ENERGY POLICIES OF IEA COUNTRIES

Finland

2018 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 conducted in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development but also encourages the exchange of and learning from international best practices 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.

One of the key topics of focus in this review is bioenergy. In a recently published article, Minister Tiilikainen and I wrote that bioenergy can play a crucial role as a transition fuel to a lower-carbon economy. This was also underlined by the findings of the recent IEA report, *Renewables 2018*. Finland is one of the global leaders when it comes to bioenergy. Its forest industry has paved the way by producing residues and wastes which can be utilised as energy sources, including as fuel in combined production of heat and power (CHP) and in transportation.

It is impressive that Finland aims to halve oil consumption in the transport sector by 2030 through the use of biofuels. Our report offers insights into how the country can rapidly reduce its oil use, boost biofuels, and promote public transport and new mobility services. We recommend a three-way strategy based on a combination of electrification, higher energy efficiency and wood-based biofuels. Finland has also already demonstrated how to ensure the impacts of greater biofuel use on sustainability can be avoided, notably by promoting second-generation biofuels. We encourage the government to maintain and boost Finland's innovation potential by pursing technology development for biofuel use in aviation, maritime, and heavy-duty road transport.

It is my hope that this report will guide Finland 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

Energy and climate policies in Finland have strongly evolved during the five years since the International Energy Agency (IEA) presented the last in-depth review (IDR) in 2013. As Nordic countries take leadership towards a low-carbon economy with ambitious climate targets, the government of Finland is placing greater emphasis on the mitigation of climate change and reducing the share of fossil fuels, while boosting economic growth and industrial innovation.

For this in-depth review, the government of Finland asked the IEA to review the lessons that Finland can learn from other countries' experiences in the low-carbon transition. Specifically, the report highlights how the transport sector could be decarbonised and what role Finland's domestic wood-based biofuels could play in it. The report also suggests how Finland could maintain energy efficient combined heat and power (CHP) production, which is challenged by the historically low power prices in the Nordic market.

Energy system transformation

Since the 2013 IEA review, the government has set out ambitious climate targets and policy action that are closely linked to energy. The 2015 Climate Act (2015) sets a goal for 2050, while specific actions are listed under the National Energy and Climate Strategy for 2030 (2016) and the Medium Term Climate Policy Plan (2017).

Under these plans, the government of Finland aims to *i*) reduce greenhouse gas (GHG) emissions by 80% by 2050 compared to 1990 levels; *ii*) reduce GHG emissions in non-ETS sectors by 39% in 2030; *iii*) phase out the use of coal for energy production by 2030; *iv*) boost the share of renewable energy to over 50% of final energy consumption during the 2020s; and *v*) increase the share of biofuels in road transport to 30% by 2030. Under the EU Energy Union Governance Regulation, Finland is finalising a National Climate and Energy Plan.

The power sector in Finland is largely decarbonised and covered under the EU Emissions Trading System (EU ETS). Finland's electricity generation mainly consists of nuclear energy (34%), hydro (22%) and biomass (18%); the share of fossil fuels has significantly declined over the past years.

The government is placing the focus on the continuous decarbonisation of transport and residential (buildings/heating) sectors. Up to 2020, Finland is largely on track to achieve its targeted 16% reduction in GHG emissions in the non-ETS sectors, with the use of flexibility measures. For 2030 Finland has the objective of reducing non-ETS emission by 39% by 2030 (from 2005 levels). As transport emissions make up the largest share

(40%) of non-ETS emissions, progress in the decarbonisation of that sector is critical to meeting the 2030 objective.

In the National Energy and Climate Strategy for 2030, Finland envisages reducing domestic oil use by 50% compared to 2005 through improved energy efficiency of the transport system, an accelerated vehicle stock renewal, a target of 250 000 electric vehicles and 50 000 gas fueled vehicles, boosting the share of biofuels in road transport to 30% and blending up to 10% bio liquids into light fuel oil for space heating.

Reaching these ambitious decarbonisation goals will require a strategy based on boosting energy efficiency and renewable energy besides contribution from fuel switching and nuclear energy.

Finland's strategy raises a number of challenges with regard to the role of biomass, of CHP and the sustainability of biofuels as well as the overall approach to the future of transport. While the medium-term reliance on biomass and nuclear is a confirmed strategy of the government, such an approach might be compromised by delays in nuclear development or low availability of domestic biofuels or technologies which can meet sustainability criteria. Technology development is required for most of the second-generation biofuels. Finland can already benefit from significant cost reductions, notably in wind power, electric vehicles and batteries, and consumers are expected to move quickly into these technologies.

Finland does not have a national quantitative target set for energy efficiency efforts under its energy and climate strategy, but uses voluntary agreements with industry and has sector-specific targets for transport. Building codes set high energy performance standards for new buildings, but energy efficiency can improve further, particularly in the older building stock.

Clean energy technology innovation is a critical success factor for reaching the long-term decarbonisation goals. Finland has been a leader among IEA member countries, when it comes to government energy research, development and demonstration (RD&D) spending (as a ratio of gross domestic product (GDP)), private sector innovation and spending, and international engagement. Under M:I Finland leads on the demand response taskforce with Denmark (under the Smart Grids Innovation Challenge), and supports the Sustainable Biofuels Innovation Challenge and the Affordable Heating and Cooling of Buildings Innovation Challenge. Finland should aim to maintain a significant public RD&D spending for the energy sector. In addition, amid decreased public RD&D spending, future contributions from the private sector need also to remain strong, as Finland aims to meet its Mission: Innovation (M:I) goals. The government should present a long-term low-carbon strategy to further support Finland's innovation potential.

As an Arctic country, Finland faces rapid changes in its climate, with potential consequences for, among others, forest growth and the occurrence and strength of winter storms. Finland's most recent National Climate Change Adaptation Plan was adopted in 2014 and a range of measures have been put in place to strengthen the resilience of the electricity distribution networks.

During 2017-19, Finland chairs the Arctic Council, an opportunity to scale up actions aimed at higher adaptation, resilience and GHG emissions reductions, notably methane and black carbon in the Arctic.

Energy security

By international comparison, Finland's primary energy supply continues to be well diversified with a large role for biomass (28%), oil (26%) and nuclear (17%), and smaller shares for coal (8%), natural gas (6%) as well as from domestic peat, hydro, and wind. With hardly any domestic fossil fuel resources, Finland imports all of its natural gas, and a large part of its oil, coal and nuclear fuel from the Russian Federation.[1] Finland has a cross-sector approach to energy security, relying on stockpiling of coal, oil, nuclear fuel and domestic peat.

Oil security continues to be robust. A member of the IEA since 1992, Finland's oil stocks equal 240 days of 2017 net-imports, much beyond the minimum of 90 days required. New natural gas infrastructure is being built; both liquefied natural gas (LNG) and pipelines, and the currently isolated Finnish gas market will be opened to competition under the New Natural Gas Market Act by 2020. Investment in small LNG terminals flourishes, mainly serving local industrial and maritime uses with two LNG import terminals (in Pori and Tornio) and a third under construction. Supported by EU funding, the Balticconnector pipeline will connect the isolated Finnish gas network to Estonia, the Klaipeda LNG terminal in Lithuania and the Baltic gas storage in Latvia (Inčukalns) by late 2019. Besides infrastructure, gas market rules need to be put in place by 1 January 2020, under EU rules for the internal gas market. These rules include the unbundling of commercial and transmission operations, the end of gas price regulation and the creation of a common gas market area with the Baltic states which will also require clarifications of how the Balticconnector pipeline and the Russian gas imports will be operated and regulated in Finland.

Energy security remains a strong priority for Finland. The reliance on imports from the Nordic market and Russia has remained high and is on the rise, in part because the 1.6 GW Olkiluoto 3 NPP has been delayed, but the project is expected to finally come online in 2019-20.

Finland's nuclear power plants have operated for around 40 years and their licenses need to be renewed. The construction of Olkiluoto 3 is still ongoing, and so is the licencing procedure for another NPP, Hanhikivi 1. Both the projects are co-owned by utilities and industrial power users, a model which is based on long-term bilateral contracts. Nuclear investment is driven by industry, and the government role is to ensure laws and regulations are in place and followed. Concerning new reactor designs, the government should actively participate in the multinational efforts to progress the international harmonisation of nuclear safety standards and licensing frameworks to leverage the resources and knowledge of national regulators. Finland is leading on nuclear waste management. Commendably, in 2015, the government has granted the construction license for the final nuclear repository of spent nuclear fuel, the first one in the world. Nuclear operators TVO and Fortum have worked together through their subsidiary Posiva to fund the R&D efforts and to construct this facility for high-level nuclear waste, which is planned to begin operations in the early 2020's.

[1] Hereafter, "Russia".

To boost electricity security, Fingrid has made significant investments in strengthening the interconnections with Sweden, the integration with the Baltic states and in removing internal bottlenecks in the Finnish system and is working also on smarter grids with a data hub in Finland. Collaboration across the Nordic countries is progressing towards a new regional market design, notably among transmission system operators (TSOs) and utilities. The government of Finland should support the regional orientation of energy and climate policies, a key feature of the Ollila report "A vision for Nordic energy co-operation", as these policies will be the fundamental drivers for the future electricity market. Nordic power market design will need to evolve towards competitive and efficient intra-day markets, reserve products and balancing services across the region, supported by greater security collaboration among TSOs, notably when it comes to adequacy assessments and strategic reserves.

Special focus 1: The future role of biomass

Well-endowed with forest resources, Finland has a strong export-oriented forest industry, ranging from timber to pulp and paper. The by-products and wood residues are used as fuels in power and heat generation or processed to second-generation biofuels, notably biodiesel where Finland's industry is leading globally. Since 2007, the supply of biofuels and waste increased by 30% whereas oil supply dropped by 9% and the supply of coal, natural gas and peat declined by almost 50%. Global demand for Finland's forest-based products is growing and, as a consequence, so is the supply of these wood-based energy sources. This has several implications for Finland.

First, forests are a major carbon sink and under new EU rules for emissions from non-ETS sectors, Finland will need to compensate for the impacts of forest management on land use, land use change and forestry. Second, the by-product wood may not be enough to meet Finland's ambitious biofuels targets in a sustainable manner and biofuel imports may be necessary. Technologies are not yet fully commercially available to produce second-generation biofuels. Third, biomass, such as woodchips, will be needed to support the phase-out of coal and heating oil in CHP and district heating.

District heating (DH) accounts for about half of all space heating in Finland. Peat and biomass are used in the centre and north of the country, while coal is still used in the cities with access to ports along the coast. Under the Powering Past Coal Coalition, which was adopted at the One Planet Summit in Paris in 2015 by 34 countries, cities and companies, Finland plans to close coal-fired CHP plants gradually by 2030 and supports operators financially that switch to efficient biomass CHP and new heating technologies already by 2025.

Special focus 2: The future of combined heat and power

Finland is well placed to make best use of its efficient CHP and related district heating and cooling (DH/C), which remain among the best ways to improve energy efficiency, help renewables and link heating with electricity for flexibility (so-called sector coupling).

However, the traditional role of CHP in Finland is impacted by the power system transformation in the Nordic market, stemming from the deployment of rising shares of wind power and low power prices. The economics of CHP is under pressure in Finland, but also Denmark and Sweden, with a trend towards heat-only boilers. At the same time, since 2008, Finnish DH prices have increased rapidly, much more than in other Nordic DH markets.

The economics of CHP are not only influenced by the low electricity prices, but also by the taxation and support schemes in Finland for CHP, electricity generation and heat production, which vary depending on the fuels used. In Finland, CHP is fired by coal, natural gas, biomass and peat. Power generation is covered under the EU Emissions Trading Scheme (EU ETS), and is priced around EUR 20 (Euros) per ton of carbon dioxide (CO_2) emitted in 2018. As the CO_2 price is rising and power prices remain low, the economics of heat-only production remain strong. Heat production, on the other side, is taxed based more on its energy and less on its CO_2 content; it favours domestic peat co-fired with biomass. If energy taxation were to be fully related to the CO_2 content, there would be more incentives for entry of lower cost and cleaner alternatives, supporting the goal of phasing out coal use in CHP by 2030. On the subsidy side there are also different schemes for different production methods of heat and power. Electricity generated from woodchips also receives subsidies.

To date, the government has focused on the reform of renewable subsidies; the most recent tax reform dates back to 2011. In 2018, the government reformed the renewable support scheme towards competitive tenders (for a targeted production of 1.4 TWh for 2018-20). Subsidies are focused on district heating companies that commit to phase out coal by 2025 and as a part of energy aid for new technologies, public support of EUR 90 million is made available to support biomass CHP, with EUR 45 million dedicated to non-combustion technologies, such as heat pumps (which are for instance used in Denmark at CHP plants to increase performance) or storage.

This is a welcome approach and much in line with regional trends, as thermal energy storage is an enabler of flexibility, renewable energy and energy efficiency (hourly/season; pilots under planning). To improve the economics of combined power and heat production, Denmark and Sweden have already reformed the taxation system and improved the flexibility of CHP plants, through more flexible contracts and integrated storage (heat accumulators).

Special focus 3: The transition to a low-carbon transport sector

Finland is at the forefront of promoting low-carbon mobility based on a strong Nordic biofuels market and the concept of Mobility as a Service (MaaS). While Finland has targets for accelerating the vehicle stock renewal with a minimum of 250 000 electric vehicles and 50 000 gas-fuelled vehicles in 2030, their penetration remains low in comparison to other Nordic countries.

The targeted paradigm shift away from individual car ownership to MaaS is commendable, and so is the implementation of a legislative reform enabling this change. However, the growth of so-called connected automated vehicles (self-driving vehicles which can communicate with other cars/drivers/road side infrastructure) could undermine the use of public transport, a strong focus of Finland's policies. It can also increase congestion, putting under pressure the transport system and raise emissions in the sector, notably if automated vehicles will not use low emission fuels.

Finland aims to halve oil consumption by 2030, i.a. through an obligation on fuel suppliers. Drop-in biofuels do not have blending limits, which makes their contribution to decarbonisation very valuable. However, any new obligation would need to be in line with high standards of sustainable biofuel production practices and availability of feedstocks. Finland is well placed to invest in advanced biofuel production from wastes and residues, but not all technologies are currently mature and RD&D investment is still needed for certain second-generation biofuels. Prioritising biofuels for long-distance modes, including aviation, can be a growth opportunity for the industry. The government also expects to see 50 000 gas-fuelled vehicles by 2030 on the road, as the number of biogas projects producing biomethane is increasing. The government has put forward a new aid scheme for alternative fuel infrastructure including gas filling stations. Today, biogas is mostly used for power and heat production.

Transport efficiency is a relatively low-cost measure with large impacts, while supply and blending obligations and biogas range at the higher end of the cost scale. To meet its ambitious decarbonisation targets for 2030 and 2050, the Finnish government should indeed take a holistic approach to mobility, focusing on raising vehicle efficiency, the rollout of zero emission vehicles, such as electric vehicles, including through a package of fiscal instruments and local traffic measures to ensure Finland has a largely decarbonised power sector and a strong biomass supply chain. Therefore, the government can benefit from a multidimensional approach to the decarbonisation of transport, based on ambitious biofuels and electrification targets.

Key recommendations

The government of Finland should:

- Guide the energy system towards a low-carbon future in the longer term towards 2050 through adaptive and robust policy frameworks that enable business to take long-term investment decisions, notably in energy technology innovation.
- Review the energy fuel taxation and subsidies to reflect their full carbon content to accelerate the switch to low emission technologies, notably in combined heat and power generation and the transport sectors.
- In the transport sector, raise the ambitions for vehicle efficiency and the rollout of zero emission vehicles, notably electric vehicles, and adopt a package of fiscal instruments and local traffic measures to ensure Finland can achieve targeted emissions reduction in transport and halve oil consumption by 2030 in a sustainable manner.
- Foster the dialogue with the Nordic and Baltic neighbours on the design and implementation of climate and energy policies, in particular with regard to cross-border implications of electricity security and adequacy.

2. General energy policy

Key data

(2017 provisional)

TPES: 34.4 Mtoe (biofuels and waste[1] 28.5%, oil 26.3%, nuclear 17.0%, coal 8.3%, natural gas 5.6%, electricity imports 5.1% and heat imports 0.6%, hydro 3.7%, peat 3.7%, wind 1.2%), -6.8% since 2007

TPES per capita: 6.2 toe/cap (IEA average: 4.1 toe)

TPES per unit of GDP: 158 toe/USD million PPP (IEA average: 106 toe)

TFC (2016): 26.0 Mtoe (industry 47.8%, residential/commercial 35.6%, transport 16.6%)

Energy production: 18.2 Mtoe (biofuels and waste 53.2%, nuclear 32.1%, hydro 7.0%, peat 4.0%, wind 2.3%, heat 1.1%, oil 0.4%), +12,8% since 2007

Country overview

Finland has a population of 5.5 million residing in the southernmost parts of the country in the Helsinki metropolitan area, including the capital city of Helsinki (population 617 000), Espoo (population 263 000) and Vantaa (population 209 000) as well as Tampere (population 222 000). Finland's territory is sparsely populated, and covered with lakes and coniferous forests. Given its geography, Finland has long, cold winters and short, warm summers. Its longest border is the 1 340 km eastern border with the Russian Federation.[2] It also shares a 614-km border with Sweden and a 727-km border with Norway (Figure 2.1).

Finland – Suomi in Finnish – is a republic, with a unicameral Parliament (Eduskunta). The head of state, the president, is elected by a popular vote for up to two six-year terms. Finland is a parliamentary democracy. The head of government is the prime minister who is elected for a four-year term. Since the last parliamentary election in 2015, the prime minister is Mr. Juha Sipilä of the Centre Party, who formed a right-wing coalition government together with the Finns Party and the National Coalition Party. Finland has been a member of the European Union since 1995, and of the Eurozone since 1999. Finland's GDP was USD 223 billion (United States dollars) (at current prices) in 2017, making it a relatively small but one of the most robust European economies. Per capita nominal GDP (around USD 40 600 in 2017) ranks above the OECD average and the Eurozone average, but still below the other Nordic countries.

[1] Biofuels and waste = solid biomass and liquid biofuels, biogases, industrial waste and municipal waste.
[2] Hereafter, "Russia".

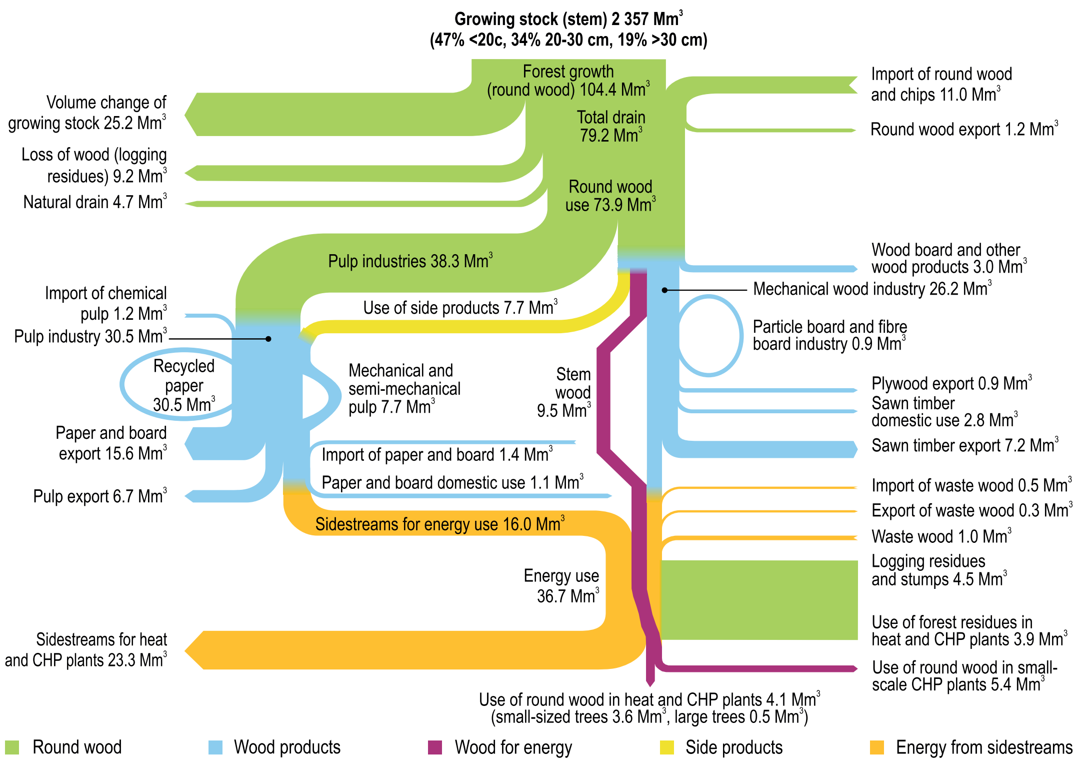
Figure 2.1 Map of Finland

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.

Finland's GDP saw growth in 2015-17, after a decrease in 2012-14, and has a low rate of unemployment but high consumer and business confidence as well as high household consumption. Growth is projected to strengthen further as higher foreign demand and improved competitiveness boost exports. Extra capacity has been built in some sectors, like paper, automotive industries and shipbuilding. Employment prospects and consumer confidence, together with low interest rates support consumption and residential investment (OECD, 2018).

Finland's energy policy is driven by an efficient and lean government and a commercially strong and innovative energy industry, which is also export-oriented. The country has a highly industrialised and open economy with robust economic growth, driven by manufacturing, particularly pulp and paper, metals, engineering, telecommunications and electronics. International trade is critical to Finland's economy, with exports of goods and services accounting for over a third of gross domestic product (GDP). Over 70% of the country is covered by forest, 60% privately owned by around 700 000 forest owners. The forest industry is a major employer, contributing 20% of the export revenues. Biomass accounts for 28.5% of total primary energy supply (TPES), the highest share among IEA countries. Biomass is typically a by-product from the extensive forest industry (pulp and paper, sawmilling) and wood chips are used for heat and power production.

Figure 2.2 Wood flows in Finland, 2013



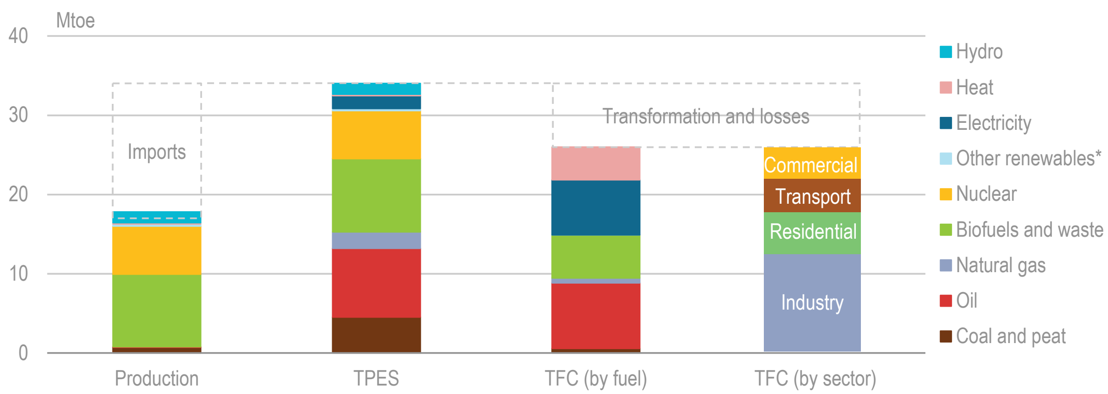
Notes: CHP = combined heat and power; Mm3 = million cubic metres; Mt = million tonnes.

Finland's industries are investing in innovative biofuels production from residues (see Figure 2.2). Forest resources are considered a solid basis for the circular bioeconomy thanks to good forest management. The government's 2014 Bioeconomy Strategy aims to generate new economic growth and jobs from an increase in the bioeconomy industry for exports, while securing the operating conditions for nature's ecosystems. In the energy policy context, this translates into a prominent role for bioenergy in meeting the country's climate and energy objectives.

Supply and demand

Finland has vast resources of forest-based biofuels, which account for the majority of energy production in the country, besides the strong contribution from nuclear power generation (see Figure 2.3). Therefore, total primary energy supply (TPES[3]) is dominated by domestic biofuels and nuclear as well as by oil which is imported mainly from Russia. Electricity and oil account for the largest share of total final consumption (TFC[4]) in the country, but direct use of biofuels and district heating also represents significant shares. Industry is the largest energy-consuming sector, accounting for nearly half of TFC.

Figure 2.3 Overview of energy production, TPES and TFC by fuel and sector, 2016



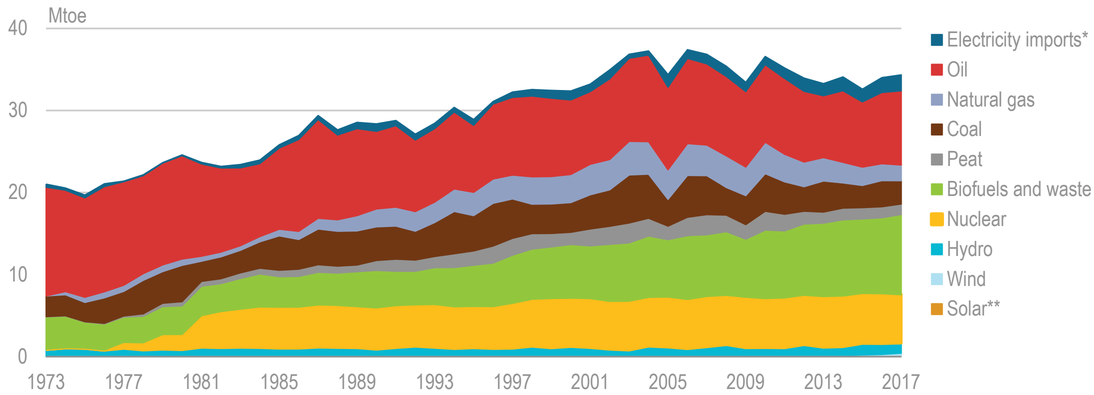
**Other renewables* includes wind power and a minor share of solar.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Primary energy supply

TPES increased steadily for many years but has flattened in the last decade (see Figure 2.4). In 2017, TPES was 34.4 Mtoe, a decline of 6.8% since 2007. Biofuels (including waste) and oil form the largest shares of fuels in energy supply, together accounting for over half of TPES, but have developed at different rates. Since 2007, the supply of biofuels and waste increased by 30.1% whereas oil supply dropped by 8.6%.

[3] 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.
[4] TFC is the final consumption of fuels (e.g. electricity, heat, gas and oil products) by end-users, excluding the transformation sector (e.g. power generation and refining).

Figure 2.4 TPES by source, 1973-2017



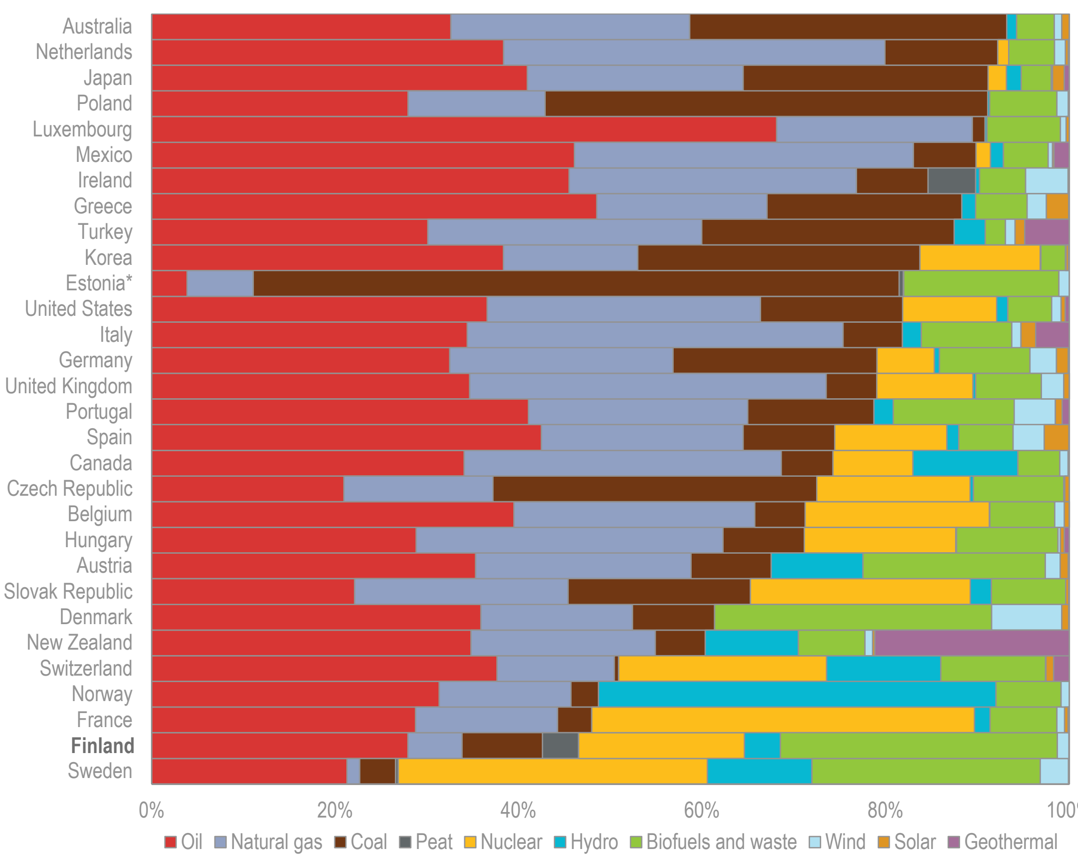
*Includes small shares of heat imports.

**Negligible.

Note: Data are provisional for 2017.

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

Figure 2.5 Breakdown of TPES in IEA member countries, 2017



* Estonia's coal is represented by oil shale.

Note: Data are provisional.

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

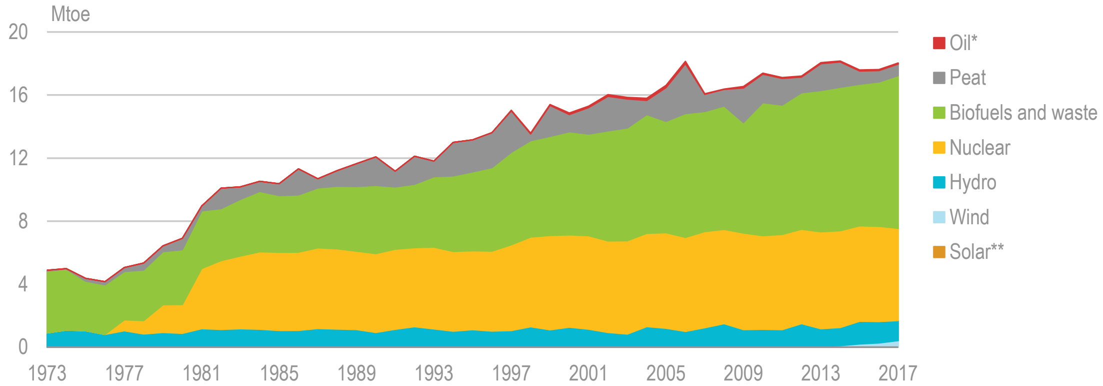
The supply of other fossil fuels (coal, natural gas and peat) fell even more dramatically and nearly halved over the last decade, leading to the overall decline in TPES. Nuclear energy represents the third-largest share in TPES that has been stable at around 6 Mtoe for many years. Hydropower varies around 1 Mtoe and wind power has started growing rapidly, however from very low levels. Electricity imports, mainly from Sweden, account for over 5% of TPES and represent nearly a quarter of total electricity supply.

Thanks to its large shares of biofuels and nuclear, Finland has the second-lowest share of combustible fossil fuels in its TPES among all IEA member countries, behind Sweden (see Figure 2.5). The share of biofuels and waste is the second-largest in the comparison. Behind Ireland, Finland has the second-highest share of peat in its energy supply. Peat plays an important role as fuel in combined heat and power (CHP) plants.

Energy production and self-sufficiency

In 2017, Finland's domestic energy production was 18.2 Mtoe, covering just over half the TPES. Biofuels and waste accounted for over 53% of total domestic energy production and has increased steadily for over two decades. Nuclear accounted for a third of total production and the remaining share comes mainly from hydro and peat, and a small share of wind. Finland has no domestic production of coal or natural gas, and a very small production of oil, and depends on imports for these fuels. Russia is the largest supplier of oil and coal, and the sole supplier of natural gas to Finland.

Figure 2.6 Energy production by source, 1973-2017



*Oil production consists of additives. Finland has no crude oil production.

**Negligible.

Note: Data are provisional for 2017.

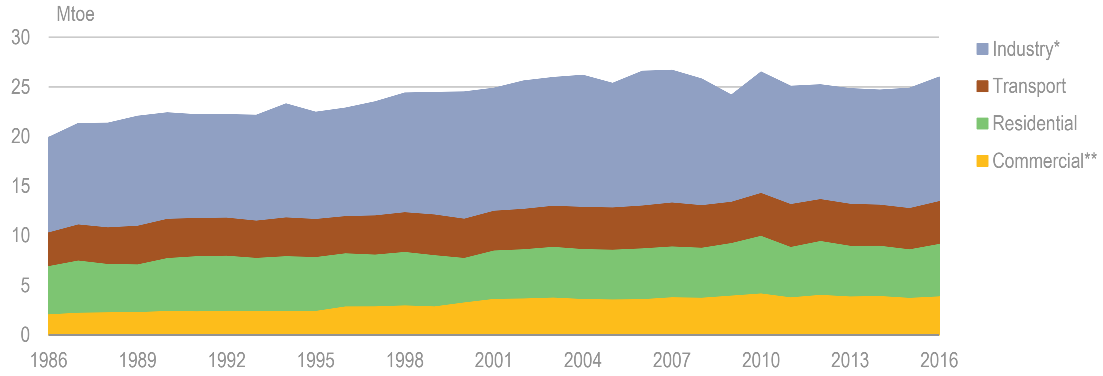
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Energy consumption

Energy consumption increased from around 20 Mtoe in the mid-1980s to around 25 Mtoe from the early 2000s (see Figure 2.7). In 2016, consumption was 26.0 Mtoe, a decline by 2.2% since 2006 but an increase by 4.5% since 2015.

