers to their systems as more people move into urban areas. However, the sector is forced to develop both technology and business models to stay attractive on the competitive heating market. DH meets increased competition from heat pumps, which benefits from the low electricity price on the Nordic market, supported by subsidies for renewable power that add production to an already well-supplied market. If many customers choose heat pumps over DH, demand for electricity will increase. From a net balancing perspective, this is unfortunate as demand for both heat and electricity capacity peaks during the winter.

The conditions for DH and co-generation can have further implications for the electricity system. In periods when revenue from electricity and green certificates has been low, heat-only production becomes more cost-competitive. If DH companies choose to invest in heat pumps and heat-only boilers instead of co-generation plants, the installed power capacity will decline. This could become an issue for the Swedish electricity system, which faces potential phase-outs of nuclear plants and increasing shares of variable renewable electricity that require controllable backup power. The government should closely monitor this situation to avoid undesired developments for the available power generation capacity.

Technological development of the DH systems could benefit both resource efficiency and system integration. The concept of utilising low-temperature heat in 4GDH networks can enable a more efficient use of the available waste heat sources from, e.g. new data centres and other industries. Stockholm Exergi’s Open District Heating concept is a good example of TPA that works on market terms. The government should encourage this development, e.g. through research and development (R&D) efforts to introduce 4GDH pilot projects in collaboration with the industry.

## Recommendations

***The government of Sweden should:***

- ☐ Closely monitor the market development for DH and its impact on the electricity system, and take into account benefits from DH when reviewing the electricity market design, in particular the potential for increased power generation in cold periods.

- Clarify the long-term role for waste incineration in DH and align strategies for DH development with waste treatment policies to enable fossil-free DH generation.
- Encourage the use of the Price Dialogue system to increase transparency in price setting and assess the need for support to expand the system further.
- Promote both R&D on efficient 4GDH systems and the integration of DH and electricity systems in smart grid developments.

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# 6. Energy technology research, development and demonstration

## Key data

(2017)

**Government energy RD&D spending:** SEK 1.7 billion

**Share of GDP:** 0.39 per 1 000 GDP units (IEA* median: 0.34)

**RD&D per capita:** SEK 167

**Exchange rate:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

* Average of IEA member countries for 2016.

## Overview

The overarching objective for public energy technology research, development and innovation (ETRDI) is to contribute to Sweden's energy and climate targets, long-term energy and climate policy and energy-related environmental objectives. ETRDI should thus help meet the goals of 100% renewable electricity generation by 2040 and net zero-carbon emissions by 2045. More specifically, these long-term goals aim to:

- Build scientific and technological knowledge and competence to enable, through new technology and services, a transition to a sustainable energy system in Sweden that unites ecological sustainability, competitiveness and energy security.
- Develop technology and services that could be commercialised by Swedish enterprises, and thus contribute to sustainable growth and the transition and development of the energy system in Sweden as well as in other markets.
- Contribute to and take advantage of international co-operation in the energy sector.

The Ministry of Education and Research is responsible for the overall general research policy and funding. This includes direct funding to universities and the Swedish Research Council. The Ministry of the Environment and Energy (MEE) is responsible for environment, energy and climate policy, and its Energy Division for ETRDI policy and funding. The MEE also funds the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS).

## Strategies and programmes

Sweden's ETRDI policy is based on the 2017 Act on energy research and innovation (R&I) for ecological sustainability, competitiveness and security of supply (Prop. 2016/17:66). It focuses on five major challenges for a sustainable energy future:

- To create a completely renewable energy system that meets the challenge of the energy system's impact on the climate, while considering the environmental impact of renewable energy sources.
- To ensure a flexible and robust energy system that provides a secure, fully renewable energy supply for the entire community.
- To create a resource-efficient society that contributes to competitiveness, enables the transition to a renewable energy system and utilises the available resources effectively.
- To increase efforts for innovations for jobs and the climate, so that Sweden can pioneer in the transition to a sustainable energy system. The transition will also be an opportunity to develop the business community.
- To enable co-operation in the energy system across actors, sectors, rules and business models to create opportunities for interaction and diversity, and so accelerate the transition.

Based on these five challenges, the government implement actions under the National Energy Research and Innovation Programme 2017-20 (ERIP). The Swedish Energy Agency (SEA) is in charge of managing the programme. Within the SEA, implementation is based on decisions by the government-appointed Energy Research and Development Board, which provides a broad expert opinion before research, development and innovation (RD&I) programmes are approved and their budgets allocated. The Board is led by the Director General of the SEA and has representatives from industry, universities and public entities.

The programme covers the following nine areas:

- sustainable power system and renewable energy sources
- bioenergy
- transport system
- industrial processes
- buildings in the energy system
- general energy system studies
- business development and commercialisation
- sustainable society
- international partnerships.

Within each area, research is organised into specific programmes, the number of which can vary depending on the identified research needs. In the first half of 2018, around 60 programmes and more than 2 500 individual projects were running. In addition, several collaboration programmes with the private sector and joint programmes with other research-funding government agencies are also being conducted. These government agencies include the Swedish Research Council, Sweden's Innovation Agency, Vinnova, and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS).

ETRDI activities are prioritised in collaboration with all the relevant agencies (e.g. the Swedish Energy Markets Inspectorate, the Swedish National Grid and the National Electrical Safety Board). Activities should be designed so that they also may contribute to other policy areas and the several government initiatives related to energy. These include the Swedish export strategy; the National Strategy for Sustainable Regional Growth and Attractiveness 2015-20; the eight Swedish regional structural fund programmes; and the National Regional Fund Programme 2014-20. The latter includes the Genentech Fund, smart industry (a strategy for new industrialisation for Sweden), the work of the National Innovation Council, and the governmental collaboration programmes, in particular, the programmes on a circular and bio-based economy, and on smart cities.

## Research areas in more detail

The government proposes guidelines for ETRDI every four years, in parallel with the proposals for general R&I policy. The latest such proposal was submitted to the parliament in 2016, and the parliament accepted the proposals in March 2017. The guidelines apply to the four-year period 2017-20.

The following is a description of the focus of the nine areas of the ERIP programme, and the changes in relation to the periods up to and including 2016.

### *Sustainable power system and renewable energy resources*

The power system area includes non-fuel-based electricity production technologies (e.g. hydropower, wind power, photovoltaics, wave power, etc.) as well as smart grids, grid flexibility solutions, and all system aspects that influence the power system including user behaviour and market aspects.

As the costs of wind power and solar photovoltaics (PV) have declined enormously in recent years, the focus has broadened from cost reduction to integrating high shares of renewables and to consumers, new services, and system aspects.

For wind power, the research focuses on resource efficiency in the Swedish conditions, the environmental and societal impacts in Sweden and the integration of wind power into the system. For solar PV, the focus now includes prosumer perspectives and PV in the built environment. For wave power, which is further from the market, the focus remains on cost-efficiency and export opportunities.

For smart grids, the focus is on increased flexibility, the digitalisation of the power system, and on security of supply. The integration with other sectors – heat, transport and industry – is increasingly included, although there is less focus on large-scale demonstration projects (three projects were funded previously but the results are yet to be reported).

## Bioenergy

The bioenergy area includes studies on the supply of biomass for energy as well as on certain conversion technologies.

Research on biomass for energy supply focuses on a few specific energy crops, such as *Salix*, *Populus*, reed canary grass and by-products from the forest industry, such as branches, treetops and stumps. Research on the environmental consequences of utilising biomass fuels for energy has also been a long-term priority. There is still room to improve the cost-efficiency and sustainability of production. The use of waste for energy is also included.

At the same time, as the demand for biomass is projected to increase as Sweden develops the market, or 'bioeconomy', new applications will require an increased biomass availability and resource efficiency. The focus 2017-20 will comprise:

- All types of biomass, not just forest and agricultural, e.g. also aquatic biomass, such as algae and waste from the fishing industry.
- A holistic perspective on the role of bioenergy in society and the whole value chain of biomass production, including ecological and sustainability aspects.
- Holistically considering how biomass could contribute to both energy and other products, as biomass is seldom produced only for energy purposes.
- Making Sweden the world leader in minimising and utilising waste. For that, new technical methods, business models and processes are needed.

On biomass conversion, ETRDI focuses on how to increase the efficiency of electricity generated from biomass, and on the combined processes of electricity generation together with, e.g. district heating and cooling, industrial products and/or liquid biofuels. It also focuses on how to meet the uneven demand for biomass from co-generation[1] plants, and the development of small-scale co-generation plants. Hence, the focus is on:

- The role of power generation from biomass in a 100% renewable and sustainable energy system.
- Integrating electricity and heat production.
- Developing new and existing technologies to transform biofuels and waste into electricity and heat. These technologies should be resource-efficient, cost-effectiveness, robust, flexible and have a reduced environmental impact.

## Transport system

Given the ongoing increase in resources used for travel, transportation and the production of vehicles, the Swedish government set a policy target of a 70% reduction in greenhouse gas (GHG) emission from fossil fuels in transport sector by 2030. Efforts in the ERIP are designed to support these goals.

The future transport system will probably include various modes of transport and types of vehicles (e.g. electric vehicles, hybrid electric vehicles, vehicles with internal combustion

[1] *Co-generation* refers to the combined production of heat and power.

engines for renewable fuels and near-zero emission). As the vehicles themselves become more energy efficient, GHG emissions from their production becomes more relevant. Future technology solutions also need to be ecologically sustainable.

The activities of the ERIP in the sector are directed towards zero emissions of both local air pollutants and GHGs from fossil fuels.

## *Industrial processes*

Swedish energy R&I in this area has focused on energy efficiency in intensive industries of importance for the Swedish economy. Focus will now be increased for 1) zero GHG emissions, 2) sustainable business and 3) energy and climate smart materials and products (such as bio-based materials and products, and the circular economy), although energy efficiency will still be a prioritised area. Activities and resources for international collaboration in this subsector will also be increased.

## *Buildings in the energy system*

This area comprises the energy use in the building sector during the entire life cycle and includes the energy use of households.

During 2017-20, there will be an increased focus on:

- renovation and reconstruction
- financial and social aspects
- human aspects; the influence of the resident on energy consumption, their commitment to energy savings and the effects of the indoor environment on health
- connecting research and market actors.

## *General energy system studies with social and interdisciplinary perspectives*

Energy systems are regarded as sociotechnical systems in which people and organisations, institutions (societal and political organisations), values and laws, and technology (including infrastructural systems) interact and are intertwined. Energy systems research aims to increase the understanding of the complex dynamics between people and actors, societal factors and technology in the energy systems, and to attain synergies and identify conflicts of interest between the actors.

The research area is characterised by a diversity of scientific and societal perspectives and issues on energy and climate, and it is often based on sociologically and politically oriented system studies, including economics. The research will for the period 2017-20 be focused on:

- complex dynamics between actors, institutions and technical solutions
- actors and their actions, politics, policy, economic factors, laws and rules connected with energy issues
- transformations, pathways, historical events and future visions and scenarios for energy systems and energy issues development
- finding sociotechnical alternatives for the energy systems.

### *Business development and commercialisation*

This area includes support for the demonstration, business development, commercialisation and dissemination of new solutions that contribute to a sustainable energy system.

Support is increasingly focused on the needs and readiness levels of companies. More weight is given to the probability of successful market penetration as a selection criterion for a company's participation in international programmes. To qualify, a company's solution should also be of use (or coming into use) in the Swedish energy system, or have the potential to contribute to growth in Sweden along with positive effects on the global energy system.

### *Sustainable society*

This area includes planning and the integration of the different infrastructures of society with the focus on energy systems solutions for sustainable cities and communities.

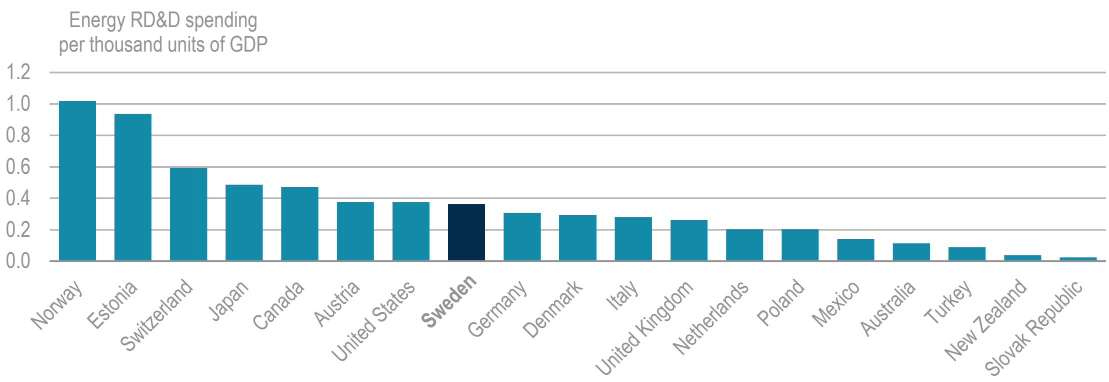
### *International partnerships*

The area includes activities to support Swedish energy R&I through international collaboration as well as to promote the competitiveness of Swedish energy R&I on international markets.

## Funding

In 2017, the Swedish government spent SEK 1.7 billion (around US dollars 190 million) on energy-related research, development and demonstration (RD&D) (IEA, 2018). As a share of the gross domestic product (GDP), Sweden spends above the median among International Energy Agency (IEA) member countries, but much less than the share of the top spenders (Figure 6.1).

**Figure 6.1 Government energy RD&D spending per GDP in IEA countries, 2017**



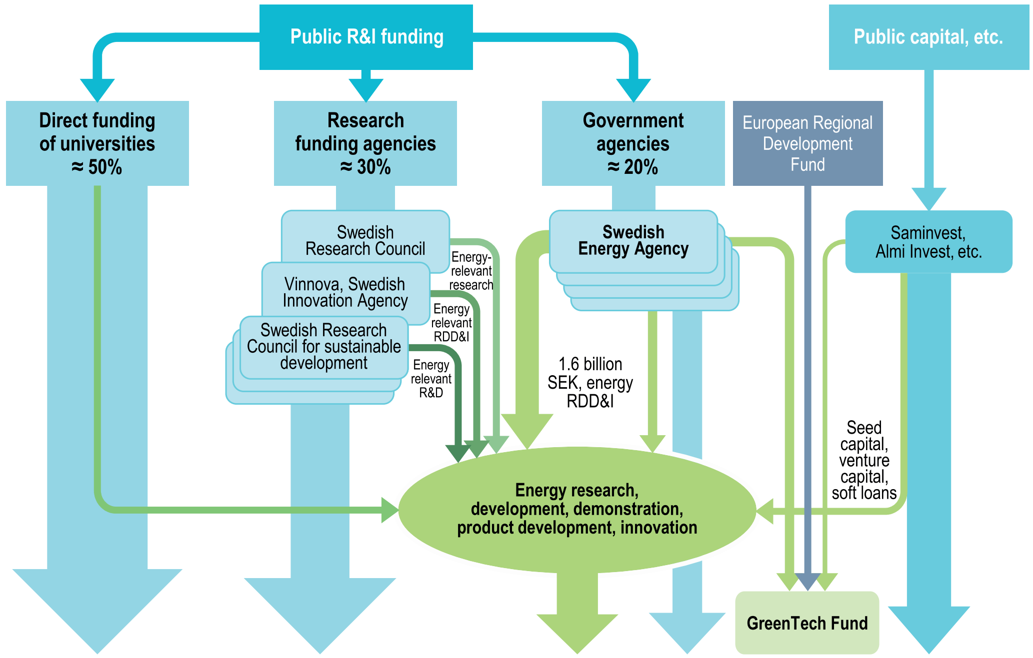

The Swedish government spending on energy RD&D per unit of GDP is the tenth highest in the IEA, but significantly lower than that of the leading countries.

Note: Data are not available for Belgium, the Czech Republic, Finland, France, Greece, Hungary, Ireland, Korea, Luxembourg, Portugal and Spain.

Source: IEA (2018), *IEA Energy Technology RD&D 2018* (database), www.iea.org/statistics/.

ERIP at the SEA provides by far most of the public funding for ETRDI. The budget for 2017 was SEK 1.48 billion, which will gradually increase to SEK 1.6 billion by 2020 (Figure 6.2). The funding of the SEA ERIP is close to the level of private sector co-funding for the programme.

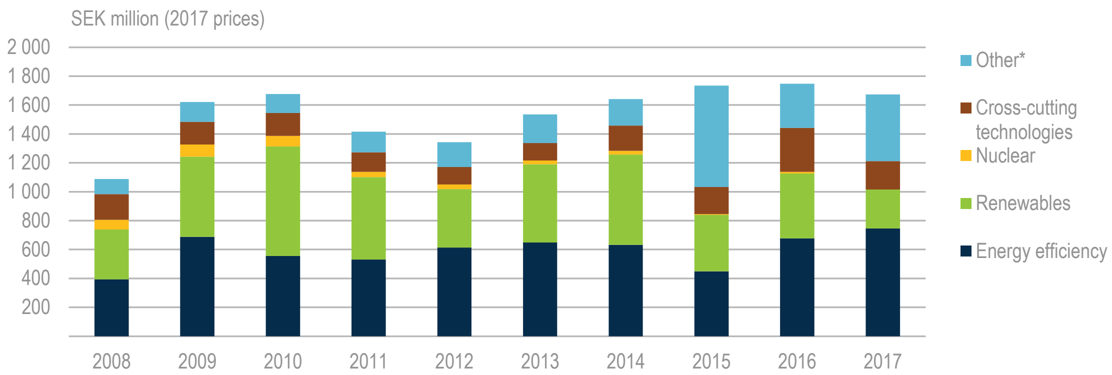
## Figure 6.2 Public RD&I funding in Sweden




Note: RDD&I = research, development, demonstration and innovation.
Source: IEA, based on information from the Swedish Ministry of the Environment and Energy.

In 2017, energy efficiency received 45% of the total funds, renewable energy 16% and cross-cutting technologies 12% (Figure 6.3). As the figure shows, however, funding by areas of energy RD&D varies from year to year.

## Figure 6.3 Government energy RD&D spending by category, 2008-17



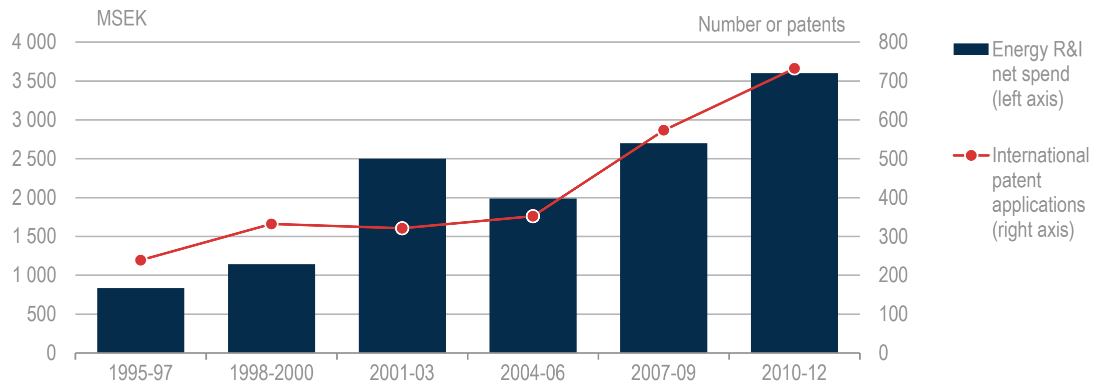

Research on energy efficiency, renewables and cross-cutting technologies receive the highest shares of public RD&D spending.

* *Other* includes fossil fuels, hydrogen and fuel cells, other power and storage technologies, and unallocated money.
Sources: IEA (2018a), *IEA Energy Technology RD&D 2018* (database), www.iea.org/statistics/.

To some extent, this depends on which large-scale demonstration projects are funded in a particular year. Nuclear research did not receive any public funding, except on safety issues, in contrast to most countries with high shares of nuclear power. Funding for cross-cutting research, however, has increased in recent years, as integration between sectors is becoming more important. A case in point is smart grid research, which often integrates electricity, heat, transport and industry sectors.

Given the relatively close correlation between net spending on energy RD&D and patent applications from 1995 to 2012, the stimulation of ETRDI is considered to have had a positive impact in the recent past (Figure 6.4). Data that are more recent would be needed to confirm this trend.

**Figure 6.4 Government energy RD&D spending and patent applications, 1995-2012**




Increased energy RD&D spending over the past decade helped trigger new international patent applications.

Note: MSEK = million SEK.
Source: SEA, based on the European Patent Office PATSTAT database.

## Monitoring and evaluation

The national ETRDI policy was evaluated in the preparation of the 2017 Bill for Energy Research and Innovation for Ecological Sustainability, Competitiveness and Security of Supply[2].

Most ETRDI projects funded by the SEA under the National Energy Research and Innovation Programme are designed and executed as part of a specific programme. These programmes are defined by their objectives, programme theory (impact logic) and delimitations, such as choice of industry or business sector, field of science or technology, and properties of companies or other organisations.

Monitoring focuses on participating actors, resources, implementation and achievement. Programme managers are responsible for gathering data of a specific programme for monitoring purposes. They are members of the Programme Council or Advisory Board and receive reports on the programme implementation in accordance with the project decisions and plans. This reporting also forms the basis for payment of the project funds.

[2] The strategic prioritisation process was evaluated by the consultancy Kontigo and the Agency for Growth Analysis.

In addition, the SEA conducts an annual follow-up survey to highlight a selection of important issues. In specific situations, midterm evaluations of the programmes may be required.

## International collaboration

Swedish energy research is closely tied to the international energy research community. The country actively leads or participates in multilateral co-operation through Mission Innovation (MI), the Clean Energy Ministerial (CEM), the European Union (EU) European Research Area Network, the EU Strategic Energy Technology (SET) Plan, Horizon 2020 and the regional Nordic Energy Research Programme. Sweden also has bilateral collaboration projects and programmes, for example with India and Indonesia. In addition, Sweden is a Contracting Party to 22 IEA Technology Collaboration Programmes (TCPs), particularly those related to energy efficiency and renewable energy.

The aims of MI are to strengthen and accelerate public and private global clean energy innovation. Each participating country will seek to double its governmental and/or state-directed clean energy research and development (R&D) investment over five years. New investments are to be focused on transformational clean energy technology innovations that can be scalable to varying economic and energy market conditions. In practice, Sweden chose to double the funding for energy R&I projects that focus on long-term, transformative R&D and are formulated bottom-up by researchers and/or industry. The doubling is based on the average of the budget allocated for such operations during the period 2013-15. Sweden was a founding participant in this initiative when it was launched in November 2015, which today includes 23 countries and the European Union.

Sweden participates in several initiatives and campaigns of CEM. It also co-hosted the ninth CEM and the third MI in May 2018, together with the Denmark, Norway, Finland, the Nordic Council of Ministers and the European Commission.

Swedish research institutions and companies participate in the EU's Horizon 2020 – the largest EU R&I programme with a budget of close to EUR 80 billion for 2014-20. One of Horizon 2020's priority thematic areas is energy, with a focus on energy efficiency, low-carbon energy and smart cities and communities.

Sweden takes part in the EU SET Plan. As part of the SET Plan, Swedish research institutes and companies can participate in the European Energy Research Alliance, the European Technology and Innovation Platforms and the SET Plan Information System.

Sweden is a member of Nordic Energy Research, an institution under the Nordic Council of Ministers to promote regional co-operation in energy RD&D and to help address the following challenges:

- infrastructure that enables system solutions
- transportation fuels and the utilisation of biomass
- energy efficiency improvements in demand sectors
- decarbonisation of energy-intensive industry.

To strengthen and better co-ordinate international collaboration, the government established the Swedish strategy group for EU co-ordination (EU-Sam) and the Swedish strategy group for international R&I.

Lastly, the SEA has initiated a platform, "A Challenge from Sweden", an innovation procurement competition for sustainable energy technology that is open to national and international participants. The platform aims to 1) facilitate needs-driven innovation, 2) strengthen public-private partnership, 3) accelerate transformative and disruptive change and 4) implement new sustainable business models.

## Assessment

Sweden has a well-established policy on ETRDI and a long history of international collaboration in this field. Given the relatively close correlation between the net spending on energy RD&D and patent applications from 1995 to 2012, the stimulation of ETRDI is considered to have had a positive impact in the recent past. In addition, the significant level of private sector co-funding is an accomplishment.

In March 2017, the parliament adopted the ERIP, formed around five major challenges. ERIP is by far the main source of public funding for ETRDI. Compared to other IEA countries, Sweden is close to the median when it comes to public spending on energy research and innovation per GDP. The IEA commends the Swedish ETRDI policy, as it contributes to the country's overarching climate and energy targets and creates economic opportunities and export potentials.

The IEA applauds Sweden's innovation system approach, the dynamic character of the innovation process, and the stimulation of the collaboration between different actors and sectors (industry and knowledge institutes, but also consumers and local authorities). The IEA also supports the focus on aspects associated with technology development, such as behavioural issues, infrastructure, new business models and market considerations, which are necessary for implementation. This holistic innovation system approach requires a broad range of instruments as well as the right expertise. The SEA is able to deliver on both issues through the entire innovation process to create a positive impact. "A Challenge from Sweden" is a fine example of innovation procurement that also enhances international exposure.

The SEA, together with the MEE, has put a lot of effort into developing a systematic approach for prioritisation, implementation, monitoring and evaluation. From the overarching policy framework, visions and objectives around nine themes were derived, followed by the formulation of ETRDI programmes with clear targets to stimulate activities and produce tangible results, and a well-functioning monitoring and evaluation system.

Currently, over 60 multiyear ETRDI programmes are in operation and comprise more than 2 500 projects. The programmes vary from zero-emission transportation to a fossil-free steel industry to ocean energy (motivated by export potentials). It is a challenge to manage this broad variety and high number of programmes and projects, absorb the knowledge gained and manage a complex budget. The impact of ETRDI can be increased with more focus on the major challenges for Sweden. Near-term market opportunities (particularly for applied research and demonstration) merit attention.