The industry sector is the largest energy consumer in Finland, and accounts for nearly half of TFC. The residential, transport and commercial sectors share the remaining consumption relatively equally.

Figure 2.7 TFC by sector, 1986-2016



**Industry* includes non-energy consumption.

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

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

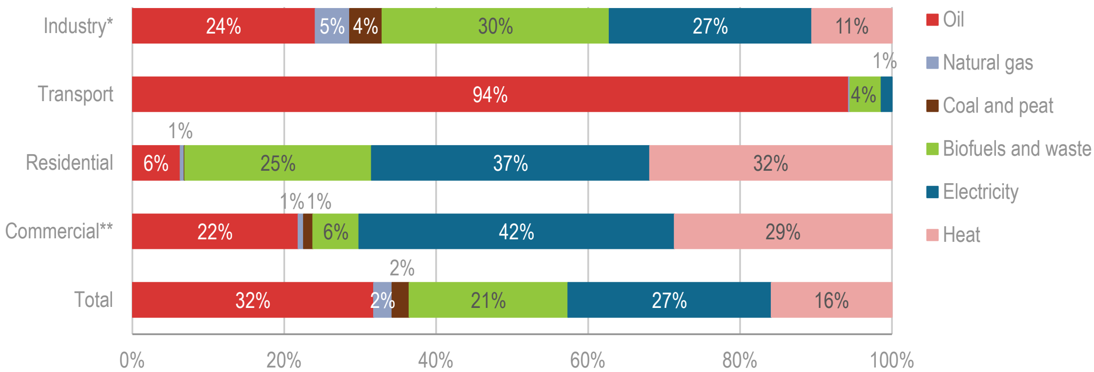
Oil, electricity, biofuels and waste, and district heating are the largest components of final consumption and together accounted for 96% of TFC in 2016 (see Figure 2.8).

The transport sector is still largely dominated by oil fuels, although the share of biofuels has grown rapidly in the last decade.

The other sectors have a bigger spread among different fuels.

The industry sector uses a large share of biofuels and waste, and residential and commercial buildings consume large amounts of electricity and district heating.

Figure 2.8 TFC by source and sector, 2016



**Industry* includes non-energy consumption.

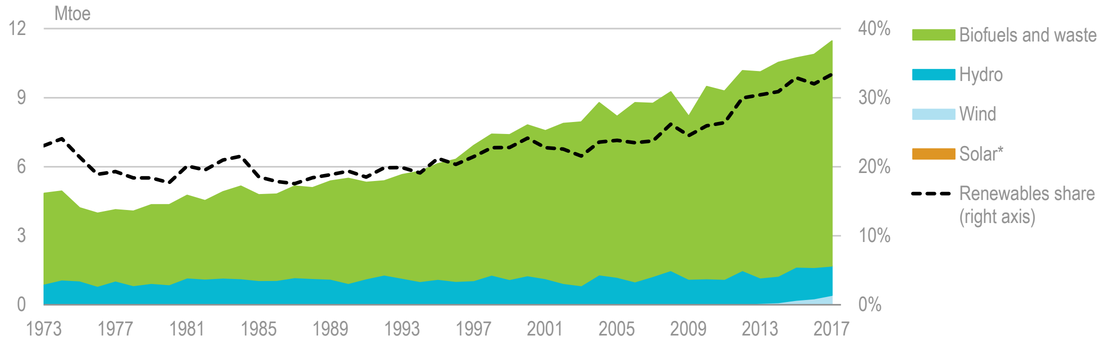
***Commercial* includes commercial and public services, agriculture and forestry.

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

Renewable energy and biofuels

The share of renewable energy in TPES has been on a steady growth path (Figure 2.9). Over the last decade, biofuels and waste supply grew on average by 2.7% per year.

Figure 2.9 Renewable energy in TPES, 1973-2017



*Negligible.

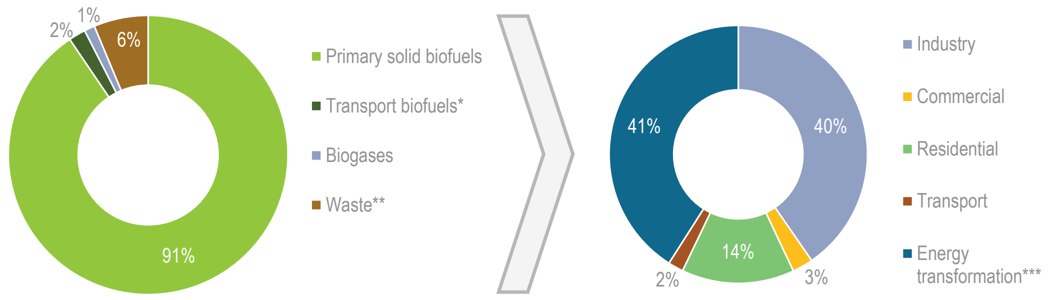
Note: Data are provisional for 2017.

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

Solid biofuels are mainly used in heat and power generation, industry and residential sectors (Figure 2.10). Biofuels and waste were introduced in heat and power generation in the 1980s, and have rapidly become an essential part of energy supply. In 2016, biofuels and waste accounted for 45% of district heat production.

In 2017, Finland had 33.4% renewables in TPES, which was the fifth-highest share among IEA member countries (see Figure 2.11), with 28.5% covered by biofuels, the second highest share in the IEA. Biofuels together with hydropower and a growing share of wind power accounted for 47% of electricity generation (see Figure 2.12).

Figure 2.10 Supply and demand of biofuels, 2016



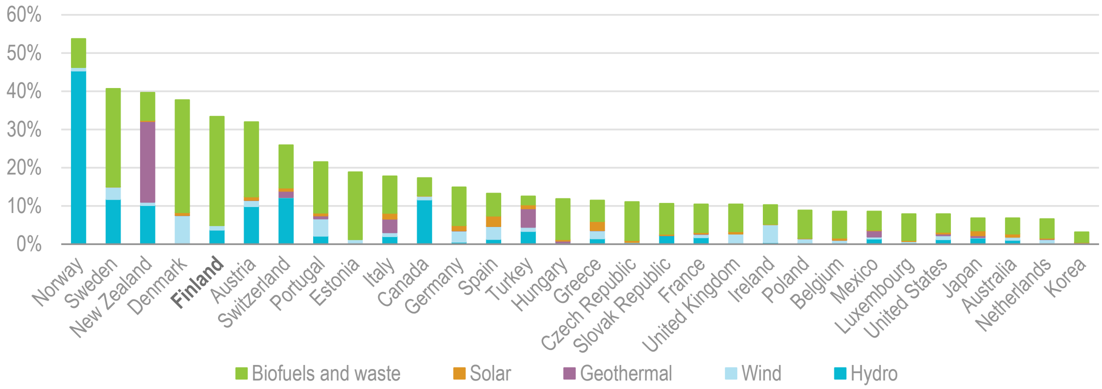
**Transport biofuels* includes biodiesel and biogasoline.

***Waste* includes industrial waste and non-renewable household waste.

****Energy transformation* is mainly heat and power generation plus a small share used in oil refineries.

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

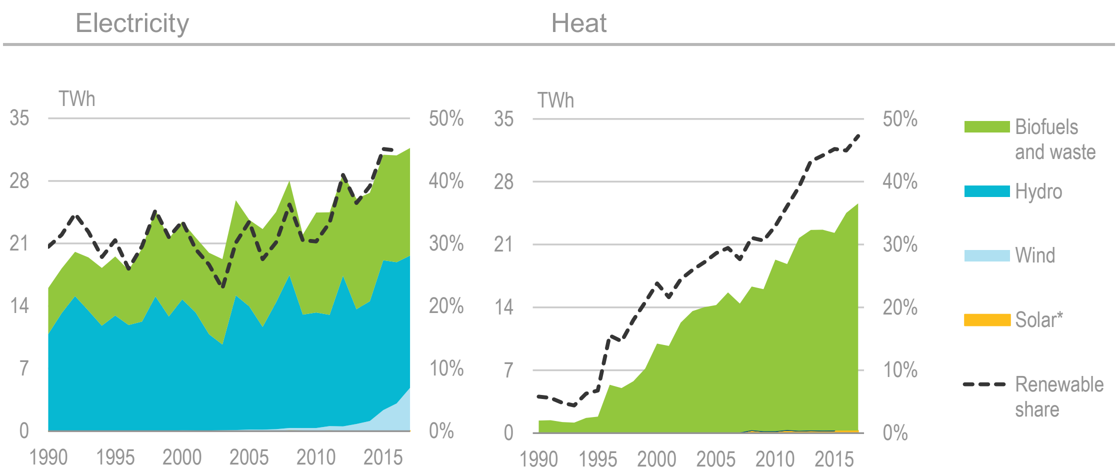
Figure 2.11 Renewable energy as a share of TPES in the IEA, 2017



Note: Data are provisional.

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

Figure 2.12 Renewable energy in power and heat generation, 1990-2017



*Negligible.

Notes: *Biofuels and waste* includes solid and liquid biofuels, and renewable and non-renewable waste. Data are provisional for 2017.

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

Institutions

The **Ministry of Economic Affairs and Employment (MEAE)** takes the principal responsibility in developing Finland's general energy policy. It has three ministers. Mr. Kimmo Tiilikainen is Minister of the Environment, Energy and Housing; he is in charge of energy policy and oversees the Energy Department which remains an integral part of the MEAE. The **Energy Department** leads on energy markets, energy efficiency and emissions trading, renewable energy, nuclear energy and fuels. It co-ordinates energy environment-related matters, including climate change, between ministries, such as the **Ministry of the Environment**, the **Ministry of Finance** for implementing energy taxation, the **Ministry of Agriculture and Forestry** for biomass and land use, land use change and forestry (LULUCF) issues, and the **Ministry of Transport and**

Communications for non-ETS sector emissions, which also oversees the promotion of energy efficiency in the transport sector.

The **Energy Authority** (EMA) is the independent national energy regulator. It is also the national emissions trading authority and promotes energy efficiency and the use of renewable energy.

The **Finnish Funding Agency for Innovation (Tekes)** finances research and development projects of companies and universities in Finland as well as international technology initiatives. **Motiva Oy** is a state-owned company that implements government policies on energy conservation and on the promotion of renewable energy sources. The **Finnish Safety and Chemicals Agency (Tukes)** is in charge of the market surveillance of both the EU Ecodesign Directive and the Energy Labelling Directive. The **Natural Resources Institute Finland (Luke)** is a research and expert organisation that works to promote the bioeconomy and the sustainable use of natural resources. Luke monitors natural resources, produces data on greenhouse gases (GHGs), supports natural resource policies and produces Finland's official food and natural resource statistics.

For nuclear power, the **Radiation and Nuclear Safety Authority (STUK)** is tasked with nuclear safety and radiation monitoring. The **National Emergency Supply Agency (NESA)** is a network of ministries and industries that maintains and develops security of supply on the basis of public–private partnership initiatives.

Finland has a strong energy industry sector with large players active across the Nordic markets.

Fortum is the major electricity producer and the second-largest heat producer in Finland (with major operations also in Russia and in the Nordic market). It also operates in power and heat sales; it is 50.8% government-owned. Fortum Power and Heat Oy owns the Loviisa site on which two nuclear power plants operate (LO1 and LO2), and also provides waste management services. **Teollisuuden Voima Oyj (TVO)** is a Finnish nuclear power company owned by a consortium of power and industrial companies. The biggest shareholders are Pohjolan Voima, whose majority shares are held by paper and pulp industries, and Fortum. TVO owns two nuclear reactors and the third nuclear plant (OL3), which was expected to be ready in 2009 but has been delayed once again to 2019. **Posiva Oy,** a nuclear waste management company, is co-owned by both Fortum Power & Heat Oy (40%) and Teollisuuden Voima Oyj (60%).

Fingrid is the national grid operator that manages the national power balance and the electricity system. **Neste** owns and operates the two oil refineries in the country which are specialised in processing Urals heavy crude. Neste is also the largest producer of biodiesel in the world. It is 50.1% government-owned.

Energy policy strategy

Finland's energy policy is set out in national climate and energy strategies in support of domestic energy goals and European Union targets.

Targets under the EU Climate and Energy Framework 2020

Under the EU 2020 goals and regulations, Finland is implementing GHG emissions reduction targets, and goals for the share of renewable energy in final energy consumption and energy efficiency. By 2020, Finland aims to reach at least 38% of renewables in final consumption and a 16% reduction in GHG emissions in the non-Emissions Trading System (non-ETS) sector below their 2005 levels, alongside the goal of keeping final energy consumption at 310 terawatt-hours (TWh). While the binding renewable energy target for the transport sector set by the European Union is 10%, Finland has decided on a higher target of 20% by 2020 (which includes double counting of the sustainably produced share).

The share of renewables has increased and the minimum target of 38% has already been met in 2014. The trend also looks positive for the future, and the government expects the share to exceed 40% before the end of its term. The 10% biofuels target was also reached in 2014 thanks to the supply obligation applied to distributors of road transport fuels.

In the first three years of the period 2013 to 2020, Finland's annual emissions have been below the targeted volumes trajectory as a result of warm weather and unfavourable economic circumstances. The trajectory cannot necessarily be achieved towards the end of the period without resorting to flexibility mechanisms. Taking the entire period in consideration, however, Finland expects to meet its emissions reduction obligations under the EU Effort-Sharing Decision by means of domestic emissions reduction measures and by banking and borrowing allowances.

The National Energy and Climate Strategy for 2030

The key pillars of Finland's energy strategy up to 2030 are defined in the Government Programme of Prime Minister Sipilä (Prime Minister's Office, 2015), with the following headline goals for the period 2020-30:

- a share of renewable energy above 50% of final energy consumption
- a level of self-sufficiency above 55% (decrease of imports)
- the phase-out of coal in energy production
- halving the domestic use of imported oil
- a share of renewable fuels in transport up to 40%.

The 2016 National Energy and Climate Strategy for 2030 (MEAE, 2016) sets out the actions that will enable Finland to attain these national targets alongside the EU targets for 2030, gradually setting the course for achieving an 80% to 95% reduction in GHG emissions by 2050, as elaborated in the 2014 Energy and Climate Roadmap to 2050 (see Chapter 3 on Energy and Climate Change). The Strategy also examines the possibility of shifting to an energy system based on 100% renewable energy by 2050. The Strategy foresees the mandatory blending of 10% biofuels into light fuel used in space heating and working machinery by 2030.

In September 2017, the government, under the lead of the Ministry of the Environment released the *Report on Medium-term Climate Change Policy Plan (MCCP) 2030* (ME, 2017) as a complement to the Strategy. This MCCP recommends a set of additional measures on how Finland could meet its ambitious 39% GHG emissions reduction target in the non-ETS sectors, under the EU 2030 Energy and Climate Framework and the Burden-Sharing Regulation. The MCCP 2030 puts forward additional measures towards Finland's stated objective to be a carbon-neutral society by 2045. For the transport sector, it includes:

- improved energy efficiency in the transport system (e.g. developing new transport services, influencing modes of travel and transport, using intelligent transport methods)
- accelerated vehicle stock renewal with a minimum of 250 000 electric vehicles and 50 000 gas-fuelled vehicles in 2030
- the share of biofuels in all fuels sold for road transport to be increased to 30% by 2030 (below the 2015 headline target).

Under the EU 2030 climate and energy framework, there are no more national targets. Finland is preparing an integrated energy and climate plan (by the end of 2018 with the final plan by the end of 2019), as part of the EU Energy Union Governance Regulation which requires the adoption of national plans to monitor and ensure that the EU member states together achieve the overall EU 2030 energy and climate targets. Such an integrated energy and climate plan will cover the five key dimensions of the EU Energy Union: 1) energy security; 2) the internal energy market; 3) energy efficiency; 4) decarbonisation; and 5) research, innovation and competitiveness. The plan will also include an analytical base with projections and impact assessments.

Reform of renewable energy support

In 2018, the government adopted legislation for a reformed renewable energy support in favour of a sliding premium based on competitive auctions in 2018 and 2019 for mature renewable energy technologies (1.4 TWh per year by 2020). The government has reduced the targeted annual renewable electricity production (from the planned 2 TWh per year), as Finland has already met its target, in favour of the inclusion of efficient and low-carbon heat production that promotes an early phase-out of coal already by 2025 and other innovative technologies. The owner of the largest onshore wind power project (Viinamäki, 5x4.2 MW) in the Nordic region, built without subsidies, has taken a final investment decision with expected generating costs of below EUR 30 (Euros) per MWh.

During 2011-18, Finland applied a feed-in premium scheme for renewable electricity produced from wind power, biogas, forest chips and wood fuels (6 TWh of annual wind power production and an annual use of forest chips to reach 25 TWh by 2020). The production support scheme consisted of two different premiums:

- A sliding premium tariff for new investments in wind power, power from biogas (landfill gas excluded) and power from small CHP production plants using wood fuel. The tariff was dependent on the market price of electricity, i.e. the difference between the target price in the legislation and the spot price of electricity. A heat premium is paid on top of the basic tariff for biogas and wood fuel plants that produce also heat with certain efficiency.
- A sliding premium tariff for electricity produced from wood chips, dependent on the EU emissions allowance price and tax rate on peat. The tariff compensated the difference in running costs between using peat and using wood chips in CHP. As the tariff did not compensate the plant's capital costs, the tariff was paid also to existing power plants.

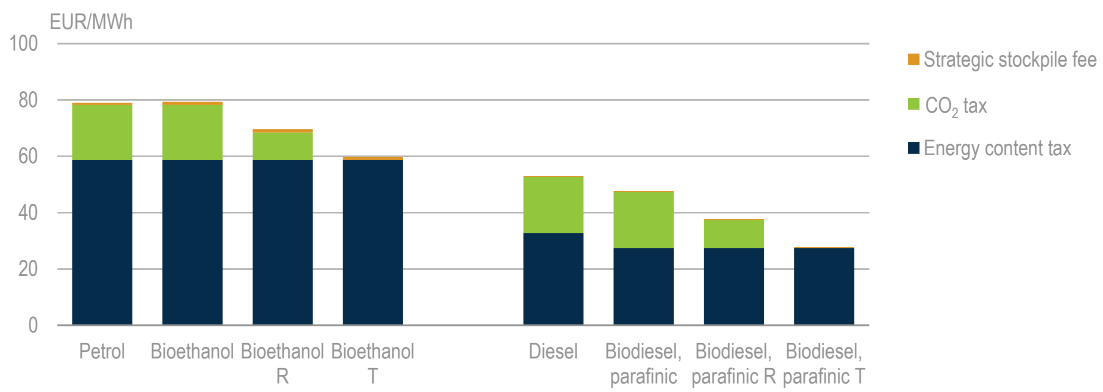
Energy taxation

In 2011, the government carried out a major revision of the energy taxation framework with the objective to better reflect environmental aspects and the energy and carbon dioxide (CO_2) content of fuels in energy taxation. In Finland, energy fuel taxation consists of *i*) the energy component, *ii*) the CO_2 component and *iii*) the strategic stockpile fee.

The energy content of fuels is based on their calorific values and levied on fossil fuels and on biofuels with the main objective to increase energy efficiency. Heating fuels are taxed at a lower level than motor fuels, and diesel has a lower tax than petrol (however, an additional annual propelling force tax applies to diesel-fuelled passenger cars).

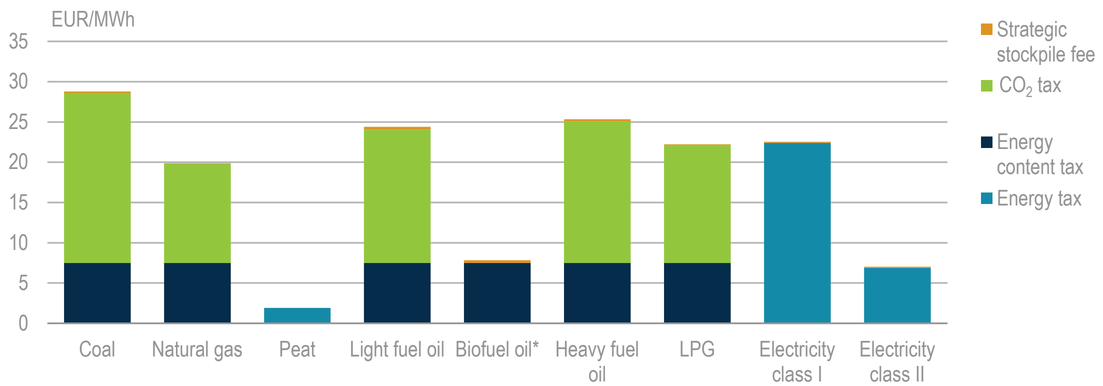
The CO_2 tax is proportional to the energy content. Biofuels are classified in three categories: *i)* biofuels that fail to meet sustainability criteria are subject to the same CO_2 tax as fossil fuels; *ii)* sustainable biofuels (first generation, agricultural origin) are subject to 50% of the CO_2 tax on equivalent fossil fuels, and *iii)* second-generation biofuels (waste, lignin cellulose, etc.) are exempt from CO_2 tax.

Figure 2.13 Tax rates on transport fuels, 2018



Source: Ministry of Finance, 2018.

Figure 2.14 Tax rates on heating fuels and electricity, 2018



*Double counted.

Source: Ministry of Finance, 2018.

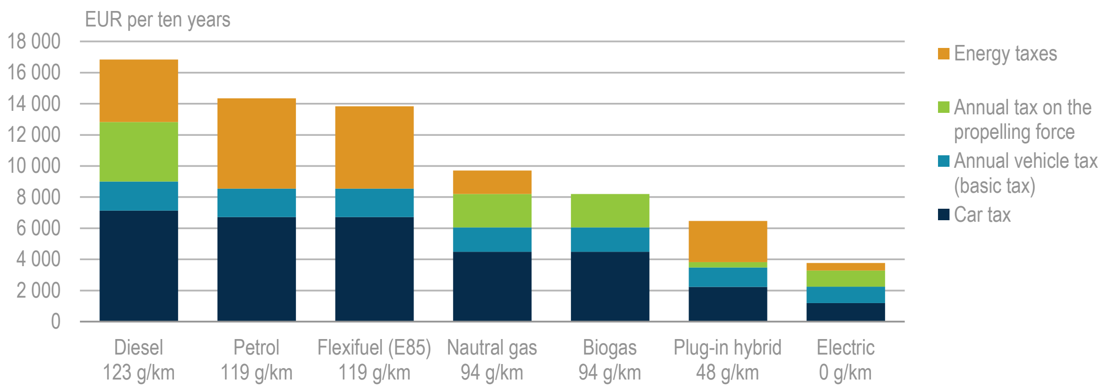
The tax on electricity has two levels, a general tax class 1 level and a lower tax class 2 level for industry, mining, data centres and agriculture. There is also a partial energy tax refund for energy-intensive industries and for agriculture.

Input fuels to electricity generation are exempted from energy taxation. For CHP production, the CO_2 tax is halved when energy products are used in CHP to avoid overlaps with ETS (as both electricity and heat fall under the EU-ETS) and to promote energy efficiency.

Transport taxation is composed of *i)* a car tax for passenger cars, vans and motorcycles based on CO_2 emissions of the vehicles; *ii)* an annual vehicle tax with a basic tax on passenger cars and vans based on CO_2 emissions and a tax on propelling force based on the mass of the vehicle and *iii)* a tax on the energy use of motor vehicles (energy content tax and CO_2 tax).

The government decided to decrease car taxation gradually in four phases over 2016-19. These tax decreases are targeted on cars with low CO_2 emissions. Some tax expenditures (tax relief and exemptions, for example) in car taxation were also abolished or reduced in 2015. The vehicle tax was increased in 2012, 2016 and at the beginning of 2017.

Figure 2.15 Tax burden from transport taxation



Notes: Price of the car without car tax, 17 000 km of driving per year, average CO_2 emissions, 2017 tax levels.
Source: Ministry of Finance, 2018.

Nordic collaboration

Finland is an integral part of the Nordic Energy Market, in terms of both its economy and its energy sector. The Nordic Council of Ministers for Business, Energy and Regional Policy commissioned in 2017 Nokia's former Chief Executive Officer Jorma Ollila to conduct a strategic review of how Nordic energy co-operation could develop over the next 5 to 10 years (Ollila, 2017). The report contains a series of concrete proposals that would further enhance co-operation among the Nordic countries, such as adopting a new vision for Nordic energy co-operation, with a programme of strategic goals and targets for 2018–2021, conducting Nordic peer reviews before decisions are taken on implementing national policies, as well as accelerating Nordic research activities through mapping and streamlining, and positioning Nordic energy solutions globally.

Making the most of the Nordic leadership in the decarbonisation of the economy, Nordic countries are well placed "*to create the smartest energy system in the world and to find the most cost-efficient solution in moving towards the low-carbon green economy*." (Ollila, 2017).

Assessment

Finland's energy policy is a result of its geographic location, its innovative business sector and commercial strongholds. With over one-third of its territory located above the Arctic Circle, the country is largely rural and sparsely populated, except for its southern tip. Finland has long, cold winters, and is 72% covered with forests. It has a large energy-intensive business sector.

Finland has a strong forest industry and developed a domestic supply chain, from timber to pulp and paper, woodchips for energy production and second-generation biofuels. The forestry sector accounts for about 20% of GDP. At the same time, the country can rely on a significant role of forestry as a carbon sink.

Finland's energy supply continues to rely on nuclear energy and biomass for electricity and heat production, on oil for transport and extensive use of CHP production based on a mix of coal, natural gas, peat and biomass. Biomass has grown steadily, reducing the contributions of coal and natural gas. In 2016, nuclear energy was the source of 18% of final energy consumption, and 34% of domestic electricity supply, whereas wood fuels contributed 26% of energy consumption and 18% in the electricity mix. Finland's energy system is driven by industry demand, which accounted for no less than 48% of Finland's total energy consumption in 2016.

Despite the phase out of coal, the country continues to reply on peat as a domestic security of supply resource; the National Energy and Climate Strategy for 2030 sets out the share of peat to amount to 20 TWh in 2020 and 15 TWh in 2030. These fundamentals make Finland's energy mix unique in Europe.

Finland's energy policy serves the triple purpose of enhancing energy security, economic growth and environmental protection. Since the last IEA in-depth review of Finland's energy policies in 2013, climate change has become a strong driver of Finland's energy policies. The government has achieved strong progress in setting out an integrated energy and climate framework for 2030, which was a recommendation in the previous review. In the National Energy and Climate Strategy for 2030, the government expects nuclear capacity to nearly double and wood fuels to increase by 30% towards 2030, together covering nearly 60% of total energy consumption by 2030, while phasing out coal in energy production and halving domestic use of oil by 2030.

According to the projections, Finland will meet the European Union 20-20-20 targets in emissions reduction, renewable energy and energy efficiency. The renewable energy target (38% by 2020) was already met in 2014.

While the IEA commends Finland's achievements in recent years, including the adoption of a framework for energy and climate to 2030, the IEA points out that the envisaged medium-term development should not be an end in itself, but part of the development path towards the stated goal of achieving a low-carbon society by 2045.

While the medium-term reliance on biomass and nuclear is a confirmed strategy of the government, such an approach could be compromised by delays in nuclear development or low availability of sustainable biofuels. It could also be overtaken by the fast pace of energy technology development and deployment across the Nordic markets, bringing about significant cost reductions, notably in wind power, electric vehicles and batteries.

The tax reform of 2011 overhauled energy taxation, taking into account the energy content, CO_2 emissions and local air pollution. Since then, no major structural changes to the energy taxation regime have been performed, but regular adjustments were made to tax levels and structure. The government has begun to more closely analyse the effects and justification of specific rules in energy taxation on incentives to invest in clean energy.

There is significant scope for using carbon taxation across the economy. The IEA sees ample opportunities for further aligning taxation and subsidies to climate and energy objectives, for instance in the taxation of natural gas and peat, and CO_2 tax reduction and feed-in premium for the use of wood chips used in CHP generation. The reform of the subsidy scheme in 2018 with half the investment aid given to innovative and new technologies is a welcome step since the market for flexibility needs to evolve as higher shares of renewable energy are being deployed and consumer preferences are changing.

The ambitious decarbonisation targets for the transport sector, with CO_2 emissions to be cut by 50% by 2030, rely on a high share of biofuels in domestic production. While the Strategy and the Medium-term Climate Change Policy Plan 2030 (MCCP) have revised the original ambitious target of reducing biofuels in transport from 40% to 30% by 2030, even such an ambition is high. To date, the production of biofuels from sidestreams of the forest industry is not enough to cover additional demand and there is a risk of non-biofuel imports not being sustainable. The MCCP therefore is heading in the right direction, building on a broader transport strategy for Finland. Low-emission vehicles are still expensive in Finland compared to other Nordic countries. Energy efficiency and the deployment of low-emission vehicles should therefore be encouraged, through fiscal and regulatory measures, to achieve clarity on how the government will implement its ambitious target.

The IEA recommends the government identify the opportunities and risks stemming from the global clean energy transformation for Finland, setting the country onto a path to a flexible energy system with net-zero energy-related emissions, while ensuring a sustainable, long-term management of its forests. The Finnish forestry industry is investing in future timber and pulp production, which will decrease the forest's function as carbon sink during the years 2020s before they return to the current level in 2035.

There is scope to evaluate actions that will accelerate the energy sector's transition to net-zero emissions up to 2045 and 2050. Finland is part of the Nordic collaboration on energy, placing the region in an excellent position to take the lead in global energy system transformation. Finland is also a member of the Clean Energy Ministerial (CEM), joined Mission: Innovation (M:I) in 2016, and is well placed to contribute to a strong Nordic research, development and innovation agenda.

Recommendations

The government of Finland should:

- ☐ Guide the energy system towards a low-carbon future towards 2050 through adaptive and robust policy frameworks that enable businesses to take long-term investment decisions, notably in energy technology innovation.
- ☐ Co-ordinate with Nordic and Baltic neighbours on the design and implementation of climate and energy policies, including a broad technology innovation agenda.
- ☐ Review the energy fuel taxation and subsidies to reflect their full carbon content to accelerate the switch to low-emission technologies, notably in combined heat and power generation and the transport sectors.
- ☐ Adopt a comprehensive package of policies and measures (taxation, supply and blending obligations, among others) in the transport sector to ensure that Finland can achieve the targeted emissions reduction in transport and halve oil consumption by 2030.

References

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

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3. Energy and climate change policies

Key data

(2016)

GHG emissions without LULUCF*: 58.8 $MtCO_2$-eq, -17.6% since 1990

GHG emissions with LULUCF*: 29.5 $MtCO_2$-eq, -44.8% since 1990

Energy related CO_2 emissions:

CO_2 emissions from fuel combustion: 45.5 $MtCO_2$, -15% since 1990, -31% since 2006

CO_2 emissions by fuel: oil 48.9%, coal 39.6%, natural gas 9.0%, other 2.5%

CO_2 emissions by sector: power and heat generation 40.3%, transport 27.1%, industry 16.4%, other energy industries 7.2%, commercial 6.5%, residential 2.5%

CO_2 intensity per GDP (PPP):** 0.22 $kgCO_2$/USD GDP PPP (IEA average 0.24)

*LULUCF = land use, land use change and forestry.

**PPP = purchasing power parity.

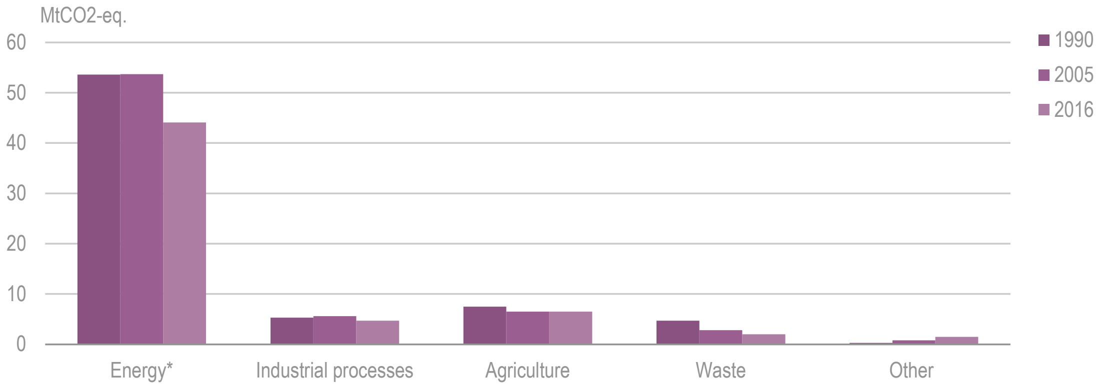
Overview

In 2016, Finland's total greenhouse gas (GHG) emissions were 58.8 million tonnes of carbon dioxide equivalents ($MtCO_2$-eq). Three quarters of those emissions stem from energy-related combustion processes, notably power and heat generation, transport and industry use (see Figure 3.1). Carbon dioxide (CO_2) emissions per unit of total primary energy supply (TPES) are directly linked to the share of renewable energy sources in TPES. In 2017, Finland has the second-highest share of biofuels among IEA member countries.

The sections of this chapter focus on energy-related CO_2 emissions, which account for the vast majority of GHG emissions.

As a member of the European Union (EU), Finland's emissions are covered under the EU Emissions Trading Scheme (ETS) and non-ETS sector regulations (Effort-Sharing Decision, Effort-Sharing and LULUCF Regulations). The government has adopted targets for GHG emissions reductions outside the ETS sectors. The country is well advanced towards its 2020 targets, with emissions about 20% lower in 2015 than in 1990 (without LULUCF). However, strong cuts are required to meet long-term targets for emissions reductions to 2030-50, in line with the Paris Agreement. In 2016, Finland adopted a *National Energy and Climate Strategy for 2030*, describing the targets and policy actions going forward, which were complemented by actions for the non-ETS sectors set out in the *Medium-term Climate Policy Plan* (MCPP) of 2017.

Figure 3.1 GHG emissions by sector, 1990, 2005 and 2015



Energy includes power and heat generation, industrial energy consumption and transport.

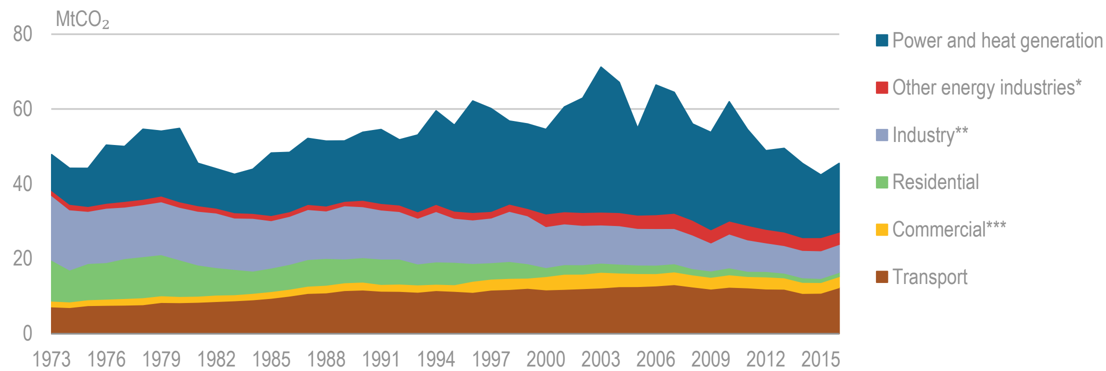
Source: SF (2018), *Greenhouse Gas Emissions in Finland 1990 to 2016*, reported to the United Nations Framework Convention on Climate Change (UNFCCC), https://unfccc.int/documents/65334.

Emissions by sector and by fuel

In Finland, the largest sectors in terms of GHG emissions were the energy transformation sector (33%), followed by transport (22%), industry's energy use (12%), agriculture (11%), industry process emissions (10%) and other energy-related emissions, including residential and commercial (9%) and waste (3%) (SF, 2018).

In 2016, energy-related CO_2 emissions were 45.5 $MtCO_2$. This was a decline by 31% compared to a decade earlier, as emissions were reduced across all sectors (see Figure 3.2).

Figure 3.2 Energy-related CO_2 emissions by sector, 1973-2016



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

***Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

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

Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

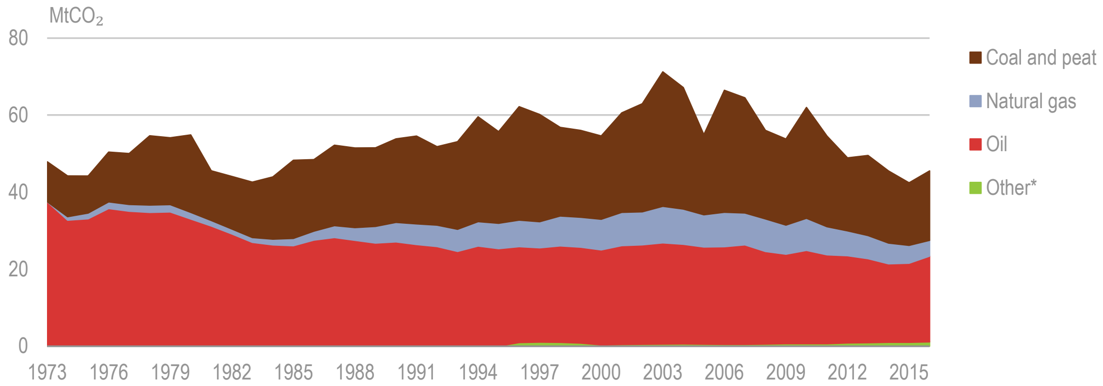
Power and heat generation accounted for the largest share of total emissions. The sector's emissions peaked at 38.7 Mt in 2003, and have since more than halved to 18.3 Mt in 2016, in line with a shift away from fossil fuels. However, emissions show large annual variations, with a rise from thermal plants in years with large energy demand but low availability of hydropower. The sector's emissions come mainly from combustion of coal and natural gas in the Nordic power market. These fuels accounted together for half total CO_2 emissions in Finland (see Figure 3.3).

The transport sector is the second-largest CO_2 emitter in Finland. In 2016, the sector emitted 12.4 Mt, a slight decrease from 12.8 Mt a decade earlier. Transport depends largely on oil-based fuels, and the sector contributes to over half CO_2 emissions from oil combustion.

The industry sector is the third-largest CO_2 emitter. Emissions from industry have been reduced by a quarter over the last decade, as a result of declining energy demand and fuel switching in the sector.

Remaining emissions come from other energy use (i.e. oil refineries, blast furnaces and coke ovens), and from the residential and commercial sectors. Emissions from the energy sector have remained relatively stable, whereas those from the residential sector have been significantly reduced, as a result of the penetration of more efficient heating systems and the shift of the heating fuel s from oil to renewable energy sources.

Figure 3.3 Energy-related CO_2 emissions by fuel, 1973-2016



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

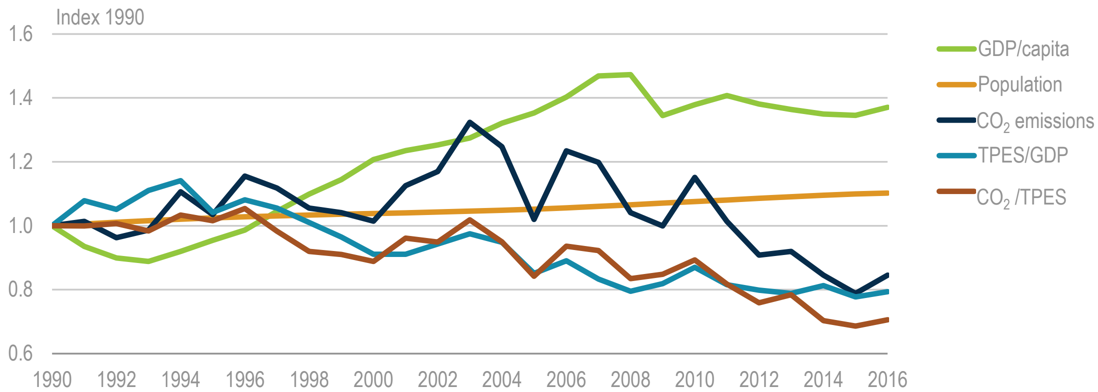
Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

CO_2 drivers and carbon intensity

Total CO_2 emissions 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. Between 1990 and 2016, Finland's population increased by 10% and GDP per capita grew by 37%. Despite this, CO_2 emissions were reduced by 15% thanks to decreasing energy intensity and falling emissions in the energy supply (see Figure 3.4). Finland has fully decoupled GHG emissions from GDP and population growth.

Energy intensity (in TPES/GDP) and emissions per unit of TPES together form the carbon intensity of the economy. By 2016, Finland's carbon intensity had been reduced by nearly half since 1990. It was 9% below the IEA average, but high in comparison to other Nordic countries (see Figure 3.5). This is partly a result of the relatively high share of fossil fuels in power generation, compared to the hydro-dominated power systems in Norway and Sweden. A large and energy-intensive industry sector in Finland is another factor that contributes to higher carbon intensity. Finland's carbon intensity varies annually in line with the power sector's emissions.

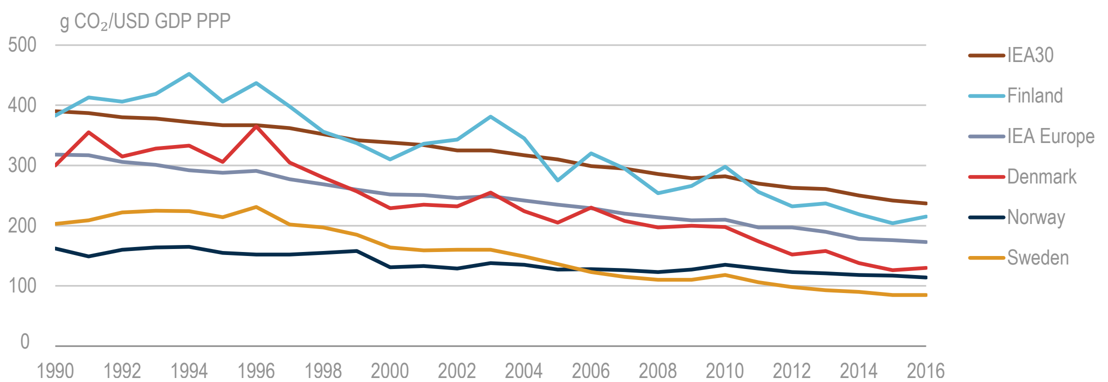
Figure 3.4 Energy-related CO_2 emissions and main drivers, 1990-2016



Note: Real GDP in USD 2010 prices and PPP.

Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Figure 3.5 CO_2 intensity in Finland and selected IEA member countries, 1990-2016



Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Institutions and regulatory framework

Climate and energy policies are strongly interlinked in the Finnish government and set out for a long-term horizon. The **Energy Department** of the Ministry of Economic Affairs and Employment (MEAE) co-ordinates energy- and climate-related matters. **The Ministry of the Environment** leads on climate change and environmental policies and housing, while the **Ministry of Agriculture and Forestry** deals with adaptation to climate change.

All national energy and climate strategies (2001, 2005, 2008, 2013, 2016, and 2017) were prepared by a **cross-government ministerial working group on energy and climate policy,** composed of representatives from all government parties and chaired by the Minister of Economic Affairs. The working group is supported by the network of officials, under the co-ordination of the Ministry of Economic Affairs and Employment. The network of officials comprises representatives from the Ministry of Economic Affairs and Employment, the Ministry of the Environment, the Ministry of Transport and Communications, the Ministry of Agriculture and Forestry, the Ministry of Education and Culture, the Ministry for Foreign Affairs, the Ministry of Finance and the Prime Minister's Office. The ministerial working group co-operates with the **Finnish Climate Panel**, an independent, interdisciplinary think tank of top-level Finnish scholars. Under the new 2015 Climate Change Act, the Panel is nominated by government and gives scientific advice for policy-making, reviews the climate policy plans, initiates reports and reinforces interdisciplinary insight in the operation of different sectors.

Integrated energy and climate planning

The 2015 **Climate Change Act (609/2015)** provides for a legal and institutional structure of co-ordinated policy planning across government, based on the legislated long-term emissions reduction target of at least 80% by 2050 compared to 1990 under the Act. The Act requires a long-term mitigation plan at least every 10 years, a medium-term mitigation plan focusing on sectors outside emissions trading every four years (once per electoral term), a national adaptation plan at least once every 10 years and an annual climate change report to Parliament.

The **National Energy and Climate Strategy for 2030** is Finland's long-term plan and was adopted in 2016. The main objectives include: *i*) reduced GHG emissions from non-ETS sectors of 39% in 2030 below 2005 levels; *ii*) reduced GHG emissions from non ETS of minimal 80% by 2050 compared to 1990 levels; *iii*) phasing out the use of coal for energy production by 2030; *iv*) renewable energy sources to account for over 50% of the final energy consumption in the 2020s; and *v*) an increase of the physical share of biofuels in road transport to 30% by 2030 (without double counting). Under the Climate Change Act 2015, the government released its first **Medium-Term Climate Change Policy Plan 2030 (MCCP 2030)** in October 2017 to set the targets as well as the implementing measures for non-ETS emissions reductions. The **2014 National Adaptation Plan** provides for Finland's adaptation policies and measures.

Under the EU Energy Union Governance Regulation, Finland is preparing a new integrated energy and climate plan for 2019 to cover the five key dimensions of the EU Energy Union: 1) energy security; 2) the internal energy market; 3) energy efficiency; 4) decarbonisation; and 5) research, innovation and competitiveness.

Climate change mitigation

As an EU member, Finland implements policies in the framework of the EU mitigation and adaptation rules. Finland's GHG emissions reduction efforts are guided under the new EU framework, notably the reformed EU-ETS, the new Effort-Sharing and LULUCF Regulations for sectors outside the ETS.

The EU-ETS covers the majority of power and heat generation plants as well as the large industries like manufacturing. Non-ETS emissions are covered under the effort-sharing rules and concern emissions from transport, agriculture, waste, buildings specific heating, some small industry and businesses as well as F-gas emissions (such as hydrofluorocarbons, perfluorocarbons, and sulphur hexafluorides).

The majority of district heating production in Finland falls within the EU-ETS, as it is produced by combined heat and power (CHP) generation. A large share of CO_2 emissions from energy use in buildings is therefore covered by the EU-ETS, which as a whole covers 46% of Finland's GHG emissions.

Targets for 2020

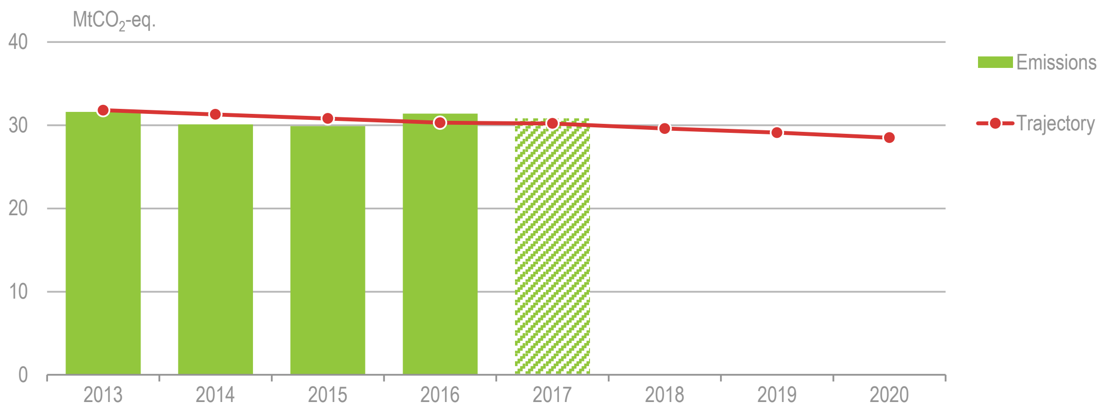
Under the Kyoto Protocol´s second commitment period (2013-20), the European Union, its member states and Iceland are committed to reducing their GHG emissions jointly by 20% below the base year. EU-ETS emissions will be reduced by 21% by 2020 below their level in 2005 and emissions not covered by the EU-ETS will be cut by approximately 10% from the 2005 level by 2020 within the European Union as a whole.

While the EU-ETS emissions reduction commitment is an EU-level commitment; member states have individual binding annual emissions reduction or limitation targets for the non-ETS emissions, set out in the EU Effort-Sharing Decision (ESD).

The ESD defines Finland's reduction obligation as -16% of the 2005 emissions, largely the same as the reduction committed under the second commitment period of the Kyoto Protocol. However, there are also differences. The commitment under the Kyoto Protocol covers also emissions and removals from the land use, land-use change and forestry (LULUCF) activities and applies to the whole commitment period, whereas the EU-ESD emission allocations are implemented on an annual basis.

The government's objective is to achieve the 2020 targets set for Finland by the European Union before the end of the government's term. Finland is on track to achieve its targeted -16% reduction in GHG emissions in the non-ETS sectors during 2012-20 with existing measures. For the first three years, Finland's annual emissions have been below the targeted trajectory volumes, as a result of the warm weather and economic slowdown, and the growth of renewable energy in line with the EU Renewable Directive and Finland's national renewable target. However, the country will need to compensate for higher emissions in 2016-20 and may need to use flexibility measures by the end of the period.

Figure 3.6 Non-ETS greenhouse gas emissions and trajectory for Finland, 2013-20



Note: 2017 data are preliminary.

Source: MEAE, 2018.

Targets for 2030

With regard to the 2030 horizon, the European Union-wide binding emissions reductions target of at least 40% by 2030 compared to 1990 is translated into an emissions reduction target for the ETS sector (43% by 2030 below 2005 levels) and the non-ETS sectors (30% by 2030 below 2005 levels). Under the new EU Effort-Sharing Regulation, this 30% target is translated into binding national GHG emissions reduction targets by 2030 for each EU member state; Finland has a target of -39% by 2030, one of the highest targets in the European Union. This translates into an effort-sharing of 20.6 $MtCO_2$-eq by 2030, from a level of 33.7 $MtCO_2$ in 2005.

Sectors outside the EU-ETS

By 2030, Finland aims to reduce its GHG emissions in the non-ETS sector by -39% or 20.6 $MtCO_2$ below 2005 levels, which is considered very ambitious in view of the emissions trend in the basic scenario from MCCP 2030. With existing policies, non-ETS GHG emissions are expected to decline throughout the 2020s to reach a level some 22% lower in 2030 than in 2005, still below the target for 2030; a further reduction of some 17% or 6 $MtCO_2$-eq. is needed.

The MCCP 2030 foresees that measures in transport will contribute in the range of 3.1 $MtCO_2$-eq per year (the lion's share coming from renewable energy sources and low-emission fuels), buildings specific heating -0.2 $MtCO_2$-eq per year, agriculture -0.5 $MtCO_2$-eq per year and -0.5 $MtCO_2$-eq per year from waste management.

Under the EU Effort-Sharing Regulation (adopted on 14 May 2018), three types of flexibility mechanisms can be used to meet a national target. In line with Article 5 of the Regulation, Finland can use borrowing, banking and transfer; under Article 6, a one-off flexibility of maximum 2% is possible from the ETS sector, which in practice means cancelling emission allowances in the ETS and creating corresponding units in the effort-sharing sector; and under Article 7 (LULUCF), Finland can use 1.4% from the LULUCF sector to cover its efforts.

The government intends to use the one-off flexibility under Article 6 and seeks the authority to do so by introducing a bill to change the Emissions Trading Act in 2018. For Finland, this would mean a 'transfer of ETS allowances' of about 0.7 $MtCO_2$-eq of units per year for the period 2021-30. From LULUCF, Finland does not expect any surplus that it could use on the ESD commitment and no decision has been taken on flexibilities under Article 5. In addition, trading of credits under Article 5 among EU member states would be possible, but the costs of such flexibility remain to be clarified as the market does not exist yet.

Under the new LULUCF Regulation (adopted in May 2018) emissions of biomass used in energy and for other purposes are reported and taken into account under national 2030 climate commitments, through LULUCF accounting rules.

Finland will need to set the forest reference level. The government's objective is to reach the LULUCF target through national measures. Under the so-called no-debit rule, accounted emissions from land use are compensated by an equivalent removal of CO_2 from the atmosphere through action in the sector. This would mean that there is no need to buy units in other member states. The LULUCF sector as a whole is a sink in Finland.

Special focus: Forest biomass and land use

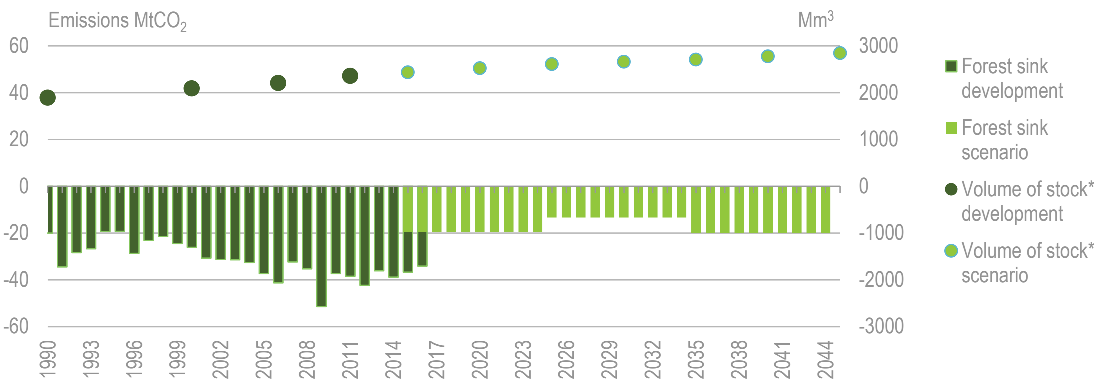
Biofuels and waste[6] (mainly solid biomass) accounted for 85% of Finland's total renewable energy in TPES in 2017, and the supply of biofuels has increased steadily. With 28.5%, Finland has the second-highest share of biofuels in TPES by comparison among IEA countries.

Forest biomass is considered to be crucial for Finland's economy as a raw material for renewable energy and will be in the future. According to the *National Energy and Climate Strategy for 2030* the majority of forest-based energy will continue to be produced on market terms from the side streams of other wood use.

Plenty of wood material is produced in forestry management operations and timber harvesting that is not suitable as raw material for wood processing, or for which there is not enough demand. By means of different policy measures, this forest biomass will be channelled to replace imported fossil fuels in heating, CHP production and biofuels for transport.

The National Energy and Climate Strategy for 2030 is based on a round-wood removal scenario in which the annual total removal of round wood is estimated to grow to 79 million cubic metres (Mm^3) per year by 2035. This is consistent with the target level set in the National Forest Strategy for 2025 and with the government's target of increasing annual wood use by 15 Mm^3 from the current values. The increased felling of round wood would reduce the yearly carbon sink to 13.5 $MtCO_2$-eq. by 2030. For the Kyoto Protocol second commitment period (2013-20), Finland set the forest management reference level of −19.3 $MtCO_2$-eq (without harvested wood products [HWP]) and −20.4 $MtCO_2$-eq, including HWP.

Figure 3.7. Evolution of the forest sink in Finland (in $MtCO_2$) and of the forest stock, 1990 to 2044.



*Volume over bark of all living trees, includes the stem from ground level up to the top, excluding branches.
Source: Natural Resources Institute Finland (Luke).

[6] Biofuels and waste = solid biomass and liquid biofuels, biogases, industrial waste and municipal waste.

Forestry has a special role, as it provides raw materials for forests industries, substitute fossil and other non-renewable raw materials, and acts as a carbon storage and sink. Sidestreams from forestry and forest industry are important for energy production. Finland has a large and ageing forest, which is a source of economic growth for the forest management. However, old trees have limited ability to absorb CO_2, while young and growing trees absorb more CO_2 (see Figure 3.7). The size of the forest carbon sink (the quantity of CO_2 that is sequestrated as the forests grow and released in harvesting) has varied between some 20 and 50 $MtCO_2$-eq in 1990–2013. Annually, the net sink of the Finnish forests has corresponded to between 30% and 60% of Finland's total emissions, a very high amount by international comparison. Despite increased investments in the forest industry and the extensive use of wood, the growth of forests still exceeds harvesting volumes.

Special focus: Transport

Given that transport emissions account for the largest share (40%) of non-ETS emissions, progress in the transport sector is considered to be critical for achieving Finland's GHG emissions reduction targets. In the MCCP 2030, the government intends to reduce transport emissions by approximately half compared to 2005 levels (see section on transport sector measures in the Energy and Climate Strategy 2030 (MEAE, 2016).

To achieve this, the government has set targets for the renewal of the vehicle fleet to have at least 250 000 electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs), representing 10% of the total car fleet, and 50 000 gas vehicles by 2030. Strong focus is given to the blending of gasoline and diesel, notably through drop-in biofuels, to meet the 30% target of renewable energy sources (RES) in transport, giving biofuels a large role. Finland wants to base the additional biofuels demand on domestic production. However, this will depend on the availability of feedstocks to produce biofuels (which to date are by-products from the domestic forest industry).

Finland's government and industry also boost research and development (R&D) efforts to develop and demonstrate a range of new biofuels technologies, including lignocellulosic feedstocks, hydrotreated vegetal oil (HVO), co-processing of bio-feedstocks in existing oil refineries, biomass-to-liquids (BTL) plants using gasification and Fischer-Tropsch (FT) process, and bioethanol from wood and straw.

However, changes in the transport sector require long-term and expensive measures, which also require behaviour changes. The MCCP does not specify the costs of the mitigation measures. However, the Technical Research Centre of Finland (VTT) evaluated the cost-effectiveness of various emissions reduction measures in the transport sector, ranking road transport efficiency as a relatively low-cost measure with large impacts, while blending obligations and biogas range at the higher end of the cost scale.

Concluding transport emissions can be tackled by reducing transport demand at a system level; by changing modes of transport to increase efficiency and by replacing fossil fuels with biofuels or electricity from low-carbon energy sources. Chapter 6 on Transport evaluates in more detail these policies and measures to support the implementation of Finland's policy goals.

Targets and pathways for 2050

In the MCCP 2030, the government sets out the ambition to become a carbon-neutral society by 2045. The industry- and academia-driven *Energy and Climate Roadmap 2050* explores a range of long-term technology and decarbonisation pathways to meet the 2050 climate goal of the Climate Change Act and the carbon-neutrality goal for 2045. The roadmap analysed how Finland can reduce GHG emissions by 80% to 95% by 2050 below 1990 levels by deploying low-carbon technologies and implementing a variety of market-based steering measures (investments, taxes, subsidies, etc.). The roadmap was prepared by the Parliamentary Committee on Energy and Climate Issues, appointed by Prime Minister Katainen's government.

The roadmap benefited from the research done by the *Low Carbon Finland 2050 Platform* and its four scenarios for low-carbon development pathways until 2050. The assumptions made in the scenarios, especially regarding the development and acceptability of carbon capture and storage technologies, the development of nuclear power capacity and sustainability criteria for wood-based biomass, have a crucial impact on the possibilities of reducing emissions.

In 2018, the government is preparing a National Climate and Energy Plan under the EU Energy Union Governance Regulation and work has begun on a government-led long-term low-emission strategy for Finland, which will examine the goal of carbon neutrality by 2045, for release in early 2019.

Climate change adaptation

Finland is an Arctic county and its energy sector and infrastructure have to withstand severe snow, ice and storms. Over the past few years, harsh winter and summer storms have caused extensive and long-lasting power outages, impacting the operational security of the electricity distribution networks.

Adaptation measures in the energy sector are being implemented. The 2013 Electricity Market Act was revised to include new standards for the security of energy supply in network fault situations, especially in sparsely populated areas. The distribution network must be designed, built and maintained to withstand severe weather and ensure electricity interruptions are kept below 6 hours in detailed planned areas and 36 hours in other areas. These time limits must be met gradually in a 15-year time period and fully by the end of the year 2028. The distribution network companies must also prepare a network development plan which should include measures on how to fulfil the new reliability standards. A significant increase in investment in underground cabling in the Finnish electricity distribution networks is under way. In addition, there is a requirement for co-operation between the network companies during emergency situations. The Highways Act will be amended so as to make it easier to install power cables along roadsides. In terms of hydropower plant investments, new turbines have been scaled to better meet the expected changes in water flow conditions.

On 20 November 2014, the National Climate Change Adaptation Plan was adopted as a government resolution. The Plan requires that climate change adaptation is mainstreamed across the economy and incorporated into the regular planning, implementation and development of all sectors and actions. The implementation of the plan is co-ordinated by the national monitoring group on climate change adaptation. Under the Climate Change Act, the government will adopt an adaptation plan at least once every ten years. The Plan contains a risk and vulnerability assessment and sector-specific action programmes for adaptation, as considered necessary. A report on the implementation, adequacy and effectiveness of the adaptation measures is to be submitted at least once in every electoral term as part of the climate change report.

The government commissions analyses on climate change resilience and impacts. Noteworthy is the ELASTINEN research programme (2015-16) and its overall assessment of the management of weather and climate risks, and of ways to promote management of these risks in various sectors, including energy. The SIETO project (2017-18) conducts vulnerability and risk mapping for weather-related phenomena and climate change, and will suggest ways to improve it further.

Internationally, Finland is a leader in arctic shipbuilding, shipping, winter navigation and logistics, maritime and offshore technology, including the manufacturing of advanced state-of-the-art arctic ice-breakers and specialised offshore vessels, arctic vessels, maritime logistics, offshore applications (including monitoring and controlling sea transport, as well as weather and ice information services). During 2017-19 Finland chairs the Arctic Council and will emphasise the implementation of the Paris Agreement on Climate Change and the UN Sustainable Development Goals in Arctic co-operation. The Arctic Council aims at putting into practice actions under the Arctic Resilience Action Framework, the Arctic Council's Framework for Action on Black Carbon and Methane and as follow up to the *Adaptation Actions for a Changing Arctic* which was adopted at the 2017 Ministerial Meeting.

Assessment

Based on the 2015 Climate Change Act, the 2016 National Energy and Climate Strategy for 2030 and the Medium Term Climate Policy Plan adopted in 2017, Finland has put in place a set of concrete policies, objectives and targets to lead the country on a path towards a sustainable and low-carbon economy for 2030 and beyond. The IEA welcomes and commends these important developments since the last IEA review.

The Climate Change Act is a framework for the long-term, cross-government and cost-effective planning and monitoring of policies to reduce greenhouse gas (GHG) emissions through a long-term plan (10 years), a medium-term plan (4 years) and a national adaptation plan every ten years. The Act fixes a binding objective of at least 80% GHG emission reductions by 2050 (below 1990 levels) and also establishes the Climate Panel as an independent advisory body. By international comparison, Finland has placed itself among the leaders with such an integrated framework. The IEA commends the government of Finland for the significant efforts made to support the preparation of both its National Energy and Climate Strategy and of its Climate Policy Plan using the same analysis and projections. Based on this framework, in 2018, the government is also preparing the national climate and energy plan for the years 2021-30 and the long-term low emission strategy, under the European Union's Energy Union Governance Regulation.

The country is well advanced towards its 2020 targets, which it will meet ahead of time. It has already reached its national target of 38% of renewable energy in gross final consumption in 2020 and intends to use flexibility measures to meet its 16% emissions reduction targets in non-ETS sectors.

Under the Paris Agreement, the European Union's 2030 contribution is to reduce GHG emissions by at least 40% in 2030 below 1990 levels. Emissions under the EU Emissions Trading Scheme (ETS) should be reduced by at least 43% compared to 2005, while emissions in the non-ETS sector should be reduced by 30% compared to 2005 at EU level. Under the new Effort-Sharing Regulation, Finland's binding target in the non-ETS sector emissions reduction is set at 39%, one of the highest in the EU. To meet its non-ETS GHG emissions target, Finland plans to use a one-off flexibility mechanism of 2% each year from the EU-ETS (under Article 6).

According to IEA data, energy-related CO_2 emissions stem from power and heat generation (40.3%), transport (27.1%), industry (16.4%), other energy industries (7%), commercial (6.5%), and residential (2.5%). Transport and residential emissions accrue at a national level, while 46% of Finland's GHG emissions are covered under the EU-ETS, mainly power and heat generation and some industries. Finland has therefore put the emphasis of its climate policies on transport and residential sectors.

The Medium-Term Climate Change Policy Plan for 2030 complements the National Energy and Climate Strategy for 2030 by detailing the scenarios, policies and measures to achieve Finland's GHG emission reduction in the non-ETS sector. However, the description and implications of existing or potential additional sectoral policies or objectives could be more detailed to ensure that they can deliver according to ambition. This applies notably to the measures to improve efficiency of the transport system, of the agriculture sector, and to reduce fossil fuel use (coal, heating oil and peat). Work is in progress. In autumn 2018, the government is expected to present a bill to ban coal use. In addition, the projected impacts of the additional energy efficiency measures included in the National Energy and Climate Strategy seem to be limited, and additional synergies with GHG emissions reduction measures remain untapped.

Finland has not yet adopted a long term mid-century strategy. In 2014, Finland completed an Energy and Climate Roadmap to 2050, which recalls the aim of Finland to become a carbon-neutral society and identifies potential pathways to reduce GHG emissions by 80% to 95% by 2050. Finland has indicated an aim to become carbon-neutral already by 2045, but no concrete measures are set out in the medium term plan. Under the Paris Agreement and the EU Energy Union Governance Regulation, the government plans to develop a long-term national low-emission strategy by 2020, setting out a concrete path, policies and measures towards meeting the Paris Agreement long-term decarbonisation objectives. GHG emissions reductions and carbon sink pathways need to be taken into account, ensuring an orderly clean energy transformation creating a link between medium- and long-term policy objectives.

As an Arctic country, Finland faces rapid changes in its climate, with potential consequences for, among others, forest growth and the occurrence and strength of winter storms. The last National Climate Change Adaptation Plan was adopted in 2014 and a range of measures are in place to strengthen the resilience of the electricity distribution networks. During 2017-19, Finland chairs the Arctic Council, an opportunity to scale up actions aimed at higher adaptation, resilience and GHG emissions reductions, notably methane and black carbon in the Arctic.

Recommendations

The government of Finland should:

- Prepare an adaptive Mid-Century Strategy for Finland and identify the opportunities and risks stemming from the global clean energy transformation for Finland to drive the path to net-zero energy-related emissions while ensuring a sustainable and long-term management of its carbon sink.
- Assess the cost-effectiveness of a broader range of policies and measures to reduce GHG emissions across various sectors of the economy in the longer term.
- For the design of the integrated National Energy and Climate Plan for 2021-30, review the measures of the National Energy and Climate Strategy for 2030 and the Medium-term Climate Policy Plan, taking into account cost-effectiveness and relevant EU legislation.