Strengthening the co-ordination of energy R&I with general R&I could further enhance these opportunities, which should be considered when preparing the bill for the new Energy Research and Innovation Programme and the budget for 2021-24.

The government has a clear vision of the importance of international collaboration on climate and energy RD&I. This is highlighted by the activities through the Nordic Energy Research Programme, the participation in 22 of the IEA TCPs, the active involvement in the EU SET Plan, MI, the CEM and bilateral collaboration with several countries. The aim is to build upon national programmes, to enhance them by working together with international partners and to gain knowledge of the development of certain innovation areas that could be of interest to Sweden. International collaboration is also needed to pave the way for Swedish innovations in a global market. The co-ordination and strengthening of the work within the European Union and in the international research context have been professionalised with the setting up of EU-Sam and the Swedish strategy group for international research and innovation.

History shows that innovations can fundamentally transform societies, and technology can develop much faster than anticipated (e.g. cost reductions in solar PV and offshore wind). This is thus further reason to assess periodically new international developments, the possible effects for Sweden, the progress with ETRDI programmes and, from a holistic innovation system perspective, what steps to take next. This could also mean adjusting energy or climate policy measures. Sweden should maintain support for the programme "A Challenge for Sweden", which focuses on innovation, transformational change and new business models.

The energy and climate policy goals of 100% renewable electricity generation by 2040 and net zero-carbon emissions by 2045 are ambitious. To progress further towards achieving these objectives, ETRDI budgets will need to be increased significantly, for technologies with expected potentials as well as those closer to market. The government needs to evaluate whether the demand for certain innovations that are market-ready could be stimulated by other energy or climate policy measures, or would need to be funded by the European Union. For example, the regulation for biofuels in transport could stimulate private investment on RD&I, and possibly reduce the need for public funding. However, it could benefit from a European market for biofuels. With these kinds of analyses, the ERIP could focus on cross-cutting themes and systems transformation to create more added-value with public money. Examples are energy conversion and storage, the use of other energy carriers in the system, the integration of a circular economy and energy and transforming the industry. ETRDI budgets should reflect the political ambition for Sweden to become the first fossil fuel-free welfare nation. For that to happen, also the right expertise and skilled workforce are required.

## Recommendations

***The government of Sweden should:***

- ☐ Consider ways to enhance the support for the energy and climate objectives through ETRDI efforts in the upcoming bill for 2020. Focus energy ETRDI efforts on the major energy challenges.

- Investigate and further prioritise topics and programmes for ETRDI to create more focus, critical mass and greater impact.
- Continue efforts to monitor, evaluate and periodically review the results of the ETRDI programmes to assess progress and to define the next steps.
- Increase the ETRDI budgets to achieve the ambitious energy and climate objectives and maintain a robust national R&D framework.

## References

IEA (International Energy Agency) (2018), *IEA Energy Technology RD&D 2018* (database), OECD/IEA, Paris, www.iea.org/statistics/.

# 7. Electricity

## Key data

(2017)

**Generation:** 164.2 TWh (nuclear 40.0%, hydro 39.7%, wind 10.7%, bioenergy and waste 8.4%, coal 0.6%, oil 0.2%, natural gas 0.2%, peat 0.1%, solar 0.1%), +10% since 2007

**Renewable electricity:** 95.1 TWh, 57.9% of electricity generation (IEA average: 24.7%)

**Net exports:** 19.0 TWh (imports 11.9 TWh, exports 30.9 TWh)

**Installed capacity:** 39.8 GW

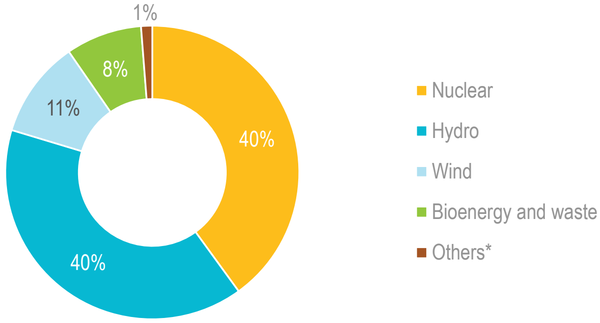
**Consumption:** 130.5 TWh (industry 39.0%, residential 34.6%, commercial 22.0%, other energy 2.5%, transport 1.9%)

**Exchange rate:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Overview

Sweden has the second-lowest share of fossil fuels in electricity generation among all International Energy Agency (IEA) member countries (after Switzerland), as its electricity mix is based on nuclear and hydropower, as well as wind and biofuels and waste (Figure 7.1). Since 2003, the market-based electricity certificate system has supported investments in new renewable capacity, especially wind power. As electricity demand has remained flat, Sweden has become a large net exporter.

**Figure 7.1 Electricity supply by source, 2017**




Electricity supply in Sweden is almost completely carbon-free and traditionally based on nuclear and hydropower.

* *Others* includes small shares of coal, natural gas, oil, peat and solar.

Source: IEA (2019a forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

The 2016 Energy Agreement includes a target of 100% renewable electricity generation by 2040. Although this does not impose a ban on nuclear power specifically, investments in new nuclear capacity are unlikely in today's market conditions. The political ambition for more renewable electricity supply seems thus clear. The Energy Agreement also extends the electricity certificate system to provide certificates until 2030 by an additional 18 terawatt hours (TWh).

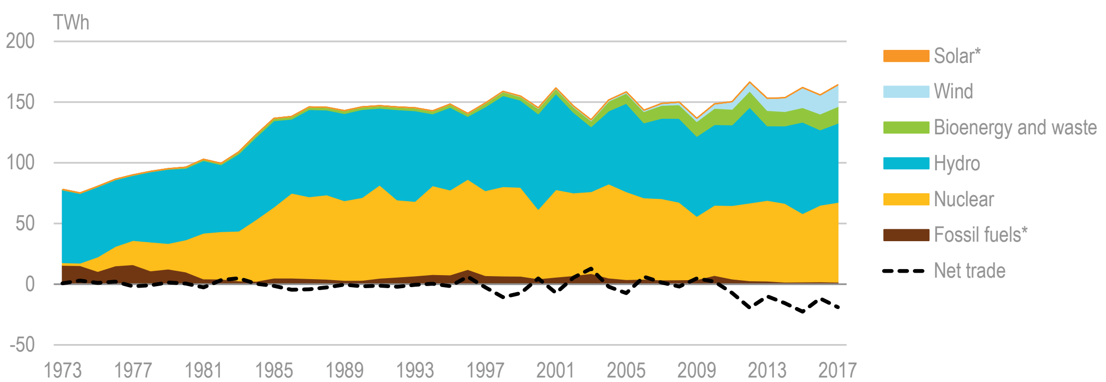
# Supply and demand

## *Electricity generation and trade are increasing*

After the commissioning of the nuclear power fleet in the 1970s and 1980s, Sweden's annual electricity generation remained stable at around 150 TWh, roughly half nuclear and half hydropower, until the introduction of the electricity certificate system in 2003. Since then, new renewable power capacity has increased significantly. The certificate system is market-based and it steers investments into the cheapest technology (large hydropower taken into operation before 2003 is not part of the system). Initially, this was mostly biofuel-based co-generation[1] plants. In recent years, however, wind power has become the cheaper option and received the majority of the issued certificates.

In 2017, the total electricity generation was 164 TWh, with 40% each for nuclear and hydropower, 11% for wind and 8% for bioenergy and waste (Figure 7.2). The power mix has the second-lowest share of fossil fuels among the IEA member countries, after Switzerland (Figure 7.3). From 2008 to 2017, hydropower generation averaged 67.4 TWh per year, ranging from 61 TWh to 79 TWh. Nuclear power averaged 61.5 TWh per year, ranging from 52 TWh to 66 TWh.

**Figure 7.2 Electricity supply and net trade, 1973-2017**




Although electricity demand has remained flat in recent years, power generation from biofuels and wind has increased rapidly and made Sweden a net exporter of electricity.

* *Fossil fuels* includes natural gas, coal, peat and oil products.

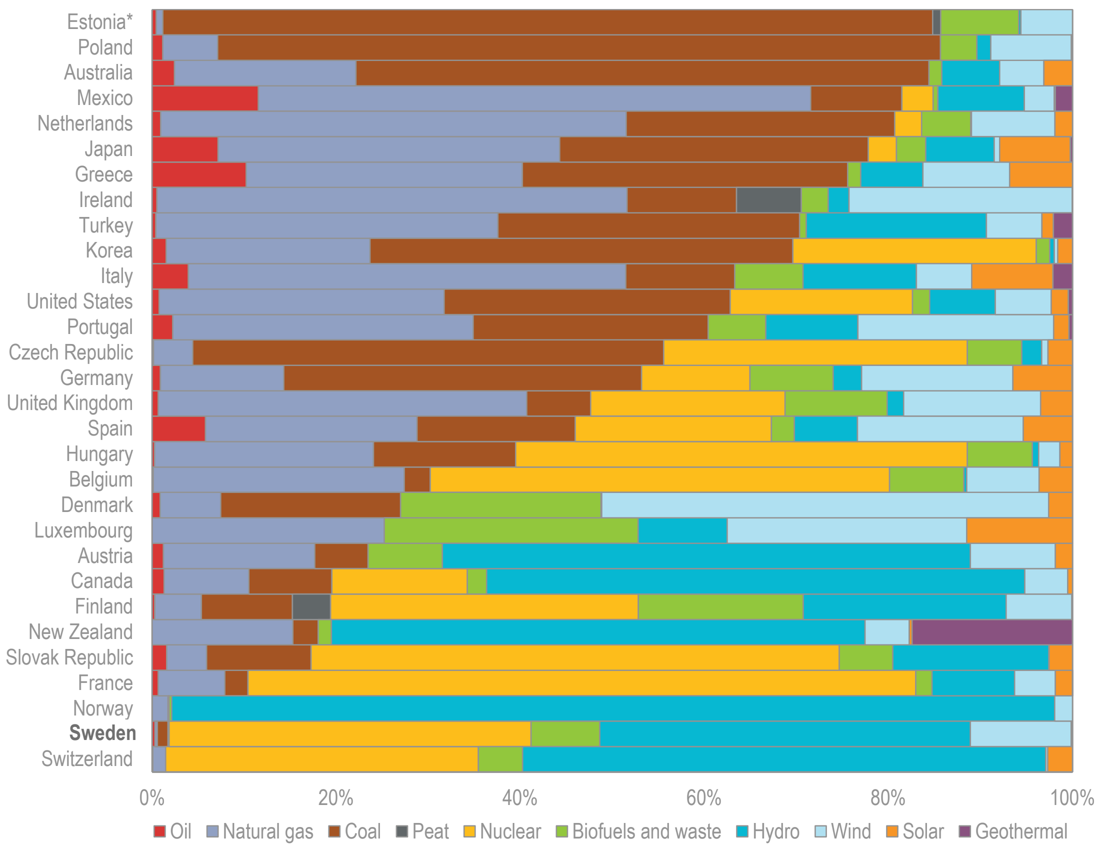
** Net trade refers to annual net imports (positive numbers) and net exports (negative numbers).

Source: IEA (2019a forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

[1] Co-generation refers to the combined production of heat and power.

Wind power generated 17.6 TWh in 2017, after more than doubling in five years and increasing more than tenfold from 2007. Bioenergy and waste generated 13.8 TWh, up by 29% since 2007. The rapid increase in new renewable power generation in the past decade has resulted in increased electricity exports. In 2017, net exports were 19 TWh, the third highest after 2012 (19.6 TWh) and 2015 (22.6 TWh) (Figure 7.4).

### Figure 7.3 Electricity generation by source in IEA member countries, 2017




Sweden has the second-lowest share of fossil fuels in electricity generation in the IEA, thanks to high shares of nuclear and renewable energy.

* Estonia's coal represents oil shale.

Note: Data are provisional.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

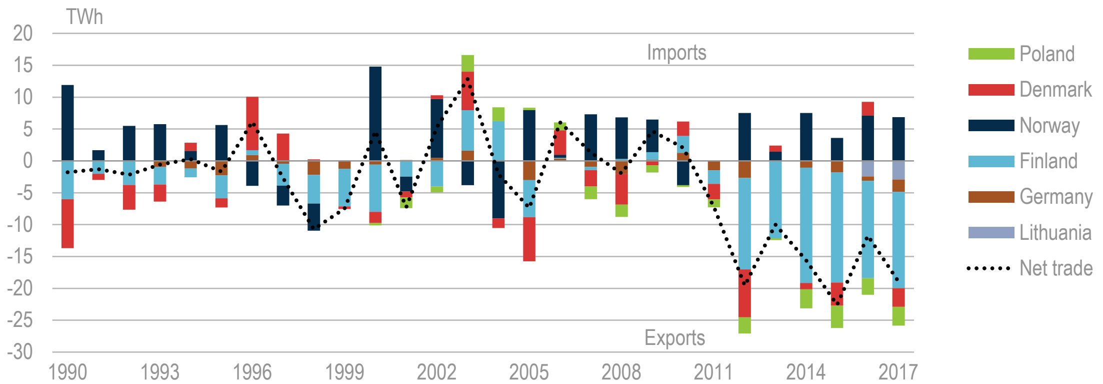
Sweden is well interconnected with neighbouring countries, mainly through land cables to Norway as well as to Finland and high-voltage sea cables to Finland and Denmark, but also to Germany, Poland and Lithuania. In 2017, half of Sweden's electricity exports went to Finland and all net imports came from Norway (Figure 7.4).

Sweden is also a net exporter of electricity on a monthly basis. Electricity generation varies with the demand throughout the year and peaks in cold winter months (Figure 7.5). In summer, when demand is low, nuclear power plants (NPPs) usually have planned maintenance periods, which decrease electricity output.

Electricity trade in the Nordic market area is governed by price differences between price areas. As low-cost hydropower is the largest electricity source both in Sweden and the Nordic market, trade flows are heavily influenced by precipitation levels.

Under the Swedish Energy Agency's (SEA's) reference scenario, Sweden will remain a net exporter of electricity in the coming decades, as the electricity certificate system adds new generation capacity and demand is growing only slowly. Net exports are expected to reach more than 30 TWh per year in the 2030s (SEA, 2016).

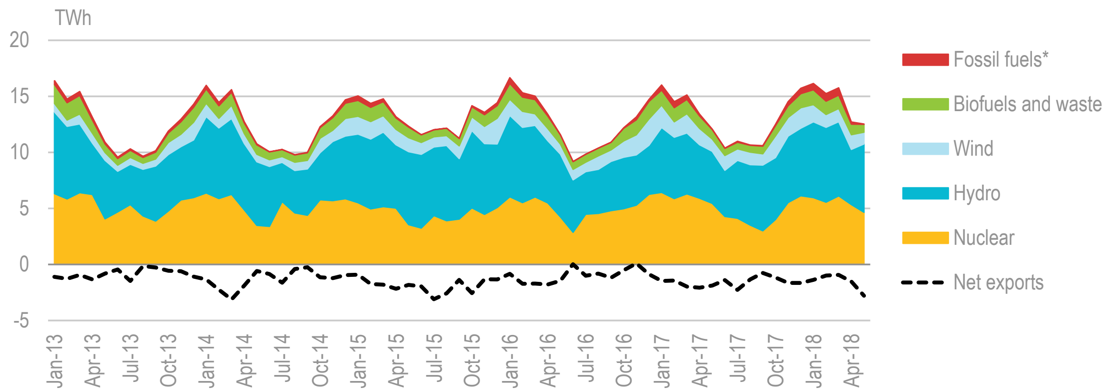
**Figure 7.4 Sweden's electricity imports and exports by country, 1990-2017**




Sweden is well interconnected with neighbouring countries, and electricity exports have increased in recent years, notably to Finland.

Source: IEA (2019b forthcoming), *Electricity Information 2019 preliminary edition*, www.iea.org/statistics/.

**Figure 7.5 Monthly electricity generation by source, Jan 2013 to May 2018**




Since 2013, Sweden has been a net exporter of electricity every month (except for one), including peak demand months in winter.

* *Fossil fuels* includes natural gas, coal, peat and oil products.

Note: The chart does not include negligible shares of solar power.

Source: IEA (2018b), *Monthly Electricity Statistics: June*, www.iea.org/statistics/.

## *Large increase in wind power capacity projected to continue*

The rapid growth in wind power is the major change in installed capacity in the recent decade. In 2017, Sweden's total installed capacity was 40 gigawatts (GW), 18% more than in 2000 (Table 7.1). Nearly all of this increase came from wind power, supported by the electricity certificate system (see below). The Swedish Wind Energy Association (SWEA) projects further fast growth with 815 MW in 2018 and 1 734 MW in 2019 (SWEA, 2018). In contrast, the Ringhals 1 and 2 nuclear units with a total of 1.8 GW will close in 2019-20, because wholesale electricity prices have remained low and operation beyond 2020 would require large investments in safety upgrades.

**Table 7.1 Installed generating capacity, 2000-17 (MW)**

| Energy source | 2000 | 2005 | 2010 | 2012 | 2014 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|
| Nuclear | 9 461 | 9 454 | 8 977 | 9 436 | 9 507 | 9 768 | 8 999 |
| Hydropower | 16 525 | 16 270 | 16 732 | 16 414 | 15 996 | 16 466 | 16 502 |
| Solar | 3 | 5 | 11 | 24 | 60 | 153 | 244 |
| Wind | 209 | 516 | 2 019 | 3 607 | 5 097 | 6 435 | 6 611 |
| Combustible fuels | 7 526 | 7 882 | 8 715 | 8 362 | 8 076 | 7 495 | 7 442 |
| Total capacity | **33 724** | **34 127** | **36 454** | **37 843** | **38 736** | **40 317** | **39 798** |

Source: IEA (2019b forthcoming), *Electricity Information 2019 preliminary edition*, www.iea.org/statistics/.

## Electricity consumption is stable

Sweden is an electricity-intensive country. In 2017, consumption exceeded 13 megawatt hours (MWh) per citizen, the fifth-highest among the IEA member countries. 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.

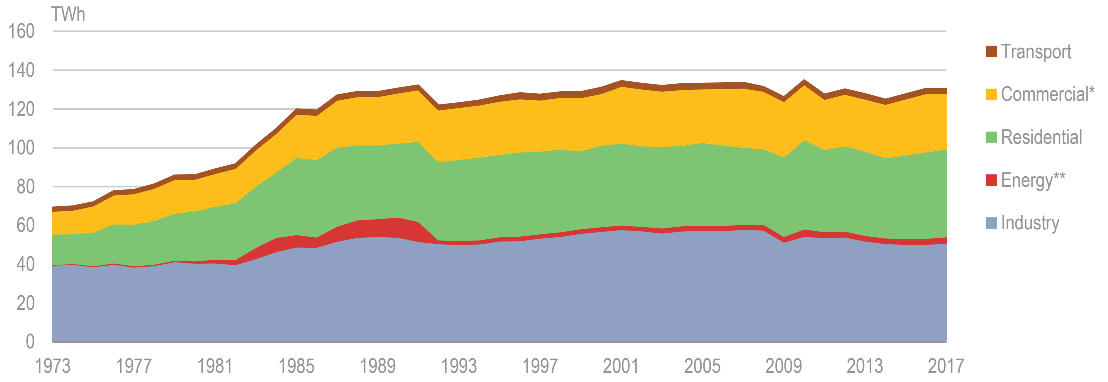
In contrast to the increasing electricity generation, electricity demand has remained relatively stable at around 130 TWh per year in the recent decades (Figure 7.6). In 2017, the total final consumption (TFC) of electricity was 130.5 TWh, 2% less than in 2007, but 4% more than in 2014. Industry is the largest electricity consumer, at 39% of the total in 2016, followed by households at 35% and the commercial sector at 22%. The paper industry alone used 16% of all electricity. Consumption varies from year to year, mostly because of changes in temperature and in the business cycle of the heavy industry.

The stable demand results from several trends that counteract each other. For example, increased electric heating in the 1980s and 1990s raised electricity demand, but the recent shift from direct electric heating to more efficient heat pumps stalled the growth in electricity demand. In industry, increased electrification has been offset by improved energy efficiency. Electricity demand is likely to increase, driven by further electrification of the transport sector and new consuming sectors, such as data centres. However, the volume of the demand increase is very uncertain.

The highest measured load in 2017 occurred on 5 January and amounted to 26 616 MW. Sweden's all-time record load, 27 000 MW, was reached on 5 February 2001. As electric heating is common in Sweden, the load is correlated with the outside temperature (SEMI, 2018).

The transmission system operator (TSO) Svenska kraftnät expects both electricity consumption and peak load to increase. In a normal year, peak load is expected to reach roughly 26 900 MW in 2020 and 28 400 MW in 2030. The 1-in-10 year winter peak load is expected to reach 28 500 MW in 2020 and 30 000 MW in 2030.

**Figure 7.6 Electricity consumption by sector, 1973-2017**




Electricity consumption has been stable for decades, as efficiency improvements have offset the growth in industry output and residential buildings and appliances.

* *Commercial* includes commercial and public services, agriculture and forestry.

** *Energy* includes petroleum refineries, coke ovens and other energy sector consumption.

Source: IEA (2019a forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

# Institutions and legal framework

## *Institutions*

The Swedish Energy Markets Inspectorate (SEMI) is the independent regulatory authority for electricity. The Inspectorate regulates the network tariffs for the transmission and distribution of electricity and natural gas. It also monitors and supervises the security of supply of the distribution network and the end-user market. The SEMI also supervises the TSO's activities and the wholesale markets for electricity and gas.

The Financial Authority is responsible for supervising the financial instruments related to wholesale energy contracts. In its investigations, it co-operates with the SEMI.

The Swedish Competition Authority is responsible for ensuring fair competition and that no market actor is abusing a dominant position in the market. This is also done in co-operation with the SEMI.

## *A liberalised low-carbon energy-only market*

Deregulated in 1996 and part of the common Nordic electricity market, the Swedish electricity system is considered a role model for market liberalisation and regional integration.

The legal basis for the Swedish electricity sector is provided in the Electricity Act of 1997, which has been amended several times since then, including to accommodate

European Union electricity market legislation, the latest of which is Directive 2009/72/EC, which is in the process of being recast.

The Swedish electricity market is fully liberalised and customers are free to choose their own supplier. Electricity transmission and supply activities are separated through ownership unbundling. Distribution network operators (since January 2010) are functionally unbundled.

Network-access tariffs for electricity transmission and distribution have been regulated *ex ante* since 2012. Distribution networks are regulated at a return rate, with a regulatory period of four years and a revenue cap that includes quality norms. Transmission maintains a regulatory period of one year. The price of electricity supply is not regulated.

The 2016 Energy Agreement focuses on the electricity sector in several ways. It sets a goal of 100% renewable energy sources for electricity (RES-E) for 2040, but does not include a phase-out of nuclear power. It also phases out the tax on nuclear thermal capacity by 2018 and reduces the property tax on hydropower stepwise to 0.5% by 2020, to the same level as other power-generation technologies (except wind power).

The parliament approved a bill related to hydropower in summer 2018. The bill introduces an ecological re-licensing process for existing hydropower plants to better comply with the EU Water Framework Directive, but it also enables refurbishing and increasing the efficiency of existing large hydropower plants.

## Support for renewable electricity

### *The electricity certificate system*

The electricity certificate system was introduced in 2003, initially to help reach the goal of 60% of electricity TFC consumption from RES-E by 2010 and the goal of 50% renewable energy in the gross of energy by 2020. Both targets were derived from EU directives. The necessary increases in generation in Sweden had to come from sources other than large hydropower, because many of the remaining rivers with the potential for additional capacity are protected.

In 2012, Norway joined the certificate system to reach its binding EU-related renewables target for 2020. Initially, the joint target was to increase RES-E by 16.4 TWh from 2011 to 2020, but the target was later increased to 28.4 TWh. In June 2017, the Swedish Parliament extended the certificate system to the year 2045 and set a target of 18 TWh more RES-E from 2020 to 2030. The increase will be linear, starting from 2022.

The certificate market works as follows:

- Electricity generators receive one electricity certificate for each megawatt hour of renewable electricity produced over 15 years.
- The demand for electricity certificates arises because electricity suppliers (and certain electricity customers) are obliged by law to buy electricity certificates to meet a certain share (quota) of their calculation-relevant electricity supply (or consumption for the large customers).

- Electricity certificates are sold in a market in which prices are determined by supply and demand. The generators receive this as extra income in addition to the electricity price.
- That way the electricity end users pay for the development of renewable electricity generation, because the cost of the electricity certificates is included in the electricity bills.
- Every year, the market participants with quota obligations must cancel electricity certificates to fulfil their quota obligation.

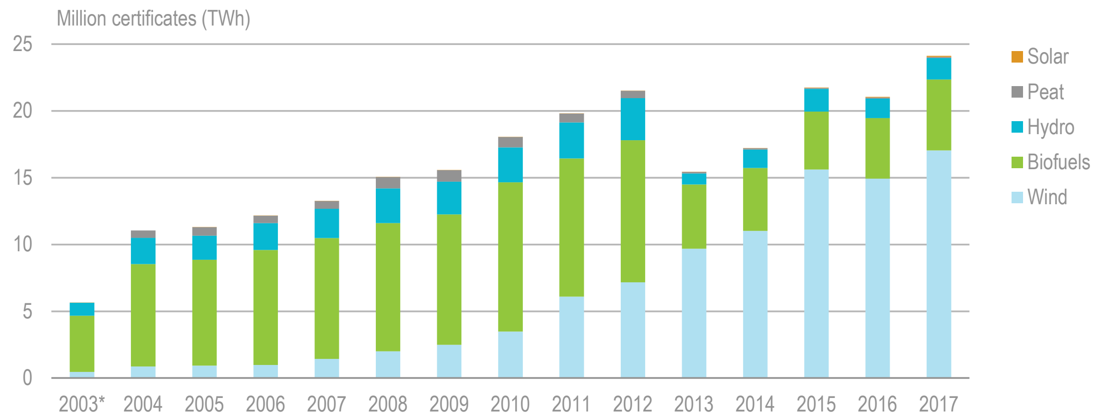
The cost of suppliers' certificates is included in the price of electricity paid by consumers. However, electricity-intensive manufacturing industries are exempted from this. The electricity consumers calculated costs for electricity certificates in Sweden between 2003 and 2016 were between 1.5 and 5.3 Swedish öre/kilowatt hour (kWh) electricity. The average subsidy per megawatt hour generated under the system was in the 18-20 euro (EUR)/MWh range in recent years, relatively low compared to support costs in other European countries, but rather high compared to the average wholesale prices in the Nordic electricity market (see Figure 7.9).