References

IEA (International Energy Agency) (2018), *CO_2 Emissions from Fuel Combustion 2018* (database), OECD/IEA, Paris, www.iea.org/statistics/.

ME (Ministry of the Environment) (2017), *Government Report on Medium-term Climate Change Policy Plan 2030*, Helsinki. http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/80769/YMre_21en_2017.pdf?sequence=1&isAllowed=y.

MEAE (Ministry of Economic Affairs and Employment) (2016), *Government Report on the National Energy and Climate Strategy for 2030*, Helsinki. http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf.

SF (Statistics Finland) (2018), *Greenhouse Gas Emissions in Finland 1990 to 2016*, reported to the UNFCCC, https://unfccc.int/documents/65334.

4. Industry

Key data

(2016)

Final energy consumption in industry: 12.4 Mtoe (biofuels and waste 29.9%, electricity 26.6%, oil 24.1%, heat 10.5%, natural gas 4.5%, coal 3.0%, peat 1.3%), decrease by 7.7% since 2006

Share of total final consumption: 47.8%

Share of energy related CO_2 emissions: 16.4%

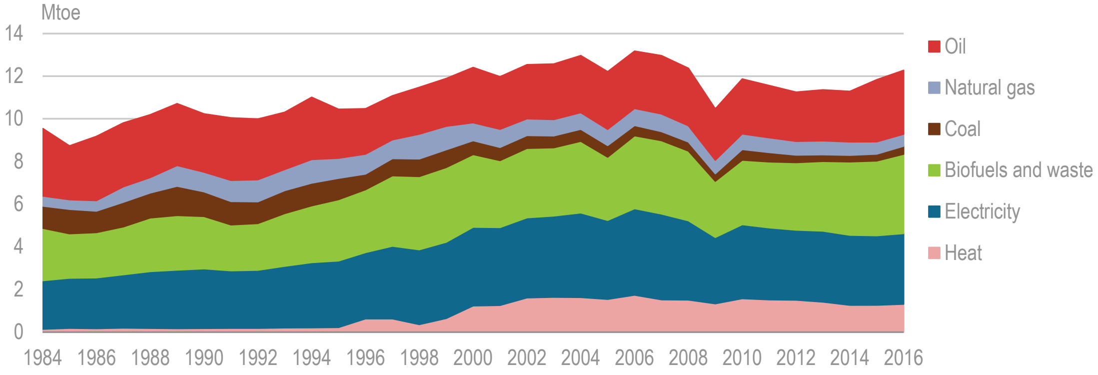
Overview

The industry sector is the largest energy consumer in Finland, accounting for nearly half the total final consumption (TFC). Large shares of biofuels, electricity (nuclear) and district heating in the energy supply make the industry sector a relatively small emitter of carbon dioxide (CO_2), compared to the heat and power, and transport sectors.

Energy consumption and CO_2 emissions

In 2016, energy consumption in industry was 12.4 Mtoe, which represented 47.8% of TFC in the country. Energy consumption peaked in 2006, and has since dropped by 7.7% and has been varying around 11 to 12 million tonnes of oil-equivalent (Mtoe) in recent years (see Figure 4.1). Non-energy use accounted for 14% of the industrial consumption, mainly oil consumed in chemical industries.

Figure 4.1 TFC in industry by source, 1984-2016



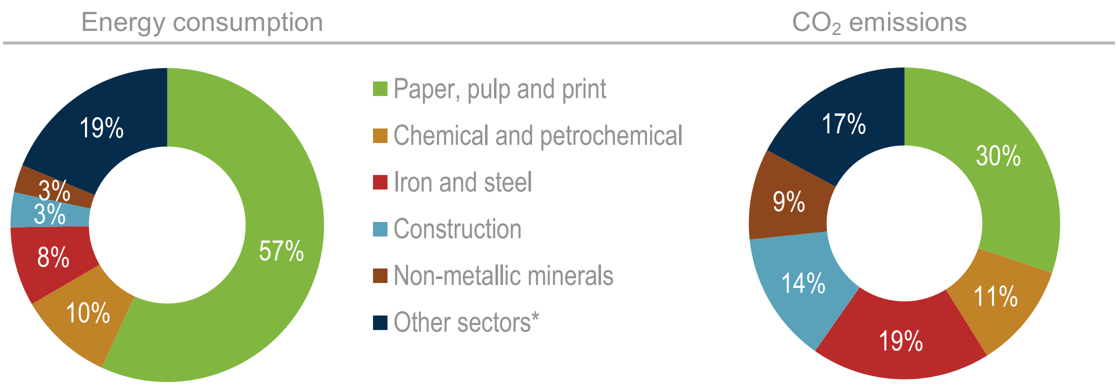
Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Biofuels and electricity are the fuels most used in industry, together accounting for 57% of total energy demand in the sector (see Figure 4.1). Oil is the third-most used fuel, accounting for around 24% of consumption, of which half is for non-energy use. District heating accounts for 11% of energy use in industry, and the remaining consumption is made of small shares of natural gas, coal and peat.

Finland is a country rich in forest resources, which is reflected in industrial production. The paper, pulp and print industry is by far the largest in terms of energy consumption and accounted for 57% of TFC in industry in 2016 (see Figure 4.2). Thanks to a large reliance on biofuels, however, the paper industry accounts for less than one-third of industrial CO_2 emissions. Other industry sectors that depend more on fossil fuels, such as construction, metals and minerals industries, are relatively heavy emitters.

Finland's tax policy has affected the competitiveness of natural gas, and gas use in CHP/district heating is not affordable compared to coal, peat and bioenergy (energy tax, including the CO_2 tax, for natural gas has sharply increased since 2011).

Figure 4.2 TFC and CO_2 emissions in industry by sector, 2016



**Other sectors* includes food and tobacco, machinery, non-ferrous metals, mining and quarrying, transport equipment, wood and wood products, textile and leather, and other non-specified industries.

Note: Excluding non-energy use.

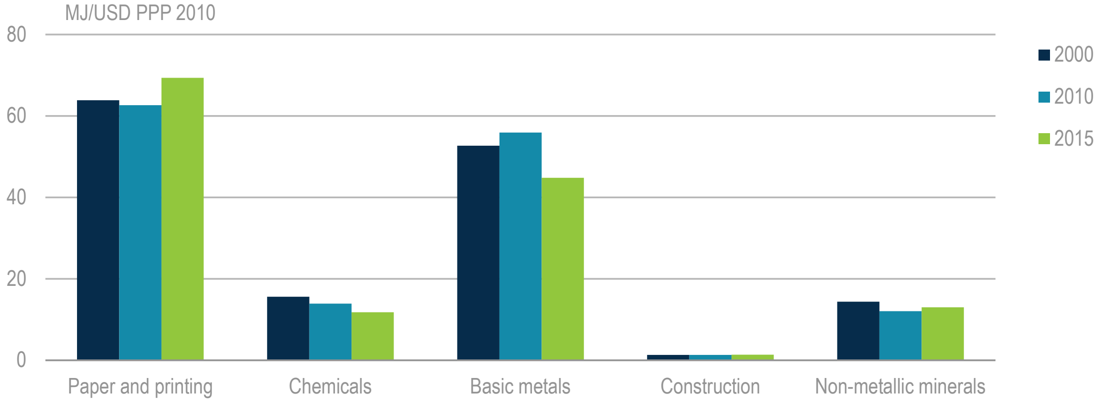
Sources: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/; IEA (2018b), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Energy intensity

Energy intensity in terms of energy consumption per value added in industry differs a lot for different industry sectors (see Figure 4.3). Overall, the energy intensity in manufacturing industries has declined over the last decade and a half, indicating more efficient production.

In certain sectors such as the paper industry, however, the trend has been increased energy intensity. This can be explained by structural changes in industry, as demand for more expensive printing paper is declining while demand for cheaper packaging material is increasing. In 2016, sales of printing paper fell by 7.3% compared to the previous year, whereas paperboard sales increased by 8.9% (FFI, 2017).

Figure 4.3 Energy intensities in manufacturing by industry sector, 2000-15



Notes: MJ = megajoule; PPP: purchasing power parity.

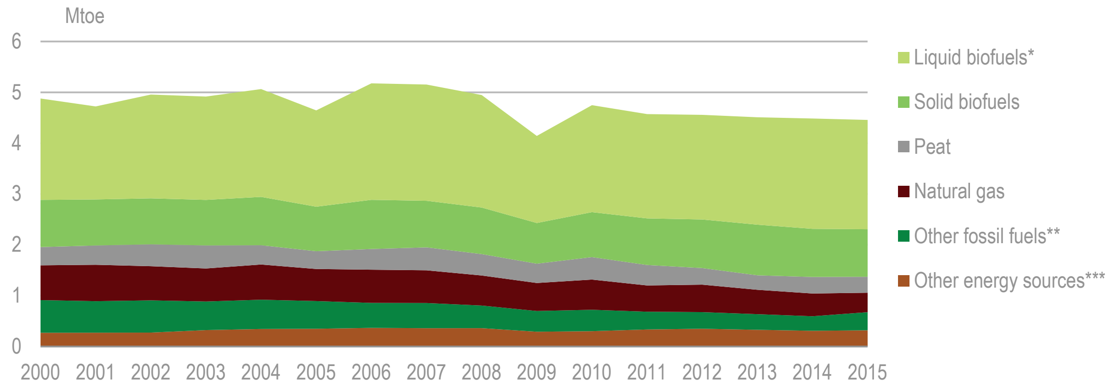
Source: IEA (2017), *Energy efficiency indicators 2017*, www.iea.org/statistics/.

Renewable energy use in industry - biofuels

Biofuels account for the largest share of TFC in the industry sector. Most energy consumed in industries, with the exception of electricity, is used for producing heat to heat up processes and buildings. Industrial heat production is heavily dominated by biofuels, of which black liquor accounts for the largest share (see Figure 4.4). Black liquor is mainly produced and used internally in pulp and paper industry processes.

In 2015, liquid biofuels accounted for 47% of total heat produced in industries, and solid biofuels for another 21% (Statistics Finland, 2017). The share of biofuels has increased from 60% in 2000 to 70% in 2015. However, 24% of industrial heat is still produced with fossil fuels. There is potential for further growth in biofuels, e.g. to replace peat, which accounts for 7% of heat production in industries.

Figure 4.4 Industrial heat production by source, 2000-15



**Liquid biofuels* is black liquor and other concentrated liquors produced and used in the paper and pulp industry.

***Other fossil fuels* include oil products, coal and non-renewable waste.

****Other energy sources* include electricity, ambient heat and geothermal heat.

Source: Statistics Finland (2017), "Production of electricity and heat", http://tilastokeskus.fi/til/salatuo/index_en.html.

Institutions and policy framework

The Ministry of Economic Affairs and Employment (MEAE) has an overall responsibility for energy efficiency policies, including on industry by supporting energy audits and analyses, as well as energy efficiency investments, fulfilling certain funding criteria, under the Energy Aid Scheme and the Energy Audit Programme.[7]

The Finnish Energy Authority is responsible for the practical implementation of certain measures to promote energy efficiency. Its tasks concern energy efficiency agreements, energy audits, consumer guidance in and communication on energy-related matters, and the ecodesign requirements and energy labelling of products.

The National Energy Efficiency Action Plan (NEEAP), currently in its fourth edition, covers all sectors of the economy, and responsibility for certain specific sectors is delegated to other ministries. The Ministry of the Environment has a central role in relation to buildings and building codes, ensuring the quality of the built environment and promoting sustainable communities.

Motiva Oy is a state-owned company which has an important role in implementing energy efficiency policies and advising government on policies and measures, including energy efficiency, implementing programmes agreed by government and stimulating sustainable energy policies and actions. Motiva Oy collects and evaluates information about the impacts of energy efficiency policy and promotes policies and new technologies through working with the business sector, local communities and individual consumers.

Energy efficiency in industry

Finland has been using voluntary agreements since the 1990s, the scope of which has been expanded from industry to other sectors (transport and buildings). Today, the voluntary agreement framework covers the industrial sectors (industries, energy sector, services sector); municipal property and buildings, and oil sectors (oil-heated properties and transport of heating and transport fuels), goods and public transport, and agricultural sectors. The agreements are the main tool for the government to achieve its energy efficiency targets and goals.

Agreement parties are ministries, industry associations, companies and communities. Subscribers to the agreements undertake to carry out energy audits or analyses in their own properties and production plants, to draw up an energy efficiency plan, and to implement cost-effective conservation measures, as well as reporting annually to the organisation concerned. The audit system for the process industry encourages companies to invest in the targets recognised and analysed in the audits. As follow-up for mandatory energy efficiency audits, a new procedure will be developed in which the cost-effective energy efficiency potential of the process industry and energy production, and

[7] The energy audit grant for large companies that served as a good incentive for concluding energy efficiency agreements was abolished, as the grant procedure was replaced by the mandatory and less extensive energy efficiency audits required under the EU Energy Efficiency Directives.

CHP production in particular, will be established by using the latest measurement technologies and analysed by drawing on the best expertise.[8]

During 2008-16, hundreds of Finnish companies and municipalities joined the Energy Efficiency Agreements, covering approximately 65% of the total energy consumption in the country. As a result of the energy efficiency measures that have been implemented, the annual energy consumption has been reduced by as much as 16 terawatt-hour (TWh) by the end of 2016, that is the annual energy consumption of more than 1.9 million detached houses, a reduction of carbon dioxide emissions by more than 4.8 million tonnes (Mt) and saving unnecessary energy costs worth EUR 540 million (Euros).

Total annual savings gained from measures implemented under the energy efficiency agreements since 1997 within industry, energy, municipal, property and building sectors were approximately 16.6 TWh per year at the end of 2015. Almost 85% of these savings came from end-use sectors and one-fourth of the savings was electricity. The savings were equal to about 4.5% of Finland's total energy consumption (362 TWh in 2015). Additional energy savings amounting to 1.4 TWh in 2015 have been achieved as a result of the energy efficiency agreement for the oil sector, covering oil-heated buildings.

CO_2 reductions under the energy efficiency agreements on industrial and municipal properties and buildings, and on oil sectors were in total approximately 6.3 $MtCO_2$ per year at the end of 2015 (based on a marginal emissions rate of 600 $kgCO_2$/MWh for electricity). It is estimated that by the end of 2020, the emissions reduction will be 7.9 $MtCO_2$ per year, and 8.4 $MtCO_2$ per year by 2030 when taking into account the start of the new agreement period at the beginning of 2017.

The third energy efficiency agreement period has started for 2017-25 with energy efficiency agreements for industries, municipalities, properties and buildings and the oil sector. They are mainly the responsibility of the Ministry of Economic Affairs and Employment. Responsibility of the action plan for rental housing properties in the property and building sector agreement lies in the Ministry of the Environment. These agreements are the successors of the second generation of agreements for the period 2008-16 (rental housing properties 2010-16, commercial properties 2011-16) and the first generation of agreements in 1997-2007 (then called energy conservation agreements).

In 2010, an energy efficiency agreement was also launched in the agriculture sector under the Ministry of Agriculture and Forestry. The agreement was updated in 2016 for the period 2016-20. Farms have received energy advice in the scope of the Farm Energy Programme in 2010-15. For the period 2015-20 energy advice is given in the sphere of the Rural Development Programme for Mainland Finland. Energy efficiency measures in agriculture are farm re-parcelling to cut down energy use in farm traffic, support for fresh grain silos where energy use for drying grain is avoided as well as support for investments in heat recovery from pig slurry to benefit unheated cattle buildings.

[8] www.energiatehokkuussopimukset2017-2025.fi/en/.

Energy audits

Energy audits analyse the energy use of the facility being audited, so as to work out the potential for energy savings and to present a profitability calculation of saving proposals. In addition to working out possible ways of using different forms of renewable energy and the energy saving potential, the energy audit reports on the impact of the proposed measures on CO_2 emissions.

Since June 2014 energy audit activities are divided into two categories: *i)* mandatory energy audits for all large companies governed by the Energy Efficiency Law based on the requirements in the EU Energy Efficiency Directive and *ii)* voluntary subsidised energy audits for other operators (the Energy Audit Programme). Subsidies can no longer be granted for large companies under the mandatory energy audit requirement.

The Energy Audit Programme is a voluntary programme promoted by a 40% to 50% subsidy by the Ministry of Economic Affairs and Employment. The ministry provides subsidies to conduct energy audits on commercial and public buildings and in the industrial and energy sectors provided that the applicants do not fall into the scope of the mandatory audits. It also supports municipalities to carry out audits concerning the promotion of renewable energy use within the municipality's territory (Renewable Energy Municipal Audit). Apart from energy audits subsidised by the Ministry of Economic Affairs and Employment, there are energy audits intended for farms which are subsidised by the Ministry of Agriculture and Forestry.

The emissions reduction of the energy efficiency measures conducted based on the proposals in the voluntary energy audits is estimated to be 0.33 million CO_2 tonnes per year by the end of 2020 and 0.28 million tonnes per year by the end of 2025. While the vast majority of energy audits are implemented in connection with the energy efficiency agreements, overlap in energy savings and emissions reductions has been removed in the estimates and the results are additive.

Assessment

In 2016, industry accounted for 47.8% of Finland's total energy consumption, a unique feature of Finland's energy economy, and 16.4% of energy-related CO_2 emissions. Energy intensity is high by international standards (only Canada and Estonia are more intensive), mainly because of the cold climate and the high share of energy-intensive industries. However, in Finland industrial heat processes are largely based on biofuels and electricity.

There has been a 7% reduction in industrial demand in the last decade, leading to more intensive energy use, and also to structural changes in industry, for instance moving from paper to more pulp industry. However, there is less scope for efficiency savings in this sector, partly because of the dominance of energy-intensive industries. Paper and pulp industry accounted for over half the total industrial energy consumption, next to other large industry sectors, such as chemicals, iron and steel, and wood products.

The framework of voluntary energy efficiency agreements and audits is the backbone to the country's energy efficiency policy, and an effective alternative to regulatory steering. It covered approximately 65% of the total energy consumption in Finland at the end of

2016, provided 15 TWh of energy savings during 2008-16; new agreements are being rolled out over the period 2017-25. Further efforts could be made to compare the performance of Finland's industry with other countries – including the sharing of best practice – in order to identify and promote additional options to improve efficiencies.

Energy-intensive industries operate under the framework of the EU-ETS. The low EU carbon price provides insufficient incentives to undertake long-term investments in energy efficiency and emissions reduction efforts. As long as the EU-ETS is not adequate to drive a structural shift towards low-carbon options, the Finnish government will need an effective complementary strategy for the sectors covered by the ETS, in particular industry. Some industrial production processes are CO_2-intensive and the use of biofuels is not always possible. The government should assess the potential of new technologies for industrial process innovation, including hydrogen and renewables, when setting out R&D priorities and opportunities in a Mid Century Strategy perspective to ensure the competitiveness of the Finnish industry.

Recommendations

The government of Finland should:

- Implement international benchmarking of the energy efficiency in industries, based on an evaluation and publication of best practice and results across the industrial sector.
- Assess the opportunities for investment in clean energy technologies in industrial process innovation as part of the Mid-Century Strategy to boost Finland's competitiveness.

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5. Buildings and district heating

Key data

(2016)

Final energy consumption in the residential sector: 5.3 Mtoe / 61.5 TWh (electricity 36.6%, district heat 31.9%, biofuels and waste 24.6%, oil 6.3%, natural gas 0.5%, peat 0.1%), a decrease by 3.3% since 2006

Final energy consumption in the commercial and public service sector: 2.9 Mtoe / 33.2 TWh (electricity 52.7%, district heat 34.4%, oil 8.7%, biofuels and waste 3.0%, natural gas 1.0%, peat 0.1%), an increase by +6.8% since 2006

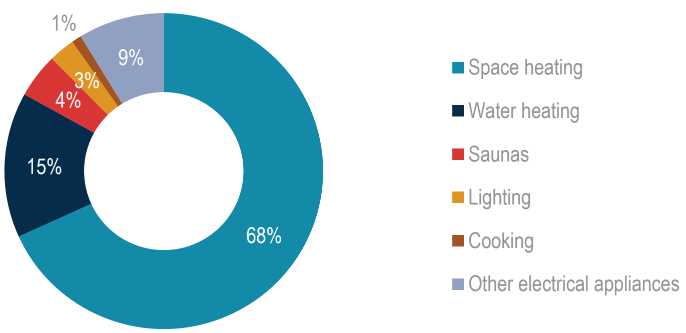
Share of TFC: Residential and commercial and public services 35.6%

Overview

Most of energy consumption in buildings is used for heating. In 2016, space heating accounted for two-thirds of total residential energy consumption, and water heating for another 15% (Figure 5.1). District heating (DH), often produced in co-generation plants, supplies over one-third of total energy consumed in buildings. In Finland, DH is dominating the heat supply in multi-dwelling buildings, whereas single-dwelling buildings are heated more with biofuels and electric heat pumps.

Finland's cold climate has encouraged the adoption of energy-efficient technologies and minimum efficiency performance standards for components used in new buildings. However, the building stock contains a large share of older buildings with poorer energy standards, and there is room for further efficiency improvements.

Figure 5.1 Residential energy consumption by sector, 2016



Source: OSF (2018a), Buildings and free-time residences, Appendix table 2. Energy consumption in households 2010-16, www.stat.fi/til/asen/2016/asen_2016_2017-11-17_tau_001_en.html.

Renewable energy sources have increased in the building sector, but the energy supply can be further decarbonised, not least in DH generation of which 57% still comes from fossil fuels. Finland uses energy and carbon dioxide (CO_2) taxes to promote renewable energy sources in DH, but the tariffs do not ensure efficient transformation towards low-carbon fuels, with e.g. tax exemptions for peat.

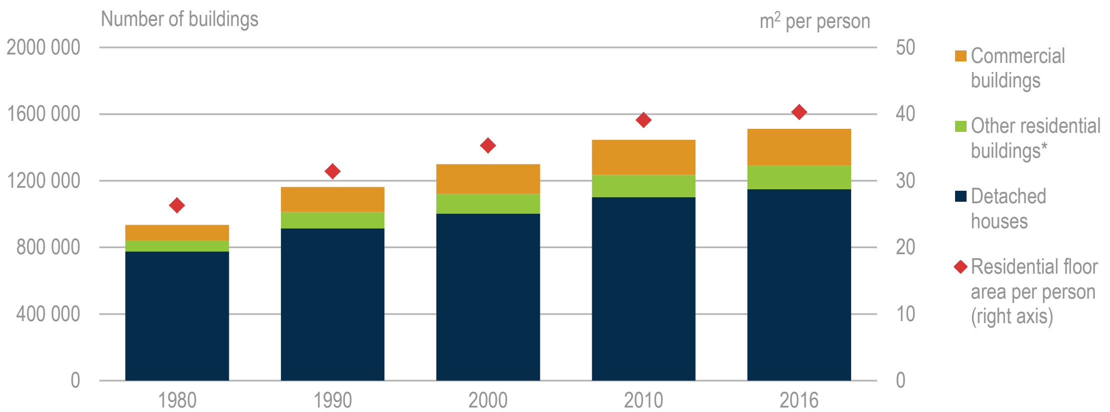
The DH market in Finland is unregulated, and customers can choose freely among other alternative heating technologies. As DH networks are natural monopolies, sufficient competition on the heat market must be ensured to avoid unfair prices.

Building stock

At the end of 2016, the building stock of Finland contained 1.5 million buildings. Of these, 85% were residential buildings, most of which were detached houses (Figure 5.2). Since 1980, the building stock has increased on average 1.3% per year. Besides the growth in number of buildings, the house sizes are also increasing. Average floor area per person among all building types increased from 26.3 m^2 in 1980 to 40.3 m^2 in 2016 (OSF, 2017).

Finland has also a large number of holiday cottages, which are not included in the building stock statistics. At the end of 2016, there were around half a million holiday residences in the country (OSF, 2018b). Another feature of the Finnish building stock is the large number of saunas inside, or in connection to houses. Saunas account for 4% of total residential energy consumption (Figure 5.1), using wood or electricity.

Figure 5.2 Number of buildings in Finland by type, 1980-2016



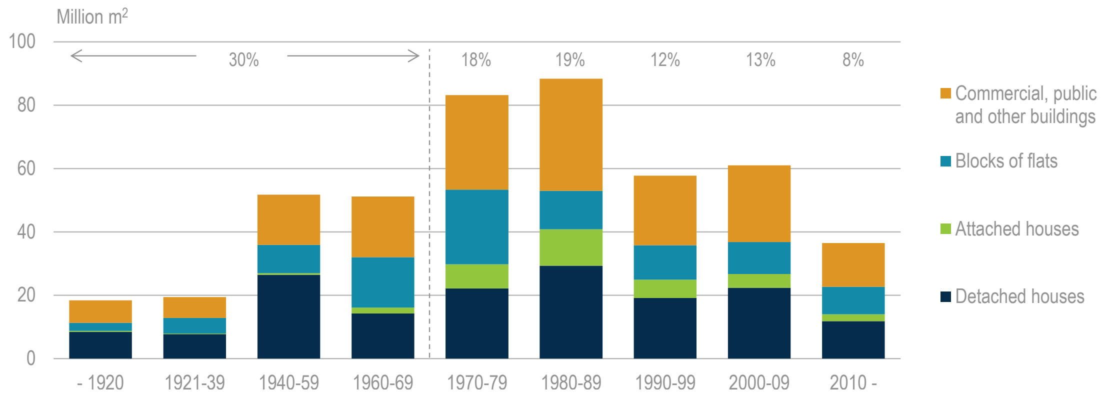
**Other residential buildings* include attached houses and blocks of flats.

Note: Free-time residences and agricultural buildings are not included in the statistics.

Sources: OSF (2018a), *Buildings and free-time residences, Appendix table 2. Number of buildings by intended use in 1980-2016*, www.stat.fi/til/rakke/2016/rakke_2016_2017-05-24_tie_001_en.html; OSF (2017), *Dwellings and housing conditions [e-publication], Appendix table 2. Floor area per dwelling by type of building 1970-2016*. www.stat.fi/til/asas/2016/asas_2016_2017-05-22_tau_002_en.html.

In terms of floor area, 34% is in detached houses, 21% in blocks of flats, 7% in attached houses, and 38% in commercial, public and other buildings (Figure 5.3). Construction peaked in the two decades 1970 to 1989, and has since declined. As of 2016, just above half the total floor area was in buildings constructed in 1980 and later, and one-third in the 1990s.

Figure 5.3 Floor area in buildings by building type and time of construction, 2016



Note: Buildings with unknown time of construction are not included (they account for around 1% of total floor area).

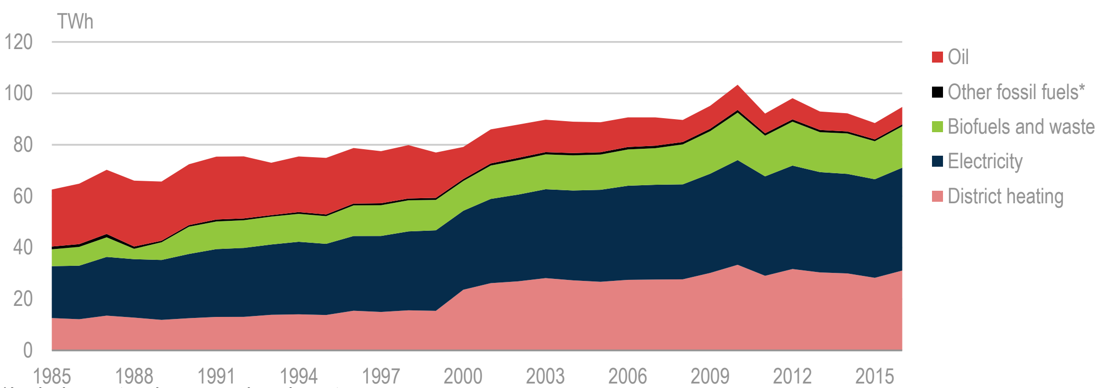
Source: OSF (2018b), *Statistics Finland's PX-Web databases, Housing – Buildings and free-time residences – 001 Number of buildings by intended use and year of construction on 31 Dec. 2016*, http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__asu__rakke/statfin_rakke_pxt_001.px/?rxid=88d39f46-45e5-4cf3-88ea-698e766d1f90.

Energy and emissions

Energy consumption in buildings

In 2016, total final consumption (TFC) of energy in the residential sector and the commercial and public service sector was 8.1 Mtoe, or 94.7 terawatt-hours (TWh) (see Figure 5.4). Despite the growth in the number of buildings, TFC has remained relatively stable around 90 TWh over the last decade, with annual variations due to weather conditions. The sectors have similar fuel mixes, but the residential sector consumes more biofuels (wood or wood pellets) and the commercial and public service sector uses a higher share of electricity.

Figure 5.4 TFC by energy source in the residential, commercial and public service sectors, 1985-2016



*Includes natural gas, coal and peat.

Notes: Includes energy consumption in commercial and public services, excluding agriculture, forestry and fishing.

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

Electricity and DH are the largest energy sources in buildings. In 2016, electricity accounted for 42% of TFC in the sectors; it is used in heating and in electrical appliances. Electrical heating includes electricity used in heat pumps, which utilise ambient heat to produce useable heat. Finland has a well-developed heat pump market (see Box 5.1). DH is the second-largest energy source with 33% of TFC in 2016, followed by direct use of wood fuels at 17%, and fossil fuels for the rest. In the decade 2006-16, electricity, DH and wood fuels increased by around 10%, while fossil fuels fell by 40%. A shift towards cleaner energy sources is thus taking place. However, direct use of fossil fuels still accounts for 8% of TFC in the sectors, most of which is fuel oil.

Residential space and water heating accounts for over 60% of energy consumption in buildings, and heating of commercial and public buildings accounts for another 20% (Figure 5.5). DH is used mainly in urban areas and is highly dominant in multiple-dwelling buildings, and in commercial and public buildings. Single dwelling residential buildings on the other hand, use mostly biofuels (wood fuels) and electricity (including for heat pumps). Most major cities with multi-dwelling buildings are located in the south and along the coast, whereas detached houses are more common in the north and inland. This gives a geographical spread in energy consumption. Fossil fuels (mainly fuel oil) accounts for 10% of total energy consumed in single dwelling houses and 17% in commercial and public buildings.

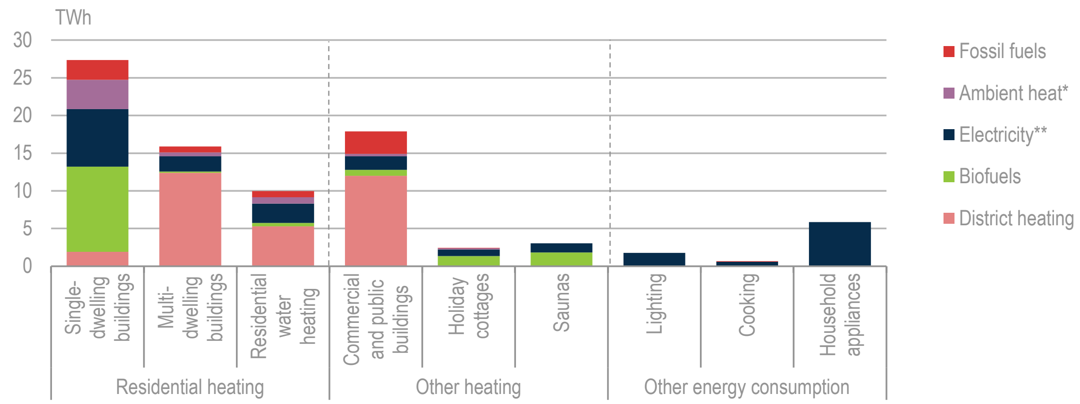
Box 5.1 Finland's heat pump market

Thanks to high efficiency and flexibility, heat pumps have become an attractive heating option in Finland, especially in houses not connected to DH networks. With 62 000 heat pumps sold in 2017 and around 850 000 installed heat pumps in total, Finland has one of the largest heat pump market in Europe in terms of heat pumps per capita (EHPA, 2018). As of 2016, heat pump installations are calculated to have brought energy savings of 5.5 TWh, and projections indicate 7.6 TWh of energy savings from heat pump installations by 2020 (FEA, 2017).

There are four types of heat pumps installed: air-air, air-water, ground source and exhaust air. Air-air heat pumps can be used in cost-effective retrofits of electrically heated houses, and is the most common technology, accounting for 76% of heat pump sales in 2017. Ground-source heat pumps have the highest efficiency factor among heat pump technologies, and are the second-most common type in Finland, with a 12% market share in 2017 (SULPU, 2018). Other types are air-water heat pumps and exhaust-air heat pumps. Heat pumps can produce roughly three times as much useful heat as consumed electricity, where efficiency depends on the outdoor temperature (lower temperature means lower efficiency) and on heat pump technology. An air-air heat pump in Finland is estimated to have a seasonal performance factor of around 2.5 and a ground source heat pump of around 3.5 (VTT, 2014).

Finland has promoted the heat pump market in several ways. Building performance standards are a main driver of the growth in heat pumps installed in new buildings and carbon taxation promotes low-carbon options for heating of both new and existing buildings. Furthermore, in 2001, Finland introduced a tax deduction scheme for various services provided to households, including work involved in installing heat pumps. A household may deduct 50% of the provided services from its personal taxation. Heat pumps are further promoted through information and communication campaigns financed by ministries, and via development projects (FEA, 2017).

Figure 5.5 TFC in buildings by type and by energy source, 2016



**Ambient heat* refers to energy extracted with heat pumps from the environment (ground, air or water) for space heating. Electricity spent by heat pumps in heating and cooling use is included in electricity consumption.

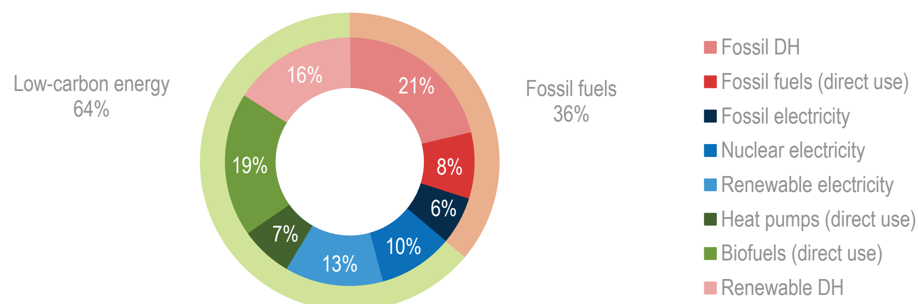
***Electricity* includes direct electrical heating, electric storage heating, electricity used by heat pumps and electricity consumed by heating systems and heat distribution equipment.

Sources: OSF (2018c), *Energy consumption in households 2016, Appendix table 2. Energy consumption in households by energy source in 2016*, www.stat.fi/til/asen/2016/asen_2016_2017-11-17_tau_002_en.html; FEA (2017) *NEEAP-4*, https://ec.europa.eu/energy/sites/ener/files/documents/fi_neeap_2017_en.pdf.

Fossil fuels and emissions

Over the last decade, the residential sector together with the commercial and public service sector accounted for less than 5% of direct total energy-related CO_2 emissions in Finland (excluding emissions related to electricity and DH). In 2016, the residential sector emitted 1.1 million tonnes (Mt) of CO_2 and the commercial and public service sector 0.9 Mt (IEA, 2018a). This includes only direct emissions that are not part of the EU Emissions Trading System (ETS), mainly from the use of fuel oil.

Figure 5.6 Renewable and fossil energy consumption in buildings, 2016



Notes: The chart includes energy for space and water heating and electricity for lighting, technical systems and household appliances, in residential and commercial buildings. Industrial buildings are not included. Only final energy consumption is presented. The chart does not take into account primary energy consumption and the transformation losses in heat and power generation.

Source: IEA analysis based on energy consumption data (OSF, 2018a and FEA, 2017), DH generation data (OSF, 2018f) and electricity generation data (IEA, 2018a).

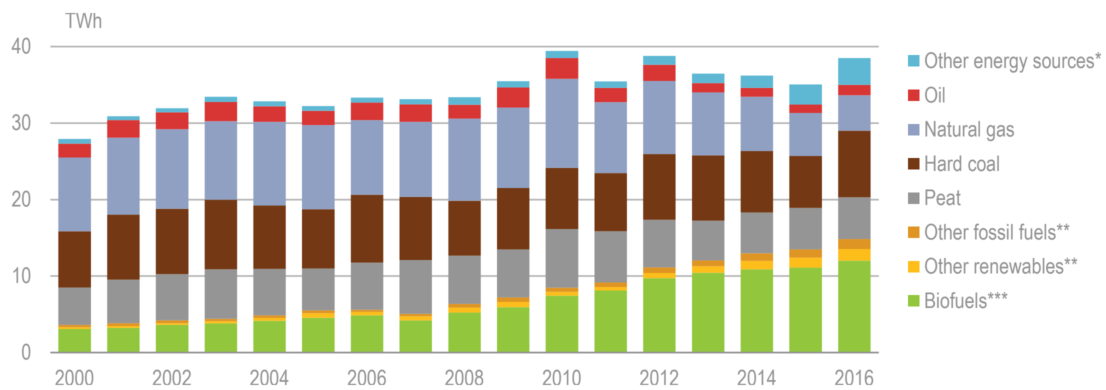
Emissions from heat and power generation are indirectly related to energy consumption in buildings, from the use of DH and electricity. Most of these emissions are included in the EU-ETS. In 2016, direct use of fossil fuels accounted for 8% of energy consumption in buildings. If indirect fuels used in electricity and DH generation are included, the share of fossil fuels used in buildings increases to 36% (see Figure 5.6). In this comparison, DH accounts for the largest share of fossil fuels and CO_2 emissions.

District heating supply and demand

In 2016, DH accounted for 37% of total energy demand in residential and commercial buildings (see Figure 5.4). Around two-thirds of DH is produced in co-generation plants with combined heat and power (CHP) production, which contributes to the high energy efficiency of the energy system. Over the last decade, biofuels and waste have increased significantly in DH production. However, a majority of the DH is still produced from fossil fuels, and the sector holds the key to further decarbonisation of the building sector.

Since 2010, annual DH production has been around 35 to 40 TWh, with yearly climate-related variations (Figure 5.7). In scenarios for 2020 and 2030 in the National Energy and Climate Strategy for 2030, DH demand is assumed to remain within the same size interval, with 40 TWh in 2020 and 38 TWh in 2030 (MEAE, 2017).

Figure 5.7 District heating production by fuel, 2000-16



**Other energy sources* include hydrogen, electricity and industrial surplus heat.

***Other fossil fuels* and *Other renewables* refer mainly to municipal and industrial waste.

***B*iofuels* includes solid wood fuels and a small share of black liquor from pulp and paper industries.

Source: OSF (2018d), *Production of electricity and heat* [e-publication], *Appendix figure 5. District heat production by fuels 2000-16*, www.stat.fi/til/salatuo/2016/salatuo_2016_2017-11-02_kuv_005_en.html.

In 2016, coal, peat,[9] natural gas and oil together accounted for 54% of total DH supply, down from over 80% in 2006. Over the last decade, natural gas decreased by half, whereas coal and peat only declined slightly. In the Strategy to 2030, coal is largely phased out in heat and power generation and is set to account for only 1-2 TWh fuel in heat plants and co-generation plants by 2030. Peat and natural gas are both projected to decline slightly to 7 or 8 TWh, whereas wood fuels increase to nearly 30 TWh and other renewables to 5 TWh.

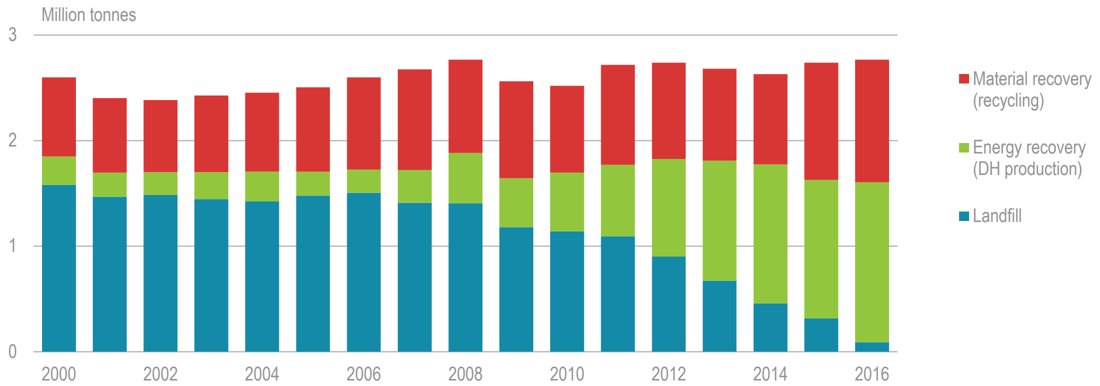
Biofuels accounted for 32% of DH generation, mainly wood fuel from large forest resources, besides a small share of black liquor from the pulp and paper industry. Over the last decade, DH from biofuels increased by nearly 150%, from 4.9 TWh in 2006 to 12.0 TWh in 2016, and biofuels accounted for nearly a third of total DH generation.

Waste incineration has also increased rapidly in recent years. In 2016, waste accounted for nearly 7% of total DH generation, up from around 2% ten years earlier, which has

9 Besides Ireland, Finland is the only country in the IEA that uses peat as a significant fuel in heating. Peat is a domestic resource that contributes to energy supply security, but it is also a source of high CO_2 emissions.

significantly reduced the waste that is put on landfills. In 2006, the share of municipal waste in Finland that ended up on landfills was 58%, which, ten years later, had fallen to 3% (see Figure 5.8). In accordance with the EU waste hierarchy and circular economy strategy, material recycling should be prioritised over energy recovery as a waste treatment method (EC, 2017). Incineration can therefore not increase much further, unless more waste is created or imported from other countries.

Figure 5.8 Municipal waste volumes by treatment method, 2000-15



Note: Energy recovery refers to waste incineration.

Source: OSF (2018e), *Waste statistics* [e-publication], *Appendix table 1. Municipal waste treatment in 2016*, www.stat.fi/til/jate/2016/13/jate_2016_13_2018-01-15_tau_001_en.html.

Electric heat and industrial surplus heat have also increased significantly in DH production in recent years. Data centres in particular have become an important source of industrial surplus heat in some DH networks. One example is Yandex's data centre which annually delivers around 20 gigawatts per hour (GWh) heat to the local DH system in the city of Mäntsälä, covering about half the city's DH demand (Patronen, Kaura and Torvestad, 2017).

District cooling

District cooling (DC) is a small industry compared to DH in Finland, but the demand is growing. In the five years 2011-16; DC sales increased by over 60%, from 126 GWh to 205 GWh (Euroheat and Power, 2017; FE, 2017). Commercial and public services account for most of the consumption, although demand for indoor comfort is increasing also in the residential sector. There are no governmental schemes for supporting DC and the market is unregulated. DC is competing with other cooling technologies on the market, mainly heat pumps, which also can provide cooling services.

DC is available in large cities, especially Helsinki, where the energy company Helen Oy produces cooling together with heating and electricity in the Katri Vala plant. This is the largest plant in the world to produce heat and cooling from heat pumps, with a capacity of 90 megawatts (MW) for heating and 60 MW for cooling. In 2016, Helen Oy delivered 141 GWh DC to over 400 buildings in Helsinki. The Katri Vala plant is an efficient tri-generation system that operates five heat pumps on heat from purified sewage water, district cooling return water and sea water. It also includes underground thermal storage.

In 2016, heat pumps accounted for 64% of total DC generation followed by free cooling at 22% and smaller shares of cooling produced in compressors and absorption chillers (FE, 2017).

Institutions, regulation and policy

Finland's Ministry of Economic Affairs and Employment (MEAE) has the overall responsibility for energy efficiency policy and co-ordinates the policy implementation across ministries and other institutions. The Ministry manages the implementation of EU directives into Finnish law and is responsible for the development and periodic review of strategy documents. In 2017, the ministry produced the National Energy and Climate Strategy for 2030, outlining the actions that will enable Finland to attain its targets adopted in the European Union for 2030 and set the course for 80% to 95% reduction in greenhouse gas (GHG) emissions by 2050 (MEAE, 2017).

EU framework and national implementation

The Energy Efficiency Directive (EED, 2012/27/EU) establishes a set of binding measures to help the European Union reach its target of 20% energy efficiency improvements by 2020 compared to 2005. In November 2016, the European Commission (EC) proposed updates to the EED. A political agreement was reached in June 2018 with Parliament and Council for an EU wide energy efficiency target for 2030 of 32.5% with an upwards revision clause by 2023.

Article 5 in the EED requires EU member governments to carry out annual energy-efficient renovations on at least 3% (by floor area) of the buildings they own and occupy. Finland has used energy efficiency agreements with local authorities to achieve the targeted savings. The agreements have included energy saving targets, development of energy efficiency plans and performance of energy audits on a large share of the local government building stock. In 2017, Finland launched a new energy efficiency agreement that extends until 2025 and that covers half the local governments in the country (in population terms).

Article 7 in the EED requires member states to introduce an energy efficiency obligation scheme for energy companies to ensure 1.5% savings in annual energy sales to final customers. The revised EED will rely on market-based and national measures. Finland has opted to take other policy measures to achieve an equivalent amount of energy savings, including national building codes and voluntary energy efficiency agreements (see below).

The Energy Performance of Buildings Directive (EPBD, 2010/31/EU) required all new buildings to be nearly zero-energy by the end of 2020, and public buildings by 2018. The EPBD was implemented in Finland by a regulation that came into force at the beginning of 2008. The Ministry of the Environment finances a national information campaign (Energy Efficient Home) that aims to encourage construction of nearly zero-energy buildings. In May 2018, the revised EPBD was adopted, which focuses more on supporting building renovations, through national decarbonisation roadmaps, long term renovation strategies, as well as utilising smart technology for building automation, including e-mobility and measures to save energy costs, notably for the energy poor.

Household appliances are subject to binding energy performance requirements under the Ecodesign Directive (2009/125/EC), implemented by Finland in law 19.12.2008/1005. The Ecodesign Directive's purpose is to increase energy-efficient products on the market and is complemented by the Energy Labelling Regulation (2017/1369/EU), which aims to encourage and empower consumers to buy the most efficient products.

National building codes and standards for new buildings

Since 1975, Finland has used a National Building Code to define minimum requirements for thermal insulation and ventilation in new buildings. The implementation of the EED and EPBD has led to successively tightened energy efficiency requirements for new buildings in Finland, supervised by the Ministry of the Environment. Measures such as triple-glazed windows and high performing thermal insulation for building components have become standard.

A building's energy performance is calculated as annual purchased energy divided by the heated indoor floor area. Energy performance requirements depend on the size and type of building, where larger residential buildings need to reach lower energy consumption per floor area, and some public buildings (e.g. hospitals) have less strict requirements. There are also building material requirements to limit heat loss from a building, specified by U-values[10] of the different surface areas (Finlex, 2017).

When calculating the energy performance, different energy sources are weighted by energy factors. On 1 January 2018, the government updated the energy factors as per Table 5.1. Fossil fuel consumption is weighted twice as high as renewable fuels or DH. Direct use of electricity has the highest energy factor, but can still be competitive when used in efficient heat pumps. The energy factors for district heating, district cooling and electricity were reduced in the recent update, to reflect the decarbonisation trends of heating, cooling and electricity generation.

Table 5.1 Energy factors used for building performance classification

Energy source	Energy factors 2013	Energy factors 2018
Electricity	1.70	1.20
District heating	0.70	0.50
District cooling	0.40	0.28
Renewable fuels	0.50	0.50
Fossil fuels	1.00	1.00

Sources: Finlex (2013), 9/2013, www.finlex.fi/sv/laki/alkup/2013/20130009; MoE (2017), *Energiformsfaktorerna för byggnader har setts över* [Energy factors for buildings have been reassessed], www.ym.fi/sv-FI/Aktuellt/Energiformsfaktorerna_for_byggnader_har_(45278).

Since 2011, instruments for measuring water consumption are compulsory in new apartment buildings. This enables individual billing according to actual consumption in each apartment and provides a direct price signal for dwellers to reduce their consumption of water and energy for water heating. In 2013, the requirement was expanded to repairs of the existing building stock.

Furthermore, a blending obligation of 10% share of bioliquids will be introduced for light fuel oil used in heating, which will partly offset emissions from fuel oil (MEAE, 2017).

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

Energy efficiency agreements and building renovations

Since 2008, Finland has used voluntary energy efficiency agreements as an important measure towards meeting the target set in article 7 of the EED. In the second programme period covering 2017-25, agreements are signed in four areas, including one for the property sector, in which the Ministry of the Environment, the Ministry of Economic Affairs and Employment, and the Energy Authority represent the government and the Finnish Association of Building Owners and Construction Clients (RAKLI) the industry.

Participants joining the Property Sector Energy Efficiency Agreement set an indicative energy savings target, based on a sectoral target of at least 7.5% energy savings for 2017-25, with an intermediate target of 4% for 2020. The Energy Efficiency Agreement has a monitoring system into which the participants report on their energy use and on the efficiency measures that they have taken each year (EEA, 2018).

In 2013, the government introduced specific energy performance requirements for deep renovations. The requirements apply to renovations that require planning permission, such as changes to the intended use of a building and the replacement of its technical systems. To further support building renovations, a subsidy programme was introduced in 2013, where property owners could apply for a support of 10% of renovation costs. The programme cost was EUR 115 million (Euros) over two years. Since 2014, the subsidies are no longer granted.

DH market and regulation

There are around 100 DH companies operating 15 000 km of pipelines in 400 networks in Finland (Euroheat and Power, 2017). Most DH suppliers are small municipal companies that deliver heat to local customers, but some larger companies that own and operate several DH networks are also present on the market. In 2015, the ten largest suppliers accounted for over half the total DH in the country. Helen Oy (owned by the city of Helsinki) operates the Helsinki network and is the largest DH supplier with around 6 TWh heat sold. Fortum (listed company with Finnish state as largest owner) is the second-largest DH supplier with close to 3 TWh heat delivered in six networks.

DH networks differ from electricity and gas networks in that they are local and supplied by one producer that normally also owns the distribution grid. Customers are thus unable to switch DH suppliers, and DH networks can be considered natural monopolies. Many countries regulate DH prices and access to the network to protect customers from misuse of monopolistic power. Finland's DH market, however, is unregulated, and DH is considered to compete on a free market with other heating technologies, such as heat pumps. DH companies are free to set the price and customers are free to choose the heating solution they want.[11] Unregulated DH markets are not common. Among neighbouring Nordic countries, only Sweden has the same approach to DH regulation, whereas Norway and Denmark use different price regulation models (Box 5.2).

11 There is an exception through article 57a in the Land Use and Building Act, which states that a municipality can decide that all buildings inside a certain area have to be connected to the DH network, unless the individual heating source is 40% more energy_efficient or supplied with renewable energy sources. The Association of the Finnish Energy Industries has recently asked the gernment to start the process to delete this article.

Box 5.2 DH regulation in other Nordic countries

DH regulation differs in the Nordic DH markets. As in Finland, Swedish DH prices are unregulated, whereas Norway uses an alternative heating cost model and Denmark moves towards a regulatory model based on benchmarking.

Sweden deregulated its DH sector together with other energy markets in 1996. DH competes with other heat sources on a free market and customers are free to choose other heat supplies. Instead of price regulation, DH companies and consumer groups participate in *Prisdialogen* [the price dialogue], a business collaboration to improve transparency and customers' market power. High taxes on fossil fuels and good access to domestic biofuels and waste resources have led to a substantial shift in DH supply, which is much less dependent on fossil fuels than in Finland.

Denmark's DH market was based on mainly small municipal companies operating on a non-profit principle. In 2015, studies ordered by the government showed that the DH sector has a large potential for becoming more cost-efficient. Following these studies in 2016, a broad political coalition decided on a target to achieve DKK 0.5 billion (Danish kroner) in cost savings in the DH sector by 2020. Costs are to be saved through consolidation of the many small suppliers into larger entities, and by introducing a market benchmarking system to evaluate and improve the efficiency of the companies. The new regulatory regime aims to encourage a marked-based development of the sector.

In **Norway**, cheap access to renewable hydropower has made electricity dominant in heating. However, the DH market is growing rapidly, mainly supplying heat to the service sector. Municipal waste is the largest fuel in DH generation and a landfill ban from 2009 has been a major driver of DH development. DH prices are regulated on the basis of the alternative cost of heating, which for Norway means electricity. A similar price regulation system is used in the Netherlands, where it is based on the price for natural gas.

Sources: IEA (2017b); Patronen, Kaura and Torvestad, (2017).

The Finnish Competition Authority (FCA) can initiate investigations if they suspect that a DH company is charging unreasonable high prices or otherwise abuses its dominant market position. Between 2009 and 2012, the FCA carried out the most recent inquiry with regard to DH prices set by the ten largest DH suppliers over the period 2004-08. Although the inquiry concluded that the average price level was high with regard to the risks and profitability of the businesses, no clear abuse of market power could be demonstrated (FCA, 2012). Since 2012, the FCA has not taken up any new investigation of the overall competition on the DH market. Allowing for third-party access (TPA) to DH networks is another way to increase competition on the market. In Finland, TPA is not guaranteed by law. DH networks are owned by the energy companies, and a third party who wishes to conduct business on the network needs to negotiate the terms with the owner.

Taxes and prices

Fuel taxation and subsidies

Finland was an early adapter of carbon taxation. Fuels used in heat production are taxed on the basis of their energy content and CO_2 emissions (Table 5.2). Peat, however, is exempt from CO_2 taxation and only imposed a small energy tax of 1.90 EUR/MWh. This makes peat, which is a domestic resource, more competitive compared to other fossil fuels. Furthermore, fuels used in co-generation production have a 50% tax reduction of the CO_2 tax component to avoid an extra burden for installations already included in the EU-ETS.

In 2013, Finland introduced a feed-in premium system for woodchips used in electricity production. This affects mainly co-generation plants that also impact the fuel choice for DH production. The support system has been designed to make woodchips competitive with peat in co-generation, and the premium paid is related to the production cost of peat-based power generation (Finlex, 2010).

Table 5.2 Fuel taxation, 2018

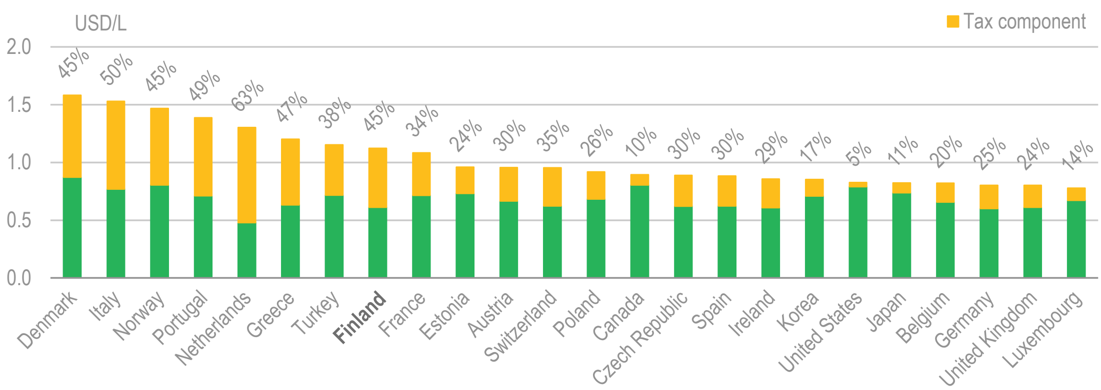
Energy source	Energy tax	CO_2 tax	Stockpile fee	Total tax
Hard coal (EUR/tonne)	53.13	149.56	1.18	203.87
Natural gas (EUR/MWh)	7.50	12.28	0.084	19.86
Peat (EUR/MWh)	1.90	0	0	1.90
Pine oil (cent/kg)	28.92	0	0	28.92
Electricity* (EUR/MWh)	6.9-22.4	0	0.13	7.03-22.53

*Electricity taxes differ for two tax classes, where industries pay the lower price and households the higher.
Source: Finlex (2018).

Household fuel oil price and taxation

Finnish households pay a relatively high price for fuel oil compared to other IEA member countries (see Figure 5.9), mainly because of high taxes. In the third quarter of 2017, the price was 1.0 USD/litre (United States dollars), of which 45% was tax.

Figure 5.9 Household light fuel oil price in IEA countries, second quarter 2018



Note: Data not available for Australia, Hungary, Mexico, New Zealand, the Slovak Republic and Sweden.
Source: IEA (2018b), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

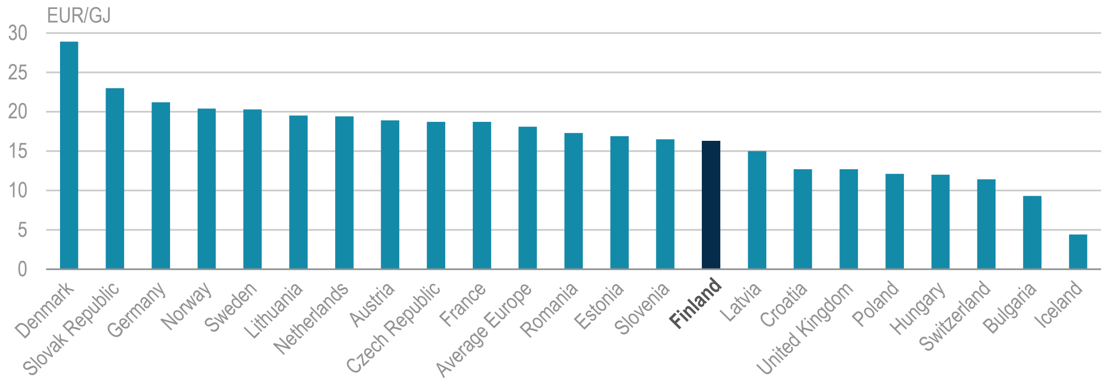
Fuel oil was still around 25% to 30% more expensive in Nordic neighbouring countries Norway and Denmark, as a result of higher fuel cost and higher taxes.

Energy poverty is a small, yet existing problem in Finland. According to the Finnish Home Owners' Association, around 5% of house owners cannot afford to retain sufficient temperature in the whole house, and many households keep lower indoor temperatures in some rooms to save energy.

DH prices

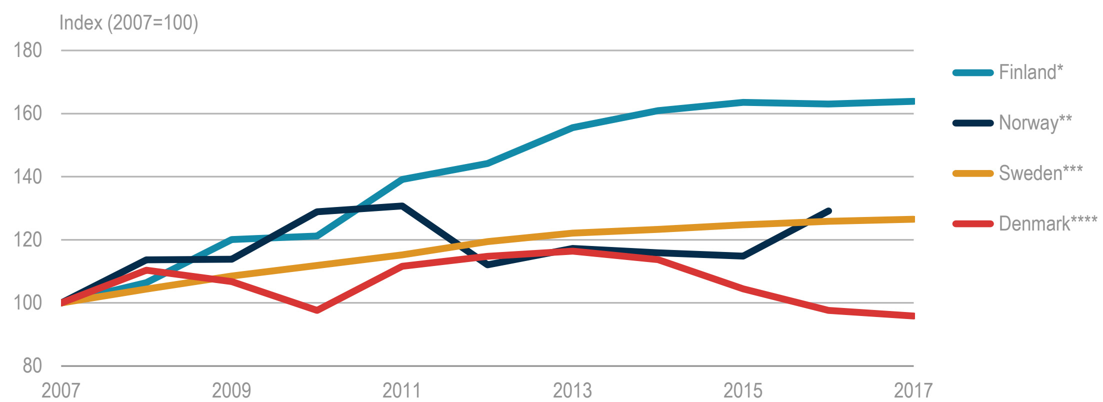
DH prices can vary significantly between local networks in the same country, and there is no database with updated international DH prices. In a study from 2016, Werner (2016) compared European DH prices in time series from 1990 to 2013 (Figure 5.10). In this comparison, Finland had the lowest price among the Nordic countries, 20% below Sweden and Norway and 44% below Denmark. Lower prices can partly be explained by cheap access to fuels. Finland has more domestic access to biofuels and peat than Denmark and lower fuel taxes than Sweden. In the recent decade, Finland's DH prices have increased compared to the other Nordic countries which have reduced the large differences from 2013 (see Figure 5.11).

Figure 5.10 DH prices in European markets, 2013



Source: Werner (2016), *European District Heating Price Series*.

Figure 5.11 DH price development in Nordic countries, 2007-17



*Different price series 2007-10 (detached house 20 MWh/year) and 2011-16 (detached house 18 MWh/year).

**Average price of total DH delivered to all end-consumers. No data available for 2017 at the time of writing.

***Average DH cost per square metre in a 1 000 m^2 apartment building.

****Weighted average DH price for standard house of 130 m^2 (18.1 MWh/year).

Note: This is a comparison of average DH prices for a typical customer, which is defined differently in the different countries. It does not take into account local price variations, inflation or differences in taxes.

Sources: IEA (2017b), Denmark 2017 Review; Dansk Fjernvarme (2017), Fjernvarmeprisen i Danmark 2017; Statistics Norway (2017), Fjernvarme og fjernkjøling; Nils Holgersson (2017), Rapport 2017; OSF (2018f), Price of District Heating by Type of Consumer.

Assessment

Building codes set high energy performance standards for new buildings, but energy efficiency can improve further, particularly in the older building stock.

The Finnish building stock is built to cope with the cold climate of the country. Since 1976, energy performance standards have been part of the building codes, with continuously stricter requirements for building components and for the energy supply. With the nearly zero-energy requirements of the EU Energy Performance of Buildings Directive (EPBD), new buildings will continue to adopt higher energy performance standards over time. The government should monitor the effects of the regulation to ensure that it continues to steer towards more efficiency and low-carbon energy sources in a modern energy system. In particular, the energy factors need to reflect the environmental impact of the different energy sources.

As the building codes regulate the energy performance in new buildings, more focus should be towards the existing building stock. Over a third of Finland's total building floor area was constructed before 1975, before energy performance standards were introduced in Finnish law. A renovation subsidy was in place in 2013-14, but the support was not continued. The government should consider new policy measures to improve energy performance of existing buildings to match the high standard required for new buildings. As an example, the tax deduction scheme for household service work could be directed more towards renovations that improve the energy efficiency of buildings. Furthermore, the government should follow up the effects of the water-metering requirement, to ensure that the intended energy savings are reached.

Energy performance requirements and taxes on fossil fuels promote renewable heat sources in Finnish buildings. However, oil heaters have kept a share of energy consumption, especially in poorer households that cannot easily invest in alternative heat sources. Blending requirements for biofuels in light fuel oil will support more renewable fuels, but they will only replace a small share of the fossil oil. Taxes on fuel oil consumption are relatively high compared to the IEA average, but lower than in the other Nordic countries, and there is room for carbon taxation to further steer consumption. To accelerate the transition towards low-carbon fuels, the government should consider a timeline for the phase-out of fuel oil for heating so as to provide a clear direction for building owners. Such a timeline should be communicated well in advance and could be complemented by a subsidy targeted on lower-income households to protect vulnerable consumers.

Carbon taxation is driving a fuel shift in DH, but the pace of the transition is limited by tax exemptions, and the role for peat is particularly unclear.

DH accounts for around 40% of heating in buildings, and the DH sector contributes the largest share of CO_2 emissions related to buildings. Energy and carbon taxation have led to a rapid increase of biofuels that accounts for nearly a third of total DH generation. However, fossil fuels still account for over half DH generation, and only natural gas has declined significantly in recent years. In Sweden, with similar conditions of DH infrastructure and biomass resources as Finland, fossil fuels play a very minor role in DH supply. Finland should increase its efforts to replace fossil fuels in DH generation so as to achieve its long-term climate targets.

Carbon-based energy taxation is an efficient policy mechanism to encourage fuel switching in the DH sector, but tax exemptions hinder this development. In order to encourage the transition to renewable energy sources, energy taxation should reflect the net CO_2 emissions of each energy source. Peat in particular is subject to lower taxation in comparison to other fuels. As a domestic fuel, peat contributes to the energy security of the country, but so do domestic biofuels and other renewable energy sources. Peat is not a renewable fuel and burning it produces as many CO_2 emissions as other fossil fuels such as lignite. The government should level the playing field for heating technologies and fuels, and focused on carbon impact and efficiency.

Wood fuels can often replace coal and peat in heat and power plants, but other sectors can start to compete more for the domestic biomass resources, such as when production of advanced transport biofuels make progress. A clear strategy for the use of domestic biofuel resources should be developed and aligned with targets and actions set out in the NECS-2030. DH from waste incineration has also increased rapidly in the last decade. However, it cannot grow much further as EU requirements for recycling will limit the share of waste that goes to incineration in the future. Long-term strategies for waste management and DH development should be co-ordinated, in collaboration with the industry and other relevant stakeholders.

Other options for replacing fossil fuels in DH are through an increased use of heat pumps and industrial waste heat. Finland has one of the largest heat pump markets per capita in the European Union, driven by increased DH prices and fossil fuel taxation. Heat pumps are mainly used as alternatives to DH in detached houses, but they can play a more important role also in DH networks and increase the integration between the heat and electricity systems. Efficient energy systems integration should be encouraged, and systems such as the Helsinki tri-generation production can act as a role model. Further growth in the heat pump market should also be combined with increased efforts to decarbonise electricity generation.

As more industries with surplus heat resources establish in Finland, e.g. data centres, the potential for more efficient DH and DC networks grows. The government should assess ways to encourage third-party access to Finnish DH networks without interfering with DH companies' ability to make profit.

The unregulated DH market allows for free competition among heat sources, but a scattered and monopolistic market can create inefficiencies in the sector.

Finland has chosen a free market approach to DH regulation. Prices are set by the companies that compete with other heating technologies, such as heat pumps and wood boilers. Customers are generally not obliged to connect to DH networks and DH customers are also allowed to disconnect without additional fees. There are thus no regulatory barriers to switching, and the large heat pump market in Finland represents an alternative to DH, especially in detached houses. DH prices have also historically been low in comparison with neighbouring countries. Nevertheless, the Finnish Competition Authority (FCA) should regularly use its capacity to check if monopoly positions are misused in the DH sector. The latest review by the FCA in 2009-12 did not find evidence of misuse of monopoly power. However, the review concerned the period 2004-08, after which Finnish DH prices have increased rapidly, more than in other Nordic DH markets. The recent price development indicates that there could be reason for another review by the FCA.

Finland's DH market is scattered in many small and local companies. Studies in Denmark showed large potential efficiency gains from consolidation of DH companies, which could be the case also in Finland. On a free and competitive market, company consolidation should be a business decision. Nevertheless, the government could assess the potential for increased efficiency in the sector and consider ways to promote co-operation between DH companies, without interfering with the free market competition.

Recommendations

The government of Finland should:

- Adopt policies and support measures, e.g. grants or tax rebates, to speed up the retrofit of the older building stock to bring it up to modern Finnish standards. Consider further promoting the phase-out of fuel oil in heating, including through a switch to renewable alternatives.
- In light of the coal phase-out, review the fuel taxation, regulation and building code design to ensure a level playing field between different technologies and fuels in the heating sector, with a clear focus on low-carbon energy sources. Specifically, remove the tax exemption for peat.
- Utilise the mandate of the Finnish Competition Authority to increase the oversight of district heating network competition to ensure a well-functioning and efficient heat market. Furthermore, promote co-operation among smaller DH companies to increase the efficiency of the sector without interfering with market competition.