By mid-2016, the electricity certificate system had contributed 16.4 TWh of new renewable electricity supply (normalised annual generation) since the beginning of 2012 when Norway joined the system. Out of this total, 2.9 TWh was generated in Norway and 13.5 TWh in Sweden.

In spring 2016, Norway's government decided not to set new targets in the electricity certificate system after 2020, as it considered that the certificate system affects the functioning of the Nordic electricity market. Instead, the Norwegian government preferred to change the focus from the support of mature generation technologies to innovation and the development of new energy and climate solutions (IEA, 2017).

In 2017, 24.1 million certificates had been allocated to renewable installations in Sweden. Wind power accounted for 71%, followed by biofuels at 22.0% and hydropower at 6.7%, with the remaining 0.6% allocated to peat and solar (Figure 7.7).

**Figure 7.7 Green electricity certificates by energy source, 2004-17**




Until 2012, electricity from biomass received most certificates, but since, wind power dominates.

* In 2003, the certificate system includes allocations during May-December.

Source: SEA (2018), Detaljerade Uppgifter om Elcertifikatsystemet 2003-2017 Avseende Kvotplikt och Tilldelning av Elcertifikat i Sverige (Detailed Information on the Electricity Certificate System Regarding Quota Obligation and Certificate Allocation in Sweden), www.energimyndigheten.se/fornybart/elcertifikatsystemet/marknadsstatistik/.

### Wind power licensing and siting

The process of approving the plans for and construction of wind power projects comprises, in the case of larger projects, several steps. The project owner must consult with the potentially affected local and government actors, such as local residents and municipal officials, as well as government representatives from, for example, the County Administrative Board, the Department of Defence and the Aviation and Water Authorities. The project owner must also commission an environmental impact assessment and apply for a permit from the County Administrative Board. Furthermore, the municipalities in which the project will be located must grant their approval for the project to proceed.

As an important part of the effort to increase the share of renewable energy, the SEA designates areas of national interest for wind power generation. When developing municipal general plans, municipal officials are to take into account such areas of national interest. These areas of national interest for wind power development, which were introduced in 2004 and updated last in 2013, have significantly raised the profile of wind power in relation to other interests in spatial planning.

The SEA is also in the process of designating areas of national interest for hydropower. The intention is to identify locations especially suitable for hydropower and give those locations a higher status for spatial planning. Offshore licences for wind have been hard to receive because there are also environmental and military interests in most of the territorial waters.

### Small-scale renewables receive additional support

The installation of photovoltaic cells is encouraged by a 30% investment aid. This aid, which has a yearly budget of SEK 915 million until 2020, is expected to lead to a small increase in the installed generation capacity (0.5 GW solar in 2020). In parallel, the incentivised production is eligible for participation in the certificate system. Besides, the microgeneration of solar photovoltaics (PV) is also supported through tax reduction. Self-generating households may also receive subsidies for investing in storage. Prosumers that are net buyers from the grid are exempted from the network charges for the electricity they feed into the network.

Biogas production from manure is supported through a programme that runs from 2014 to 2023 and has a total budget of SEK 385 million. In 2018, the programme was temporarily reinforced with SEK 270 million and its scope broadened to include biogas from other sources than manure. The programme reduces both greenhouse gas emissions and water eutrophication. The biogas generated can be used to generate electricity or heat, or as vehicle fuel. The subsidy amounts to a maximum of SEK 0.4/kWh of biogas produced. Between January 2015 and September 2016, a total of SEK 69 million was paid out to 51 biogas plants.

## Transmission and distribution networks

### Transmission

The Swedish electricity network consists of 564 000 kilometres (km) of power cables, of which around 382 000 km are underground and 182 000 km overhead lines. The high-voltage (400/220 kilovolts (kV)) transmission network covers around 15 000 km. The transmission system is owned and operated by Svenska kraftnät, the TSO, which is 100% state-owned and fully unbundled from any other activities in the electricity sector.

The transmission system runs from the north, where most hydropower and wind power is generated, to the south, where the consumption centres and the country's NPPs are located. Svenska kraftnät sees a need to increase both the national north-south capacity and the cross-border capacity. This is justified both by the increasing volumes of wind power generation in the north of Sweden and in neighbouring countries, and by the existence of bottlenecks in the Swedish grid. Also, many transmission lines, coming to the end of their lifetime, must be replaced in the next decade.

More than in the national context, the Swedish electricity system should be seen as part of the regional Nordic/Baltic electricity market, which spans across the Nordic (Norway, Sweden, Denmark and Finland) and Baltic (Estonia, Lithuania and Latvia) states. It is coupled with the Western European electricity markets (since 2014). Sweden, Finland, Norway and Eastern Denmark form one synchronised zone.

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 which form a basis for the close co-operation between regulators (NordREG) and TSOs.

## Congestion management

In the Nordic market area, congestion is managed on the basis of countertrading or market splitting through the creation of price areas. Such price areas are determined by the TSOs on the basis of the congestion at the price determined on the Nord Pool wholesale market.

Sweden moved to a system of four price areas in 2011. The areas are the Luleå bidding area (SE1), Sundsvall bidding area (SE2), Stockholm bidding area (SE3) and Malmö bidding area (SE4) (Figure 7.8). SE3 and SE4 have a generation shortage, while SE1 and SE2 have a generation surplus. The price differences between the price areas are generally expected to encourage increasing generating and/or transmission capacity which will, in turn, lead eventually to price convergence across the areas and to the elimination of the need for separate price areas.

## Cross-border connections

Sweden is located at the heart of the Nordic electricity system and well connected to its neighbours. It also has direct links to Germany, Lithuania and Poland. The total export capacity from Sweden is 10 575 MW and the import capacity to Sweden 9 645 MW (Table 7.2).

In addition, two interconnector projects are at an advanced planning stage.

The Hansa Power Bridge is a high-voltage direct current (HVDC) line that will connect southern Sweden (SE4) with Germany. In January 2017, a co-operation agreement was signed between the Swedish TSO, Svenska kraftnät, and the German TSO, 50Hertz. The HVDC subsea interconnector between Hurva in southern Sweden and Güstrow in northern Germany has a planned capacity of 700 MW. Svenska kraftnät and 50Hertz are preparing the respective official approval procedures. A final investment decision is expected for late 2022 and the interconnector to be in operation in 2025/26.

The 3AC is an alternation current (AC) line that will cross the land border between Sweden (SE1) and Finland. It will increase trading capacity and the possibility to exchange system services as well as increase the power adequacy in Finland. The project will be built by Svenska kraftnät and Fingrid, the Finnish TSO. The interconnector is expected to come online in 2025 and the planned capacity is 800 MW.

**Table 7.2 Cross-border electricity connections, 2017**

| To | AC (MW) | DC (MW) | From | AC (MW) | DC (MW) |
|---|---|---|---|---|---|
| Finland | 1 500 | 1 200 | Finland | 110 | 1 200 |
| Norway | 3 995 | N/A | Norway | 3 995 | .. |
| Denmark | 1 300 | 680 | Denmark | 1 700 | 740 |
| Germany | .. | 600 | Germany | .. | 600 |
| Poland | .. | 600 | Poland | .. | 600 |
| Lithuania | .. | 700 | Lithuania | .. | 700 |

Source: Information from the Ministry of the Environment and Energy.

## Cross-border TSO collaboration

In the Nordic market, the national TSOs retain control over system operations and transmission planning. The Swedish National Grid (Svenska kraftnät) develops its own transmission development plan for Sweden, but it also participates in the regional transmission development planning. Since 2002, the Nordic TSOs have published joint transmission development plans.

Regional co-operation for both planning and operations is necessary to maintain the security of supply. Svenska kraftnät therefore co-operates closely with the other Nordic TSOs. For example, although the interconnector capacity is allocated implicitly through the Nord Pool day-ahead market, the available capacity and net transmission capacity are calculated by the respective TSOs.

## Distribution

There are around 170 distribution network companies in Sweden, and around 5.4 million customers are connected to the electricity network. The largest network companies – Vattenfall Eldistribution AB (owned by the Swedish state), Ellevio AB and E.ON Energidistribution AB – each have more than 800 000 customers. The smallest network companies have less than 1 000 customers. The companies are a mix of co-operative economic associations, privately owned companies and municipalities. It is common that production, distribution and trade are carried out within the same corporate group, but are unbundled in different legal entities. Distribution network companies that have more than 100 000 customers must be functionally separated from companies that produce or trade in electricity.

## Figure 7.8 Electricity infrastructure in Sweden and in the Nordic/Baltic market area


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: Russia = Russian Federation. km = kilometre.

The 1997 Electricity Act states that everyone has the right to be connected to the grid. The distribution system operators (DSOs) set their own prices for connection, but their pricing methods must be approved by the regulator. Customers may appeal to the regulator about the level of the connection fee.

### *Allocation of grid connection costs*

When generators plan to connect their projects to the electricity grid in areas where the grid lacks the capacity to accommodate the new project, the generator can be forced to pay the entire cost of upgrading the grid's capacity, which includes capacity that the generator's project may not need. Generators that subsequently connect to the same part of the grid are not required to bear this cost. For this reason, generators are reluctant to be the first to connect to the grid in a given area. Referred to as the "threshold effect", this complicates the connection of new renewable energy projects to the grid.

To reduce the threshold effect for new renewable electricity generation, the government developed a transitional solution that came into effect in May 2015 and remains in place as of September 2018. Since then, DSOs may recoup the entire investment cost for upgrading the grid, while generators that connect to the grid only pay for the additional share of grid cost due to their connection to the grid. DSOs may apply for grid-upgrading loans from the TSO for the portion of the investment cost that corresponds to the unused capacity.

## Generation

Electricity generation in Sweden is dominated by a few major generators. The state-owned Vattenfall generates slightly over 40% of the total. The three largest generators, Vattenfall, Fortum (50.8% owned by the Finnish state), and Uniper (47% owned by Fortum), are responsible for around 73% of the total. These three companies also own the nuclear power capacity in the country (Chapter 8). However, the competition in generation should be seen in the context of the well-interconnected Nordic market. SEMI considers that the conditions for competition in the wholesale market are good (SEMI, 2018).

Although Sweden's price area 1 is mainly dominated by one producer and frequently has surplus electricity, it typically forms a common price area with area 2. This limits the market power of individual producers. In the south, price area 4 also has only one major producer, but it typically forms a common price area with price area 3 or with Denmark. Also, the Sydvästlänken transmission grid cable, to be commissioned in 2019, will improve the situation in price areas 3 and 4.

## Market design

### *Wholesale market*

Around 95% of the physical power trade in Sweden takes place at the Nord Pool, a regional power exchange that includes Sweden, Norway, Finland, Denmark, Estonia, Latvia and Lithuania. There were 380 market participants of various sizes in 2017. For the regional market to function properly, regulations are harmonised across the member countries.

The Nord Pool has two physical power markets: a day-ahead market (Elspot) and a continuous intraday market (Elbas). Although the intraday market is growing, the vast majority of trading occurs in the day-ahead market. In 2017, the Elspot traded volume was 387.3 TWh and the Elbas volume 6.7 TWh. The combined volume of 395 TWh is a new record.

The Nord Pool is responsible for the market up to the point of gate closure, which is currently defined as one hour before real time. After the gate closure, the responsibility for the power system is handed over to the various national TSOs.

In addition to the physical Nord Pool markets, a separate market for financial derivatives is operated by the National Association of Securities Dealers Automated Quotations (Nasdaq). This Nasdaq OMX (also known as Nasdaq Nordic) market offers market participants products for long-term financial hedging. In 2016, 761 TWh of power products were traded on it.

At present, the Nord Pool is the only power exchange in the Nordic region. Under the European Union’s network codes, additional power exchanges are allowed, and therefore may be developed within the Nordic area. The Nordic power market, which also participates in the Price Coupling of Regions, is coupled to the rest of Europe. Therefore, price developments in other regions can affect Sweden, and vice versa. The increasing level of interconnection is set to increase price convergence across regions.

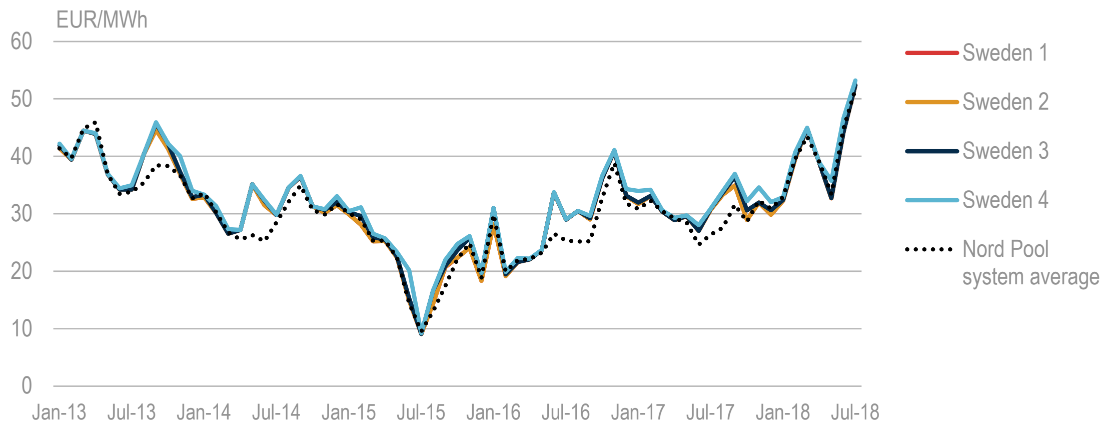
Market participants are responsible for balancing (see below), and the “balancing responsible parties” are defined by the TSOs (for Sweden, it is Svenska kraftnät). The Nord Pool is a zonal market, with zones defined at the national level by the relevant TSO. In 2011, Sweden moved from a system of one zone to four zones (see “Congestion management” above).

In 2017, Sweden was a uniform price region 59.7% of the time. For 30.7% of the time, there were two price regions and for 9.6% of the time the country was divided into three price regions. Most price differences occur between southern (price areas 3 and 4) and northern (price areas 1 and 2) Sweden (Figure 7.9), primarily during periods of transmission restrictions or production losses, particularly in price area 4. The price differences between areas 3 and 4 are expected to fall considerably when the 1.2 GW Sydvästlänken (South-West Link) transmission project is commissioned in 2019 (SEMI, 2018).

Wholesale electricity prices in the Nordic region have been relatively low for several years, after a decline that began in 2011. Demand has barely grown, while supply has increased. The Nord Pool Elspot day-ahead price has varied between 20 and 40 EUR/MWh, in contrast to peak levels of around EUR 90/MWh in 2010 and 2011 (Figure 7.9). In comparison, the levelised costs of electricity (LCOE) for nuclear, hydropower and biomass co-generation in Sweden were all around EUR 34/MWh, according to the 2016 Energy Commission. The LCOE for wind power was EUR 70/MWh and for waste co-generation, EUR 28/MWh. As a result, market-driven investment in new capacity has been low.

Price variation is typically often related to the availability of hydropower, the most abundant source for large-scale generation in the Nord Pool. In a normal year, hydropower generation in the Nordic market area amounts to around 200 TWh, but it can range from 150 to 250 TWh.

**Figure 7.9 Monthly spot electricity prices in the Nord Pool system and in Sweden by price area, 2013-18**




The four price areas of Sweden show very small differences and most of the time are close to the system average.

Source: Nord Pool (2018), *Historical Market Data - Elspot Prices*, www.nordpoolspot.com/historical-market-data/.

## *Nordic balancing market*

One area of active collaboration on the Nordic market is to provide balancing services. Electricity supply needs to be secured at all times, an increasing challenge in a power system with a growing share of wind power and changing consumption patterns. By 2025, the Nordic region is expected to add around 23 GW of wind power, which will require a much more flexible power system. Also, peak power availability and rotating mass will be needed, despite ample generating capacity.

The balancing markets remain national, but the Nordic TSOs have agreed to develop Nordic balancing markets in the forthcoming years. Their 2018 agreement outlines their roles and responsibilities and a roadmap for implementation. For example, the common Nordic capacity market for automatic frequency restoration reserves is to be operational in the second quarter of 2019 and the one for manual frequency restoration reserves by the fourth quarter of 2019.

In 2017, three of the Nordic TSOs (in Norway, Finland and Sweden) combined their balance settlement processes in a single organisation, eSett Oy. Since summer 2018, they and the Danish TSO Energinet.dk are investigating options for Energinet.dk to join the common balance settlement.

## *Retail market and prices*

The Swedish end-user market has around 5.4 million customers who are served by more than 120 suppliers. At the end of 2017, the largest suppliers were Vattenfall (960 000 customers), E.ON (670 000) and Fortum (630 000) (SEMI, 2018). Some of the suppliers only operate locally or regionally.

Suppliers are free to decide what products to offer. Variable price contracts (monthly based) are most common among household customers. Fixed-price contracts with durations up to 10 years are available, but 1-3 year contracts are more common. Moreover, mixed contracts as well as contracts with winter/summer-tariffs are available. With a 100% roll-out of smart meters, dynamic price contracts (usually hourly based) are steadily becoming more popular.

Most suppliers offer only one type of tariff, known as a single tariff, to customers with low consumption. The single tariff means that customers pay the same price per kilowatt hour, regardless of the time of use during the day. Some companies also offer an alternative, the time-of-use tariff, in which the price depends on the time of day when the electricity is used.

Electricity suppliers to end users must report the most common contract types to the price comparison site of SEMI (elpriskollen.se). In 2017, 9.5% of end users switched their supplier, consuming 9.8% of electricity in the country. These shares are relatively representative of recent years.

As other Nordic countries, Sweden is moving towards a centralised information exchange system in retail markets. In 2016, the government assigned Svenska kraftnät and SEMI to develop a so-called data hub and related rules and regulations. The hub will hold all metering data for the electricity market. Concentrating electricity use information in one place could simplify supplier switching and enable new services, for example related to energy efficiency and aggregating demand-side response capacity. SEMI estimates households to hold a potential of 5 GW for demand-side flexibility (in winter). The TSO will operate the data hub, which is foreseen to be operational in late 2020 at the earliest (Svenska kraftnät, 2018a).

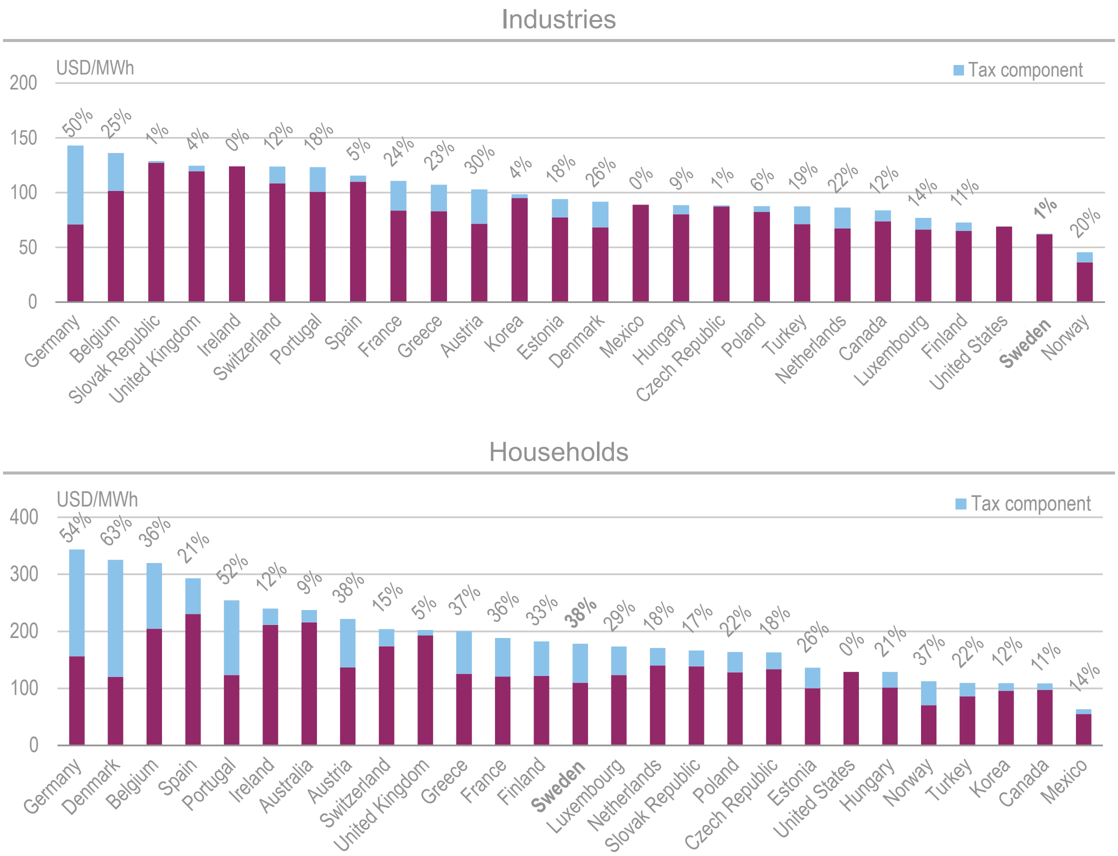
More generally, in 2016 the Ministry of the Environment and Energy set up the Swedish Smartgrid Forum. Its task is to promote dialogue about the possibilities of smart grids, and to help create international business opportunities and partnerships within the smart grid field. The Forum is placed at the SEA.

Electricity prices are relatively low, especially for industry. In 2017, industry paid on average US dollars (USD) 62.5/MWh, the second-lowest price for electricity among all the IEA member countries (Figure 7.10). The cheap electricity is a result of both low wholesale prices and the applicable level of taxation for the manufacturing process in the industry. Taxes accounted for only around 1% of the industry electricity price. Swedish households, on the other hand, paid on average 178.3 USD/MWh, of which 38% were taxes. This was around the median in the IEA comparison.

Both industry and household prices fell during 2011-15, similar to neighbouring countries (Figure 7.11). In recent years, prices have started to increase again slightly.

Average end-user prices differ very little across the price areas. In 2016 and 2017, an average customer who consumed 20 000 kWh a year under a fixed-price one-year contract in price area 4 paid SEK 20 more per megawatt than an average customer in price areas 1 or 2, or SEK 400 more for the whole year (SEMI, 2018).

## Figure 7.10 Electricity prices in IEA member countries, 2017



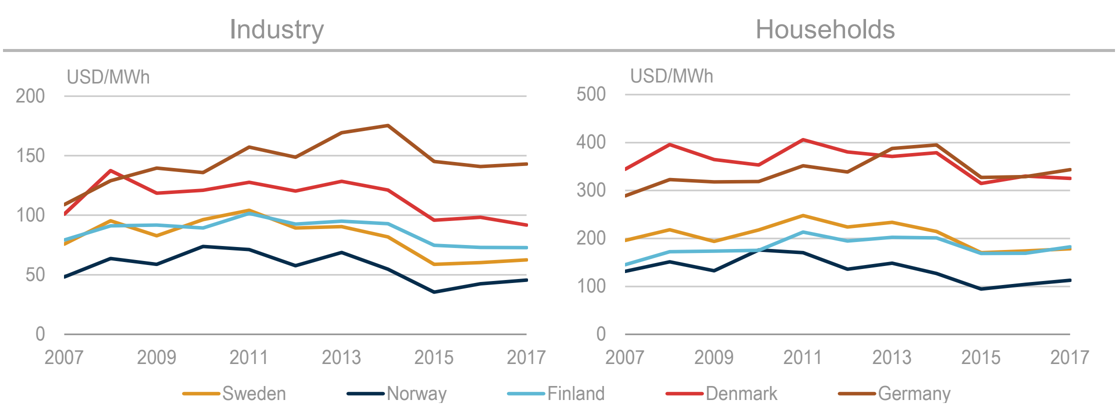

Swedish industry pays the second-lowest electricity prices in the IEA, partly thanks to low taxes, whereas prices for households are around the median.

Notes: Data missing for Australia, Italy, Japan and New Zealand. Differences in data reporting methods can lead to different price data compared to that reported by the European Commission.

* Tax information not available for the United States.

Source: IEA (2018c), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

## Figure 7.11 Electricity price trends in selected IEA member countries, 2007-17




Sweden's electricity prices follow similar trends as those of the Nordic neighbours.

Source: IEA (2018c), *Energy Prices and Taxes, First Quarter 2018*, www.iea.org/statistics/.

# Security of supply

The responsibility for the security of electricity supply is divided between the market and the government authorities. The market is expected to develop adequate generation and distribution capacity, for which it needs the right incentives. The SEMI is responsible for supervision, the SEA for setting priority end users, rationing and other regulation, and the TSO for preparedness, supervision and market development.

The TSO and the DSOs have operational responsibility for grid management and system security. They can give directions to grid users. The grid companies are also responsible for preventive measures.

The concept of electricity system security comprises three main types of disturbances: outages, power shortages and energy shortages. The responsibility for minimising these three is divided and controlled through laws and regulations. The market actors are generally responsible for balance, continuity, preventive work and the preparedness for disturbances. All of this is regulated and supervised by SEMI, SEA and the TSO.

Regarding outages, according to the 1997 Electricity Act, customers affected by an outage of at least 12 hours are entitled to compensation from the DSO to which they are connected, unless the outage is caused by events beyond the DSO's control. This compensation obligation has encouraged DSOs to improve the robustness of their grids against weather-related events.

Rural networks are generally more exposed to weather-related disruptions, partly because frequently uninsulated overhead cables are used, whereas in urban areas cables typically run underground.