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6. Transport

Key data

(2016)

Final energy consumption in transport: 4.3 Mtoe (oil 94.3%, biofuels 4.1%, electricity 1.4%, natural gas 0.2%), -2.4% since 2005

Share of total final consumption: 16.6%

Share of energy-related CO_2 emissions: 27.1%

Overview

Despite the government's stated policy ambitions to significantly increase biofuel use and some remarkable growth in recent years, transport remains the most carbon-intensive sector of the Finnish energy system, accounting for over a quarter of energy-related carbon dioxide (CO_2) emissions in the country.

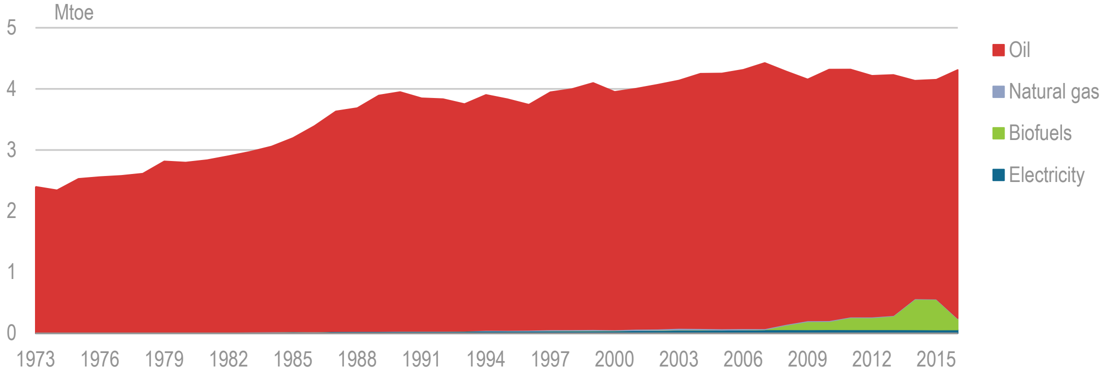
Besides the targeted increase in biofuel use, Finland identified several strategies to meet the binding EU targets for annual greenhouse gas (GHG) emissions reductions for 2021-30 for sectors that are outside the scope of the EU Emissions Trading System (ETS) providing a large role for the transport sector. These strategies rely on the increase in low-carbon fuels, policies aiming to limit the growth in the number of cars in circulation, reducing the number of car trips made by individuals (including a remarkable policy framework on "Mobility as a Service"), and measures aiming to increase the share of electric mobility.

Regarding low-carbon fuels, it is critical to ensure that their uptake relies on feedstocks produced by using sustainable practices, focusing on low-carbon fuels with high emissions reduction performances. Policy action is critical to ensure that "Mobility as a Service" is effectively delivering towards the goals of the new policy framework. Finland's transition to low-emission vehicles, notably electric vehicles, can be strengthened, in line with the global leadership of the Nordic region. New models are introduced to the Nordic market as the region relies on a power generation mix with a carbon intensity well below the EU average.

Energy use in transport

In 2016, the transport sector accounted for 17% of total final energy consumption (IEA, 2018a). Energy consumption in the sector peaked at 4.4 Mtoe in 2007 and has since declined only slightly to 4.3 Mtoe (see Figure 6.1). In addition, international marine bunkers accounted for 0.3 Mtoe, and international aviation bunkers for 0.6 Mtoe.

Figure 6.1 TFC in transport by source, 1973-2016



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

The vast majority of transport energy consumption comes from oil products. In 2016, oil accounted for 94.3% of total energy consumption in domestic transport (excluding international bunkers). Although still dominant, the share of oil in transport has decreased from 98% in 2005 as a result of a rapid increase in biofuels in the fuel mix.

Biofuels increased from negligible levels in 2005 to 0.5 Mtoe in 2015, accounting for 12% of transport energy consumption. However, in 2016, the share of biofuels in the sector fell to 4.1% after a 75% drop in renewable diesel consumption. Fuel distributors have biofuel blending obligations that can be fulfilled in advance, which can lead to annual variations in the biofuel supply and explain the sharp drop in 2016 (Statistics Finland, 2017).

Finland has a large biodiesel market. In 2016, renewable diesel accounted for 62% of total transport biofuel consumption and it can be blended without limitations. This is a remarkable development given that today renewable diesel production in Finland is largely based on hydrotreating of oils and fats that are for the vast majority categorised as waste and residues.[12] Biogasoline accounts for the rest of transport biofuels.

The remaining share of transport energy is made up of electricity, mainly used in rail transport, complemented by a small share of natural gas used in road transport.

GHG emissions

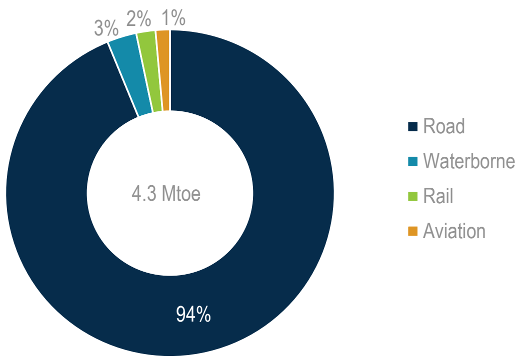
The transport sector accounts for over a quarter of Finland's energy related CO_2 emissions, and almost one third if international marine and aviation bunkers are included (IEA, 2018b). Furthermore, the transport sector accounts for 40% of the GHG emissions that are not included in the European Union Emissions Trading System (ETS) (Ministry of Transport and Communications, 2016).

[12] Neste Corporation produces a renewable paraffinic diesel fuel at worldwide capacity of 2.6 Mtoe/year. In 2016, almost 80% of Neste's global renewable diesel production was based on waste and residue raw materials. The Finnish pulp and paper company UPM also produces approximately 0.12 Mtoe annually of hydrotreated renewable diesel from crude tall oil (IEA AMF, 2016).

Drivers of energy demand and GHG emissions

Road transport accounted for 94% of total domestic transport energy demand in 2014, with the remaining shares made up of shipping, aviation and rail transport (see Figure 6.2). The largest share of energy demand for road transport comes from passenger cars, followed by freight vehicles and small shares of buses and motorcycles.

Figure 6.2 Transport energy consumption by mode of transport, 2016



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

The structure of energy demand in road transport is consistent with the very large share (more than 90%) of cars and light commercial vehicles in the total travel activity (expressed in vehicle kilometres (vkm)) (Saarinen, Eilittä and Laurikko, 2017), and the higher fuel use per kilometre of trucks and buses.

During the period 2005 to early 2010s, energy demand in transport has plateaued thanks to stabilised road transport vehicle km (Saarinen, J. et al. 2017) combined with better fuel economy rates for light-duty vehicles (LDVs) (EEA, 2018). This development was accompanied by increasing diesel use. The share of diesel-powered LDV sales resulted in a larger portion of diesel fuel demand in total road transport (almost two-thirds in 2015) than a decade earlier, when diesel accounted for roughly 50% of the road fuel demand (IEA, 2018a). On a per capita basis, energy use for road transport in Finland is similar to the consumption observed in Denmark and Norway, and lower than in Iceland and Sweden.

EU policy framework relevant for transport

As an EU member state, Finland implements EU measures that have direct implications for energy use and GHG emissions from transport, including:

- The “Euro” emissions regulations, setting limits on the emissions of local pollutants from transport vehicles. First established in 1993, these limits have been tightened progressively over time and are now at the Euro 4 phase for motorcycles, Euro 6 for light duty road vehicles, and Euro VI for heavy-duty road vehicles.
- Regulations setting emission performance standards in terms of CO_2 emissions/km for new passenger cars (443/2009) and vans (510/2011).

- Testing procedures, including improved laboratory test (World Harmonised Light-Vehicle Test Procedure – WLTP), updating the earlier provisions of the New European Driving Cycle for the estimation of pollutant and GHG emissions, and pollutant emissions tests in real driving conditions (Real Driving Emissions – RDE).
- The Renewable Energy Directive I (RED) mandates at least 10% of all energy in road transport fuels to be produced from renewable sources by 2020 (2009/28/EC). The 2009 amendment of the Fuel Quality Directive (FQD) requires the road transport fuel mix in the European Union to be 6% less carbon-intensive than a fossil diesel and gasoline baseline by 2020 (2009/30/EC amending 98/70/EC, consolidated here). Sustainability criteria were introduced in 2015 (based on amendments to the RED and FQD) in response to concerns about the impacts arising from crops grown for conventional biofuel production on indirect land use change (ILUC) (2015/1513). The EU limits the contribution from biofuels produced from crops that could be used for food production to 7% of the overall European Union 10%.
- The Directive on the Deployment of Alternative Fuels Infrastructure (AFI) (2014/94/EU) and a communication (Action Plan) to the European Parliament (COM(2017)652).
- The revised Energy Performance of Buildings Directive (amending 2010/31/EU) will provide for minimum requirements to facilitate the installation of electric vehicle chargers in new and refurbished buildings and in public parking lots (adopted on 14 May 2018).
- The regulation sets conditions under which compensation payments for public service contracts and concessions for public service obligations in public passenger transport services are compatible with the rules of the internal market (1370/2007).
- The Renewable Energy Directive II (2030) promotes biofuels to account for at least 14% of transport fuels by 2030, while capping food-crop biofuels at 7% of the energy used in road and rail transport after 2020, and phasing out food-crop biofuels with high ILUC (through a new certification process). RED II promotes shares of advanced biofuels and biogas of 1% in 2025 and at least 3.5% in 2030 (date: June 2018).
- The amended Electricity Market Directive provides for dynamic pricing to facilitate smart charging, and the aggregation of EVs to enable the best use of their economic potential from demand response – including vehicle-to-grid services (date: June 2018).

The EU Clean Mobility Package proposed measures in 2017 and 2018 including:

- Tighter regulations on CO_2 emissions per km for cars and vans, with a 30% improvement target between 2021 and 2030, including incentives for the production of components and deployment of zero-emission vehicles in the European Union (Battery initiative, EC, 2017).
- The CO_2 emissions and fuel consumption of new heavy-duty vehicles (HDVs) need to be monitored and reported. Emissions from HDVs have to be reduced, by 2025, by 15% below 2019 levels, and also by 2030, with a review in 2022 to consider a mandatory target (30% vs. the 2019 baseline), including incentives to low- and zero-emission vehicles (EC 2018).
- The use of distance-based pricing, differentiated by CO_2 emission performances (and pollutant emissions for light vehicles), and the application of congestion charges.
- The promotion of the uptake of clean vehicles through public procurement.
- The stimulation of multimodal integration through the combined use of trucks and other modes of transport (including trains, barges and ships) for the transport of goods.
- Connected and automated mobility to promote autonomous and safe mobility systems.

National measures

EU member states are fully responsible for policies and measures limiting GHG emissions from the sectors of the economy not falling under the EU-ETS. In Finland, transport is the most prominent sector. The Ministry of Transport and Communications has the main responsibility for the development of transport-related energy and climate policies. The National Energy and Climate Strategy for 2030 and the related Medium-term Climate Change Policy Plan for 2030 (Ministry of the Environment, 2017) set key objectives to meet the GHG emissions reduction objectives in sectors outside the EU-ETS (TEM, 2017a).

The Government Programme of Prime Minister Sipilä set out the ambitious target of halving oil product demand and increasing the share of renewable transport fuels to 40% (23.5% of the fuel energy content) by 2030. The National Energy and Climate Strategy for 2030 anticipated GHG emissions reductions to materialise in three main areas: transport system level changes, improvements in vehicle energy efficiency and increased use of renewable fuels by:

- changing the organisation of transport services through the concept of "Mobility as a Service", public transport and cycling, thus reducing the reliance on private vehicles
- deploying EVs to improve vehicle efficiency and reduce carbon intensity of the transport energy mix, especially for short-distance road modes and urban mobility
- increasing the role of advanced low-carbon biofuels, notably for long-distance transportation with the aim to reduce the carbon intensity of the transport fuel mix.

The actual GHG emissions savings estimated in the Strategy correspond to:

- 1 Mt from measures that reduce transport demand at a system level, or change the modes of transport to increase efficiency; this includes expectations of a 30% increase in the number of journeys taken by walking and cycling.
- 0.6 Mt from measures that improve the efficiency of vehicles, including the deployment of 250 000 electric vehicles and 50 000 gas vehicles.
- 1.6 Mt from the replacement of fossil fuels with biofuels, with a blending target (excluding double counting) for renewable energy sources of 30%.

In 2017, the Ministry set up a parliamentary working group to identify policy measures to implement these targets, including the required changes in taxation and legislation in addition to state aid and other measures,[13] and create preconditions for digital transport services and the automation of transport (LVM, 2017a).

[13] In April 2018, the Ministry of Transport and Communications has also set a new working group to investigate different ways to eliminate GHG emissions from the transport sector by 2045. This working group will present three different scenarios, which each will lead to the zero-emission target that has been set. One of the scenarios will be based on biofuels, a second one on a range of different technologies. The third scenario will be based on a radical change of the whole traffic system and the habits of people's moving patterns. The working group will also present measures and impact assessments for these objectives, taking into account the economic growth potential of different measures in Finland. The final report of this working group will be released in November 2018. This work

Following an interim report of August 2017, several measures have already been included in the 2018 state budget: the Finnish government agreed to adopt, for example, an investment programme which aims to support citizens in purchasing EVs and converting old cars for alternative fuels (EUR 6 million/year for the period 2018-21). The government is targeting additional public funds for public charging infrastructure (EUR 3 million/year for the period 2018-21) and in residential buildings (EUR 1.5 million/year for the period 2018-21).

The following sections of this assessment will look more closely at the measures envisaged to meet the GHG emissions reductions identified by the Strategy, focusing on the three main action areas of: A) Transport system level changes including mobility as a service, B) Improvements in the energy efficiency of transport vehicles, and C) Increased use of renewable fuels.

A. Changing the transport system

The Finnish government intends to manage the growth in travel activity and modal choice in a way that could limit energy demand and deliver net GHG emissions savings. The co-ordination of transport and land-use planning and the promotion of walking, cycling and public transport are key pillars (TEM, 2017a; Ministry of the Environment, 2017). The Medium-term Climate Change Policy Plan for 2030 mentions several key measures enabling a change in the transport system, including:

- The use of municipal land policy and land-use planning instruments in a way that ensures co-ordination between land use for housing, services and economic activities, and the development of the public transport system.
- The promotion of infill construction and the development of regional centres and sub-centres integrating the development of public transport nodes.
- The need to steer the location of jobs and services around these nodes.

These efforts include the revision of the Land Use and Building Act, reforming the national land-use guidelines, and promoting agreements on land use, housing and transport to contribute to climate change objectives.

The promotion of walking and cycling and the effective utilisation of public transport have also received more attention. In March 2011, the Ministry of Transport and Communications published a National Strategy for Walking and Cycling 2011–2020), and the Finnish Transport Agency published a national action plan for implementing the strategy in early 2012. Both aim to increase the share of journeys undertaken on foot or by bicycle – in 2020 at least 20% more journeys should be made on foot or by bicycle than in 2005 (Ministry of the Environment, 2017), and 30% more journeys by 2030. The 2030 target was confirmed in the programme for the promotion of walking and cycling released by the Ministry of Transport and Communications in 2018. This programme outlines key measures for this purpose, including the development of infrastructure and land use, allocating funds for the promotion of walking and cycling and shaping public

intends to help the discussion of transport sectors emission targets in the long term and the decisions of the next governments.

opinion regarding people's patterns of physical activity (Ministry of Transport and Communications, 2018).

The Medium-term Climate Change Policy Plan for 2030 also refers to an allocation of EUR 2 million (Euros) in the central governmental budget for 2018 to increase contractual rail transport services (Ministry of the Environment, 2017).

Finland has a strong focus on public transport and is implementing the Public Transport Act, developed in 2009, to comply with the requirements of the EU Regulation on public service obligations. The Act focuses on ways individuals can approach mobility, anticipating the changes coming with Mobility-as-a-Service (MaaS). Examples of measures introduced with the Public Transport Act include a nation-wide ticketing system, and a schedule and journey-planner service. Another development that promotes public transport, walking and cycling (and anticipated more recent developments on MaaS) is the mobility management concept. This offers better information about alternative transport modes and more attractive services to encourage the use of public transport, cycling, walking, car-pooling and car-sharing. The concept has been supported through research and development (R&D) calls for projects, and through a support programme of EUR 0.9 million under the 2015 and 2016 budgets.

At the level of cars, energy efficiency of heavy-duty vehicles can be improved by allowing larger trucks on the road (resulting in a lower amount of energy required per tonne/km [tkm]). In 2013, the Ministry of Transport and Communications prepared a decree on new maximum masses and dimensions of heavy goods vehicles and vehicle combinations (407/2013). The decree raises the maximum allowed height of a vehicle from 4.2 metres to 4.4 metres and the maximum allowed mass from 60 tonnes to 76 tonnes (Ministry of the Environment, 2017).

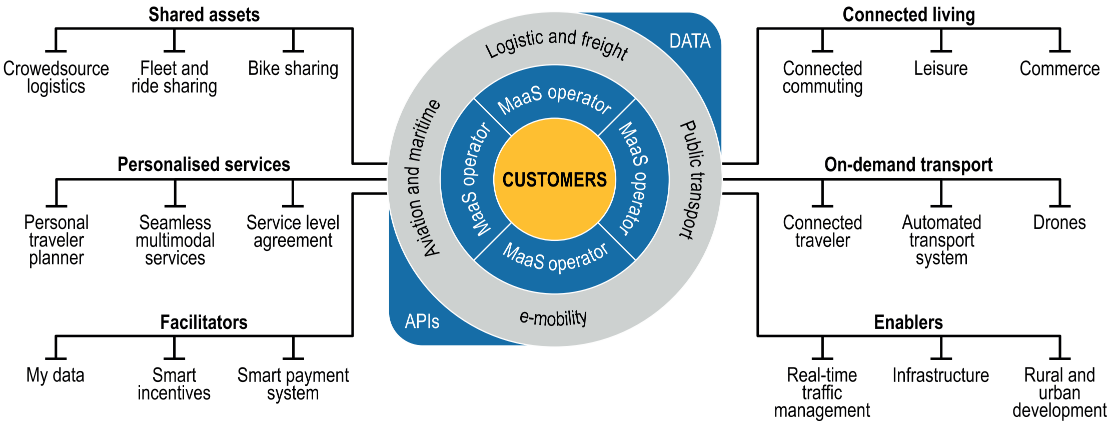
Finland promotes energy efficiency in transport also by a voluntary management system developed by the Finnish Transport Safety Agency, in co-operation with transport sector stakeholders such as companies engaged in commercial transport. This Responsibility Model takes into account finance, safety, quality and environmental aspects, including energy efficiency, to promote multiple sustainable transport goals. In 2017 the Responsibility Model replaced the Energy Efficiency Agreements that were previously used in the transport sector and expired in 2016 (Ministry of the Environment, 2017).

Mobility-as-a-Service (MaaS)

The National Energy and Climate Strategy for 2030 aims at the transition from the individual vehicle ownership to a service market enabling easy access to a range of integrated mobility options. Different modes of transport are foreseen to work seamlessly together, accessible with a single payment method. The promotion of the "Mobility as a Service" model aims to reduce the number of solo car journeys and to halt the increase in the transport by cars in urban areas regardless of a growing population. The MaaS concept envisions the creation of a high-quality and affordable basket of market-based services that meet the mobility needs of customers, especially in cities.

The Ministry of Transport and Communications launched in 2016 the Transport Code project, an overall reform of transport market legislation, accompanied by tests and pilot projects. The Transport Services Act (LVM, 2017b) which entered into force in July 2018 establishes common rules for all providers of mobility services. All public and private transport service providers will be required to disclose essential data such as routes, timetables, actual location and projected itinerary, prices and other accessibility information. Ticketing and payment systems will become increasingly open, online, and interoperable. For example, transport service providers will be required to apply a programming interface (APIs, i.e. smartphone "apps"), allowing users to purchase entire trips, regardless of whether these consist of a single leg by one mode, or are multistage and multimodal. The Act positions Finland as a global leader for MaaS.

Figure 6.3: Schematic showing the actors and connections providing MaaS.



Source: Finnish Ministry of Transport and Communications.

MaaS requires public transport agencies to move beyond simply providing public transport services, to the role of a partner and facilitator, exploring and exploiting new business opportunities and facilitating demonstration projects, removing obstacles and promoting compatibility. Public authorities could work in concert with private companies to develop station districts as transport nodes to improve standards in travel chains and mobility services, and to create automatic transport development areas in urban areas (TEM, 2018). Public agencies will nonetheless maintain an important role in establishing minimum standards, for example for safety, security and data privacy. The critical steps in transiting to this new model include:

- First, streamlining and/or scrapping existing regulations, eliminating rules that favour incumbents or that unnecessarily burden businesses.
- Next, creating a level playing field for open competition, based on transparent and easily accessible data that enable public authorities to monitor and measure performance.
- Finally, targeting public efforts towards research, development and innovation and procurement of promising technologies and business models.

This structural shift in public agency work will allow Finland to establish itself as among the global leaders of digitally enabled transport services.[14]

[14] In this vision, an ecosystem of complementary and coherently integrated transport modalities provides the shared assets. Together with digital and physical 'enablers,' these form the basis for open data on which a variety of personalised service business models compete. One of the points of departure for MaaS is to see information as embedded in, rather than separate from, provision of transport services. The Finnish authorities recognise the

The Transport Sector Growth Programme (TEM, 2018) confirms this vision of Finnish cities as an incubator for innovative MaaS ecosystems and shall enable the promotion of business- and export-oriented economic growth opportunities in big data and artificial intelligence, including across other sectors such as health care, learning, and the industrial internet (TEM, 2018). The first phase of the Transport Services Act has focused on road transport. Finland aims to expand MaaS in a second phase to integrate all modes of transport, including road, rail, shipping and aviation. This would require further streamlining of regulations and allow mobility service providers "to act, on certain conditions, on behalf of their clients, using their digital client accounts."

The ultimate goal of the Transport Sector Growth Programme is that, by 2030, Finland becomes an attractive and competent environment for experiment and innovation, and that novel technologies and businesses that have been proven to thrive in a conducive ecosystem can then be scaled and modified for international adoption (Ministry of Economic Affairs and Employment and Ministry of Education and Culture, 2017).

B. Improvements in the energy efficiency of transport vehicles

Several targets shall improve the energy efficiency of transport vehicles in Finland:

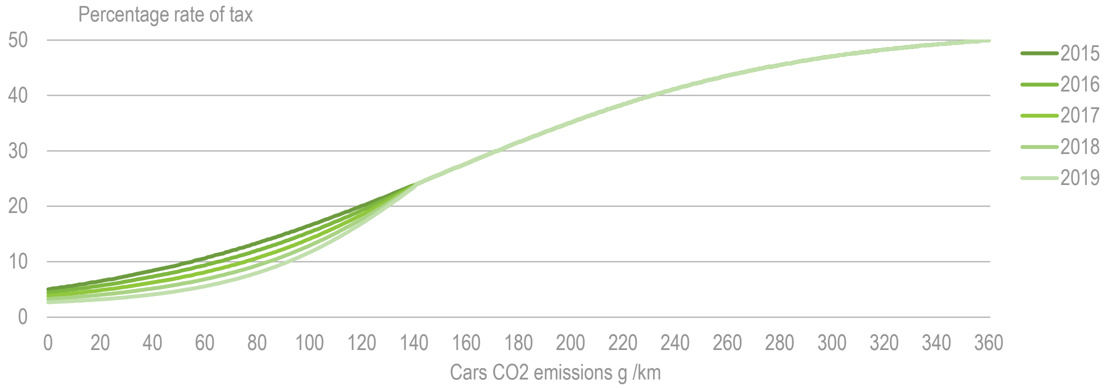
- the development and the update of legislation to implement EU CO_2 emissions/km for new passenger cars and vans in 2021
- imposing tighter limits by 30% in 2030 in line with new EU plan
- the proposed regulation on CO_2 emissions from fuel consumption of new heavy-duty vehicles (Ministry of the Environment, 2017).

The current tax structure for vehicle registration and vehicle circulation is geared to support the deployment of fuel-efficient cars. The vehicle registration tax for passenger cars and vans is linked to CO_2 emissions, in order to promote the purchase of zero- and low-emission vehicles. The highest tax rate (50% of the import price) applies when the emissions are above 360 gCO_2/km. The lowest tax rate applies when emissions are zero gram CO_2/km. The tax rate was lowered in four steps from 3.8% in 2017 to 2.7% in 2019 (ACEA, 2017a). The taxation scheme should ensure that EVs have similar acquisition costs to internal combustion engine (ICE) vehicles.

Experience shows that taxation is critical to boost the share of low emission cars. In Norway, deep tax cuts created an EV market. Other countries, like France, have negative tax rates, compensated by higher taxes for inefficient cars (in a system that is, overall, revenue generating).

potential benefits – in convenience, reliability and resource efficiency – that could be accrued by making data that are in the sole possession of public transit agencies or private companies openly available through Application Programming Interfaces (APIs) to service providers. By shifting competition to the provision of convenient trips and mobility services, new incentives are established to focus on remaining gaps in data coverage or provision of mobility services. The results could be both the further improvement of the availability and quality of transport data, and the more flexible and efficient targeting of scarce public monies.

Figure 6.4. Car registration taxes, 2015-19



Source: Ministry of Finance, 2018.

The retail price of the car is used as the taxable value in car taxation. Finland also applies a value-added tax (VAT) rate of 24% on cars (ACEA, 2017a). Despite the variation of registration taxes based on GHG emissions, tax rate decreases are steeper for vehicles emitting more than 50 gCO_2/km (Figure 6.4). This means that the current taxation structure aims to favour low- and zero-emission vehicles over conventional cars, but it does not give an additional premium to zero-emission vehicles.

Finland also applies an annual circulation tax ("vehicle tax"), levied on passenger cars, vans and trucks. The circulation tax consists of two components: a base tax, dependent on a CO_2/km rating (or, in the absence of this information, on the vehicle mass) and a tax dependent on the fuel used (driving force tax), intended primarily to rebalance the effect of lower taxes on diesel fuel, natural gas and electricity compared to gasoline, and also differentiated on the basis of the vehicle mass. Battery electric vehicles (BEVs) pay the minimum amount (EUR 106 per year) and plug-in hybrid electric vehicles (PHEVs) pay less than ICE cars.

In addition, the Finnish government aims to speed up the replacement rate of the vehicle fleet. To achieve this, it is investigating the possibility of reducing the current purchase taxes on low- and zero-emission vehicles, and it reserved EUR 8 million in the 2018 budget for the scrapping premium offered to users of old cars when purchasing a low-emission vehicle (TEM, 2017a).

Finally, an opportunity to meet energy efficiency goals and climate objectives is offered by electric mobility. The status of electric mobility in Finland, as well as Finland's policy goals on this topic are discussed in below, and further developed in IEA's *Nordic EV Outlook 2018* (IEA, 2018c).

Electric mobility

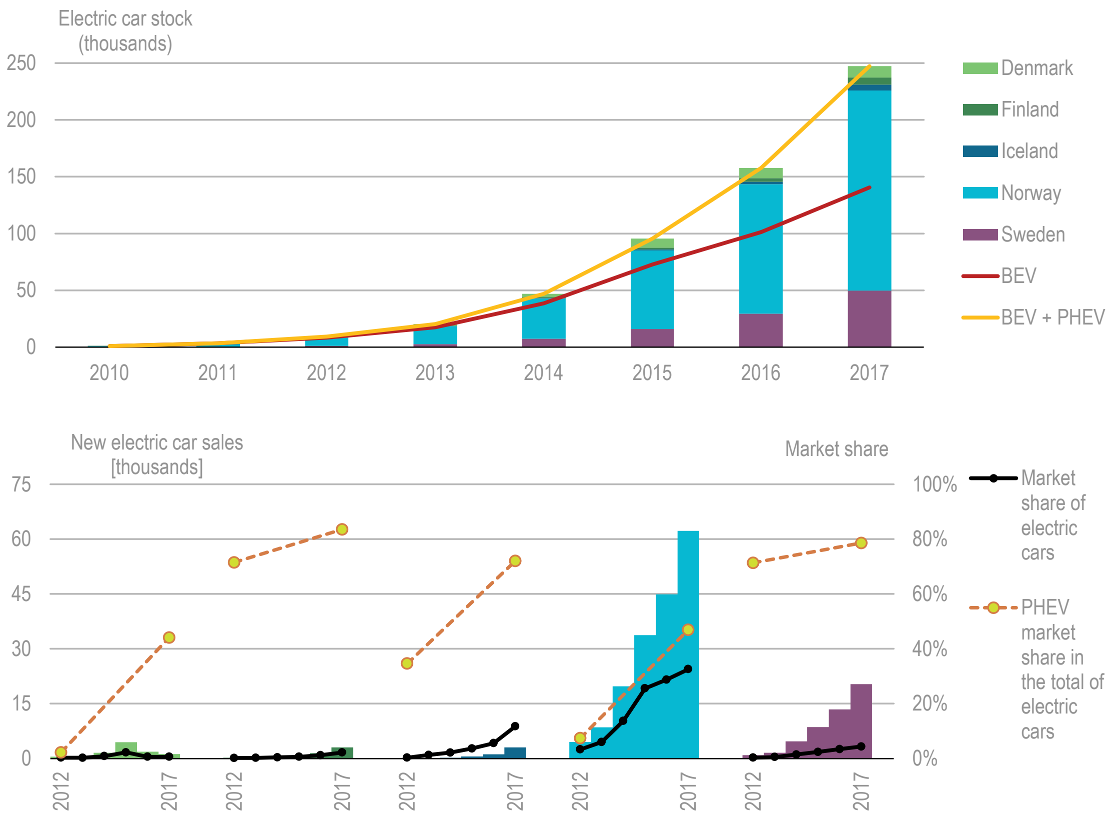
Electric cars

In the Nordic region – Denmark, Finland, Iceland, Norway and Sweden – the stock of electric cars has been expanding steadily since 2010. It reached almost 250 000 cars by the end of 2017 and accounted for roughly 8% of the global total of EVs in 2016 (IEA, 2018c). The Nordic region has one of the highest ratios of electric cars per capita in the world.

In 2017, the sales of new electric cars in the Nordic region reached around 90 000, up 57% from the previous year and setting a new record in absolute terms. The market shares of electric cars in the Nordic countries are among the highest globally, and the average for the region is 10.6% (IEA, 2018c). Taken together, the Nordic countries represent the third-largest electric car market by sales volume in the world, after the People's Republic of China and the United States (IEA, 2018d).

Despite this dynamic development in the Nordic region, Finland's electric car stock is still relatively small (6 300 vehicles in 2017), despite significant increases in electric car shares in 2017, when battery EVs and plug-in hybrid EVs, taken together, accounted for 2.6% of the total car sales; 84% of these electric vehicles were PHEVs (Figure 6.5).

Figure 6.5. Number of electric cars, new sales and market share in Nordic countries, 2010-17



Note: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. The electric car stock shown here is primarily estimated on the basis of cumulative sales since 2005. When available, stock numbers from official national statistics have been used, provided good consistency with sales evolution.

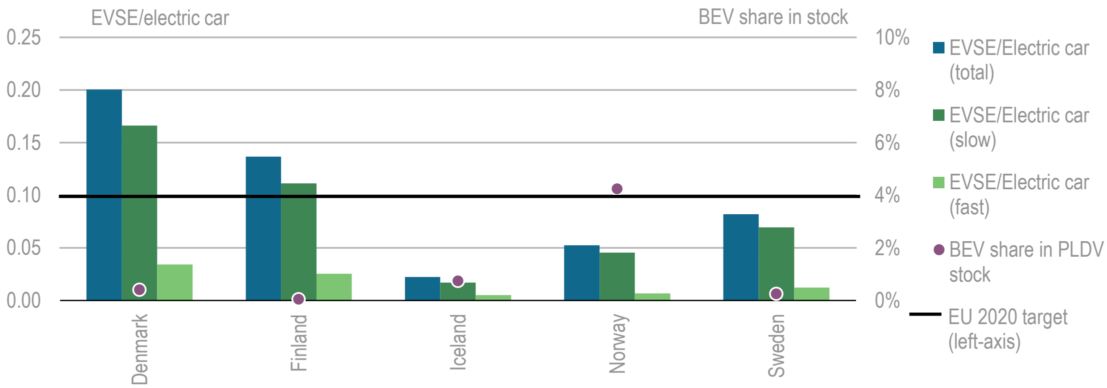
Sources: IEA analysis based on country submissions, complemented with ACEA (2017b, 2017c); Autoalan tiedotuskeskus (2017); EAFO (2017); EEA (2018); and personal communications with J. Høj, M. Andersen and N. Frees in period November 2017 to January 2018.

Chargers

Given the strong consumer preference for private charging, the deployment of chargers tends to mirror fairly closely the spread of electric cars and tends to be primarily focused on slow home or workplace chargers. Finland is no exception to this.

Regarding publicly accessible chargers, Finland saw a rapid development of electric vehicle supply equipment (EVSE) in the 2013-16 period, but a limited increase in the number of publicly accessible chargers in 2017. The country has a high ratio of chargers per electric car compared to its Nordic neighbours, second only to Denmark (Figure 6.5). This is justified by a need to ensure greater availability of publicly accessible charging points per electric car in the early phase of market deployment (publicly accessible chargers are instrumental to ensure accessibility and build trust in electric mobility); it also indicates that there is further growth potential in the electric car market with the charging infrastructure already in place.

Figure 6.6. Ratio of publicly accessible EVSE outlets per electric car in the Nordic region, 2017



Note: Data for Denmark and Finland are updated until 30 September 2017.

Sources: IEA analysis based on country submissions, complemented by EAFO (2017) and Flader (2017).

Targets for electric mobility

Finland supports the Electric Vehicle Initiative's EV30@30 campaign, which sets a collective aspirational goal to reach a 30% sales share for electric vehicles by 2030 (EVI, 2017). By 2030, Finland targets a deployment of 250 000 electric vehicles in total (fully electric vehicles, hydrogen-powered vehicles and rechargeable hybrids); electric vehicles should make up 10% of the total car fleet (TEM, 2017a). The IEA analysis shows that the target of 250 000 electric cars on the road by 2030 is consistent with the objective of the EV30@30 campaign (IEA, 2018c). Finland proposes both a short-term and a long-term target for charging infrastructure: it aims to achieve 2 000 publicly accessible charging points in 2020 and 25 000 in 2030 (EC, 2017). This is consistent with the national deployment goal of electric vehicles and the recommended ratio of one publicly accessible charging point per ten electric vehicles outlined in the Alternative Fuels Infrastructure (AFI) Directive (IEA, 2018c).

Electrifying public transportation is also seen as an option, especially in larger cities, having many benefits to offer, since it is emission-free, has low noise levels and net benefits (in comparison with internal combustion engine vehicles) for local air quality.

Policies to promote electric mobility

Key instruments for the promotion of electric mobility are:

- The proposal for tightened EU regulations on CO_2 emissions per km for cars and vans, with a 30% improvement target between 2021 and 2030, including incentives for the deployment of zero-emission vehicles, fully supported by Finland (EC, 2017).
- The differentiated vehicle registration and circulation taxes, combined with the scrapping premium and the possibility of reducing further the current purchase taxes on low- and zero-emission vehicles.[15]
- An appropriation of EUR 6 million reserved in the central government budget for 2018 for low-emission transport solutions (including electric cars, among other options, such as cars using gas and ethanol) (Ministry of the Environment, 2017).
- A Green Deal model for car dealers, directing them to present low-emission vehicle alternatives to customers (Ministry of the Environment, 2017).
- The government's intention to examine the introduction of congestion charges based on emission performances (Ministry of the Environment, 2017).

The AFI Directive and related Action Plan provide for a range of other policies, including:

- the standardisation of EVSE hardware, including plugs and sockets
- communication protocols between electric vehicles and EVSE, including inter-operability requirements
- the establishment of an EVSE deployment target, associated with an indicative ratio between publicly accessible chargers and the number of electric cars
- direct financial support for research and development (Horizon 2020) and cross-border infrastructure projects (e.g. trans-European transport network, TEN-T).

The National Energy and Climate Strategy for 2030 indicates that the distribution infrastructure for new fuels (including methane gas and hydrogen) and that the network of recharging points for electric cars will mainly be built on market terms in Finland (TEM, 2017a). Despite this, Finland currently supports the deployment of public smart charging stations and intends to boost the implementation of fast chargers. The subsidy rates are 30% for normal chargers and 35% for fast chargers. The budget available for the implementation of this support scheme (EUR 4.8 million) is equally split between both types. Funding will only be made available if the charger has an open payment system (TEM, 2017b). Additionally, a fixed-term (2018-21) annual EUR 3 million risk subsidy is available to build up electric vehicle recharging points (as well as gas filling stations) (TEM, 2017a). The government also reserved EUR 1.5 million in the 2018 budget for promoting the infrastructure of electric vehicles for residential housing (Ministry of the Environment, 2017).

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[15] Despite the purchase incentives, cars with internal combustion engines (ICE) in the mid-size segment currently have a lower upfront price than the electric models in Finland (IEA, 2018a). This is because the difference between the registration tax of BEVs and PHEVs is lower than the import value gap between ICE and EV versions. This reflects the relatively narrow range in registration tax rebates compared with other markets in the Nordic region. Given the importance of closing the price gap for early EV market deployment, this is one of the elements that explain the comparatively low market shares of EVs in Finland, with respect to other countries in the Nordic region, and one area where the current policy framework could be improved.

Finland also hosts a global hardware provider for EVSE (Ensto) and one of the global suppliers of electric buses (Linkker). Looking beyond cars, it is worth mentioning that Helsinki also invested in fast-charging stations for buses in 2017 (HSL, 2017).

The MaaS concept also promotes shared mobility, which is an important tool for the promotion of transport electrification, given the favourable economics of electric vehicles with high daily mileages.[16]

C. Increased use of renewable fuels

The strong priority given to renewable fuels in the National Energy and Climate Strategy for 2030 is consistent with the large biomass resource base of Finland, and the availability of biomass waste and residues from the forest, and pulp and paper industries. It also aligns with the objective for increased energy self-sufficiency.

Finnish biofuel policy is set under the Law on the Promotion of Biofuel Use in Transport (446/2007) and the Law on Biofuels and Bioliquids (393/2013), both amended in 2017 to comply with the EU Directive aiming to reduce indirect land use change (ILUC). These instruments oblige companies to supply transport fuels with an average minimum biofuels blending (defined as a percentage of energy content). The directive also includes provisions for double-counting of advanced biofuels, i.e. biofuels relying on biomass originating from waste and residues, non-food cellulosic and lignocellulosic materials.[17]

Fuel taxation favours biofuels over petroleum gasoline and diesel. Following the energy taxation reform of 2011, the taxation of motor and other fuels takes account of the energy content, CO_2 emissions and particulate emissions that have adverse effects on health.[18]

- The energy content component of the tax on motor and other fuels was adjusted to reflect the energy content of the fuel and is imposed on both fossil fuels and biofuels. Transport fuels that create fewer local/particle emissions, including paraffinic renewable diesels produced from hydrotreating of vegetable and waste oils, have a reduced energy tax.
- The CO_2 tax component is based on average equivalent life-cycle CO_2 emissions of the fuel, accounting not only for fuel combustion but also for emissions during production and transportation. A 50% reduction is applied to all biofuels that meet the sustainability criteria of the first EU Renewable Energy Directive, and advanced biofuels are fully exempted from the CO_2 tax. As a result, the CO_2 tax component is lower for biofuels than for petroleum fuels.

All biofuel blending obligations have been met and the share of renewable energy in the transport sector was 22% (including double counting of advanced biofuels) in 2014 and 2015. In 2015, approximately 12% of all transport fuels used were biofuels in actual terms (i.e. excluding double counting). This is also the obligation for 2017; it translates in

[16] Already with current battery prices, the total cost of ownership per km of battery-electric cars is on par with conventional cars if adopted in fleets with intensive usage, such as taxis, vehicles providing ride-hailing services and shared cars) (IEA, 2018b).

[17] The energy content of advanced biofuels (produced, for example, from waste material) is taken into account as double its actual energy content when calculating the share of biofuels for the purposes of the distribution obligation.

[18] In the case of natural gas and biogas, the emission benefits to the local environment are taken into account in terms of a lower level of taxes on the driving force tax component of the vehicle tax.

an estimated 1.5 million tonnes of CO_2 reduction in transport-related GHG emissions. The high share of double counting reflects the production of advanced biofuels in Finland, notably Neste's renewable paraffinic diesel fuel, largely based on waste and residue raw materials, complemented by production based on pulp and paper residues (tall oil) from the Finnish pulp and paper company United Paper Mills (UPM).

Looking forward, Finland has a 20% target for biofuel shares in 2020 (including double counting), twice as high as the binding renewable energy target for the transport sector set under the EU's first Renewable Energy Directive. This is consistent with a 13.5% share, where 7% comes from conventional biofuels and 6.5% from advanced low-carbon fuels (double counted under EU rules to account for advanced biofuels). The 2030 biofuel blending target set in the National Energy and Climate Strategy, excluding double counting for advanced biofuels, is 30%.[19] If EU rules on double credits are applied, this share increases from 20% to about 53%.

The Finnish government estimates that meeting the 2030 objective would lead to a demand for biofuels (mostly drop-in fuels) of 1.6 Mtoe/year, of which 0.6 Mtoe/year would consist of advanced biofuels produced in Finland from local feedstocks and, eventually, imported raw materials. The investment costs in refinery installations to produce the targeted volume of domestic production are estimated to be around EUR 1.5 billion (TEM, 2017a). Finland also targets blending other fuels, machinery and heating oil.

Key policy drivers to accommodate such an increase in the demand and supply of road transport biofuels remain blending mandates, supply obligations for drop-in biodiesel and fuel taxes differentiated on the basis of carbon content and quality. As many new production technologies are still being developed, policies also include instruments to reduce investment risks, estimated to account for a total budget of EUR 40 to 50 million over the next few years (TEM, 2017a). One such instrument already in place is the Energy Aid Programme, providing aid for up to 40% of the costs for projects concerning renewable energy sources and energy efficiency using new technology, and up to 30% for projects using conventional technology. In 2015, an energy investment aid programme was announced for the period 2016-18 with a total budget of EUR 100 million (Energiakärkihankkeet) dedicated to renewable energy and innovative technologies. By September 2018, a total of EUR 80 million has already been allocated to 18 projects to support biogas use in transport, smart energy and demand-response services.

Beyond national policy instruments, Finland relies on policies promoting the biofuel market across the European Union, as an individual national market would hardly be sufficient for the industry to develop and invest in new biofuel technologies.

Assessment

Finland is at the forefront of promoting low-carbon mobility through more efficient vehicles, changes in the transport system and, most importantly, by increasing the role of biofuels, in line with its strong policy and industrial competitive edge for bioenergy.

[19] The increase in transport biofuel use will be examined as a whole together with the blending obligation applicable to the light fuel oil used in machinery and in heating.

The targeted paradigm shift from individual car ownership to Mobility-as-a-Service (MaaS) is commendable, and so is the implementation of a legislative reform enabling this change. Nevertheless, there is a risk that connected automated vehicles compete with public transport, which is a strong focus of Finland's policies. Therefore, the transition to MaaS should not weaken the role of public transport, given the advantages of public transport modes in reducing the need for dedicated road space and their ability to limit congestion. Managing this transition will pose significant challenges, which require a wide range of policy tools. Examples include charges aimed at minimising empty rides in ride-hailing services, time-variable congestion charges, and restrictions for ride-hailing services aiming to limit car use in urban areas that public transportation serves well.

Co-ordinated transport and land use as well as the promotion of conditions for walking, cycling and public transport contribute to more efficient urban transport systems. The ambitious emissions reduction goals of the National Energy and Climate Strategy for 2030 require the introduction of pricing measures that stimulate changes in the choice of transportation modes: the road usage fees foreseen in the Strategy are very appropriate. To date, the government has considered congestion charges only from the emissions reductions point of view; the Helsinki Regional Transport Authority suggests that congestion charging may be an efficient tool. However, the IEA believes that congestion charging should be given serious consideration, together with access restrictions and investments in strengthening the public transport network in urban areas, in order to ensure sustainability of transport from an environmental and economic/budgetary point of view. These instruments will gain importance in managing structural changes in governmental revenues from the transport energy mix.

Given their cost effectiveness, fuel economy measures aimed at reducing the specific consumption and emissions of new cars and vans, and heavy-duty vehicles should indeed be priorities. However, these measures are not sufficient to ensure coherence with the long-term objective to achieve carbon neutrality by 2045, and to address the need to strengthen emissions reductions in the energy system to compensate for the anticipated changes in the LULUCF sector. A higher market penetration of low- and zero-emission vehicles (such as PHEVs and BEVs) is an effective way to meet this ambition.

Enabling a rollout of zero-emission vehicles more ambitious than foreseen in the Strategy requires the adoption of co-ordinated measures at the national and local levels, so as to increase the cost-competitiveness of EVs and stimulate the deployment of charging infrastructure. New national policy instruments reducing the costs of zero-emission vehicles may include:

- A revision of the current differentiated vehicle registration to give greater benefits to low-emission vehicles, ensuring that it can offer greater advantages for vehicles emitting less than 50 gCO_2/km at the tailpipe, at the expense of vehicles emitting more than the national average.
- Measures targeted to the increased uptake of low- and zero-emission vehicles among company cars, such as a differentiated taxation for company cars (as used in other Nordic countries) based on environmental performances, favouring vehicles with the best performances at the expense of vehicles emitting more than the national average. These should be adjusted over time, responding to changes in the evolution of the market, so as to avoid changes to the overall average taxation rate on income.

These policies can also be strengthened by measures that accelerate the pace of vehicle fleet renewal, such as circulation taxes that increase over time. National policies stimulating the development of charging infrastructure could include fiscal incentives for the installation of home, destination and workplace chargers; and the development of a strategy for the deployment of a network of fast chargers, in consultation with stakeholders in the power and automotive sectors.

Local measures encouraging consumer demand for EVs to transport passengers and goods include:

- the development of a strategy to adopt zero-emission vehicles in major cities and a timeline for its implementation
- the adoption, in an initial phase of market uptake, of differentiated congestion and parking charges, using waivers or reduced rates for zero-emission vehicles
- the adoption of access restrictions, combined with temporary waivers or weaker limitations for zero-emission vehicles
- the deployment of publicly available chargers, prioritising business models and deployment practices that maximise the likelihood that they are economically sustainable.

This roll-out can leverage the greater availability of models in Europe. It is best implemented if local support instruments are developed in co-ordination with solutions adopted for the optimisation of the transport system, including “Mobility-as-a-Service” (thanks to the synergies between electric mobility and vehicles having a high capital utilisation profile, given the much lower operation costs of electric vehicles in comparison with vehicles using conventional power systems). These instruments include the adoption of public procurement plans prioritising zero-emission vehicles and deep changes in the technologies used for the propulsion of urban buses, for which electrification already makes full economic sense.

Opportunities for the uptake of electric mobility also exist in freight transport, especially in the case of urban deliveries and short-distance shipping, something the Strategy does not mention to date.

Instead, the Strategy foresees a transition from conventional fossil fuels to other alternatives, and builds on the argument that this transition has already begun in Finland. In this context, it remains critical to ensure that the targeted biofuel uptake in transport is met by using low-carbon fuel standards or mandates to foster sustainable biofuel production practices and feedstocks, and by encouraging biofuels with high emissions reduction performances.

Despite the successful development of some pilot plants, the production of biofuels based on waste and residues from the pulp and paper industry (and, in turn, the forest resources), is still facing significant challenges with respect to cost reductions. This suggests that RD&D activities and funding for the achievement of cost reductions in this area, possibly by leveraging synergies with the production of other outputs from biomass processing plants, will need to be prioritised. Given the challenges posed by the weight of batteries, technology pathways enabling the sustainable use of biomass for drop-in jet kerosene are needed for international aviation, and Finland can take a leadership role in this respect. Aviation fuels will need to meet sustainability requirements; RD&D activities related to biofuel production should reflect these needs.

Ensuring that fuel taxation reflects the carbon content of fuels is critical to align market responses with energy and climate policy goals. The government should consider a revision of the current taxation structure for transport fuels, which has comparatively low taxes for petroleum diesel. The higher vehicle tax (annual tax) on diesel cars compensates the lower taxation on petroleum diesel. If taxation on diesel fuel were to be increased, annual vehicle circulation taxes should then also be adjusted, removing the components that aim to adjust the carbon tax component for passenger cars. The revision of fuel taxes to reflect the carbon content of fuels also links with a broader need to align CO_2 taxes for other fuels.

Recommendations

The government of Finland should:

- ☐ Raise the ambitions for vehicle efficiency and the roll-out of zero-emission vehicles, notably electric vehicles, and adopt a package of fiscal instruments and local traffic measures to ensure Finland can achieve targeted emissions reduction in transport and halve oil consumption by 2030.
- ☐ Create an enabling framework for municipalities to define actions for a more efficient transport system (including congestion charges, access restrictions) and to ensure that the transition to “Mobility-as-a-Service” delivers the emissions reductions anticipated in the National Energy and Climate Strategy for 2030.
- ☐ Ensure that the biofuel obligation in transport is in line with sustainable biofuel production practices and availability of feedstocks, and foster RD&D investments to deliver cost reductions while prioritising biofuels for long-distance modes, including aviation.

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7. Energy technology research, development and demonstration

Key data

(2016)

Government energy RD&D spending: EUR 166.4 million

Share of GDP: 0.077% (IEA* median: 0.034% average: 0.043%)

RD&D per capita: EUR 30.3

Exchange rate: EUR 1 = USD 1.11; USD 1 = EUR 0.90

* Median of 24 IEA member countries for which 2016 data are available.

Overview

Finland is a leader among International Energy Agency (IEA) member countries when it comes to government energy research, development and demonstration (RD&D) spending as a ratio of gross domestic product (GDP) and private sector and international engagement.

Under Mission:Innovation the government seeks to double its spending on clean energy technology RD&D by 2020. However, there has been a restructuring of energy RD&D efforts, including lower budget contributions. The government has a very strong policy framework, private sector engagement and world-class research facilities, which are highly specialised to advance Finland's competitive edge in energy technology, including for the export.

Institutional framework

The **Finnish Ministry of Economic Affairs and Employment** oversees Finland's technology and innovation policy. The Ministry of Education is responsible for the country's science policy. Science, technology and innovation are high priorities for the Finnish government. Key issues are co-ordinated by the **Research and Innovation Council**, which is chaired by the prime minister.

Programmes are implemented by the Finnish **Funding Agency for Technology and Innovation (TEKES)**. As of January 2018, TEKES is merged with Finpro, the Finnish export promotion agency, to form **BusinessFinland**, which has now become the most important publicly funded expert organisation for financing research, development and innovation in Finland. BusinessFinland boosts wide-ranging innovation activities in research communities, industry and service sectors. TEKES is under the Ministry of Economic Affairs and Employment.

The **Academy of Finland** is the prime agency for basic research funding under the Ministry of Education, with a mission to advance scientific research and its application, to support international scientific co-operation, to act as an expert in science policy issues, and to allocate funding to research and other areas of science. Under the Academy of Finland there is the **Strategic Research Council (SRC)** which funds high-quality research that produces economic and society-wide impacts with multidisciplinary scope.

Under the Finnish Ministry of Economic Affairs and Employment, **VTT, the Technical Research Centre of Finland Ltd,** provides research and innovation services and information for domestic and international customers and partners, both in private and public sectors. As a state-owned and controlled non-profit company, VTT has several unique R&D and laboratory facilities, among them Bioruukki, the largest bioeconomy pilot and research facility in the Nordic countries, the Centre for Nuclear Safety, TVV Mikes Metrology lab, the ROViR (Remote Operations and Virtual Reality Centre) among others. VTT operates in partnership with universities, with private funding (32%), complemented by funding from the public sector (36%), and from foreign public and private sectors (32%).

The Finnish Innovation Fund, Sitra is an independent public foundation that operates under the supervision of the Finnish Parliament. **Finnvera** is a specialised financing company governed by the Finnish state with official Export Credit Agency (ECA) status. Finnvera provides businesses with loans, guarantees, venture capital investment and export credit guarantees.

Strategies, priorities and programmes

Research, development and demonstration is an integral part of the government strategies for boosting Finland's economic growth and competitiveness. The government's "Vision: Finland 2025" builds on several strategic priorities, notably on bioeconomy and clean solutions and digitalisation. The government promotes cost-efficient carbon-free, clean and renewable energy, "wood on the move" and new products from forests, a circular economy and improvement on water quality, profitable food production and nature policy. The transformation towards a sustainable bioeconomy, based on renewable materials and fossil-free energy is a top priority, which spans across sectors (forest, chemical, information technologies, and buildings) and is driven by consumer behaviour and cross-industrial partnerships.

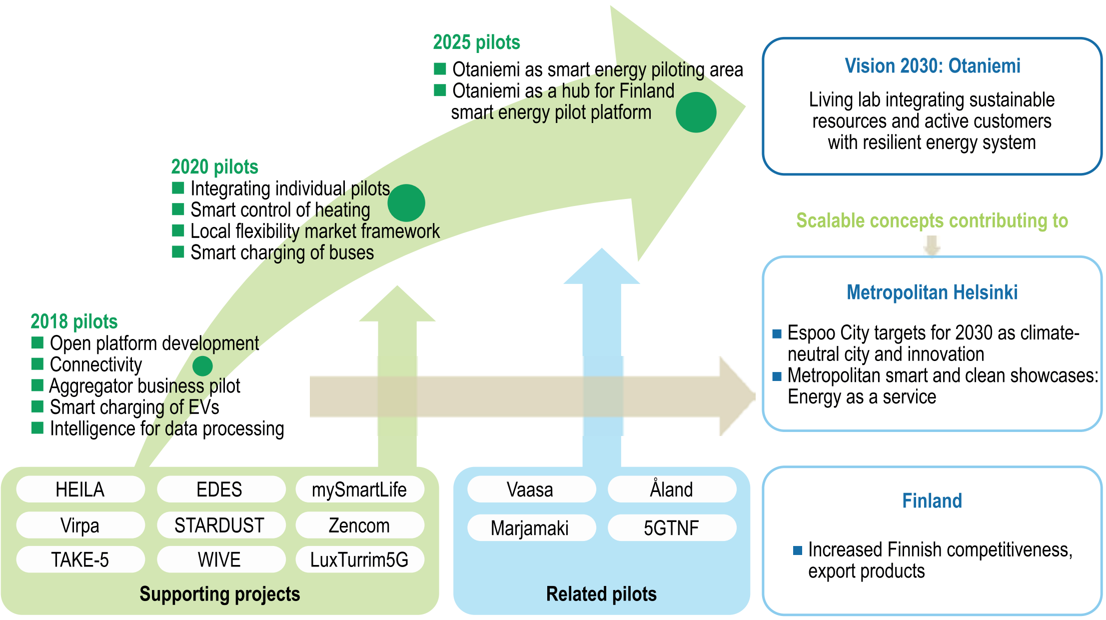
The National Energy and Climate Strategy for 2030, the Bioeconomy Strategy, the Cleantech Strategy, the National Circular Economy Roadmap, "Reboot Finland" (digitalisation agenda) and the National Forestry Strategy detail those strategic priorities into actions for the development of new business models, new markets, networks and know-how in Finland. For 2016-18, the government of Finland has put forward EUR 300 million (Euro) to support the bioeconomy and clean energy solutions priority.

Every year, the Strategic Research Council (SRC) prepares a proposal on key strategic research themes and priorities to be approved by the Finnish government. The government determines the research needs and decides the final themes, which the SRC then formulates into research programmes and funding calls. SRC programmes run for 3 to 6 years. The SRC's annual funding budget is some EUR 55 million. In the energy sector there is one theme, a climate-neutral and resource-scarce society.

VTT is providing cross-industry and cross-sectoral interactions through five lighthouse programmes: Climate Action, Resource Sufficiency, Good Life, Safety and Security, and Industrial Renewal. Within the Climate Action Programme, VTT focuses on low-carbon mobility and communication, energy intelligence, low carbon energy (renewables and nuclear), and climate-neutral industrial processes (zero-C industry). VTT is developing unique research and demonstration pilots, based on smart platforms and living labs and simulations to test new business models, develop R&D concepts and support to real-world deployment and commercialisation.

Carbon capture, utilisation and storage has not been a strong focus for Finland, since onshore storage is banned in Finland due to unsuitable geological conditions; and the government has no policies to promote carbon capture and storage (CCS not being incorporated in Finnish energy scenarios). There was a full-scale retrofit CCS-project (MeriPori, 565 megawatts) but that project was closed in October 2010.

Figure 7.1. TEKES Smart Otaniemi vision and pilots



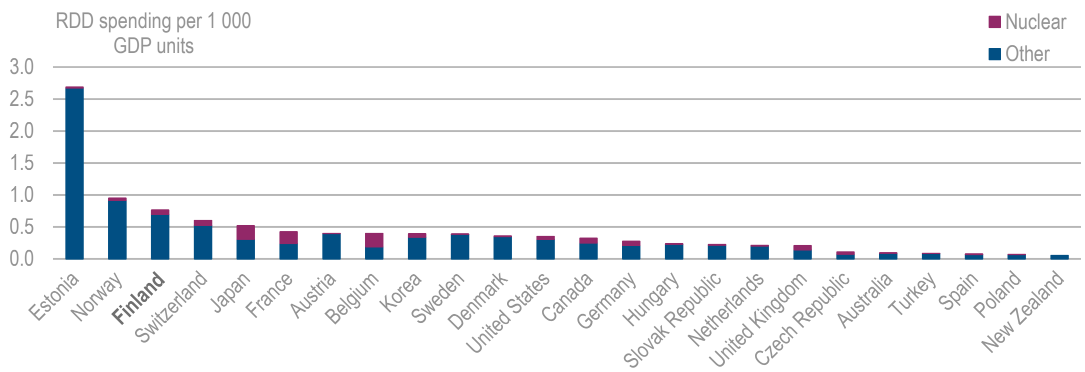
TEKES has a range of programmes aimed at creating Finnish know-how and business solutions and services for exports, including Arctic Seas (2014-17), Innovative Cities (2014-17), Smart & Green Growth – clean transition to the bioeconomy (2015-18), and Smart Energy (2017-21) and Witty City (2013-17), a smart city programme.

TEKES' Smart Energy programme for 2017-21 has a funding envelope of EUR 100 million dedicated to smart energy solutions. Smart Energy is a joint programme between TEKES and Finpro, aimed at attracting international investments in energy, supporting digitalisation in the energy field, utilising Mission Innovation initiatives to create new business opportunities for Finnish companies in energy efficiency, clean and smart energy systems and related products and services (storage, microgrids, EV charging, smart homes, power to gas, aggregators, distribution automation, etc.). TEKES has several test platforms, notably the Otaniemi Smart Energy Platform (see Figure 7.1) or the Smart Energy Platform in Aland Islands and the integrated business platform for distributed energy resources (HEILA) and Smart Energy Connection. TEKES carries out evaluations of its projects, which are co-funded.

Public spending

In 2016, Finland spent EUR 166 million on energy-related RD&D, a decrease by 31% from 2015. Compared to other IEA member countries, Finland ranked in top three in terms of RDD spending as a share of the total economy after only Estonia and Norway (Figure 7.2).

Figure 7.2 Government energy RD&D spending as a ratio of GDP in IEA member countries, 2016



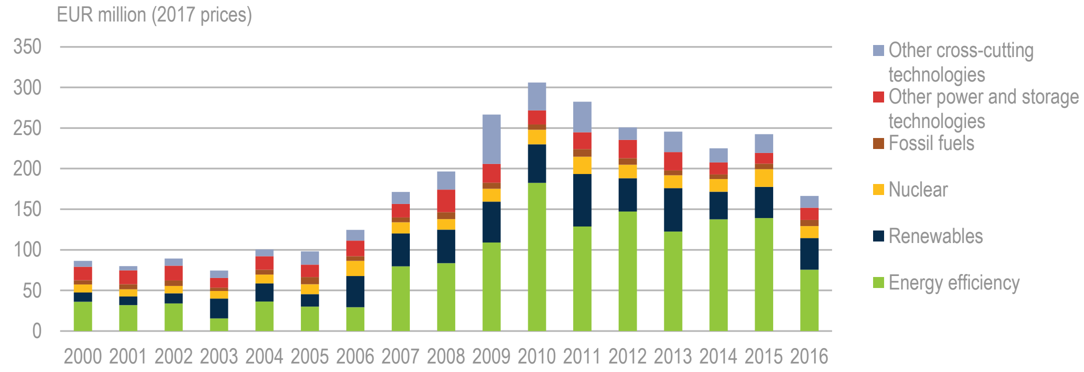
Note: Data are not available for Greece, Italy, Luxembourg, Mexico and Portugal.
Source: IEA (2018), *IEA Energy Technology RD&D Database, 2018*, www.iea.org/statistics/.

Finland's public spending on energy RD&D more than tripled from 2005 to 2011 (see Figure 7.3). Since 2010, Finland has spent around EUR 250 million annually, until the 2016 drop. The government has cut public spending on energy RD&D from almost EUR 250 million to EUR 166 million in 2016. Almost one-fourth of the funding of TEKES has been cut purely because of the economic situation in Finland. In 2017, TEKES used more EU funds than in the past, mainly from Horizon 2020, thanks to active international collaboration and private-sector participation.

In 2016, energy efficiency research received 45% of total energy-related RD&D spending, followed by renewable energy at 23% and nuclear, energy storage and cross-cutting technologies at 9% each.

The Finnish industry invests strongly in RD&D. The country widely uses the practice of co-investment between private venture capital and equity funds administered by publicly owned organisations or, in some cases, public grant financing. Private energy technology research, development and innovation (RD&I) spending in TEKES covers about 60% of the total costs, which is high by international standards.

Figure 7.3 Government energy RD&D spending by category, 2000-16



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

International collaboration on energy RD&D

Public -private partnership and international co-operation in the European Union, the Nordic region and IEA initiatives are essential for Finland. Finland's RD&D programmes in the energy field are strongly interlinked with the EU Strategic Energy Technology Plan (SET Plan), the IEA technology collaboration programmes (TCPs), Mission:Innovation, which Finland joined in 2016 and the Clean Energy Ministerial (since 2010). TEKES's global operations in the *Team Finland* network boost international R&D co-operation and business. Team Finland network provides a gateway for international enterprises wishing to connect with partners in Finland – whether they are looking for business contacts, cutting-edge research, or R&D resources. TEKES has offices in the People's Republic of China (three), Belgium, the United States and the Russian Federation (hereafter "Russia"). It is also the nodal point of many European research activities in Finland, such as the EUREKA network, the EU Horizon 2020, COST, and the European Space Agency (ESA).

Under Mission:Innovation, the government aims to double by 2020 RD&D investments in clean energy (renewable energy, energy systems, energy storages and electricity transmission and distribution), with a baseline funding of EUR 54.9 million (average of 2013-15 funding) and a doubling target of EUR 109.8 million in 2020. However, this targeted level would be much below the historic funding peak in 2010. Under the seven innovation challenges, Finland's VTT is leading the new demand response taskforce with Denmark (under the Smart Grids Innovation Challenge), and the government supports the Sustainable Biofuels Innovation Challenge and the Affordable Heating and Cooling of Buildings Innovation Challenge.

Finland participates in 19 IEA Technology Collaboration Programmes (TCPs), with a particular focus on end-use efficiency (12 programmes) and renewables (5). Within Clean Energy Ministerial (CEM), Finland participates in ISCAN and in the 21st Century Power Partnership initiatives and the Energy Management Working Group; in August 2017 Finland applied to join the Electric Vehicles Initiative (EVII and is interested in joining the gender-equality Energy Future Technology Collaboration Programme (C3E). Finland also participates in the Energy Management Group (EMG) Campaign and in August 2017 joined the EV30@30 Campaign and is planning to join the Advanced Power Plant Flexibility Campaign. Clean Energy Ministerial activities are connected to national programmes and schemes, for example EMWG is connected to the Energy Efficiency Agreement Scheme, and EVI to the TEKES Intelligent Energy Programme.

Assessment

Finland's industry has a strong leadership in innovation and private R&D spending; Its cities, local communities and citizens are active in driving smart and clean-tech solutions. Finland is among leading IEA countries in terms of public spending on energy R&D: in 2015, with 0.114% of GDP, together with Norway (0.112%). As part of a general budget cut, however, in 2015 the government reduced R&D expenditure sharply, from around EUR 270 million (2010) and EUR 239 million (2015) to EUR 166 million in 2016. Funding has shifted from industrial and technological R&D-driven projects towards clean energy technology R&D in services firms, non-technical innovation and small and medium-sized enterprises.

In 2016, Finland joined Mission:Innovation (M:I). The government aims to double by 2020, public RD&D spending in clean energy technologies (renewable energy, energy systems, energy storage and electricity transmission and distribution), with a baseline funding of EUR 54.9 million (average of years 2013-15 funding) and a target of EUR 109.8 million in 2020. However, this is much below the historic peak level of public energy R&D spending in 2010.

In order not to lose momentum and investments made along the innovation chain, the government should evaluation programmes, review R&D priorities to identify areas which benefit from an increase in public funding for energy R&D as the Finnish economic growth is picking up. Public funding is also the basis for public-private partnerships and EU co-financing.

The Finnish government has set out a "Vision: Finland 2025", where bioeconomy and clean solutions are among the five key strategic priorities. The export-oriented bioeconomy strategy of 2014, based on forestry, food production and circular economy, is considered a success story. The energy sector will benefit from a greater alignment of energy, innovation, export and growth policies. The Finnish Ministry of Economic Affairs and Employment is ideally placed to do this, as it oversees all of these policies.

The main player in financing energy R&D, the Finnish Funding Agency for Technology and Innovation (TEKES) has put forward the Smart Energy Programme for the period 2017-21 with projects in smart, renewable energy production, smart grids, demand-side management, integrated to a smart flexible energy system using digital services. The government has earmarked EUR 100 million for investments in demonstration projects during 2016-18. The state-owned research and technology company, VTT Technical Research Centre of Finland carries out technology development from bench-scale to pilot-scale to demonstration. However, it has discontinued a number of programmes, despite good progress.

TEKES and Finpro, the Finnish export agency, collaborate in the Smart Energy Programme. The creation of the newly merged entity, Business Finland in 2018 could foster a shift of energy RD&D activities to export-oriented segments, in support of M:I and economic growth. In this context, high value-added segments should be prioritised, where Finland is a global leader, such as smart grids, smart services and smart meters, new technologies in CHP for smart buildings and waste to heat, as well as biofuels for chemical and medical purposes and material efficiency. As part of such a renewed effort, the government should develop a roadmap to prioritise clean energy R&D, such as material substitution to enable higher efficiency in the industry sector and bioenergy.