The electricity system is very reliable. In 2016, in the transmission system, the average interruption time was 0.3 seconds and energy not supplied totalled 1.1 MWh. In the local distribution system, the interruptions per customer averaged at 1.17 in 2016 and their duration averaged 75.6 minutes.

In terms of power shortage, the TSO has several measures to activate, if a sudden need arises. These include:

- The disturbance reserve (around 700 MW of gas turbines).
- The strategic reserve (see below).
- Support from neighbouring countries in accordance with the operational agreement.
- Load shedding, both automatic and manual. If manual (after 15 minutes), load shedding is activated, the Swedish Styrel system prioritises users important to society. Prioritised users are identified by the municipalities and counties together with the grid owner, according to a government ordinance from 2011. The system does not guarantee electricity supply, but is rather a planning and prioritisation tool for cases when load shedding is needed. All electricity users have a responsibility to prevent and handle disturbances.

In the case of a long-term electricity shortage, for example, extremely dry years, rationing is needed, which can only be activated by government decision. The purpose of rationing electricity is to avoid load shedding and disconnecting consumers.

## Strategic reserve

For the winter season (from 15 November to 15 March), the TSO may contract strategic reserves in an annual procurement process. These resources must be in price areas 3 or 4, and they are activated after all the commercial bids on the market are used. Demand response can also be included in the strategic reserve to increase the competition in procurement. Under the current legislation, the strategic reserve is in force until 2025. Sweden aims eventually to replace the strategic reserve with a market-based solution whereby the market would provide price signals for supply-side and demand-side investments that would meet strict requirements on the security of supply.

In recent years, the contracted volumes have gradually declined, from around 1 900 MW in the winter of 2010/11 to around 750 MW in the winter of 2018/19.

Each year the TSO produces a forecast of the power balance for the coming winter. Electricity consumption in Sweden is highly influenced by the temperature due to the presence of electric heating. Therefore, two scenarios are presented:

- A forecast of the power balance when temperatures are normal (normal winter).
- A forecast of the power balance when temperatures are lower (1-in-10-year winter).

In the winter outlook for 2018/2019, Sweden is expected to be at a deficit. The power balance was expected to amount to -400 MW in a normal winter and to -1 500 MW in a 1-in-10-year winter (Svenska kraftnät, 2018b).

## Regional security collaboration

In 2017, the four Nordic electricity TSOs published the Nordic Grid Development Plan and a common report on generation adequacy. The common report identifies security of supply as a main driver for grid development. Other main drivers are new renewable generation, increased transmission north-south, new interconnectors towards continental Europe and the United Kingdom, and the decommissioning of nuclear plants in Sweden (Statnett, 2017).

In 2018, the four TSOs set up the Nordic Regional Security Co-ordinator (RSC) to support them in maintaining the operational security of the power systems in the region. The RSC looks at security from the regional perspective and can issue recommendations to the national TSOs. It is tasked with the following operations:

- co-ordinated calculation of cross-border transmission capacity
- co-ordinated security analysis to identify preventive action for the individual TSOs
- outage planning co-ordination through a joint register and streamlined maintenance
- short- and medium-term adequacy forecasts for market players
- improved individual grid models and a common grid model.

# Assessment

Sweden has an almost fully decarbonised electricity generation sector, quite unique among the IEA member countries. Since the 1980s, electricity generation has been based on hydropower and nuclear power, a combination of stability and flexibility. In recent years, under the support system for renewable electricity, wind power has emerged as the fastest-growing source of electricity. It is expected to continue to grow rapidly over the next decades.

## *Wholesale electricity market*

Sweden is part of the generally well-functioning Nordic electricity market and well interconnected with other countries. Cross-border lines with Norway, Finland and Denmark as well as Poland, Germany and Lithuania, with planned extensions, enable intensive trade and help to cope with possible capacity shortages. In recent years, Sweden has been a net exporter of electricity (19 TWh in 2017) and is projected to remain so in the coming decades.

Sweden's 2016 Energy Agreement sets the ambitious target of a 100% renewable electricity system by 2040. The policies and measures to this end need to be well designed and based on evidence. Therefore, the government, along with the TSO, should analyse different scenarios of future development, with the focus to ensure the security of supply and the economic efficiency. These scenarios should be concentrated on capacity and its availability rather than on electricity generation. This should be the first step in defining how the target should be reached and on understanding what the impacts would be on the electricity balance, grid infrastructure and security of supply.

The 2016 Energy Agreement also brings stability to the nuclear energy sector for which policies have changed several times since the 1980 referendum. Existing NPPs are allowed to run as long as they are safe. Building new nuclear units is not banned either. Also, the tax on nuclear capacity is abolished. Therefore, the nuclear phase-out can be expected around 2040 as plants reach 60 years of operation. The possible earlier closure by the owners for economic reasons may result in a sudden decrease in the available capacity.

Sweden and the rest of the Nordic countries have indicated a preference for energy-only markets. However, wholesale prices in the Nordic market area have remained rather low in recent years and do not suggest a need for investment, something for the decision makers to consider. The surplus of capacity in Sweden and the availability of low-cost resources from the rest of the Nordic region are almost certainly primary reasons for this. This has been partly driven by divergent approaches to the implementation of renewable energy support schemes in the Nord Pool, which have distorted investment patterns throughout the region, as well as through Europe more broadly.

As electricity demand in the market is not expected to grow fast and adding new supply to the market will put pressure on electricity prices, the Nordic governments should consider ways to harmonise their policies on renewable electricity and, more generally, on climate change mitigation. A case for building more interconnections with the countries to the south from the Nordic market area could also be made.

## Security of supply

Under normal conditions, Sweden has been self-sufficient for electricity. The level of installed capacity and the potential for a demand-side response have been sufficient to cover the peak demand of 25-28 GW that occurs in winter. *Svenska kraftnät* figures for the winter of 2018/19 indicate, however, that the country would be at a deficit both in normal winter (at -400 MW) and in a 1-in-10 cold winter (at -1 500 MW), which could be covered by imports and a strategic reserve.

The TSO, however, will be challenged to maintain the system in balance in the face of the expected gradual phasing out of nuclear power, the expiry of the current capacity reserve in 2025 and the foreseen significant increase in volatile wind generation. The IEA encourages the government and the TSO to take determined actions to ensure a sufficient level of system flexibility and availability of dispatchable capacity.

Monitoring the capacity situation in the interconnected market area is advisable, as the low wholesale prices discourage investments and, in the medium to long term, imports might not be readily available in the case of capacity shortages. This is exacerbated by the fact that wind power, the growing technology, does not offer a stable supply and baseload generators are retiring, particularly nuclear power. However, the prices of European Union Emissions Trading System allowances are expected to rise and encourage low-carbon investment, but it is not clear to what extent this would be reflected in the low-carbon Nordic market.

Sweden’s transmission system works in a stable way, but it needs strengthening for future challenges. Most lines are older than 30 years, and almost 30% are older than 60 years. Also, the system requires more transmission capacity from north to south and at the entry points of large cities. Encouragingly, the TSO is working on these issues and transmission capacity will be expanded in the forthcoming years.

## Retail market

In the retail market, more than 120 companies serve around 5.4 million customers. The three largest suppliers have around 40% of the customers, with higher shares in specific regions, and the regulator considers the level of market competition to be healthy. Electricity prices for households are moderate (with a relatively large tax component) and prices for industry are relatively low. This benefits the country’s economy, but may limit incentives for demand-side response and energy efficiency.

Sweden has a high penetration of smart meters compared to most European countries. This creates a fine opportunity to develop smart grid systems and to introduce measures to foster demand-side response in the residential sector. The development of a data hub will help to realise this potential, simplify consumer participation and facilitate the emergence of aggregators for demand-side response capacity. According to the SEMI, households have a potential of 5 GW for demand-side flexibility (in winter), which is considerable and should be utilised.

The data hub is also a critical element of regional retail market integration. In general, the efforts to develop a Nordic retail market should be intensified. Creating a common balancing market, which is work in progress, is an important step in this process.

## *Increasing renewable electricity supply*

Since 2003, Sweden has relied on the electricity certificate system to increase renewable electricity supply. The system has delivered the expected volumes and proved relatively cost-efficient, particularly compared to countries that have used feed-in tariffs as the support mechanism.

The target for renewable electricity in 2020 was revised since the start of the certificate system. In 2009, a target of an additional 25 TWh to 2020 compared to 2002 was defined to support meeting the 50% renewable goal by 2020. When Norway entered the system in 2012, a common goal for 2020 was set to increase the renewable electricity production in the certificates system with 16.4 TWh, a goal raised in 2015 to 28.4 TWh. Although Norway will not support an increased renewable electricity production in the certificate system after 2020, Sweden has decided to add another 18 TWh of renewable electricity from 2021 to 2030. The wind power industry sees that this share might be achieved by 2022 with new wind power alone.

The electricity certificate system was one of the first technology-neutral mechanisms to promote renewable electricity and has served as an important learning case for other countries. At the same time, as electricity demand in Sweden is growing only slowly, increasing the generation under the system has led to increasing electricity exports and thus the system is effectively subsidising electricity use in other countries.

As renewable electricity is becoming market competitive, always the long-term aim of support policies, the system will eventually have to be closed. The question is how exactly to do that (for example by a predefined date or a production goal reached). Also, what, if any, support mechanisms will be needed to reach the 2040 goal of an all-renewable electricity system? Although certificate prices were higher in the past decade, recent technological progress has reduced the production costs substantially which, in turn, has directly reduced the certificate prices. The first movers that invested in the previous decade did not anticipate such a drastic decrease in certificate prices and are today struggling to cover their total costs. The closing mechanism of the system is yet to be decided, and this should be done without undue delay, as the closing mechanism will have an impact on the price of the certificates.

Apart from the certificate system, there are further technology-specific incentives for the promotion of renewable electricity production. For example, an investment subsidy is granted for solar PV and the power generated is eligible for participating in the certificate system. The mix of incentives is problematic, especially in the case of small PV installations. Certificates are also granted to electricity from biogas, and manure-based biogas benefits from production subsidies of up to SEK 400/MWh.

Initially, biomass was the most popular technology in the certificate system. It had the lowest production costs, thanks to opportunities for simple fuel switching at existing co-generation plants. Since 2010, however, as demand for heat became increasingly met, wind power has been the fastest expanding technology and has grown from 3.5 TWh in 2010 to 17 TWh in 2017. Today, it seems that almost all the necessary new RES-E to reach the 2040 goal will come from wind power. In addition, the current expectations for future electricity prices seem to be sufficient to support investment in new wind turbines.

Around half of the capacity of the wind turbines that are installed or under construction is in the northern price areas SE1 and SE2. In addition, most new capacity is expected to be built in those areas as the vast space and lack of opposition facilitate the licensing.

In contrast, in the south of the country wind power is facing low public acceptance and resistance within the administrations (out of environmental and military concerns). The resistance in more densely populated areas could be overcome by designating zones of national interest for wind power (the same could also be applied to hydropower in some cases), a task the SEA is already doing. The authorities could also preselect offshore locations and confirm the suitability of a site, but leave a detailed technical project open to investors. They should also engage with local stakeholders early and frequently. The resistance of different administrative authorities could be addressed by channelling the application process to one designated authority in charge of co-ordinating the licensing procedure within the whole administration.

Hydropower is by far the most important renewable electricity source, but it is sometimes neglected in the energy debate. This is undeserved, given its importance as a deployable carbon-free electricity source with a seasonal storage capacity of about 33 TWh. The remaining potential for large hydropower is about 35 TWh, but there is a political consensus not to harness the last large wild rivers. Although the property tax for hydropower will successively be brought to a level that is even with other technologies, there are no signals for future investments in hydropower, given its high capital costs and participation at grid costs. The government should monitor the competitiveness of existing hydropower and ensure its policies and measures do not discourage maintaining the generation of this dispatchable low-carbon source of electricity.

## Recommendations

***The government of Sweden should:***

- Analyse the long-term impact of having a 100% renewable electricity generation in 2040 on the generation adequacy, system resilience and cost-effectiveness of the electricity supply.
- Clarify how to reach the national target of 100% renewable electricity generation in a Nordic energy-only electricity market.
- Prepare and consider several scenarios for how to achieve fossil-free electricity supply and focus both on production (MWh) and capacity (MW) to cover peak demand.
- Explore future solutions that ensure a sufficient level of flexibility, and capacity for ancillary and balancing services for the system:
  - do so in the regional electricity market context
  - clarify whether the strategic reserve will be continued beyond 2025.
- Take measures to ensure the transmission system will be able to cope with the future challenges: reinforce and expand transmission capacity, in particular north-south lines and wind power connections (including offshore) and take action to reduce the lead times of permitting.
- Analyse and introduce measures to utilise smart grid solutions, for example for the purpose of load shifting or limiting peak demand in winter.
- Decide on a fair closing mechanism for the certificate system once the 2030 target has been met and communicate this decision as soon as possible.

- Avoid implementing multiple incentive systems for the same technology.
- Consider addressing long-term capacity concerns by increasing the dispatchable renewable capacity, e.g. at existing hydropower sites or by pumped storage.
- Ease planning procedures for wind power, especially in southern Sweden and offshore, and consider other instruments that help optimise the location of new wind power with respect to grid congestion.

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# 8. Nuclear energy

## Key data

(2017)

**Number of reactors:** Eight reactors operating at three sites

**Installed capacity:** 8.86 $GW_{net,}$ 22% of the total generation capacity

**Electricity generation:** 65.7 TWh, -2% since 2007

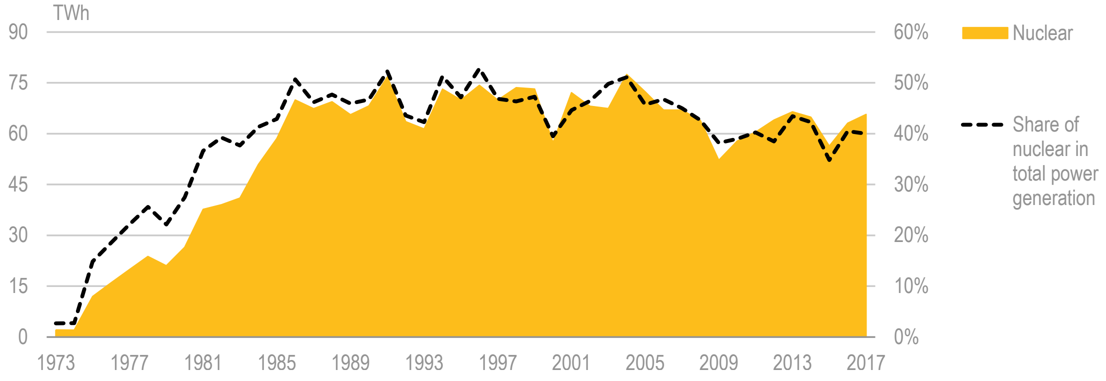
**Share of nuclear:** 34.9% of TPES and 40.0% of electricity generation

**Exchange rate:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Overview

Nuclear power has been a crucial part of Sweden's power system since the commissioning of the nuclear reactor fleet in the 1970s and 1980s. In 2017, it accounted for 40% of the total electricity generation and provided about one-third of the total primary energy supply. Electricity generated from nuclear power has decreased in the past decade from the peak of 75 TWh in 2005 (Figure 8.1), as three nuclear units were closed in 2005, 2015 and 2017. The rapid build-up of renewable electricity generation supported by the green certificate system has also contributed to further reducing the share of nuclear in electricity generation from around 50% a decade ago to around 40% now. Despite this development, however, Sweden has the fifth-highest share of nuclear production among the International Energy Agency (IEA) member countries (Figure 8.2).

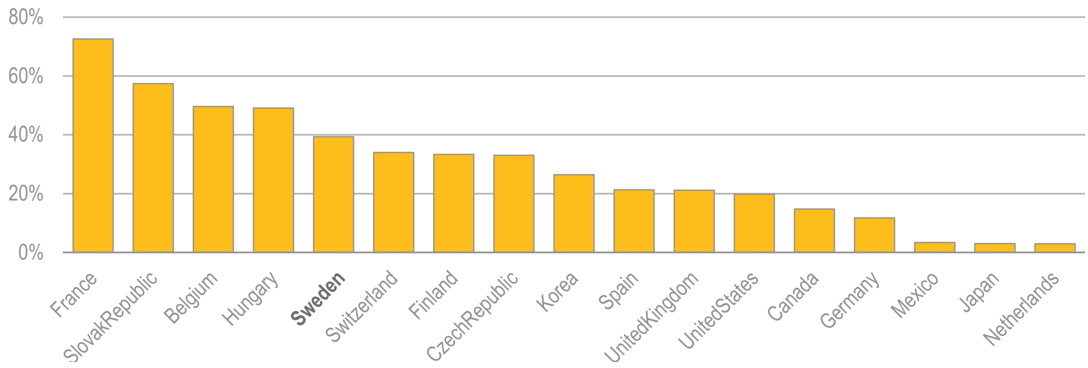
**Figure 8.1 Nuclear power generation and share in electricity generation, 1973-2017**




The share of nuclear power in electricity generation has fallen slightly because three reactors were closed and renewable power increased, but it remains at around 40%.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

**Figure 8.2 Share of nuclear power in electricity generation in IEA member countries, 2017**




Sweden has the fifth-highest share of nuclear in electricity generation among IEA member countries.

Note: Data are provisional.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Nuclear technology was introduced in Sweden in 1947, when the atomic research organisation AB Atomenergi was established to carry out a development programme decided upon by the parliament. A nuclear research centre was then created in Studsvik, with research reactors, fuel and other laboratories. In 1964, the first prototype pressurised heavy water reactor nuclear reactor was built in the suburbs of Stockholm. A total of 12 nuclear units were commissioned from 1975 to 1985 on four sites: three in Oskarshamn, two at Barsebäck, four in Ringhals and three in Forsmark (Figure 8.3).

All the nuclear power plants (NPPs) are located near the capital and in the south of Sweden, where electricity demand is concentrated. This also balances the large hydropower capacity in the north of the country. However, the two units at Barsebäck, close to the Copenhagen region, were closed in 1999 and 2005 for political reasons. Since the 2013 in-depth review (IDR), the two oldest reactors at Oskarshamn were closed for financial reasons. The consequent loss of nuclear capacity has been partially offset by an important programme of modernisation of the nuclear plants and power uprates, which increased the nominal power by 17% on average: this has added more than 1 600 MW of nuclear power above the original capacity. Over the course of operation, the Swedish nuclear fleet has generated about 2 388 terawatt hours (TWh) of carbon-free electricity[1] and has contributed to the security of energy supply in Sweden.

As of 2018, Sweden has eight nuclear power units in operation at three sites (three pressurised water reactor [PWRs] and five boiling water reactors [BWRs]) with a total capacity of 8.9 gigawatts (GW), about 1.5 GW less than the peak in 1999. Ownership of the three Swedish NPP sites is shared by three utilities: Fortum (majority owned by the Finnish state), the Germany-based Uniper (47% owned by Fortum) and Vattenfall (owned by the Swedish state). A group of utilities also has a small stake in the NPPs of Oskarshamn and Forsmark. NPPs have been operated efficiently in Sweden, with availability and load factors in line with those of other Organisation for Economic Co-operation and Development (OECD) member countries (Figure 8.4).

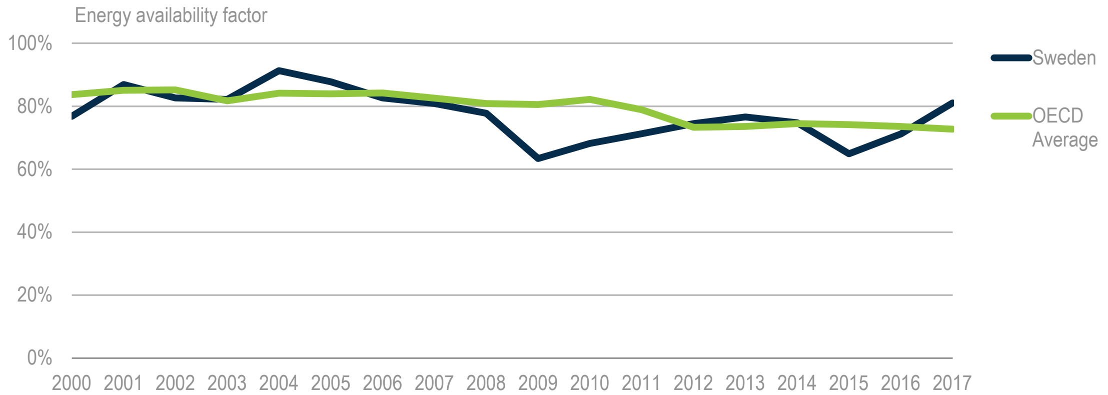
[1] Avoided carbon emissions can be estimated at 875 million tonnes (Mt) of $CO_2$, assuming that gas would have been used instead of nuclear, and at 2 100 Mt of $CO_2$ had coal been used.

**Figure 8.3 NPPs in Sweden**


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Notes: Russia = Russian Federation. km = kilometre.

**Figure 8.4 Energy availability factor of NPPs in Sweden and the OECD, 2000-17**




Sweden's nuclear power fleet had a higher availability than the OECD average in 2017.

Source: NEA, based on IAEA (2018).

However, in 2015 Vattenfall announced the decision to shut down permanently the two oldest reactors at Ringhals permanently in 2019 and 2020 instead of 2025, as previously planned. This decision was motivated by the declining profitability and the high investments required to keep the plants in operation beyond 2020. Utilities have planned to undertake significant investments in the six remaining units to comply with the post-Fukushima requirements. These units are therefore expected to be operating for up to 60 years (Table 8.1). According to this hypothesis, the entire nuclear capacity in Sweden is expected to be shut down permanently on a short time frame, between 2040 and 2045.

The Swedish nuclear sector also includes a fuel factory, two waste storage facilities and one waste treatment facility. The nuclear fuel fabrication plant, owned by Brookfield Business Partners and operated by Westinghouse Electric Sweden AB, is located in Västerås and produces around 400 tonnes of fuel for BWR and PWR reactors. It manufactures the nuclear fuel and control rods used in Swedish power and research reactors, and exports nuclear fuel to other EU countries and to Ukraine.

Looking ahead, the long-term outlook for nuclear power is uncertain in Sweden. Since the 2013 IDR, some positive outcomes in term of energy policies as well as of industrial development have provided more certainties to the nuclear industry. These include:

- Removal of the tax on nuclear capacity.
- Abolishment of the phase-out policy for nuclear, and the possibility to build new reactors at the existing sites
- Substantial progress towards the construction of the final repository for nuclear waste.

However, wholesale electricity market prices have been very low in the Nordic electricity market, and might remain in a low range in the future, as existing support schemes will progressively add renewable capacity in a system with uncertain potential for demand growth. New investment in nuclear power is extremely unlikely in the medium term. Also, despite the utilities' commitment to significant investments in six reactors to continue the operations beyond 2020, the existing nuclear capacity may not stay on line in the medium term if wholesale electricity prices decline severely and system services provided by nuclear power are not properly rewarded. Despite this, the nuclear industry will still require skilled personnel to work with the decommissioning of reactors and managing a final repository for spent nuclear fuel.

**Table 8.1 Nuclear reactors in Sweden**

| | Unit | Type | Original and upgraded capacity ($MW_e$) | Commissioning and shutdown* | Operation time* (yr) | Lifetime production (TWh) | Owners** |
|---|---|---|---|---|---|---|---|
| In oper-ation | Ringhals 1 | BWR | 750<br>895 | 1976<br>2020 (p) | 44 (p) | 203.1 | V (70%),<br>U (30%) |
| | Ringhals 2 | PWR | 820<br>910 | 1975<br>2019 (p) | 44 (p) | 204.3 | V (70%),<br>U (30%) |
| | Ringhals 3 | PWR | 915<br>1 110 | 1981<br>2041(e) | 60 | 236.1 | V (70%),<br>U (30%) |
| | Ringhals 4 | PWR | 915<br>1 160 | 1983<br>2043 (e) | 60 | 227.1 | V (70%),<br>U (30%) |
| | Oskarsham n 3 | BWR | 1 100<br>1 450 | 1985<br>2045 (e) | 60 | 265.4 | U (55%),<br>F (43%),<br>O (2%) |
| | Forsmark 1 | BWR | 900<br>1 014 | 1980<br>2040 (e) | 60 | 258.3 | V (66%),<br>F (22%),<br>U (10%),<br>O (2%) |
| | Forsmark 2 | BWR | 900<br>1 134 | 1981<br>2041 (e) | 60 | 252.2 | V (66%),<br>F (22%),<br>U (10%),<br>O (2%) |
| | Forsmark 3 | BWR | 1 100<br>1 190 | 1985<br>2045 (e) | 60 | 275.7 | V (66%),<br>F (22%),<br>U (10%),<br>O (2%) |
| | **Total** | | **7 400**<br>**8 863** | | | | |
| Shutdown | Oskarsham n 1 | BWR | 460<br>490 | 1972<br>2017 | 45 | 110.3 | U (55%),<br>F (43%),<br>O (2%) |
| | Oskarsham n 2 | BWR | 580<br>630 | 1975<br>2015 | 40 | 154.0 | U (55%),<br>F (43%),<br>O (2%) |
| | Barsebäck 1 | BWR | 580<br>630 | 1976<br>1999 | 23 | 93.8 | U |
| | Barsebäck 2 | BWR | 580<br>630 | 1978<br>2005 | 27 | 108.0 | U |

Note: $MW_e$ = megawatts of electricity.

* (p) = planned, (e) = expected.

** V = Vattenfall, U = Uniper, F = Fortum, O = Others.

## *Nuclear policy*

Nuclear power has been an important but controversial component of the Swedish energy system, as reflected by changing governmental policies.

Sweden decided to develop nuclear energy as a source of electricity generation in the mid-1960s to complement the existing electricity generation mix based on large hydropower and fossil fuels. Nuclear power was seen as an effective option to meet the rapid increase in electricity demand, to reduce the dependency on oil imports and to reduce the volatility of energy prices, and therefore enhance the security of energy supply.

After the accident at the Three Mile Island NPP in 1979 in the USA, Sweden held a non-binding referendum to vote on three different proposals for phasing out nuclear energy.

Following the popular vote, the parliament adopted in 1980 a phase-out policy from nuclear energy. While authorising the completion of the five nuclear units under construction, the "Phase-out Act" banned any further expansion of nuclear power and set 2010 as a target year for permanently shutting down all NPPs.

However, in 1994 an energy commission mandated by the government concluded that a complete phase-out from nuclear energy would not be economically and environmentally sustainable. This study led to a revision of the previous nuclear phase-out policy. In 1997, the parliament decided to shut down the two oldest units at the Barsebäck site permanently, but removed the 2010 deadline for completing the nuclear phase-out. However, the government could decide on the closure of nuclear units at any point in time, irrespective of safety issues, provided that the incurred economic losses by utilities were compensated for.

A decade later, in 2008, the conservative-led coalition Alliance for Sweden revised the previous energy policy, stating that the government would not require any reactor closures, and closures would be based exclusively on technical and economic grounds. In 2010, the government lifted the ban on the construction of new nuclear units, under the conditions that new units would replace existing shutdown units at the same site. Also, any new build initiative would need to be undertaken by industry without any direct or indirect government subsidies and would have to compete with renewable energy sources that were actively being promoted and subsidised by the government.

In 2016, the five main political parties concluded a broad agreement on the long-term energy policy for Sweden, which clarified nuclear energy policy and broadly confirmed the principles of the 2008 Government bill. First, the Nuclear Power Phase-Out Act was definitively repealed and nuclear power is not banned. Achieving a 100% renewable generation by 2040 should be interpreted as a target and does not imply a closure of nuclear plants by political decision. Second, new NPPs may be built at the existing sites to replace current nuclear units that have reached the end of their life. Third, the government will not directly or indirectly subsidise nuclear power. Fourth, the tax on nuclear capacity was eliminated.

### *Taxation*

Nuclear power and hydropower generation have been taxed since the 1980s. In 2000, the tax on nuclear power was shifted from a tax on generation to a tax on the installed thermal capacity set at SEK 5 514 per thermal megawatt hour ($MWh_{th}$) per month. It was then progressively increased to SEK 14 440/$MWh_{th}$ per month, or more than SEK 70 per megawatt hour (MWh) (or about EUR 8/MWh), according to the World Nuclear Association. The tax constituted about one-third of the operating costs of nuclear power and, in combination with low wholesale electricity prices in the Nordic market area, severely undermined the economics of nuclear energy. The government started to phase out the nuclear capacity tax in 2017 and effectively abolished it from January 2018 (WNA, 2018; NEA, 2017).

## Institutions

Nuclear activities are regulated by the Swedish Radiation Safety Authority (SSM), which was created in 2008 by merging the Swedish Radiation Protection Institute and the

Swedish Nuclear Power Inspectorate. The SSM is the administrative central authority under the Ministry of the Environment and Energy, with national collective responsibility for radiation protection, nuclear safety and nuclear non-proliferation.

In particular, the SSM is the regulatory, supervisory and licensing authority for all the activities that involve radiation, which include the nuclear power industry, nuclear research, medical uses of radioactive materials and other industrial activities. The SSM is also responsible for the emergency preparedness and response to radioactivity accidents or incidents. The SSM also advises the general public on how to protect themselves from radiation exposure. Employing around 300 people, it is largely financed through taxes and fees collected from licence holders.

In 2018, The Swedish Debt Office took over all the financial issues connected with the management of radioactive waste and spent fuel from nuclear activities.

The Swedish Nuclear Fuel and Waste Management Company (SKB) is jointly owned by the three NPP utilities in Sweden. SKB was created in 1977 to assist its owners in handling the management and disposal of all radioactive waste from Swedish NPPs. It operates a repository for short-lived radioactive waste (SFR) in Forsmark and an interim storage facility for spent nuclear fuel (Clab) near Oskarshamn.

The Swedish National Council for Nuclear Waste is an independent scientific and advisory committee established by the government in 1992. It is mandated to investigate and clarify matters that relate to nuclear waste and decommissioning and the dismantling of nuclear facilities.

Studsvik AB was created in 1947 as a research organisation. Today, it is a public company that operates in seven countries and provides a vast array of services from consultancy on nuclear issues, fuel and material technology services to the development of software for nuclear applications. Studsvik Nuclear is also responsible for managing waste from medicine, research and non-power related activities.

AB SVAFO was founded in 1992 and is jointly owned by the NPP utilities. It is responsible for the decommissioning of research reactors and nuclear development facilities as well as for the management and disposal of legacy waste.

## Nuclear safety

The following five acts constitute the basic nuclear safety and radiation protection legislation in Sweden: the Nuclear Activities Act (1984), the Radiation Protection Act (2018), the Environmental Code (1998), the Act on the Financing of Management of Residual Products from Nuclear Activities (2006) and the Nuclear Liability Act (1968). The first four acts are supplemented by secondary legislation that contains more detailed provisions for particular aspects of the regime. In June 2017, the government set up an inquiry to review the Nuclear Activities Act.

The SSM is in charge of licensing nuclear facilities and safety controls. To ensure compliance, it conducts inspections at nuclear installations. The SSM's licensing and regulatory activities, as well as those concerning nuclear waste management, are entirely financed by fees paid by nuclear operators. The SSM reports to the Ministry of the Environment and Energy, which is not directly involved in energy policy.

Swedish NPPs are licensed to operate provided the SSM considers them safe. According to national regulations, an overall assessment of the safety of nuclear facilities must be conducted every ten years (Periodic Safety Review). This assessment ensures compliance with the current regulations. It also identifies the need for any further safety improvements to maintain the level of safety and to ensure that older facilities can be as safe as the newer ones.

Since the beginning of the Swedish nuclear programme, the NPPs have been continuously monitored, maintained and improved. Additional safety measures and plant upgrades have been systematically implemented to integrate effectively the lessons learned from incidents and accidents, and safety analyses and research. In particular, accidents in the nuclear industry triggered improvements in the Swedish regulatory system. More stringent safety requirements were adopted, which led to significant plant upgrades and back-fits.

After the severe accident at the Fukushima Dai-ichi NPP in 2011, a comprehensive safety risk assessment was carried over all the NPPs and spent fuel storage facilities in the EU countries, Switzerland and Ukraine (the “EU stress tests”). The Swedish National Action Plan (NAcP) was developed to implement the lessons learned from the accident and to strengthen the plant protection against external hazards and extreme events.

The NPP operators have already implemented several short-term technical and administrative measures, and all the measures identified in the NAcP are expected to be completed by 2020. An important measure required by the NAcP to continue operation beyond 2020 is the implementation of a permanent independent core cooling system. Such a system is designed to prevent core damage from extreme events not covered by previous safety analysis. The Swedish NPPs require considerable investments to comply with the upcoming safety requirements, and the industry has decided to shut down the four smaller nuclear units permanently by 2020.

### *Incidents of note*

Since the 2013 IEA in-depth review (IDR), Sweden has reported to the International Atomic Energy Agency (IAEA) only one event above level 1 of the International Nuclear and Radiological Event Scale (INES).[2] The incident, rated at level 2 of the INES scale, occurred in September 2017 in the hot cell laboratory of Studsvik Nuclear AB and involved contamination outside the hot cell in a controlled area of the laboratory. No personnel were involved in the accident. From 2010 to 2015, four events at level 1 of the INES scale were reported in Swedish nuclear facilities. This is an indication of the high safety levels of the Swedish nuclear industry.

## Fuel cycle, waste management and decommissioning

At the beginning of the Swedish nuclear programme, initial plans were made to reprocess the nuclear fuel. About 140 tonnes (t) of nuclear fuel were sent to Sellafield, in

[2] The INES scale was introduced by the IAEA and Nuclear Energy Agency in 1990 and comprises seven levels of severity, from 1 (anomaly) to 7 (major accident); each level represents an accident around ten times more severe than the previous level. Level 0 indicates events with no safety significance. Initially, the INES scale was constructed so that about one INES-1 event and ten INES-0 events would occur per year in a “normal” NPP. The IAEA requires the reporting of events of level 2 or above on the INES scale.

the United Kingdom, which resulted in 136 kilogrammes (kg) of reprocessed uranium and about 800 kg of plutonium, which are still hosted in Sellafield. A contract for the reprocessing services was also established with France, for a total of 672 t of spent fuel. However, attitudes towards reprocessing changed and, at the end of the 1970s, the Swedish government adopted the current once-through policy of a direct disposal of irradiated nuclear fuel. As a consequence, the contract with France was terminated after the shipment of only 55 t of spent fuel.

The 1984 Nuclear Activities Act defines the main principles and allocation of responsibilities concerning radioactive waste management and decommissioning in Sweden. First, a nuclear plant operator is responsible for the safe handling and disposal of spent fuel and radioactive waste, for the associated research and development (R&D), and for the related costs. The operator must also provide for those costs as they occur. Second, the expenses for radioactive waste management and decommissioning are to be covered by revenues from electricity generation, according to the Organisation for Economic Co-operation and Development (OECD) polluter pays principle. Third, the state, however, bears the ultimate long-term responsibility for the supervision of the disposal facility after it has been closed. Fourth, each country must be responsible for the final disposal of nuclear waste generated in that country. Disposal of nuclear waste generated abroad would be permitted in Sweden only under exceptional circumstances.

The management and disposal of all radioactive waste is handled by SKB. It is also responsible for the R&D on radioactive waste management and must report on these activities to the government.

## Front end of the fuel cycle

Sweden has some conventional uranium resources located in four main regions across the country. Also, significant unconventional low-grade resources are reported. However, no uranium is produced in Sweden. Sweden also has no facilities for fuel enrichment. It therefore imports all its nuclear fuel and enrichment services, and utilities are free to negotiate their own purchases. In recent years, fuel was imported from Australia and Canada and was enriched within the European Union. Fuel elements used in Swedish BWR and PWR nuclear plants are fabricated domestically at the Westinghouse Electric Sweden AB factory in Västerås.

## Waste management: Very-low, low and intermediate waste

Very-low-level radioactive waste (VLLW) is disposed of in four shallow land burial sites, located at the three main NPPs and at the Studsvik site. These sites host radioactive waste from both the nuclear power industry and from industry, research and medical care. The combined volume of licensed sites is around 40 000 cubic metres ($m^3$) for a maximum permissible activity of 1 600 gigabecquerel. If the VLLW activity is below a certain level, the material is cleared for unrestricted use or for disposal as conventional, non-radioactive waste.

The low- and intermediate-level waste (LILW) from the nuclear power industry is directly treated and conditioned at the reactor sites or sent to the Studsvik waste treatment facility for volume reduction and stabilisation. Short-lived LILW is disposed of at the SFR repository, in operation since 1988. The repository, owned and operated by SKB, is located close to the Forsmark site and consists of four rock caverns and a silo around 50 metres (m) below the seabed. SFR is designed to contain all the short-lived LILW waste that arises from the nuclear programme, as well as that from research facilities, industry and medicine. It is licensed for a total capacity of 63 000 $m^3$ of which 39 700 $m^3$ had already been used by December 2017.

According to the reference scenario, a total of 200 000 $m^3$ of short-lived LILW and 10 000 $m^3$ of long-lived LILW will arise from the operations and decommissioning of NPPs. In 2014, SKB submitted a licence application for an extension of the SFR to host all the expected LILW. Operations are planned to begin in 2028.

According to the current plans, long-lived LILW will be disposed of in a geological disposal facility (SFL), at a depth of 300 m in crystalline bedrock. SFL will most probably be located at the same site as one of the existing disposal sites (Clab or SFR). The decision on the exact siting is expected to be taken by mid-2030, and SFL should be fully operational by mid-2040. Until then, the long-lived LILW will be stored at the NPPs, at the Studsvik site or in storage pools at the Clab site.

## Waste management: High-level waste

Sweden has chosen a once-through fuel cycle, with direct disposal of the spent nuclear fuel without reprocessing. Spent nuclear fuel is stored in the fuel pools at the NPP sites for about one year, before being transported by sea to a central interim storage facility (Clab) close to the Oskarshamn site.

The Clab facility, in operation since 1985, was financed by the nuclear utilities and is owned and operated by SKB. It comprises an above-ground building in which fuel assemblies are discharged from casks, and ten storage pools in the bedrock, at a depth of 25 m, in which spent fuel is stored. According to the current plans, fuel elements will be stored in Clab for 30-40 years and will then be transported to the final repository for spent nuclear fuel. At the end of 2016, Clab hosted about 6 300 t of spent nuclear fuel, or around 80% of the total licensed capacity of 8 000 t. The storage capacity limit is expected be reached in 2024. SKB has already started the administrative procedure to increase the total capacity of the repository to 11 000 t which would allow the disposal spent fuel until 2034.

The development work for the final repository of spent nuclear fuel has continued according to plans and has advanced significantly since the 2013 IDR. In March 2011, SKB submitted a licence application for the siting and construction of a spent fuel disposal facility in Forsmark, as well as for a new encapsulating plant (Clink) to be built near to the interim storage facility Clab. For final disposal, the spent fuel elements will be encapsulated in copper canisters with a cast iron insert. The copper canisters will be embedded in bentonite clay and then positioned in individual deposition holes at a depth of about 400-700 m in the bedrock.

In January 2018, the SSM and the Court of Land and Environment submitted their respective opinions to the government on the application for a licence. The SSM recommended the approval of the application, estimating that the remaining uncertainties can be resolved in the following phase. The Court of Land and Environment required further documentation on the strength of the copper capsules in the long-term. The government will make the final decision after a consultation with the concerned municipalities that could veto the application. This decision is not expected before 2019. SKB expects that, if the government grants the construction licence, work could be started by 2020 and all the facilities, the final repository and a new encapsulating plant could be operational in 2030.

## Decommissioning

SKB's main strategy for decommissioning is to start to dismantle a plant as soon as it has been taken out of service. This minimises the surveillance and operations costs at the shutdown plant and allows the release of the site and the associated infrastructure for future electricity generation. The dismantling process is expected to begin two years after the final shutdown of the plant, and operations are expected to be completed in five years.

The strategy of immediate dismantling, however, was not applied to the Barsebäck nuclear site, where the two BWRs were permanently shut down in 1999 and 2005. Some preparatory work and decontamination of the primary system was already carried out in 2007/2008 in both units. However, comprehensive dismantling activities are planned to begin after 2020, pending the extension and re-licensing of the SFR repository that will host the short-lived LILW from the decommissioning activities.

## Funding

The basic legal principle in Sweden is that the licence holder in a nuclear facility must cover all the long-term costs of the safe handling and disposal of spent nuclear fuel, for waste management as well as for dismantling the nuclear facilities and the disposal of decommissioning waste. The licence holder must also bear all the costs for R&D and other costs associated with waste management and regulatory oversight.

Since the mid of 1970s, the nuclear companies have allocated funds to cover these expenses, first on the company balance sheet. In 1981, the parliament enacted a financing system in which licensees had to pay a special fee to the state. The fees were deposited in a separate interest-bearing account at the Swedish central bank.

In the current system, which dates from 1996, the licence holder pays a fee to an external segregated fund. The Nuclear Waste Fund is an independent governmental agency, separate from the SSM, which manages the fund and presides over disbursement. The Nuclear Waste Fund does not have any staff, only a board whose members are appointed by the government and by the nuclear industry. The licensee of nuclear installations must also provide some financial guarantees that cover the fees not already paid as well as unplanned events.

The SSM reviews the cost assumptions, which are provided every three years by the SKB, and proposes to the government the level of the waste fee. The government sets the level of the fee as well as the financial guarantees required.

The level of contribution to the Nuclear Waste Fund has been increased to an average of 40 SEK/MWh of electricity produced, taking into account more recent cost estimates and an operating lifetime of 50 years for the existing NPPs. For the period 2018-20, the government has decided an average fee level of 50 SEK/MWh. In August 2017, the government transferred primary responsibility for the financing of the Nuclear Waste Fund from the SMM to the National Debt Office. In 2018, the government also revised the investment rules for the Fund to allow for a wider range of investment opportunities, thus potentially increasing the long-term returns of the fund.

## Communication to stakeholders

Sweden has a tradition of open and transparent communication to stakeholders at the local level as well as inside and outside the country. This is critical for building trust in nuclear institutions in Sweden and may explain the overall positive attitude towards nuclear power among the general public.

In particular, local safety boards are established in the municipalities that host major nuclear infrastructure. They gather information on the safety and radiation protection measures at the facility to inform the residents and interested parties further in a timely and reliable manner. The licence holder of a nuclear facility must provide this information and relevant documents, and must grant access to the site upon the request of the board members.

Several government entities have a proactive role in disseminating information to the public. In particular, the SSM is responsible for informing the society about radiation protection issues within and outside the Swedish borders. The SSM has a policy to provide proactive and fast information to the media and to the public, and its management and experts have overall responsibility for communication. The SSM periodically informs the public on major activities and issues reports on the main R&D results and regulatory assessments. In addition, the media and the general public have open access to SSM's reports. SSM also runs (from 2004) an education centre to teach radiation protection.

Openness, transparency and trust are also key factors in the success of the Swedish nuclear waste management programme. The SKF has systematically engaged in a formal consultation process with the SSM, non-governmental organisations and the representatives and population of the municipalities that host or will host the infrastructures needed to manage nuclear waste.

## Assessment

Nuclear power has a long tradition in Sweden, with 12 nuclear units commissioned in a relatively short time, between 1975 and 1985. Currently, there are eight units in operation with a total capacity of 8.9 GW, around 1.5 GW less than the peak nuclear capacity in 1999. The units are located at three sites, near the capital and in southern Sweden, where most electricity demand is concentrated. However, nuclear capacity will decrease to 7.1 GW by 2020, when the two oldest units at the Ringhals site will be permanently shut down.

Nuclear power has operated efficiently in Sweden, at high availability and load factors, in line with those of OECD member countries. In the past decade, nuclear power has averaged 40% of the electricity generated in Sweden. Together with hydropower, it has contributed to the low-carbon intensity of the Swedish electricity generation, as well as to the cost-effectiveness of electricity provision and stability of electricity prices. Currently, NPPs provide a large array of system services and guarantee the majority of the inertia of the electricity grid, which helps to maintain grid stability. With the planned reductions in nuclear capacity, the share of nuclear power in electricity generation is expected to diminish in the coming years.

The 2016 Framework Agreement on Energy Policy presents some important clarifications to nuclear energy policy. First, there is no ban on existing reactors, which can be operated provided they meet the safety and regulatory requirements. Second, new reactors can be built on existing sites, provided the government does not directly or indirectly subsidise this. Third, beginning in 2018, the "nuclear tax" is to be phased out. This tax on nuclear thermal capacity was first introduced in the late 1990s, and then increased over time to equal around SEK 70/MWh (or EUR 8/MWh) in 2015. These measures provide more certainty to operators of the existing nuclear facilities. Specifically, the nuclear tax and the property tax on hydropower capacity (Chapter 7) hampered the competitiveness of these low-carbon electricity sources and placed them at a disadvantage with respect to other generating options. The IEA applauds the decision to abolish these measures.

Six of the eight nuclear units will make large investments in the refurbishment and safety upgrades required to continue their operations beyond 2020. However, wholesale electricity prices in the Nordic market have been very low and might remain in a low range, as existing support schemes will progressively add renewable capacity in a system with uncertain potential for demand growth.

The existing nuclear capacity may not stay on line in the medium term, such as in the case of a severe decline in wholesale electricity prices and if system services provided by nuclear power are not properly rewarded. New investment in nuclear power is extremely unlikely in the medium term. However, if new dispatchable low-carbon sources are needed after the closure of existing nuclear plants, appropriate steps should be taken in a timely manner to ensure a level playing field for all the available low-carbon technologies, including nuclear power.

Sweden has a well-established legal and regulatory framework for nuclear energy, an independent and effective nuclear regulator and clear and advanced policies on spent fuel and nuclear waste management. Since the 2013 IDR, significant progress has been made on the development of the final repository for spent nuclear fuel. In March 2011, SKB applied for the licensing of the final repository for the spent nuclear fuel to be built at the Forsmark site as well as for a new encapsulating plant. The SSM recommends the approval of the application, while the Court of Land and Environment has required further documentation on the strength of copper capsules in the long-term before deciding. The final decision will be made by the government, after a consultation with the concerned municipalities that could veto the application. Currently this decision is not expected before 2019. Local support appears high, mainly thanks to an open and transparent policy in engaging with the municipalities. SKB expects that, if the government grants the construction licence, work could be started by 2020 and all facilities, the final repository and a new encapsulating plant could be operational in 2030.

The spent nuclear fuel is currently stored at Oskarshamn in the Clab interim facility, which has a total licensed capacity of 8 000 t of uranium. The storage capacity limit is expected be reached in 2024. SKB has already started the administrative procedure to increase the total capacity of the repository to 11 000 t to allow for disposal of spent fuel until 2034. The government and SKB should ensure that sufficient capacity in the Clab facility is available, if the licensing or construction of the final repository are delayed.

In Sweden, the cost for nuclear waste management and decommissioning is borne by the operator, according to the polluter pays principle. Nuclear operators pay a yearly fee into the Nuclear Waste Fund, an independent governmental agency, separated from the SSM, to cover these long-term liabilities. In 2015, following a proposal from SSM and assuming an estimated operating lifetime of 50 years, the government raised the contribution to the Nuclear Waste Fund to SEK 40/MWh. The government also revised the investment rules for the Fund to allow a wider range of investment opportunities, and thus potentially increase the long-term returns of the fund. These policies should ensure the availability of sufficient funds for nuclear waste management and decommissioning and thus reduce the residual risk for the government. In addition, the start of construction of the final spent fuel repository will further reduce uncertainties related to cost.

It is important to ensure the availability of a competent and well-trained workforce in the energy sector, particularly in the nuclear sector. Given the specific set of competences required and the uncertainties over the future of nuclear energy in Sweden, it is challenging to attract young workers to this sector. In 2016, the government mandated the SSM to investigate the different competences required in the nuclear sector as well as the availability of these competences in Sweden. A final report from the SSM is due by the end of 2018. Nuclear companies have also started training programmes. However, it is important to continue the effort in this area to ensure that sufficient personnel are available at the government entities and in the nuclear industry to guarantee an effective operation of the NPPs in the forthcoming decades.

## Recommendations

***The government of Sweden should:***

- ☐ Develop scenarios to assess the contribution of nuclear power up to 2040 and the impact of potential early closures.
- ☐ Continue the progress towards the licensing and construction of the final repository for spent nuclear fuel. Monitor that sufficient storage is available in the existing interim storage facility in case of delays in licensing or construction.
- ☐ Ensure that the required human resources will be available for the nuclear power sector.

### References

IEA (International Energy Agency) (2019 forthcoming), *World Energy Balances 2019 preliminary edition* (database), OECD/IEA, Paris, www.iea.org/statistics/.

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# 9. Oil and biofuels

## Key data

(2017)

**Crude oil net imports:** 18.7 Mt (19.8 Mt imports, 1.1 Mt exports), +5% since 2007

**Oil products:** Production 20.1 Mt, +12% since 2007, net exports 7.4 Mt

**Biofuel supply:** 1.5 Mtoe (0.2 Mtoe produced, 1.3 Mtoe imported)

**Share of oil:** 21% of TPES and 30% of TFC

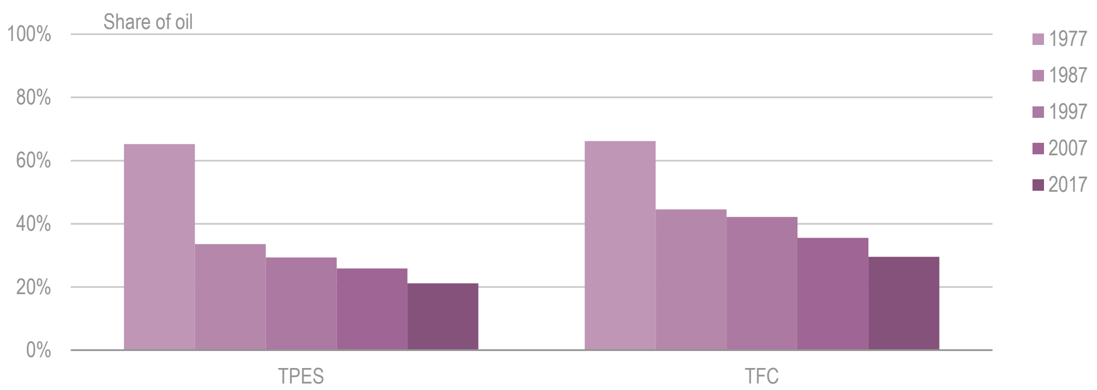
**Consumption by sector:** 10.4 Mtoe (transport 57.7%, industry 26.1%, other energy 11.5%, commercial 3.6%, heat and power generation 0.9%, residential 0.2%)

**Exchange rate:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Overview

Oil is the only fossil fuel that provides a large share of Sweden's energy supply, accounting for 21% of total primary energy supply (TPES) and 30% of total final consumption (TFC) (Figure 9.1). However, oil consumption has decreased for decades: initially, when electric boilers or district heating replaced fuel oil boilers in households, and more recently as biofuels have replaced oil in transport and industry. In 2016, liquid biofuels accounted for 17% of energy consumption in the transport sector, by far the highest share among the International Energy Agency (IEA) countries. Sweden imports all its crude oil, as well as most biofuels, despite its large domestic biomass resources.

**Figure 9.1 Share of oil in different energy supplies, 1977-2017**




Oil is the largest fossil fuel in Sweden, but its share is decreasing in both TPES and TFC.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

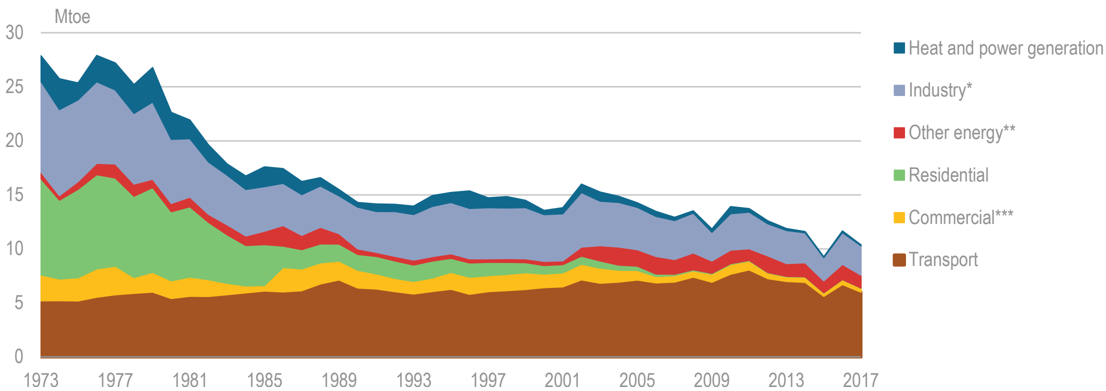
# Supply and demand

## *Oil consumption is declining*

As nuclear power was introduced in the 1970s and 1980s, many households switched from fuel oil to electric heating or district heating, which had a large impact on the overall oil consumption. In recent decades, oil consumption decreased across all sectors, in volume terms most deeply in industry (Figure 9.2). The transport sector declined the least and has become the dominant oil consumer in Sweden. In 2017, transport consumed 58% of the oil supply, of which 97% in road transport.

Industry is the second-largest oil consumer, at 26% of the total in 2017. Over 70% of industrial oil consumption was for non-energy purposes: liquefied petroleum gas (LPG), ethane and naphtha in chemical industries and bitumen in construction. From 2007 to 2017, industrial oil consumption declined by 25%. Most of this decline was in energy-related oil consumption, which indicates that oil used as an industrial feedstock is harder to replace.

**Figure 9.2 Oil consumption by sector, 1973-2017**




Oil demand has declined across all sectors over recent decades, but only slowly in the transport sector, which accounts for nearly 60% of the total oil consumption.

* *Industry* includes non-energy consumption.

** *Other energy* includes consumption in refineries.

*** *Commercial* includes commercial and public services, agriculture, forestry and fishing.

Notes: TPES by consuming sector. Mtoe = million tonnes of oil equivalent.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

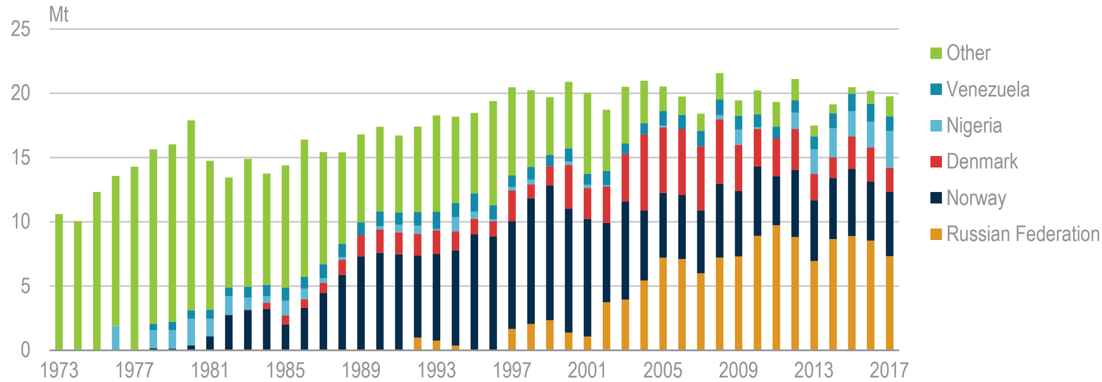
## *Sweden imports all its crude oil; oil products are net export*

Sweden does not produce any crude oil, and imports around 20 million tonnes (Mt) annually to feed its refineries. In 2017, the country imported 19.8 Mt, of which 37% was from the Russian Federation (Russia) and 35% from the North Sea oil production in Norway and Denmark. The rest came from various countries, which include Nigeria and Venezuela (Figure 9.3). Sweden also exports some of its imported crude oil, mostly to the United Kingdom and the Netherlands.

The output of Swedish refineries exceeds domestic demand, and the country is a net exporter of oil products. In 2017, domestic production amounted to 20.1 Mt and net exports to 7.4 Mt. The largest export markets were the UK (22% of exports) and the Netherlands (18%) (Figure 9.4).

Related to diesel imports, Sweden, together with Finland, maintains a more stringent environmental fuel quality for diesel, known as Mk1, than the rest of the European Union. Given the heavily dieselised character of these countries, this makes Sweden and Finland a somewhat harder diesel market to access for other European and former Soviet Union actors. The main refiners in the Baltic and north German markets have, however, built capacity to produce and supply Mk1 to Sweden and Finland to compete with domestic refiners.

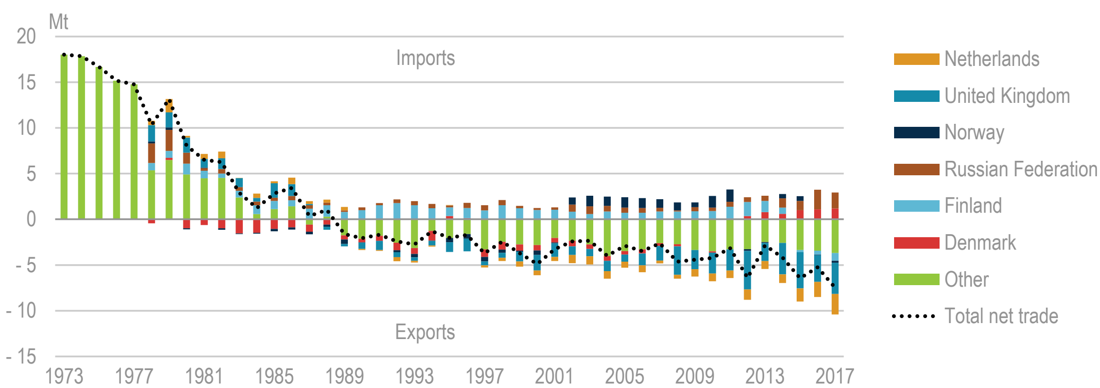
**Figure 9.3 Crude oil imports by country, 1973-2017**




Sweden imports all its crude oil, mostly from Russia and the North Sea.

Source: IEA (2019b forthcoming), *Oil Information 2019 preliminary edition*, www.iea.org/statistics/.

**Figure 9.4 Oil product imports and exports by country, 1973-2017**




With its large refining capacity, Sweden is a net exporter of oil products (since 1989) and sells to various European markets.

Source: IEA (2019b forthcoming), *Oil Information 2019 preliminary edition*, www.iea.org/statistics/.

## *Biofuels have rapidly increased, mostly through imports*

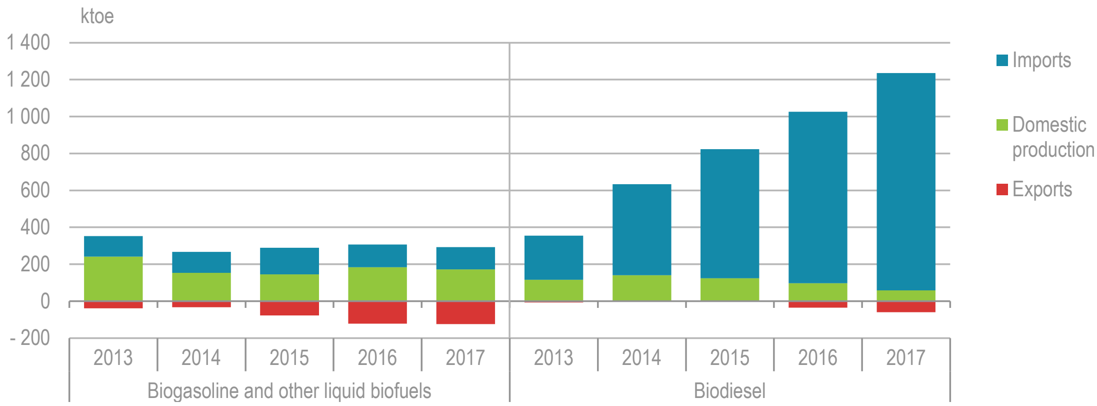
Sweden is the leading IEA country for biofuels as a transport fuel. In 2017, liquid biofuels accounted for 17% of the total energy supply in the transport sector. Initially, bioethanol was the most common biofuel, used for low blends in gasoline or as an E85 fuel in special vehicles. In recent years, biodiesel has become the dominant biofuel (Figure 9.5).

Biodiesel has the advantage that it can be used directly in the existing infrastructure to replace fossil diesel.

The main types of biodiesel used are fatty acid methyl ester and hydrogenated vegetable oil (HVO). In recent years, HVO has become the dominant liquid biofuel in Sweden, mainly supplied through imports. In 2017, biodiesel net imports accounted for 75% of the total supply of liquid biofuels in Sweden.

The growth in biofuels use is a result of a dedicated policy, which rests on several measures, such as tax exemptions and blending obligations. More generally, the government targets a fossil-independent transport sector by 2030.

**Figure 9.5 Liquid biofuels supply, 2013-17**




The total supply of liquid biofuels has increased rapidly in recent years, led by a significant growth in imports of biodiesel (mainly HVO).

Note: ktoe = kilotonnes of oil equivalent.
Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

# Infrastructure

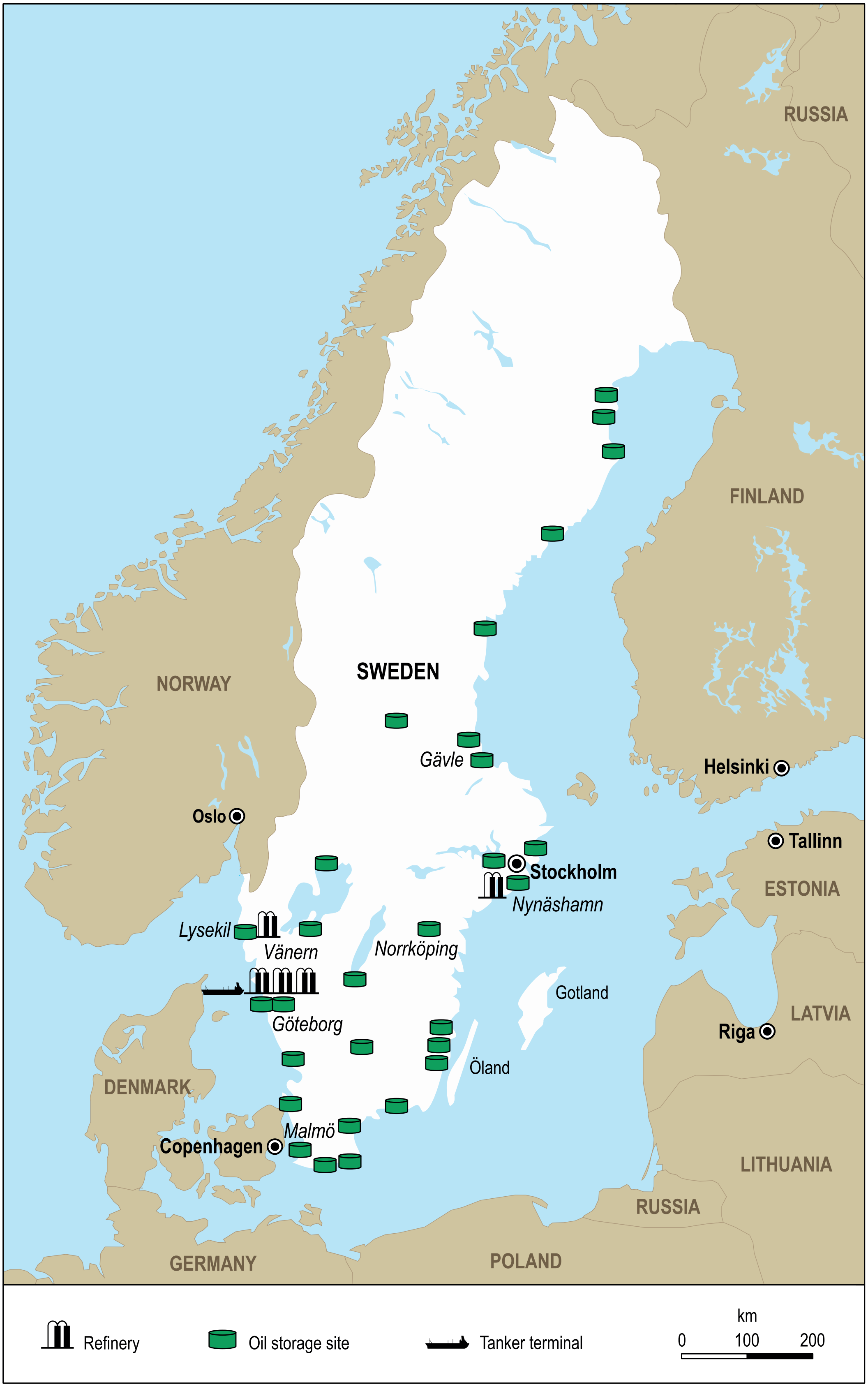
## *Refineries*

Sweden has three refineries and two plants focused on petrochemicals. Their total capacity stands at 463 thousand barrels per day (kb/d). Four of the facilities are on the west coast and one on the east coast.

Preem operates the two largest ones, in Lysekil and in Gothenburg. Lysekil is Scandinavia's largest refinery, distilling 11.4 Mt of crude per year (228 kb/d). In total, Preem has around 80% of the total refining capacity in Sweden. St1 operates the third-largest refinery, also located in Gothenburg, and Nynas Refining operates the two smaller refineries, which specialise in bitumen and lubricants, one of them in Gothenburg and the other one in Nynäshamn, south of Stockholm.

The refineries are able to meet domestic demand in all product categories except for kerosene, LPG, ethane and naphtha. In 2016, the country's refined product output averaged 413 kb/d. and the average capacity utilisation rate was 89%. The detailed composition of production in 2016 is shown in Figure 9.7.

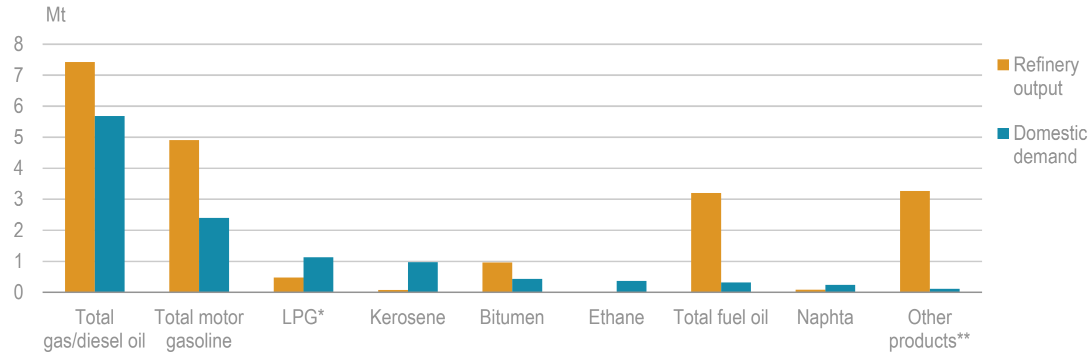
## Figure 9.6 Map of Sweden's oil infrastructure




This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: Russia = Russian Federation. km = kilometre.

**Figure 9.7 Refinery gross output and domestic consumption by product, 2016**




Refinery output and domestic demand differ, but Sweden is self-sufficient in most oil products, with the exception of kerosene, LPG, ethane and naphtha.

* liquefied petroleum gas.

** *Other products* includes lubricants, petroleum coke and other non-specified products.

Source: IEA (2018a), *Oil Information 2018*, www.iea.org/statistics/.

## Ports

Sweden has three main ports for importing crude oil and refinery feedstocks, located at Göteborg, Nynäshamn and Lysekil (Sjöbol). The combined total capacity of these ports is roughly 450 kb/d. Imports of refined products flow primarily through six main ports, three of which are in the Stockholm area. They have a total capacity of more than 190 kb/d.

## Storage

The retail networks are supported by a network of around 28 storage depots throughout the country, a number largely constant since the last IDR. Sweden has a comparatively large oil storage industry that attracts international oil and oil trading companies holding their stocks in bonded areas before moving them on to the end markets. Such stocks are rarely imported to Sweden, but are held in bonded areas. The total storage capacity in Sweden stands at around 73 million barrels (mb) of product and around 22 mb of crude.

Sweden has an advantageous location for the storage industry, as it is positioned along major trade routes in the middle of Scandinavia, bordering on both the North Sea and the Baltic Sea and relatively close to Rotterdam and ports in Russia.

# Retail market and prices

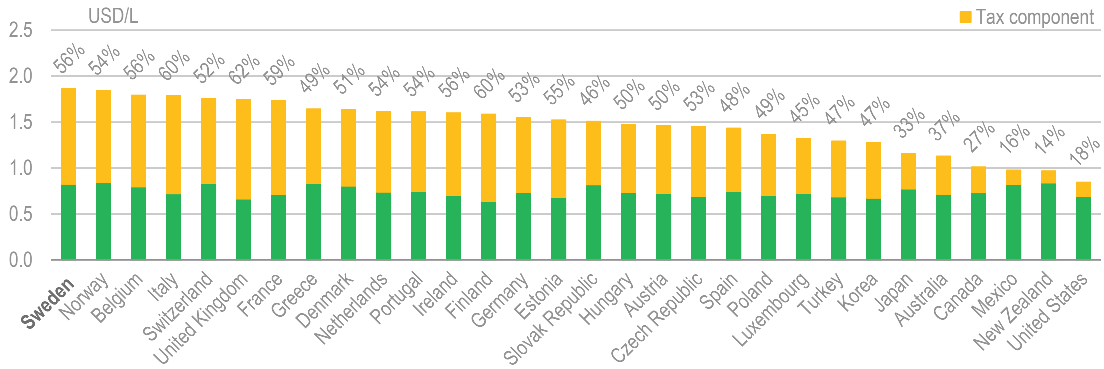
The retail oil sector is dominated by four large private actors with countrywide service station networks: Circle-K, OKQ8, Preem and St1. Circle-K, a subsidiary of the Canadian retail conglomerate Alimentation Couche-Tard Inc., is the most recent arrival to the Swedish market, having bought Statoil's Swedish retail and logistics network.

Sweden has around 2 800 retail service stations. The number of service stations has declined only slightly over the past decade, after having fallen very sharply in the preceding decade as part of a far-reaching wave of consolidation and automation, particularly in the least-populated rural areas of Sweden.

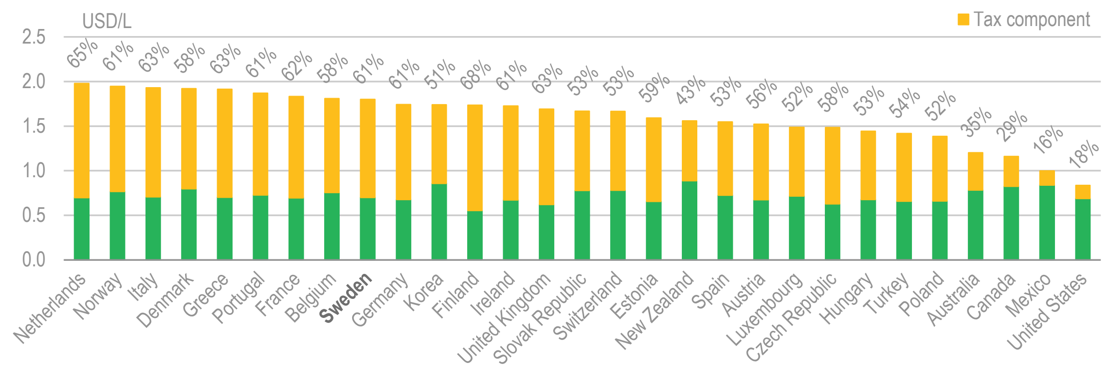
Sweden has a long history of imposing energy and carbon taxes on fossil fuels, which has led to high fuel prices. In the second quarter of 2018, Swedish consumers paid the highest diesel price among the IEA countries, largely an effect of high taxes (Figure 9.8). The Swedish gasoline price was the ninth highest in the comparison.

**Figure 9.8 Oil fuel prices in IEA member countries, second quarter 2018**

Automotive diesel fuel




Premium unleaded gasoline (95 RON)




Sweden has the highest price for diesel among IEA member countries, and the ninth highest for gasoline.

Note: Data are not available for Japan. USD/L = US dollars/litre.
Source: IEA (2018), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

# Security of supply

## *Emergency response policy*

The Ministry of Environment and Energy has the overarching responsibility within the government for handling an oil supply crisis. The Swedish Energy Agency (SEA) is tasked through several ordinances concerning an oil supply crisis, and it coordinates with the industry and other appropriate agencies. The government sees the dialogue and co-operation with industry as generally very good.

The primary response to an oil supply disruption is the release of emergency stocks, in close co-ordination with the country's industry association – Swedish Petroleum and Biofuel Institute. The government has the legal competence to authorise a stock draw of emergency stocks, but it may take up to 15 days for it to do so. However, the government is certain that in reality this would not be an issue.

In a major crisis, the framework of "crisis laws" provides the administration with powerful tools, such as fuel rationing, expropriation of stocks and limiting consumption. In 2012, a new act and the Ordinance on Emergency Stockholding of Oil were adopted to implement the EU Oil Stocks Directive 2009/119. This legislation, however, changed the Swedish system only a little. The 2012 law and ordinance brought improved control mechanisms and called for a contingency plan that should contain organisational measures, propose a plan for training and exercises and set rules for the implementation of demand-side measures.

## Emergency stocks

During the Cold War, Sweden held substantial amounts of government-owned stocks in its own defence depots. These stocks and depots were sold and decommissioned in the 1990s and Sweden's present-day obligation towards the IEA and the European Union is maintained via a purely industry-based system.

All importers and retailers are obliged to hold stocks if they import at least 2 500 cubic metres ($m^3$) of crude oil or products or if they re-sell at least 50 000 $m^3$. The obligation is issued for four products: petrol (gasoline), diesel, jet-1A and fuel oil. A refiner is allowed to hold up to two-thirds of its stock in crude, depending on the yield rates of its facilities. The emergency stocks are commingled with commercial stocks. The emergency stocks are financed entirely by the industry and costs are passed to the end consumer through pump prices at service stations.

The SEA calculates the total volume of stocks Sweden needs to hold and then allocates this volume on the importers and retailers based on the most recent statistics of their imported/sold volumes, i.e. all companies must hold the same percentage of their previous year's imported/sold volumes as stocks.

As of end of April 2018, the emergency stocks amounted to 42.3 mb, equalling 187 days of net imports, according to IEA methodology. All the stocks are held by industry, with 40% in the form of crude oil and 60% in the form of products.

Industry held 3.3 mb of emergency stocks abroad, primarily in the Netherlands (1 mb), Latvia (1 mb) and the United Kingdom (0.8 mb). An additional 2.9 mb of stocks were being held in Sweden on behalf of other countries – the main user being the United Kingdom with 1.5 mb of stocks. All bilateral stocks, both abroad and in Sweden on behalf of other countries, are reported as ticketed stocks. Companies are allowed to hold a maximum of 30% of their obligation abroad.

### Compliance and monitoring

Sweden is consistently compliant with the IEA's minimum obligation. Any company that fails to maintain the 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 from 200% up to 1 000% for failing to meet the requirement and if it fails to correct the shortage.

The SEA is responsible for monitoring companies' compliance. It is currently working towards a programme of regular controls. However, capacity constraints prevent a proper auditing of all the actors, especially periodically and at location.

### *Drawdown procedures*

The emergency stocks may only be used after a decision by the government to do so and a subsequent decision by the SEA. The government can take up to 15 days to issue a formal decision, in this time the SEA would prepare the technical aspects of the stock draw, such as the product mix, and remain in close co-operation with the industry. Therefore, once the government has made the formal decision, the release can be implemented within hours. As the stocks are held by the industry commingled directly in their supply chains, they would reach the market instantly and at the right specifications (which is important, e.g. because of Sweden's low winter temperatures).

## *Demand restraint*

In a major crisis, the framework of "crisis laws" provides the administration with powerful tools, which include fuel rationing or limiting consumption. The SEA also maintains and updates a set of public information campaign messages for the reduction of fuel consumption in an emergency.

A decision to implement demand restraint (DR) measures would be made by the government based on a proposal from the SEA. In severe fuel disruptions when allocation becomes necessary, the decision making and implementation also take place on regional and local (municipality) levels in terms of prioritising customers. The SEA would co-ordinate and provide advice. It has also prepared a handbook on special contracts with storage operators on this issue.

# Assessment

Sweden has successfully phased out the use of oil in the residential and commercial sectors and substantially reduced its use in industry. Oil is still used in heat and electricity during peak demand, but at negligible volumes. Swedish oil consumption has fallen by half since the 1970s, but the challenge remains to reduce oil in the transport sector substantially, and, less so, in industry (including non-energy uses).

Despite these efforts, oil still accounts for 30% of the total final energy consumption. In the transport sector, oil dominates with a share of 81% (94% at EU level), with biofuels standing at 16% in 2016.

All crude oil is imported, around 20 Mt in 2016, and then refined into oil products in three refineries and two petrochemical facilities. Sweden is a net exporter of oil products. Crude oil is imported mostly from Russia (42% of the total imports in 2016), but import sources are otherwise well diversified. In addition, Sweden imports HVO and biomass, which is converted into biofuels through co-production in the domestic refineries.

Oil use in transport is the main component of energy-related carbon dioxide ($CO_2$) emissions (in 2016, its share was about half of the total). $CO_2$ reduction is, thus, a strong driver to reduce the use of oil. To continue decarbonising the transport sector, the government has set a target to reduce greenhouse gas emissions in transport by 70% from 2010 to 2030, which supports a switch to biofuels and other renewable fuels. A new quota system was implemented in July 2018, with initial emissions reduction requirements of 19.3% for diesel and 2.6% for gasoline (see Chapter 3).

Sweden has seen a rapid increase in the share of biofuels in diesel, reaching no less than 24% in 2016. The new quota system may potentially be a strong driver for biofuels production based on domestic feedstocks (forest based). However, views diverge on the best ways to use wood-based feedstocks in the medium to long term.

Sweden fulfils its obligations to hold emergency stocks of crude oil and/or petroleum products, in accordance with the IEA and European Union requirements. The SEA is tasked with managing the requirements and it charges commercial actors with stockholding obligations, with the requirement that stocks should be fully accessible at any time. The system is upheld by means of detailed reporting and transparency requirements, and a robust penalty system for, i.e. deficits in stocks or late reporting by the obliged parties.

The share of biofuels use in Sweden is reflected, but not mandated, in the stockholding. The EU oil stock directive limits how biofuels may be calculated towards the actual stock levels. Currently, it is unclear what impact an increased use of biofuels could have in this respect.

In 2016, IEA performed an Emergency Response Review of Sweden, which covered oil, natural gas, and electricity that resulted in a series of detailed recommendations to the government. The current in-depth review provides additional recommendations beyond security issues.

## Recommendations

***The government of Sweden should:***

- Implement the recommendations of the 2016 IEA Emergency Response Review of Sweden on its oil emergency response policy and organisation, emergency oil reserves and oil DR.
- Analyse the impact of the expected higher shares of biofuels in the transport sector (including a large share of imports) on the opportunities to develop a sustainable domestic supply chain, on the potential risks for the overall security of supply as well as on fulfilling the EU requirements on stock levels to meet stockholding obligations.
- Ensure a long-term and predictable policy framework that provides the right signals and confidence to invest in additional biofuels production.
- Closely monitor the structural changes in the oil sector, such as market fragmentation; analyse to what degree this has implications for oil security.

### References

IEA (International Energy Agency) (2019 forthcoming), *World Energy Balances 2019 preliminary edition* (database), OECD/IEA, Paris, www.iea.org/statistics/.

IEA (2019b forthcoming), *Oil Information 2019 preliminary edition* (database), OECD/IEA, Paris, www.iea.org/statistics/.

IEA (2018), *Energy Prices and Taxes, Second Quarter 2018*, OECD/IEA, Paris, www.iea.org/statistics/.

# 10. Natural gas and biogas

## Key data

(2017)

**Gas supply:** Natural gas imports 0.75 bcm / 0.67 Mtoe (100% from Denmark), -25% since 2007; biogas production 0.17 Mtoe, +259% since 2007

**Share of gas:** 1.8% of TPES, 0.2% of electricity generation, 2.1% of TFC (2016)

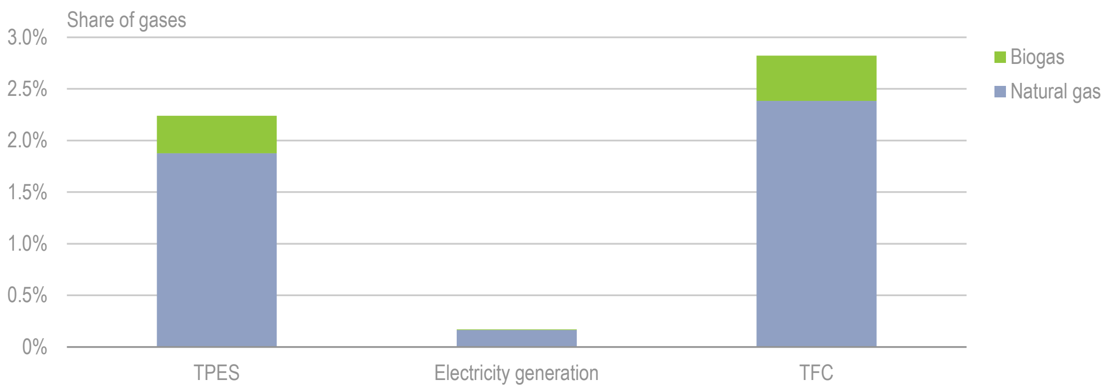
**Natural gas consumption by sector**: 0.9 Mtoe (industry 71.2%, power and heat generation 11.5%, commercial 8.7%, residential 3.9%, other energy 2.8% transport 1.9%)

**Exchange rate:** Swedish kronor (SEK) 1 = USD 0.117 = EUR 0.104

## Overview

Natural gas is a minor fuel in Sweden. Together with biogas, it provides 2-3% of total primary energy supply (TPES) and total final consumption (TFC) of energy and less than 0.2% of electricity generation (Figure 10.1). Sweden has the lowest shares for gas in its energy system among the International Energy Agency (IEA) countries. The natural gas network is limited to the west coast of the country where gas provides around 20% of the TPES, on a par with many other IEA countries. There, gas is a relatively important fuel both for heating and for process industries.

**Figure 10.1 Share of natural gas and biogas in different energy supplies, 2017**




Sweden has the smallest role for natural gas among the IEA countries.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

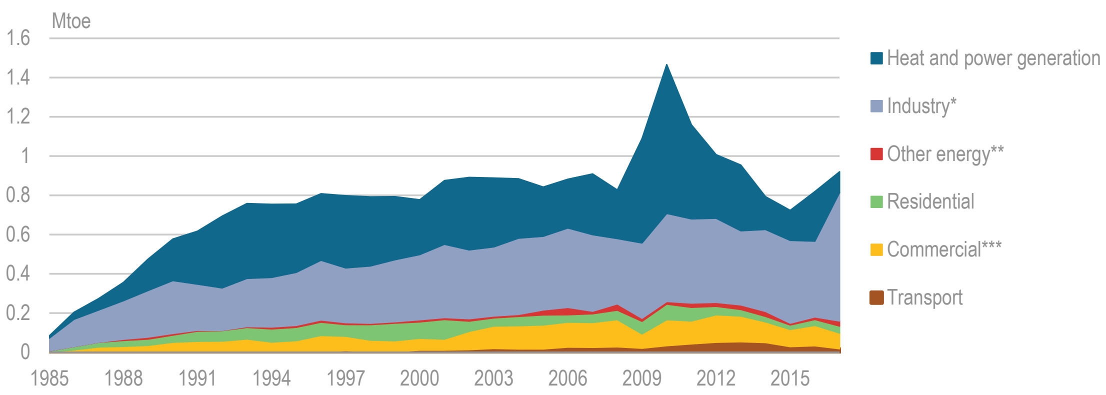
All natural gas is imported from Denmark through a single pipeline, which can be seen as a risk for security of supply. Biogas, on the other hand, is produced domestically and the potential remains for more. Consistent with Sweden's decarbonisation goals, the government's long-term plan is to replace natural gas with biogas. As a renewable energy source, biogas may play a larger role in a future sustainable energy system. Also liquefied gases can become more important, e.g. as a shipping fuel and to improve the security of supply.

## Supply and demand

Natural gas is mostly consumed in the process industries along the gas transmission network in the south-west of the country. Chemical and petrochemical facilities are the largest industrial gas consumers, using gas for both energy and non-energy purposes (Figure 10.2). Non-energy use in chemical industries increased in 2017, leading to a total growth in natural gas consumption by 12% compared to 2016.

Biogas is mostly produced domestically through anaerobic digestion of wastewater or municipal organic waste (Figure 10.3). In 2017, Sweden produced 178 kilo tonnes of oil equivalent (ktoe) (2.1 terawatts [TWh]) biogas, an increase by 40% in five years. Nearly two-thirds of the produced biogas is upgraded to vehicle gas and used in transport.

### Figure 10.2 Natural gas consumption by sector, 1985-2017




With the exception of the cold winter peaks of 2010-11, gas demand is relatively stable.

* *Industry* includes non-energy consumption.

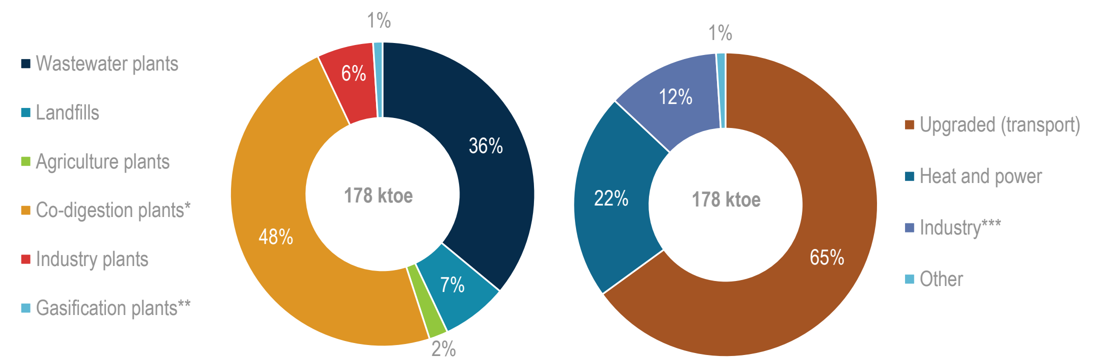
** *Other energy* includes the energy sector's own consumption.

*** *Commercial* includes commercial and public services, agriculture and forestry.

Note: TPES of natural gas and biogas by consuming sector.

Source: IEA (2019 forthcoming), *World Energy Balances 2019 preliminary edition*, www.iea.org/statistics/.

**Figure 10.3 Breakdown of biogas production and consumption, 2017**




Most biogas is produced in anaerobic digestion plants and largely used in transports.

* Co-digestion plants use mainly municipal organic waste.

** In 2018, production in the gasification plant GoBiGas was closed.

*** *Industry consumption* includes gas flaring.

Source: ES (2019), *Statistik om Biogas* [Biogas Statistics], www.energigas.se/fakta-om-gas/biogas/statistik-om-biogas/.

## Support for biogas production

The main support scheme for biogas use is the exemption from energy tax and the $CO_2$ tax when the gas is used for transport or heating. To be eligible for the exemption, the gas must meet EU sustainability criteria. Also, EU state aid rules must be complied with

In addition, biogas production by farmers is supported from the partly EU-funded Rural Development Programme (*Landsbygdsprogrammet*). The budget for biogas investments up to 2020 is SEK 279 million, and it is financed between the government (59%) and the European Union (41%).

In January 2015, the government also introduced a support scheme for biogas production through the anaerobic digestion of manure. The support aims to both reduce methane emissions from manure and substitute fossil fuels. The subsidy amounts to a maximum of 0.40 SEK per kilowatt hour (SEK/kWh) of biogas produced. Between January 2015 and September 2016, a total of SEK 69 million in aid was granted to 51 biogas plants. The subsidy programme runs until 2023 and has a budget of SEK 385 million. The subsidy programme was temporarily reinforced in 2018 with SEK 270 million as well as given a broader scope, as not only biogas from manure is eligible for aid.

The Swedish gas industry has developed a plan to increase biogas production to somewhere between 7 TWh and 15 TWh; the upper limit is well above the current gas supply and to reach it will be challenged by competition from subsidised biogas production in Denmark. The government is setting up a committee on biogas to analyse its future role in the energy system and to consider instruments to support it.

# Regulatory framework

Sweden's gas market legislation is based on EU directives and regulations. Under the 2005 Natural Gas Act, non-household customers became eligible to choose their supplier in July 2005 and households in July 2007.

The Swedish Energy Markets Inspectorate (SEMI) is established as the regulator. The network owners are obliged to provide third-party access (TPA) on objective, non-discriminatory and reasonable terms. TPA is also provided for storage and, if connected to a transmission or distribution pipeline, for regasification facilities.

Sweden applies the ownership unbundling model. A transmission company may not trade or produce natural gas or electricity and must be independent from companies that do so.

On network tariff regulation, Sweden has moved to *ex ante* regulation through a revenue cap. The SEMI sets the cap for a four-year regulatory period, the first one of which runs from 2015 to the end of 2018. This revenue cap regime applies for transmission, distribution, storage and regasification.

The regulatory model considers operating and capital costs when defining the revenue cap. Operating costs (operation and maintenance of networks, metering and billing) are divided into controllable and uncontrollable costs. The controllable costs are reduced year by year by an efficiency target. This requirement on higher productivity is not applied to uncontrollable costs.

Capital costs include the cost of capital depreciation and the return on capital. The regulatory asset base is defined by the principle of replacement value. The rate of return is decided by the method of weighted average cost of capital.

# Infrastructure

The Swedish transmission system for natural gas begins at Dragør in Denmark, crosses the Öresund strait via the Öresund pipeline to Klagshamn south of Malmö, from where the trunk pipeline heads northward along the west coast up to the chemical and petrochemical industries in Stenungssund. The technical capacity of the Öresund trunk line is 8.4 million cubic metres per day (mcm/d) and the technical capacity of the entry point of Dragør (in Denmark) is 7.8 mcm/d. The pipeline is buried under the sea floor, and therefore has a very low probability of an accident (statistically once per 26 300 years according to the administration). The natural gas network consists of around 620 kilometres (km) of transmission lines and roughly 2 700 km of distribution lines. It is not expected to expand substantially.

There are two liquefied natural gas (LNG) terminals in operation in Sweden: Skangas's terminal in Lysekil with a storage capacity 30 000 cubic metres ($m^3$) and AGA's terminal in Nynäshamn with a capacity of 20 000 $m^3$. The existing LNG terminals are not connected to the natural gas system.

**Figure 10.4 Map of Sweden's natural gas infrastructure**


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The Nynäshamn terminal, south of Stockholm, has operated since mid-2011. It provides gas to the Nynas refinery, and LNG is trucked to several other industrial customers and various municipalities, including Stockholm, which has a city gas network that supplies residential and commercial users, and a transport network that supplies gas stations.

The Lysekil terminal opened in late 2014 and is connected to the Preem refinery. It also provides LNG by truck as far as to the SSAB steel mills in Borlänge (over 400 km), and to other industrial customers.

Plans exist for four smaller LNG terminals: two in Gävle, one in Åhus and one in Gothenburg. The one in Gothenburg (planned by Swedegas and the city harbour) would be connected to the natural gas system, if constructed.

There is only one small storage facility in Skallen, in the southwest, used to meet peak demand. It is a lined rock cavern with a total working capacity of 8.8 mcm and a maximum withdrawal capacity that varies from 0.6 mcm/d to 0.9 mcm/d. This represents only around 10-20% of the market's needs under winter conditions. In April 2018, this storage was mothballed, but it can be taken into service within a month, if needed. Seasonal swings are compensated from storage facilities in Denmark (Stenlille and Lille Torup), which have a combined maximum drawdown capacity of 16.2 mcm/d.

## Industry and market structure

Swedegas owns and operates the transmission system and the storage facility. It is also the country's gas transmission system operator (TSO) and responsible for balancing the gas system. Swedegas is owned by the Belgium-based Fluxys and Enagás, which is the Technical Manager of the Spanish gas system. Swedegas has no relationship to other participants in the Swedish natural gas market.

There are six gas distribution system operators (DSOs) in Sweden: E.ON Gas Sverige the largest, and the municipality-owned Öresundskraft, Varbergs Energi, Göteborg Energi, Kraftringen Energi and Gasnätet i Stockholm.

There are also seven supply companies that operate in the retail market: E.ON, Öresundskraft, Varbergs Energi, Göteborg Energi, Kraftringen Energi, Apport Gas, and Stockholm Gas. There are no official data on the retail sales by supplier.

Sweden does not have an exchange for trading in wholesale gas and gas trades are carried out abroad either bilaterally or through exchanges, such as Gaspoint Nordic.

Sweden and Denmark are preparing to form a joint balancing zone in April 2019. If implemented, this change is expected to integrate the two markets further, and so make it easier and cheaper for more market participants to be active in both markets.

## Prices

Retail prices for natural gas are not regulated. The Swedish pipeline network is essentially a large consumer in the Danish market and Swedish gas prices are linked to those in Denmark, which, in turn, is well integrated to the Central European gas markets.

Natural gas consumption is subject to an excise tax, which includes both an energy tax component and a $CO_2$ tax component. Tax rates vary according to user category. They are particularly high for households but have been raised significantly also for industry in recent years (Figure 10.5). From 2010 to 2017, the combined tax on natural gas used in non-ETS industry rose from SEK 0.04/kWh to SEK 0.25/kWh.

In 2016, 0.7% of all household customers and 1.6% of other customer segments switched natural gas supplier. There are in total seven suppliers in the retail market for natural gas; 6–7 offer gas contracts to customers who reside in the south-west of Sweden. To promote supplier switching, the Swedish Consumer Energy Markets Bureau[1], which is an independent bureau that provides advice and guidance to consumers, operates an online price comparison tool on its website (www.energimarknadsbyran.se/Gas/Dina-avtal-och-kostnader/Gaspriskollen/).

**Figure 10.5 Natural gas prices in IEA member countries, 2017**


Swedish households pay the highest price for natural gas among all IEA member countries, and the industry price is the fourth-highest in the comparison.

* Tax information not available for the United States.

Notes: USD/MWh = US dollars per megawatt hour. Data are not available for Australia, Canada, Greece, Finland (household), Italy, Japan, Mexico and Norway.

Source: IEA (2018), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

[1] The board consists of the Swedish Consumer Agency, SEA and the Energy Markets Inspectorate together with the industry organisations Swedenergy and Swedish Gas Association.

# Security of supply

The emergency response policy for natural gas was based on Regulation (EU) 994/2010 but is now being adjusted to the new Regulation (EU) 2017/1938. Under Regulation (EU) 2017/1938, gas supply must be guaranteed for protected customers for 30 days of exceptionally high gas demand or disruption of the largest infrastructure under average winter conditions and during seven days of extreme temperatures.

Sweden, however, continues to have a derogation from the new Regulation's N-1 obligation for as long as it has no gas transit to other member states and its annual gas consumption is less than 2 million tonnes of oil equivalent (Mtoe) and less than 5% of the TPES (currently it is 0.8 Mtoe and 2% of the TPES).

Sweden defines protected customers as all households directly connected to the gas distribution network. Some 33 000 customers fall under this definition and collectively they accounted for around 3% of natural gas consumption in 2016. Supplies to them are estimated to be maintainable for around one month in the case of high demand, and for several months in the case of low demand.

The Swedish Energy Agency (SEA) is designated as the Swedish Competent Authority and responsible for all the tasks under the Regulation (EU) 2017/1938. It is thus responsible for preparing a national and regional risk assessment, a preventive action plan and an emergency plan, and updating them every four years. Under the emergency plan, once the SEA has declared the crisis level emergency, the TSO Swedegas as the system-balancing entity may order DSOs to increase or reduce the input or offtake of the gas and to restrict or discontinue the natural gas supply to customers. The TSO and the DSOs must maintain a plan (also submitted to SEA for review) to reduce consumption.

Disconnecting large users of natural gas is the main way to safeguard supplies to protected customers in a gas crisis. Around 60 large consumers that account for nearly 85% of the total gas demand in Sweden can potentially be cut-off from supplies very rapidly in an emergency. Large co-generation[2] units, which constitute around one-quarter of all gas demand in Sweden, can quickly switch from natural gas to gasoil. Large industries, which represent around 40% of total gas demand, also have some capacity to switch to other fuels, primarily fuel oil. At high demand and/or a total cut-off, the pressure will fall in the transmission network if the input pressure in Dragör is not high enough. At pressure levels below 45 bar, the users with a need for high pressure will automatically disconnect. The Swedish protected customers are in the lowest pressure group and can be supplied with gas at a pressure under 45 bar.

Other means to respond in a crisis include the use of line pack, which maximises the input of biogas supplies into the network and draws on the available volumes in storage. Sweden does not maintain strategic stocks of natural gas, nor are gas suppliers, grid owners or the system operator obliged to hold minimum reserves.

Swedish gas customers may also bid for interruptible contracts in an auctioning system operated by the Danish TSO Energinet. The system is open to gas users who consume more than 2 mcm/yr and it is activated by Energinet when a crisis level alert is declared in accordance with Regulation (EU) 2017/1938. In winter, the interruptible capacity in

[2] *Co-generation* refers to the combined production of heat and power.

Sweden amounts to around 1 mcm/d (the combined demand of Denmark and Sweden in cold winter conditions is about 28 mcm/d).

Incidents that affect the Danish supply could potentially also affect gas supply to Sweden. They include the failure of supply from the North Sea, failure of supply from Germany, and failure of the Stenlille gas storage facility. The North Sea supply will be affected by the temporary closure of the Tyra field, by far Denmark's largest, for refurbishment from 2019 to 2022. During this period, the Danish and Swedish market will be dependent on the supply from Germany and enough volumes in Danish storage.

On 1 March 2018, Swedegas together with the SEA, issued an "Early warning" for a potential gas shortage, after the Danish TSO Energinet had done the same a few days previously. The reasons for the Swedish warning were imbalance and a pressure drop in the transmission network for several consecutive days, partly caused by a high consumption because of cold weather. Swedegas cancelled the early warning after 20 days, again after that decision was made in Denmark.

Under Regulation (EU) 2017/1938, Sweden is included in three regional risk groups: 1) Denmark, 2) the Baltic Sea and 3) the North Sea. The purpose of these risk groups is to serve as the basis for an enhanced regional co-operation to identify transnational risks and enable agreement on the effective cross-border measures. The groups will thus increase the security of gas supply. The risk groups will set up scenarios of disturbances in important supply routes in various regions and analyse the effect of these on the affected countries. The new regulation also contains a solidarity clause that sets out that a solidarity agreement shall be adopted between Denmark and Sweden by 1 December 2018.

## Assessment

Natural gas has limited importance in the Swedish energy system. In 2016, it accounted for 2% of the TPES and 0.4% of electricity generation. However, in south-west Sweden, where natural gas is mainly available, it provides around 20% of the TPES, on a par with that of many other IEA countries.

The total natural gas supply in 2017 was 0.7 Mtoe (0.8 billion cubic metres [bcm]), around the average of the past two decades. The exception was the cold year of 2010 when gas-fired heat and power generation sharply increased. Sweden has no domestic gas production and imports all its gas from Denmark via a single pipeline. Most gas is used in the process industry and at co-generation plants. Households account for less than 10% of gas use. Biogas production amounts to around 0.2 bcm, which is partly injected into the natural gas system, but mostly used in transport, notably in public transport.

The long-term projections of the government show a gradual decline in natural gas supply in Sweden as biogas production increases. Natural gas has a limited role in power generation, and the government does not expect that role to increase when the nuclear power plants eventually close. Unlike in many other countries, gas is not expected to be a transition fuel in Sweden.

Gas demand in most sectors is seasonal and sensitive to temperature. On a cold day, the total demand is estimated to be three times higher than on an average day. Sweden has only one small storage with a capacity of 8.8 mcm, of which 1 mcm is at the disposal of the TSO to supply gas to protected customers in times of need. The send out capacity of the facility is between 0.6 and 0.9 mcm/d, but the storage has been mothballed and can be taken into use within a month. Therefore, if imports are interrupted, gas supply to almost all but the protected customers will have to be stopped. Some of the gas consumers, notably co-generation and heat plants, have a dual-fired capability and can switch to fuel oil.

Swedish gas mainly comes from the Tyra field in Denmark, which will be closed for maintenance between December 2019 and March 2022. During that period, the Swedish market will be completely dependent on natural gas from Germany via Ellund. This will increase the vulnerability of the Swedish natural gas supply, as there will be no secondary pipeline route option during this time.

Retail prices for natural gas are not regulated. The Swedish pipeline network is essentially a large consumer in the Danish market. Swedish gas prices are close to those in Denmark, which, in turn, is well integrated to the Central European gas markets. From April 2019, Denmark and Sweden are expected to function as one balancing zone, which will increase the market liquidity and security of supply in Sweden. Only in a crisis will the balancing zone be split into two again.

Two LNG terminals are in operation, but they are connected to industrial facilities, not to the natural gas grid. However, more terminals are being planned, partly to supply bunker LNG for shipping. The planned terminal in Gothenburg would be connected to the natural gas system, if constructed. The IEA encourages the government to consider the role of LNG in shipping as a means to reduce environmental risks and carbon intensity in this sector.

Biogas production, mainly from organic waste and wastewater treatment, has increased significantly in the past decade. In 2016, around 2 TWh of biogas (0.2 bcm) was produced, of which nearly two-thirds were upgraded and used in vehicles. The government is setting up a committee on biogas to analyse its role in the society and the energy system and consider instruments to support it. The Swedish gas industry has developed a plan to increase biogas production to somewhere between 7 and 15 TWh; the upper limit is well above the current gas supply and can only be reached once a level playing field with biogas production in Denmark has been established.

## Recommendations

***The government of Sweden should:***

- ☐ Work closely with the TSOs of Denmark and Germany to ensure ample supplies to Sweden during the closure of the Tyra field.
- ☐ Consider the role of LNG in the shipping industry as a means to reduce environmental risks and carbon intensity in this sector.
- ☐ Facilitate an increasing role for domestically sourced biogas to increase the security of supply and reduce the use of imported fossil fuels.
- ☐ Assess the role biogas can play as a complementary fuel for power generation towards a 100% renewable electricity system, and promote biogas as a fossil-free transport fuel.

## References

ES (Energigas Sverige) (2019), *Statistik om Biogas* [Statistics on Biogas], ES, Stockholm, www.energigas.se/fakta-om-gas/biogas/statistik-om-biogas/.

IEA (International Energy Agency) (2019 forthcoming), *World Energy Balances 2019 preliminary edition* (database), OECD/IEA, Paris, www.iea.org/statistics/.

IEA (2018), *Energy Prices and Taxes, Second Quarter 2018*, OECD/IEA, Paris, www.iea.org/statistics/.

# ANNEX A: Organisations visited

## Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews (IDRs) conducted by the IEA. The Shared Goals are presented in Annex C.

### Review team and preparation of the report

The IEA in-depth review team visited Sweden from 16 to 20 April 2018. The team met with government officials, energy suppliers, interest groups and other organisations. This report was drafted on the basis of the review team's preliminary assessment of the country's energy policy and information on subsequent policy developments from the government and private-sector sources. The members of the team were:

IEA member countries
Mr Tomas Smejkal, the Czech Republic (team leader)
Dr Christian Dupraz, Switzerland
Mr Madis Laaniste, Estonia
Mr Janusz Michalski, Poland
Ms Martine Roza Molenschot, the Netherlands

European Commission
Dr Arne Eriksson

OECD Nuclear Energy Agency
Dr Marco Cometto

IEA Secretariat
Mr Aad van Bohemen
Mr Oskar Kvarnström
Mr Miika Tommila

The team is grateful for the co-operation and assistance of the many people it met throughout the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable. The team expresses its gratitude to Minister Ibrahim Baylan and State Secretary Emil Högberg for their time and encouragement. The team also appreciates Director General Robert Andrén and the staff of the Ministry of the Environment and Energy, in particular Magnus Blümer, Anna Törner, Björn Telenius and Filip Ehrle Elveling, and the Swedish Energy Agency for the professionalism they displayed throughout the review process.

Miika Tommila managed the review process and drafted Chapters 1, 2, 6, 7, 9 and 10. Chapters 3-5 were drafted by Oskar Kvarnström and Chapter 8 by Marco Cometto. Oskar Kvarnström drafted the supply and demand sections of the report.

The report was prepared under the guidance of Aad van Bohemen, Head of Energy Policy and Security Division. Helpful comments and updates were provided by the review team members and IEA staff, including Cyril Cassisa, Sean Calvert, Ute Collier, Rebecca Gaghen, Ian Hamilton, Sara Moarif, Carrie Pottinger, Sacha Scheffer and Matthew Wittenstein.

Oskar Kvarnström prepared the figures and Bertrand Sadin prepared the maps. Roberta Quadrelli and Rémi Gigoux provided support on the statistics. Therese Walsh managed the editing process, and Astrid Dumond and Isabelle Nonain-Semelin managed the production process.

## *Organisation visited*

During its visit in Sweden, the review team met with the following organisations:

Chalmers University of Technology

Confederation of Swedish Enterprise

Energigas Sverige

E.ON Gasnät

E.ON Biofor

Ministry of the Environment and Energy

Ministry of Finance

National Board of Housing, Building and Planning

Price dialogue (Prisdialogen)

Riskbyggen

Royal Institute of Technology (KTH)

Stockholm Environment Institute

Swedegas

Swedish Association of Public Housing Companies

Swedish Bioenergy Association

Swedish Energy Agency

Swedish Energy Markets Inspectorate

Swedish Smartgrid Forum

Swedish Society for Nature Conservation

Svenska kraftnät

SwedEnergy

Swedish Nuclear Fuel and Waste Management

Swedish Petroleum and Biofuels Institute

Swedish Radiation Safety Authority

Swedish Wind Energy Economic Association

Uppsala University

# ANNEX B: Energy balances and key statistical data

Unit: Mtoe

| SUPPLY | | 1973 | 1990 | 2000 | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| **TOTAL PRODUCTION** | | **9.3** | **29.7** | **30.5** | **32.8** | **33.8** | **34.7** | **35.9** |
| Coal | | 0.0 | 0.0 | - | - | - | - | - |
| Peat | | - | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| Oil | | - | 0.0 | - | - | - | - | - |
| Natural gas | | - | - | - | - | - | - | - |
| Biofuels and waste[1] | | 3.5 | 5.5 | 8.3 | 11.3 | 10.9 | 11.3 | 11.4 |
| Nuclear | | 0.6 | 17.8 | 14.9 | 15.1 | 14.7 | 16.4 | 17.1 |
| Hydro | | 5.1 | 6.2 | 6.8 | 5.7 | 6.5 | 5.3 | 5.6 |
| Wind | | - | 0.0 | 0.0 | 0.3 | 1.4 | 1.3 | 1.5 |
| Geothermal | | - | - | - | - | - | - | - |
| Solar/other[2] | | - | 0.0 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 |
| **TOTAL NET IMPORTS[3]** | | **29.1** | **17.3** | **17.3** | **17.3** | **12.2** | **14.2** | **10.9** |
| Coal | Exports | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | Imports | 1.7 | 2.6 | 2.4 | 2.5 | 2.0 | 2.2 | 2.0 |
| | Net imports | 1.7 | 2.6 | 2.3 | 2.4 | 1.9 | 2.2 | 1.9 |
| Oil | Exports | 1.4 | 8.6 | 11.0 | 12.8 | 15.3 | 17.0 | 18.0 |
| | Imports | 30.0 | 23.9 | 26.7 | 28.3 | 28.4 | 30.9 | 29.5 |
| | Int'l marine and aviation bunkers | -1.2 | -1.0 | -2.0 | -2.6 | -2.5 | -2.8 | -3.2 |
| | Net imports | 27.4 | 14.3 | 13.7 | 12.9 | 10.5 | 11.1 | 8.3 |
| Natural Gas | Exports | - | - | - | - | - | - | 0.0 |
| | Imports | - | 0.6 | 0.8 | 1.5 | 0.7 | 0.8 | 0.9 |
| | Net imports | - | 0.6 | 0.8 | 1.5 | 0.7 | 0.8 | 0.9 |
| Electricity | Exports | 0.4 | 1.3 | 1.2 | 1.1 | 2.7 | 2.2 | 2.7 |
| | Imports | 0.5 | 1.1 | 1.6 | 1.3 | 0.8 | 1.2 | 1.0 |
| | Net imports | 0.1 | -0.2 | 0.4 | 0.2 | -1.9 | -1.0 | -1.6 |
| **TOTAL STOCK CHANGES** | | **0.5** | **0.2** | **-0.2** | **0.7** | **-1.2** | **0.2** | **2.2** |
| **TOTAL SUPPLY (TPES)[4]** | | **38.8** | **47.2** | **47.6** | **50.9** | **44.8** | **49.2** | **49.0** |
| Coal | | 1.6 | 2.7 | 2.2 | 2.1 | 2.0 | 1.9 | 1.9 |
| Peat | | - | 0.2 | 0.2 | 0.4 | 0.1 | 0.1 | 0.1 |
| Oil | | 27.9 | 14.3 | 13.6 | 13.9 | 9.3 | 11.7 | 10.4 |
| Natural gas | | - | 0.6 | 0.8 | 1.5 | 0.7 | 0.8 | 0.9 |
| Biofuels and waste[1] | | 3.5 | 5.5 | 8.3 | 11.5 | 11.8 | 12.4 | 12.9 |
| Nuclear | | 0.6 | 17.8 | 14.9 | 15.1 | 14.7 | 16.4 | 17.1 |
| Hydro | | 5.1 | 6.2 | 6.8 | 5.7 | 6.5 | 5.3 | 5.6 |
| Wind | | - | 0.0 | 0.0 | 0.3 | 1.4 | 1.3 | 1.5 |
| Geothermal | | - | - | - | - | - | - | - |
| Solar/other[2] | | - | 0.0 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 |
| Electricity trade[5] | | 0.1 | -0.2 | 0.4 | 0.2 | -1.9 | -1.0 | -1.6 |
| ***Shares in TPES (%)*** | | | | | | | | |
| *Coal* | | *4.2* | *5.8* | *4.7* | *4.2* | *4.4* | *3.9* | *3.9* |
| *Peat* | | *-* | *0.5* | *0.5* | *0.7* | *0.3* | *0.3* | *0.3* |
| *Oil* | | *71.8* | *30.3* | *28.5* | *27.3* | *20.7* | *23.7* | *21.2* |
| *Natural gas* | | *-* | *1.2* | *1.6* | *2.9* | *1.6* | *1.7* | *1.9* |
| *Biofuels and waste[1]* | | *9.1* | *11.7* | *17.4* | *22.6* | *26.4* | *25.1* | *26.3* |
| *Nuclear* | | *1.4* | *37.6* | *31.4* | *29.6* | *32.8* | *33.4* | *34.9* |
| *Hydro* | | *13.3* | *13.2* | *14.2* | *11.2* | *14.5* | *10.8* | *11.4* |
| *Wind* | | *-* | *-* | *0.1* | *0.6* | *3.1* | *2.7* | *3.1* |
| *Geothermal* | | *-* | *-* | *-* | *-* | *-* | *-* | *-* |
| *Solar/other[2]* | | *-* | *0.0* | *0.8* | *0.6* | *0.5* | *0.4* | *0.4* |
| *Electricity trade[5]* | | *0.2* | *-0.3* | *0.8* | *0.4* | *-4.3* | *-2.1* | *-3.3* |

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

| DEMAND | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FINAL CONSUMPTION** | **1973** | **1990** | **2000** | **2010** | **2015** | **2016** | **2017** |
| **TFC** | **34.8** | **32.1** | **35.3** | **34.9** | **32.2** | **33.4** | **33.5** |
| Coal | 1.0 | 1.1 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 |
| Peat | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oil | 24.4 | 14.0 | 14.2 | 11.2 | 9.4 | 9.9 | 9.9 |
| Natural gas | - | 0.3 | 0.4 | 0.7 | 0.7 | 0.6 | 0.8 |
| Biofuels and waste[1] | 3.5 | 4.6 | 5.3 | 5.7 | 6.5 | 6.7 | 6.8 |
| Geothermal | - | - | - | - | - | - | - |
| Solar/other[2] | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 6.0 | 10.3 | 11.1 | 11.3 | 10.7 | 11.0 | 10.9 |
| Heat | - | 1.7 | 3.6 | 5.1 | 4.2 | 4.4 | 4.4 |
| ***Shares in TFC (%)*** | | | | | | | |
| *Coal* | *3.0* | *3.3* | *2.2* | *2.4* | *2.3* | *2.1* | *2.1* |
| *Peat* | - | - | - | - | - | - | - |
| *Oil* | *70.0* | *43.6* | *40.2* | *32.2* | *29.1* | *29.8* | *29.5* |
| Natural gas | - | *1.0* | *1.3* | *1.9* | *2.1* | *1.7* | *2.4* |
| *Biofuels and waste[1]* | *9.9* | *14.4* | *15.0* | *16.3* | *20.1* | *20.2* | *20.3* |
| *Geothermal* | - | - | - | - | - | - | - |
| *Solar/other[2]* | - | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* | - |
| *Electricity* | *17.1* | *32.2* | *31.4* | *32.4* | *33.4* | *32.9* | *32.7* |
| *Heat* | - | *5.3* | *10.1* | *14.7* | *13.0* | *13.3* | *13.1* |
| **TOTAL INDUSTRY[6]** | **15.4** | **13.8** | **15.4** | **13.8** | **12.8** | **13.1** | **13.4** |
| Coal | 0.9 | 1.0 | 0.7 | 0.8 | 0.7 | 0.7 | 0.7 |
| Peat | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oil | 8.2 | 4.1 | 4.8 | 3.2 | 2.5 | 2.9 | 3.0 |
| Natural gas | - | 0.3 | 0.3 | 0.4 | 0.5 | 0.4 | 0.7 |
| Biofuels and waste[1] | 2.9 | 3.7 | 4.3 | 4.2 | 4.3 | 4.3 | 4.2 |
| Geothermal | - | - | - | - | - | - | - |
| Solar/other[2] | - | - | - | - | - | - | - |
| Electricity | 3.4 | 4.6 | 4.9 | 4.7 | 4.3 | 4.3 | 4.4 |
| Heat | - | 0.2 | 0.3 | 0.4 | 0.5 | 0.5 | 0.5 |
| ***Shares in total industry (%)*** | | | | | | | |
| *Coal* | *5.8* | *7.3* | *4.8* | *6.0* | *5.7* | *5.4* | *5.1* |
| *Peat* | - | - | - | *0.1* | - | - | - |
| *Oil* | *53.2* | *29.4* | *31.1* | *22.9* | *19.4* | *22.1* | *22.1* |
| *Natural gas* | - | *1.8* | *2.0* | *3.1* | *3.9* | *3.0* | *5.0* |
| *Biofuels and waste[1]* | *19.0* | *26.6* | *28.1* | *30.7* | *33.4* | *32.7* | *31.1* |
| *Geothermal* | - | - | - | - | - | - | - |
| *Solar/other[2]* | - | - | - | - | - | - | - |
| *Electricity* | *22.0* | *33.6* | *31.8* | *33.9* | *33.7* | *33.1* | *32.8* |
| *Heat* | - | *1.2* | *2.2* | *3.3* | *3.8* | *3.8* | *3.9* |
| **TRANSPORT[4]** | **5.3** | **6.9** | **7.4** | **7.8** | **7.8** | **8.2** | **8.2** |
| **OTHER[7]** | **14.1** | **11.4** | **12.5** | **13.3** | **11.6** | **12.1** | **11.9** |
| Coal | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Peat | - | - | - | - | - | - | - |
| Oil | 11.1 | 3.3 | 2.3 | 0.9 | 0.4 | 0.5 | 0.4 |
| Natural gas | - | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| Biofuels and waste[1] | 0.5 | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 | 1.1 |
| Geothermal | - | - | - | - | - | - | - |
| Solar/other[2] | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 2.4 | 5.5 | 5.9 | 6.4 | 6.2 | 6.4 | 6.3 |
| Heat | - | 1.5 | 3.2 | 4.7 | 3.7 | 3.9 | 3.9 |
| ***Shares in other (%)*** | | | | | | | |
| *Coal* | *1.0* | *0.6* | *0.2* | *0.1* | - | - | - |
| *Peat* | - | - | - | - | - | - | - |
| *Oil* | *78.5* | *28.6* | *18.2* | *6.8* | *3.3* | *3.8* | *3.6* |
| *Natural gas* | - | *0.7* | *1.0* | *1.5* | *1.1* | *1.1* | *1.0* |
| *Biofuels and waste[1]* | *3.7* | *8.4* | *7.6* | *7.9* | *9.8* | *9.6* | *9.6* |
| *Geothermal* | - | - | - | - | - | - | - |
| *Solar/other[2]* | - | - | - | *0.1* | *0.1* | *0.1* | *0.1* |
| *Electricity* | *16.8* | *48.1* | *47.2* | *48.2* | *53.5* | *52.9* | *53.3* |
| *Heat* | - | *13.5* | *25.7* | *35.4* | *32.1* | *32.5* | *32.4* |

Unit: Mtoe

| DEMAND | | | | | | | |
|---|---|---|---|---|---|---|---|
| **ENERGY TRANSFORMATION AND LOSSES** | **1973** | **1990** | **2000** | **2010** | **2015** | **2016** | **2017** |
| **ELECTRICITY GENERATION**[8] | | | | | | | |
| Input (Mtoe) | 8.2 | 26.7 | 26.2 | 29.1 | 28.7 | 29.7 | 31.0 |
| Output (Mtoe) | 6.7 | 12.6 | 12.5 | 12.8 | 13.9 | 13.4 | 14.1 |
| Output (TWh) | 78.1 | 146.0 | 145.2 | 148.4 | 162.0 | 155.9 | 164.2 |
| ***Output Shares (%)*** | | | | | | | |
| *Coal* | *0.6* | *1.1* | *1.7* | *1.3* | *0.7* | *0.5* | *0.6* |
| *Peat* | *-* | *-* | *-* | *0.5* | *0.1* | *0.1* | *0.1* |
| *Oil* | *19.4* | *0.9* | *1.1* | *1.2* | *0.2* | *0.3* | *0.2* |
| *Natural gas* | *-* | *0.3* | *0.3* | *1.9* | *0.3* | *0.4* | *0.2* |
| *Biofuels and waste* [1] | *0.5* | *1.4* | *3.0* | *9.0* | *7.4* | *8.4* | *8.4* |
| *Nuclear* | *2.7* | *46.7* | *39.5* | *39.0* | *34.8* | *40.5* | *40.0* |
| *Hydro* | *76.7* | *49.7* | *54.1* | *44.7* | *46.5* | *39.8* | *39.7* |
| *Wind* | *-* | *-* | *0.3* | *2.3* | *10.1* | *9.9* | *10.7* |
| *Geothermal* | *-* | *-* | *-* | *-* | *-* | *-* | *-* |
| *Solar/other* [2] | *-* | *-* | *-* | *-* | *0.1* | *0.1* | *0.1* |
| **TOTAL LOSSES** | **3.4** | **15.8** | **13.8** | **15.3** | **14.1** | **15.7** | **16.3** |
| of which: | | | | | | | |
| Electricity and heat generation[9] | 1.5 | 12.3 | 10.6 | 11.4 | 10.8 | 12.1 | 12.7 |
| Other transformation | 1.0 | 0.7 | 0.8 | 1.3 | 0.9 | 1.1 | 1.0 |
| Own use and transmission/distribution losses[10] | 1.0 | 2.8 | 2.4 | 2.7 | 2.4 | 2.5 | 2.6 |
| **Statistical Differences** | **0.6** | **-0.7** | **-1.5** | **0.7** | **-1.5** | **0.2** | **-0.7** |
| **INDICATORS** | **1973** | **1990** | **2000** | **2010** | **2015** | **2016** | **2017** |
| GDP (billion 2010 USD) | 228.81 | 321.51 | 397.04 | 488.91 | 543.06 | 557.64 | 569.37 |
| Population (millions) | 8.14 | 8.56 | 8.87 | 9.38 | 9.80 | 9.92 | 10.06 |
| TPES/GDP (toe/1000 USD)[11] | 0.17 | 0.15 | 0.12 | 0.10 | 0.08 | 0.09 | 0.09 |
| Energy production/TPES | 0.24 | 0.63 | 0.64 | 0.65 | 0.75 | 0.71 | 0.73 |
| Per capita TPES (toe/capita) | 4.77 | 5.51 | 5.36 | 5.43 | 4.57 | 4.96 | 4.87 |
| Oil supply/GDP (toe/1000 USD)[11] | 0.12 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| TFC/GDP (toe/1000 USD)[11] | 0.15 | 0.10 | 0.09 | 0.07 | 0.06 | 0.06 | 0.06 |
| Per capita TFC (toe/capita) | 4.28 | 3.75 | 3.98 | 3.72 | 3.28 | 3.36 | 3.33 |
| $CO_2$ emissions from fuel combustion ($MtCO_2$)[12] | 83.6 | 52.1 | 52.0 | 46.1 | 37.1 | 38.0 | 37.6 |
| $CO_2$ emissions from bunkers ($MtCO_2$)[12] | 3.9 | 3.2 | 6.4 | 8.3 | 8.0 | 8.8 | 10.1 |
| **GROWTH RATES (% per year)** | **73-90** | **90-00** | **00-10** | **10-14** | **14-15** | **15-16** | **16-17** |
| TPES | 1.2 | 0.1 | 0.7 | -1.4 | -7.1 | 9.9 | -0.4 |
| Coal | 3.1 | -2.0 | -0.4 | -2.5 | 2.4 | -3.7 | 0.2 |
| Peat | - | -0.1 | 4.3 | -16.8 | -19.0 | - | - |
| Oil | -3.9 | -0.5 | 0.3 | -4.4 | -20.1 | 25.8 | -11.1 |
| Natural gas | - | 3.0 | 6.6 | -14.2 | -8.8 | 13.0 | 12.5 |
| Biofuels and waste[1] | 2.6 | 4.1 | 3.4 | -0.1 | 3.5 | 4.6 | 4.2 |
| Nuclear | 22.7 | -1.7 | 0.1 | 2.9 | -13.1 | 12.0 | 4.1 |
| Hydro | 1.1 | 0.8 | -1.7 | -1.0 | 18.1 | -17.6 | 5.0 |
| Wind | - | 44.2 | 22.6 | 34.0 | 45.2 | -5.1 | 13.7 |
| Geothermal | - | - | - | - | - | - | - |
| Solar/other[2] | - | 61.5 | -2.5 | -2.8 | -11.1 | -16.5 | -4.3 |
| TFC | -0.5 | 0.9 | -0.1 | -2.2 | 1.0 | 3.6 | 0.4 |
| Electricity consumption | 3.3 | 0.7 | 0.2 | -1.8 | 2.2 | 2.1 | -0.2 |
| Energy production | 7.1 | 0.3 | 0.7 | 1.1 | -1.5 | 2.7 | 3.5 |
| Net oil imports | -3.8 | -0.4 | -0.6 | -2.1 | -11.2 | 6.0 | -25.4 |
| GDP | 2.0 | 2.1 | 2.1 | 1.5 | 4.5 | 2.7 | 2.1 |
| TPES/GDP | -0.9 | -2.0 | -1.4 | -2.9 | -11.0 | 6.9 | -2.4 |
| TFC/GDP | -2.4 | -1.2 | -2.2 | -3.7 | -3.3 | 0.8 | -1.7 |

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

# Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases, 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, natural gas and electricity, the total net imports also include peat, biofuels and waste.
4. Excludes international marine bunkers and international aviation bunkers.
5. The total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, co-generation and heat plants. Output refers only to electricity generation.
9. Losses that arise in the production of electricity and heat at the 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 power and 100% for hydropower, wind power and solar photovoltaic.
10. Data on "losses" for the forecast years often include large statistical differences that cover differences between the expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Tonnes of oil equivalent per thousand US dollars at 2010 prices and exchange rates.
12. "$CO_2$ emissions from fuel combustion" were estimated using the IPCC Tier I Sectoral Approach from the *2006 IPCC Guidelines.* In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 2013 and applying this factor to forecast energy supply. Projected emissions for coal are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

# ANNEX C: International Energy Agency "Shared Goals"



The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

**1. Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and 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** are central to the achievement of these shared goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

**4. More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

**5. Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

**6.** Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

**7. Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

**8. Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

**9. Co-operation among all energy market participants** helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

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

# ANNEX D: Glossary and list of abbreviations

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

## *Acronyms and abbreviations*

| | |
|---|---|
| BEV | battery-electric vehicles |
| BWR | boiling water reactor |
| C | Centigrade |
| CEM | Clean Energy Ministerial |
| CHP | combined production of heat and power |
| $CO_2$ | carbon dioxide |
| DC | district cooling |
| DH | district heating |
| DR | demand restraint |
| DSO | distribution system operator |
| EED | Energy Efficiency Directive |
| ELD | Energy Labelling Directive |
| EPBD | Energy Performance of Buildings Directive |
| ERIP | Energy Research and Innovation Programme |
| ETRDI | energy technology research, development and innovation |
| ETS | emissions trading scheme |
| EU | European Union |
| EU-Sam | Swedish strategy group for EU co-ordination |
| EV | electric vehicle |
| FORMAS | Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| HVDC | high-voltage direct current |
| HVO | hydrogenated vegetable oil |
| IAEA | International Atomic Energy Agency |
| IEA | International Energy Agency |
| LCOE | levelised cost of electricity |
| INES | International Nuclear and Radiological Event Scale |
| LNG | liquefied natural gas |
| LPG | liquefied petroleum gas |
| LULUCF | land use, land-use change, and forestry |
| MEE | Ministry of the Environment and Energy |
| MI | Mission Innovation |

NAcP National Action Plan
Nasdaq National Association of Securities Dealers Automated Quotations
NPP nuclear power plant
OECD Organisation for Economic Co-operation and Development
PHEV plug-in hybrid electric vehicles
PPP purchasing power parity
PV photovoltaics
PWR pressurised water reactor
R&D research and development
R&I research and innovation
RD&D research, development and demonstration (or deployment)
RD&I research, development and innovation
RES-E renewable energy sources for electricity
RSC Regional Security Co-ordinator
SEA Swedish Energy Agency
SEMI Swedish Energy Markets Inspectorate
SEPA Swedish Environmental Protection Agency
SET Strategic Energy Technology
SFL geological disposal facility
SFR short-lived radioactive waste
SME small and medium-sized enterprise
SSM Swedish Radiation Safety Authority
TFC total final consumption
TPA third-party access
TPES total primary energy supply
TSO transmission system operator
USD United States dollar

## Units of measure

bcm billion cubic metre
$CO_2$-eq carbon dioxide equivalent
g gramme
$gCO_2$ grammes of carbon dioxide
$gCO_2$/km grammes of carbon dioxide per kilometre
GW gigawatt
GWh gigawatt hour
kb/d thousand barrels per day
$kgCO_2$ kilogrammes of carbon dioxide
km kilometre
ktoe kilotonnes of oil equivalent

| | |
|---|---|
| kV | kilovolts |
| kWh | kilowatt hour |
| $kWh/m^2$ | kilowatt hours per square metre |
| m | metre |
| $m^3$ | cubic metre |
| mb | million barrels |
| mcm | million cubic metres |
| mcm/d | million cubic metres per day |
| Mt | million tonnes |
| $MtCO_2$ | million tonnes of carbon dioxide |
| $MtCO_2$-eq | million tonnes of carbon dioxide equivalent |
| Mtoe | million tonnes of oil equivalent |
| MW | megawatt |
| $MW_e$ | megawatts of electricity |
| MWh | megawatt hours |
| $MWh_{th}$ | thermal megawatt hour |
| $tCO_2$-eq | tonne of $CO_2$ equivalent |
| toe | tonnes of oil equivalent |
| TWh | terawatt hours |
| USD/L | US dollars/litre |

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Typeset in France by IEA - April 2019
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Sweden is leading the way towards a low-carbon society. In recent years, the country has adopted an energy and climate framework with ambitious long-term and interim goals, including a target of 100% renewable energy in electricity generation by 2040. In this review of Sweden's energy policies, the International Energy Agency (IEA) looks at how the country is managing its energy transition, as well as how this transition affects energy security.

Sweden's electricity system – based on nuclear, hydro and a growing share of wind power – is nearly fossil-free. The country, which is well interconnected with its neighbours, has become a large net exporter of electricity. However, the power sector faces uncertainty from the likely phase-out of nuclear within the next few decades. The challenge will be to maintain stability while more variable forms of renewable energy enter the system to replace nuclear power.

Sweden's energy policies give preference to technology-neutral measures and market mechanisms, with the aim to reduce emissions in a cost-effective way. Carbon taxation in particular has been an effective driver of decarbonisation, and Sweden has showed that high environmental taxes can be combined with sustained economic growth. As the electricity and heat supply is largely decarbonised, the main challenge for Sweden is to reduce emissions in the transport sector, which gets special attention in the review.

In this report, the IEA provides recommendations for further improvements of Sweden's energy policy to help the country continue to transform its energy sectors in a secure, affordable and environmentally sustainable manner.

# ENERGY POLICIES OF IEA COUNTRIES

# Sweden

## 2019 Review