In view of the success of the bioeconomy strategy and the circular economy, TEKES is supporting the creation of an ecosystem for energy RD&D along the whole energy system instead of supporting one or other technology. While the private sector leads in innovative solutions, various entities are active across many segments in the same smart energy space. The role of the government at the initial stage is critical to bring together both government agency initiatives and clusters of industries and start-ups.

Despite innovative potentials in the smart energy industry sector, efforts are scattered and regulatory barriers can stifle fast progress and make innovation spending less effective. The government should first remove those barriers, and apply the recommendations of the Smart Grid Working Group in order to optimise public funding and leverage private funding.

The Finnish energy R&D sector is based on the practice of co-investment between private venture capital and equity funds administered by publicly owned organisations or in some cases public grant financing. Private energy technology RD&I spending in TEKES covers about 60% of the total costs, which is exemplary. The use of tax breaks or tax incentives has not been successful in the Finnish energy sector. Involvement of industry becomes a crucial success factor, in light of declining public funds.

The government supports M:I challenges in affordable heating and cooling of buildings, sustainable biofuels and smart grids. Together with Denmark, Finland's Technical Research Centre VTT is now chairing the new demand response taskforce. Since 2010, Finland has been an active in the Clean Energy Ministerial (CEM). It works to improve the links between CEM and M:I to leverage synergies (tech demos, electric vehicles, smart grids). The CEM Ministerial in May 2018 provided an excellent opportunity in this context and the government should build on the strong collaboration within the Nordic Research Council to accelerate M:I pledges further.

Public-private partnership and international co-operation in the European Union, Nordics and IEA initiatives are strong priorities for the government. Finland's total participation in IEA Technology Collaboration Programmes (TCPs) amounts to around 20 TCPs, with a particular focus on end-use efficiency (12) and renewables (5). Among the TCPs, TEKES and VTT are the main partners, next to academic and research institutes. At EU level, Finland is an active member of the Strategic Energy Technologies (SET) Plan where it leads on renewable fuels, bioenergy, and integrated SET Plan actions on energy efficiency in industry.

Recommendations

The government of Finland should:

- Align energy, innovation, growth and export policy agendas within the Ministry of Economic Affairs to leverage innovation capacity of the energy sector in line with Mission:Innovation.
- Raise the level of public R&D expenditure and maintain the dedication to engage the industry in RD&D at least to the levels of 2010.
- Continue to support smart energy clusters by streamlining R&D efforts across government entities and research organisations, to boost innovative ideas and R&D projects, leverage private capital and export opportunities for Finnish technologies.
- Strengthen Nordic research funding and private-sector engagement, notably through the Clean Energy Ministerial in 2018 and beyond.
- Remove regulatory barriers in the smart energy sector, following the Smart Grid Working Group recommendations, with a view to optimise public funding and identify the best opportunities to leverage private R&D investment.
- Develop a roadmap to prioritise clean energy R&D activities, such as material substitution to enable higher efficiency in the industry sector and bioenergy.

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8. Electricity markets and co-generation

Key data

(2017 provisional)

Electricity generation*: 67.4 TWh (nuclear 33.3%, hydro 21.9%, biofuels and waste 17.9%, coal 9.9%, wind 7.1%, natural gas 5.0%, peat 4.1%, oil 0.3%, solar 0.1%), -17% since 2007

Electricity net imports: 20.4 TWh (imports 22.2 TWh, exports 1.8 TWh)

Installed capacity (2017): 16.6 GW

Peak demand: 15 177 MW (7 January 2017)

Electricity consumption (2016): 82.1 TWh (industry 46.9%, residential 27.4%, commercial 23.3%, other energy 1.5%, transport 0.9%), -5.6% since 2006

* Excluding power imports.

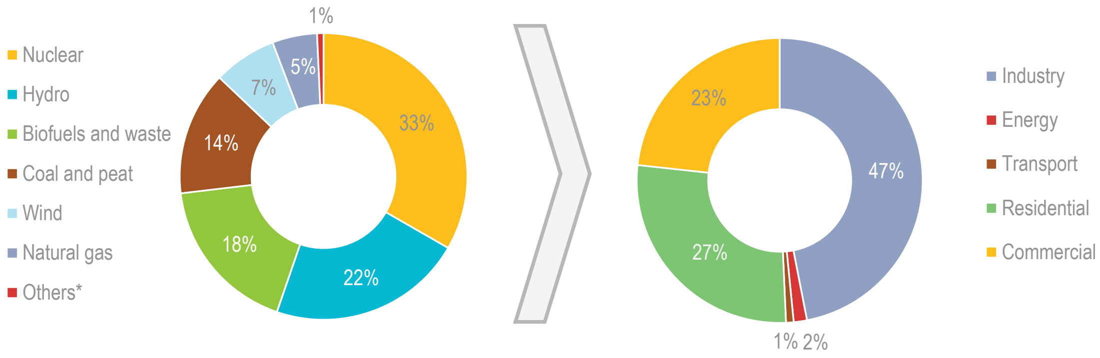
Overview

Finland is well interconnected with neighbouring countries, and a large amount of electricity is traded on the common Nordic market. Nuclear power, followed by hydro, are the main sources of electricity in Finland, but biomass, wind power and electricity imports have increased in recent years, whereas fossil fuels are declining in importance. Around one third of electricity generation is produced in co-generation with heat. The wholesale spot market, Nord Pool, is characterised by low prices driven by growth in new capacity, mainly from renewable energy with low operating costs and by lower than anticipated demand across the Nordic region. The current low-price environment has made electricity in co-generation less competitive, making district heating producers replace co-generation with pure heat production and leading to increased electricity imports to cover peak demand in the winter. As electricity wholesale and balancing market are regional, discussions are ongoing in the Nordic market with regard to reforming the electricity market design and greater collaboration on system security and adequacy.

Electricity supply

Since the commissioning of Finland's nuclear fleet around 1980, nuclear power has been the largest source of electricity supply. However, its position has become less dominant as other power sources and electricity imports have grown. In 2017, nuclear power accounted for a third of total net generation. Imports accounted for the second-largest source of power supply, ahead of hydro and biofuels.

Figure 8.1 Electricity supply by source 2017 and consumption by sector 2016



Others includes oil, solar and industrial waste heat.

Notes: Data for 2017 are provisional. Latest consumption data are from 2016.

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

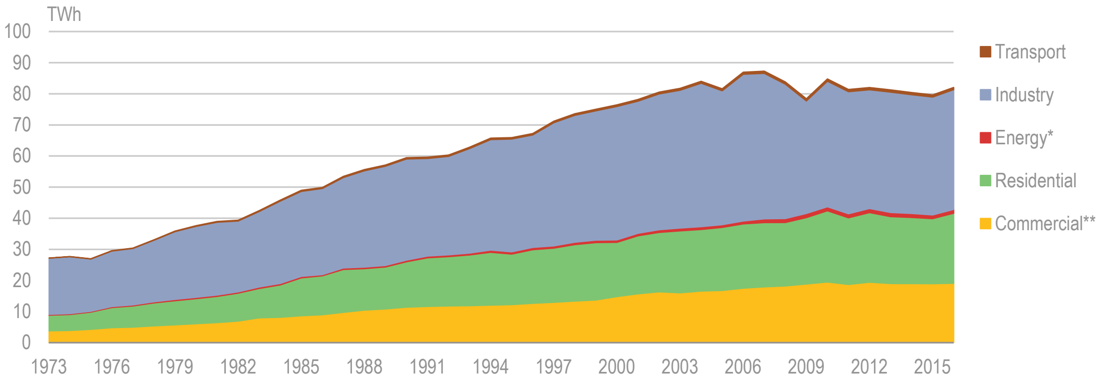
Electricity consumption

Over the past decade electricity consumption has been stable around 80-90 terawatt-hours (TWh) (Figure 8.2). In 2016, consumption was 82.1 TWh, a decline by 5.6% since 2006.

The industry sector is the largest electricity consumer, accounting for 47% of total electricity demand. Within this category, the paper industry is the biggest electricity consumer in Finland, accounting for nearly half the industrial electricity consumption, followed by iron and steel and chemical industries. Industrial electricity consumption has declined by 18.4% since 2006, leading to the overall decline in total electricity demand. Petroleum refineries accounted for 1.5% of total electricity consumption.

The residential and commercial sectors together consume the other half of electricity demand, with roughly equal shares. The use of electricity for heating is relatively large in Finland, because of cold weather and the large number of saunas. The transport sector accounts for the remaining small share, which is mainly rail transport.

Figure 8.2 Electricity consumption by consuming sector, 1973-2016



**Energy* includes petroleum refineries.

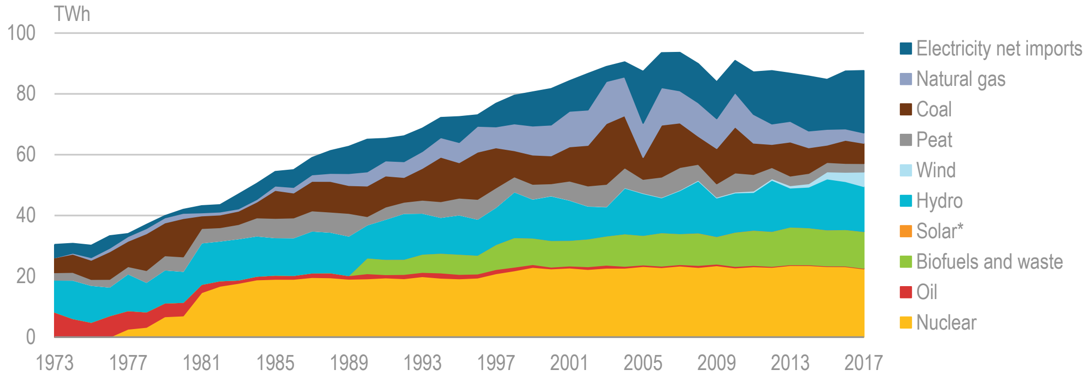
***Commercial* includes commercial and public services, agriculture and forestry.

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

Electricity generation and imports

In 2017, total electricity supply was 87.9 TWh, of which 77% was generated in the country and 23% was imported. Total supply stabilised around 90 TWh over the last decade and a half, after a steady increase since the 1970s (Figure 8.3). Nuclear power overtook hydro as the largest source of electricity in 1981, and has been dominating the electricity generation since. Finland has four nuclear reactors, and a fifth is scheduled to go online by 2019 (see Chapter 9 on Nuclear).

Figure 8.3 Electricity supply by source, 1973-2017



*Negligible.

Note: Data for 2017are provisional.

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

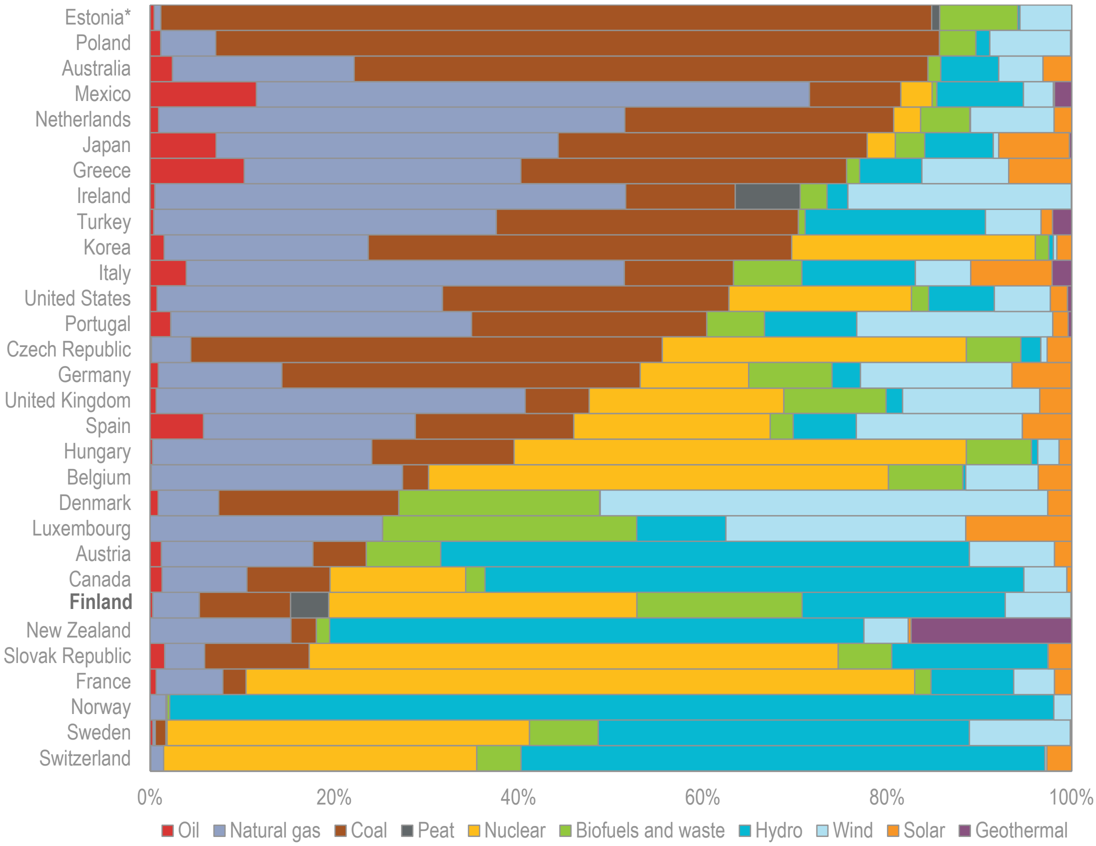
Biofuels and waste has increased from around 5 TWh in the early 1990s to around 12 TWh in recent years. Finland has a large pulp and paper industry that produces heat and power from process waste products, which has contributed to the growth of biofuel-based power. The share of biofuels in electricity generation is therefore the third highest in the IEA. Wind power production has increased rapidly in recent years, from 0.5 TWh in 2012 to 4.8 TWh in 2017, and accounts for 7% of electricity generation. In 2018, Finland has been awarded the contract for the largest and first subsidy-free wind power project in the Nordic region, whose generating costs are estimated to be less than EUR 30 (Euros) per megawatt-hour (MWh).

Coal and natural gas power both peaked in 2003, coal at 20 TWh and gas at 14 TWh, but have since fallen to a total of 10 TWh. Peat has also declined from over 7 TWh in 2007 to below 3 TWh in 2017. Nevertheless, Finland has the second-highest share of peat in electricity generation among IEA member countries, after Ireland. Peat is mostly used in co-firing mode with biomass.

The large shares of nuclear, hydro and biofuels gave Finland only 19% fossil energy sources (coal, peat, natural gas and oil) in its power generation in 2017. This was the seventh-lowest share among IEA member countries (see Figure 8.4).

The biggest change in electricity supply in recent years has come from growing imports. In the last decade, net imports increased by nearly two-thirds driven by falling electricity production from fossil fuels. In 2017, net imports were 20.4 TWh. Sweden accounts for over 80% of electricity imports, followed by the Russian Federation (Russia) (see Figure 8.5). Since 2007, Finland has also traded electricity with Estonia.

Figure 8.4 Electricity generation by source in IEA, 2017

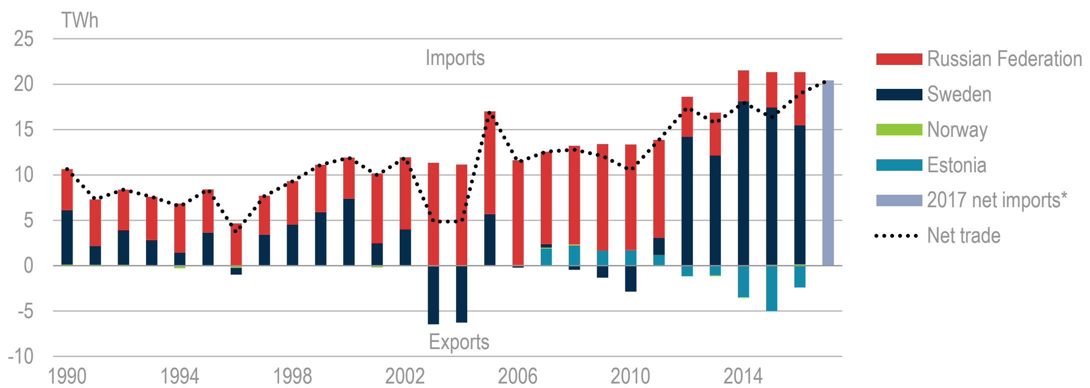


*Estonia's coal represents oil shale.

Note: Data are provisional.

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

Figure 8.5 Electricity imports and exports by country, 1990-2017



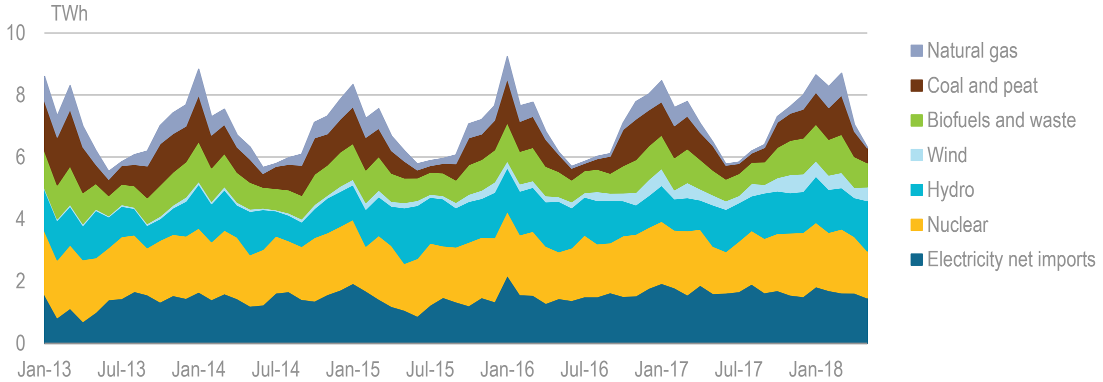
*Data for 2017are provisional and not specified by country.

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

The monthly electricity production profile shows that nuclear power, hydropower and electricity imports are relatively stable over the year, whereas combustion fuels are varying significantly over summer and winter seasons to cover the variable demand (Figure 8.6). Generation from coal, peat and natural gas in particular varied over the year, with a total electricity generation from around 0.4 TWh in July and August 2017 to

2 TWh in March 2018. Biofuels and waste also show seasonal variations, but not as large as for fossil fuels. All combustible fuels are often used in co-generation in connection with district heating, which has the highest demand in cold winter months.

Figure 8.6 Monthly electricity generation by source, January 2013 - May 2018



Note: The chart does not include negligible shares of oil, non-renewable waste and solar power.
Source: IEA (2018c), *Monthly Electricity Statistics* [June], www.iea.org/statistics/.

Installed capacity

Fuel combustion plants (coal and peat, natural gas, biofuels) account for the largest share of installed capacity, followed by hydro and nuclear (see Table 8.1).

Table 8.1 Installed electricity-generating capacity, 1995-2016 (MW)

Energy source	2000	2005	2010	2011	2012	2013	2014	2015	2016
Nuclear	2640	2671	2716	2716	2732	2752	2752	2752	2764
Hydro	2882	3035	3155	3196	3196	3224	3248	3249	3249
Solar	2	4	7	7	8	9	11	15	35
Wind	38	82	197	199	257	447	627	1005	1565
Combustible fuels	***10698***	***10676***	***9607***	***9562***	***9939***	***10275***	***9661***	***9591***	***8659***
Steam	7215	7193	7227	7205	7243	7579	6965	6930	6023
ICE*	50	50	125	102	98	98	98	98	99
Gas turbine	1847	1847	945	945	1278	1278	1278	1278	1269
Combined cycle	1586	1586	1310	1310	1320	1320	1320	1285	1268
Total capacity	**16260**	**16468**	**15682**	**15680**	**16132**	**16707**	**16299**	**16612**	**16272**

*ICE = internal combustion engine.
Source: IEA (2018b), *Electricity information, 2018*, www.iea.org/statistics/.

Wind power has grown rapidly and reached 1 gigawatt (GW) in 2015 and 1.6 GW in 2016. Power generation capacity from combustible fuels has declined since 1995. Steam turbines are most common in combustion plants; they are used for biofuels, coal and peat combustion. The capacity factors[20] in 2016 were 96% for nuclear power, 55% for hydro power, and only 22% for combustible fuels.

Co-generation

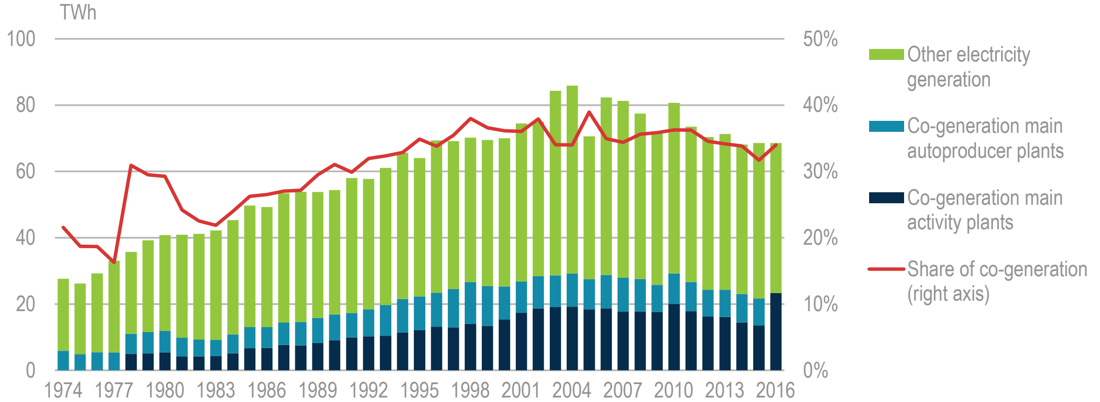
Around one-third of electricity is co-generated in combined heat and power (CHP) plants, often connected to a district heating system. In 2016, 34% of electricity and 70% of all district heat was produced in co-generation.

However, the business case for co-generation depends on the electricity price, notably for combined-cycle gas turbine plants. As wholesale prices have declined in recent years, co-generation of heat and electricity has decreased. In the five-year period 2012-16, electricity production in CHP plants was 23.4 TWh on average, compared to 27.4 TWh in the previous five-year period (Figure 8.7). There is a trend towards the replacement of CHP with biomass-heat-only boilers.

With district heating as the main driver, co-generated electricity will follow the demand for heat. Co-generation plants will thus produce on maximal capacity during cold periods, which also correlates with peak load in the electricity system (Figure 8.7). Furthermore, declining co-generation leads to a larger demand for electricity supply from other sources during peak periods, which has resulted in increasing electricity imports.

Fossil fuels, mainly coal and gas, still represent some 42% of the total energy input used for district heat production in 2015; however, their use has decreased by some 3% per year on average between 2002 and 2015.

Figure 8.7 Electricity generation in co-generation and other, 1974-2016



Notes: Data on share of co-generation in 2016 are drawn from the Finnish energy questionnaire submission to the IEA; the breakdown on main activity and autoproducer plants is not available.

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

Institutions and regulatory framework

The **Energy Department** within the **Ministry of Economic Affairs and Employment (MEAE)** is in charge of energy markets, including electricity markets, besides its

[20] Measured as power generated as share of maximal output based on the installed capacity.

responsibility for energy efficiency and emissions trading, renewable energy, nuclear energy and fuels.

The **National Emergency Supply Agency (NESA)** deals with the preparedness of the energy sector with an emergency response covering several fuels and sectors, including nuclear, coal, peat, oil and natural gas.

The **Energy Authority (EA)**, previously Energy Market Authority, is the independent national energy regulator of the gas and electricity markets with responsibilities under the Electricity Market Act and the EU third internal energy market package. EA also has administrative competences with regard to renewable energy, emissions trading, energy efficiency, energy labelling and security of supply and consumer issues.

The **Finnish Competition and Consumer Authority** implements competition and consumer policy in line with Finnish competition legislation and EU competition rules, and with a view to improve the financial and legal position of the consumer. The Director General of Consumer Affairs of the Authority is the Consumer Ombudsman. The Authority also houses the European Consumer Centre Finland. The Authority can also investigate suspected abuse of dominant position of companies in the energy markets, but has done so only for district heating.

Fingrid Oyj is the national transmission system operator (TSO) that manages the national power balance, the power system and develops the transmission network under the Electricity Market Act. Finland implemented ownership unbundling and changes were made to Fingrid, previously owned by generators Fortum Power and Heat Oy (25%) and Pohjolan Voima Oy (25%); these sold their shares to the state of Finland. Fingrid was certified in 2014, following the opinion of the European Commission. Fingrid's shares are owned by the state of Finland and the NESA (making up together 53.14%) and the remainder held by the Finnish financial and insurance institutions. Finland has 77 **electricity distribution system operators** (DSOs) which have security of supply responsibilities for their network areas. In 2015, 34% of the companies were privately owned and 66% were owned by local municipalities. Out of the total, by end of 2016, 48 DSOs were legally unbundled, with the remainder pursuing supply/retail activities.

The **legal framework for the electricity market** is set out in the Electricity Market Act and government decrees based on the Act. The Energy Authority monitors compliance with the electricity market legislation and promotes the operation of the competitive markets. The **Electricity Market Act** provides the legal basis for the ownership unbundling of transmissions from generation and trade and the legal unbundling of the distribution system operation from supply. Fingrid has to maintain the power balance at all times. DSOs have to comply with reliability standards for security and quality of supply. Electricity security is governed under the 2011 Act on Peak Load Reserves to Ensure Balance between Supply and Demand (so-called Capacity Reserve Act). Finland does not have regulated retail prices for electricity (or gas).

Electricity networks

Transmission networks and interconnectors

Fingrid owns and operates the main transmission grid in Finland. The transmission grid encompasses approximately 14 600 kilometres of transmission lines (including subsea cables) and nearly 119 substations, connecting the grid to the major consumers, production plants and neighbouring countries.

Interconnectors play a crucial role for Finland's security of supply and are a major source of flexibility for the Finnish energy system (see below section on security of electricity supply). Finland has interconnections to Norway (one), Russia (one), Estonia (two) and Sweden (several). The interconnection to Estonia has been strengthened over the last years. At the end of 2016, the electricity transmission capacity from Sweden, Russia and Estonia to Finland amounted to around 5 250 MW.

Finland is connected to Sweden via two 400 kilovolts (kV) alternating current (AC) connections in northern Finland. Finland also has a 220 kV AC connection to Norway. Direct current (DC) links have also been built: Fenno-Skan 1 from Rauma (400 MW) to Dannebo in Sweden, and Fenno-Skan 2 (800 MW) from Rauma to Finnböle in Sweden. The third interconnector Northern Sweden to Finland (400 kV), promoted by Fingrid and Svenska Kraftnät, has been selected by the European Union as project of common interest (PCI) for the Baltic Sea region's electricity market and security of the synchronous inter-Nordic system, and for supporting the security of electricity supply in Finland during the winter periods. The line should be commissioned by 2025. Finland and Estonia are connected by DC lines Estlink 1 (350 MW) and Estlink 2 (650 MW).

There are three 400-kV transmission links from Finland to Vyborg in Russia. Russia and Finland are also connected by 110-kV connections from Ivalo and Imatra in Finland, which connect hydropower plants in Russia to the Finnish grid (see Figure 8.8).

Table 8.2 Interconnectors of Finland

Interconnector	Voltage (kV)	Import capacity (MW)	Export capacity (MW)
Finland-Russia	DC 400	1 400	350
Finland-Sweden		1 500	1 100
Petäjäskoski	400		
Keminmaa	400		
Ossauskoski	220		
Fenno-Skan 1	HVDC	550	
Fenno-Skan 2	HVDC	800	
Finland-Sweden	400	800	
Finland-Estonia (Estlink1)	HVDC	350	
Finland-Estonia (Estlink2)	HVDC	650	
Finland-Norway	220	120	100

Distribution networks

Finland has a large variety of DSOs with different sizes, ownership structures and legal requirements, including for their unbundling. This makes the task of distribution regulation and governance challenging. The distribution networks operate at a voltage level of 0.4 to 110 kV and are characterised by long overhead radial networks with an average network length of 115 metre per customer.

Figure 8.8.The electricity grid in Finland

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.

In 2017, Finland had 77 DSOs which have security of supply responsibilities for their network areas. In 2015, 34% of the companies were privately owned and 66% were owned by local municipalities. Most DSOs have economic ownership of the assets; some DSOs' network assets are partially leased. The largest DSOs are Caruna (457 000 customers), Elenia (415 000) and Helen (369 000), while the smallest DSOs have only a customer base of 750 clients.

There is no requirement for ownership unbundling of DSOs, in line with EU law. The Electricity Market Act requires DSOs to be legally unbundled if the annual quantity of electricity transmitted to their customers has been 200 GWh or more during three consecutive calendar years. All DSOs below this level can choose legal unbundling. At the end of 2016, there were 36 DSOs over the threshold but 48 were in fact legally unbundled. Most legally unbundled DSOs belong to a parent company that is a generator and/or electricity retail company. At the end of 2016, 20 DSOs had more than 50 000 customers and in their case, a separate management or functional unbundling is demanded. All other DSOs that are not legally unbundled have to apply account unbundling. The same is however also required from those legally unbundled companies if they have other activities besides the network business and are small DSOs (with annual revenues below EUR 500 000, which is less than 10% of the company's total revenue).

The Energy Authority does not regulate the distribution tariffs *ex ante*, but approves the methodology of DSOs' rate-of-return calculations. Distribution prices have steadily increased in recent years, mainly because of the investments to make their networks more reliable to reduce interruptions and the roll-out of smart meters. A limit is set in legislation that network tariffs must not raise more than 15% per year. The Authority approves, every second year, plans on how DSOs will fulfil the reliability standards. Underground cabling is adopted in most cases, which will improve resilience against climate and weather impacts. Greater digitalisation and the transformation of the energy system will impact the operations of the DSOs in the future.

Wholesale market

The Finnish power system is part of the most advanced European power market, spanning across the Nordic (Norway, Sweden, Denmark, Finland) and Baltic states (Estonia, Lithuania, Latvia), coupled with the Western European electricity markets since 2014. Sweden, Finland, Norway and Eastern Denmark form one synchronised zone.

The market operator across the Baltic Sea region is Nord Pool AS, which is also the electricity market operator in Finland. Elspot is the day-ahead market and Elbas the intra-day market (for capacity not used in Elspot). The Nordic transmission system operators (TSOs) have established a power market with common regulation based on a joint Nordic merit order list for a specific operating hour so as to balance management across the Nordic control areas as one system of all four TSOs. Since May 2017, there is also a common Nordic Balance Settlement.

Intra-day gate closure between Finland, Latvia and Estonia is currently piloted for 30 minutes (instead of 60 minutes in the Nordic market). Since the introduction of such a shorter gate closure, intra-day trading volumes have increased according to Fingrid (2017a).

In 2017, the Nordic market volume traded on the day-ahead market reached a total of 391 TWh and 5 TWh on the intra-day market. The price cap in the day-ahead market is EUR 3 000 per MWh and EUR -500 per MWh. Discussions are ongoing to increase the price cap in the intra-day and balancing power markets to reflect the increasing need for flexibility (see below section on security of electricity supply).

Finland is organised as one bidding zone in the Nordic market (different from the other Nordic countries which have several price zones) and congestion in national and inter-regional lines is managed by countertrades. In 2016, the costs of Fingrid amounted to EUR 3.9 million. Congestion on the interconnectors is managed by implicit auction in the day-ahead market, and Fingrid had a total income of EUR 39.9 million in 2016, which it uses to finance investments that aim at relieving these congestions (Fingrid, 2017a).

The Baltic states are not synchronised with the Nordic wholesale electricity spot market (Nord Pool), but with Russia. The heads of state or government of Lithuania, Latvia, Estonia and Poland and the European Commission reached an agreement in June 2018 on the Political Roadmap for synchronising the Baltic states' electricity grid with the continental European network by the target date of 2025. In September 2018, the Baltic states supported the formal launch of the procedure by the Polish and Baltic states' Transmission System Operators (TSOs). The synchronisation process will be managed by the European Network of Transmission System Operators (ENTSO-E).

Having a significant deficit in generating capacity compared to peak load, Finland is heavily dependent on this integrated European electricity market and imports have increased. In 2016, 72% of electricity consumption in Finland was bought through Nord Pool and 28% through bilateral contracts (EA, 2017).

Generation and competition

According to the Energy Authority, there were around 150 power generators and 400 generation plants in Finland in 2017 (EA, 2017). Many are municipally owned companies that produce electricity in co-generation (heat and electricity), while half the installed generating capacity is owned by three big companies. Around 40% of total electricity production comes from these power plants, which have several owners (co-ownership). In recent years, competition has come from new wind power plants. However, market concentration has also increased amid the closure of condensing power plants.

A large part of the electricity generated is for producers' own use (energy does not go to the open market but directly to the producers' own use, notably from nuclear power plants) and significant capacity is co-owned by different companies of the Finnish industry through cross-ownership. In terms of capacity ownership, Fortum Power and Heat Oyj, and Teollisuuden Voima are the largest incumbent generators with market shares of 17.8% and 10.6% respectively (Table 8.3).

The regional Nordic-Baltic market is another market area to consider when judging the level of market concentration. There are four large players, Vattenfall, Fortum, Statkraft and E.ON. However, in cases of cross-border congestion, Finland becomes an isolated price area and generators could have the ability to exert market power. In 2016, Finland had 65% of the time the same price area as Sweden and 90% of the time as Estonia (EA, 2017).

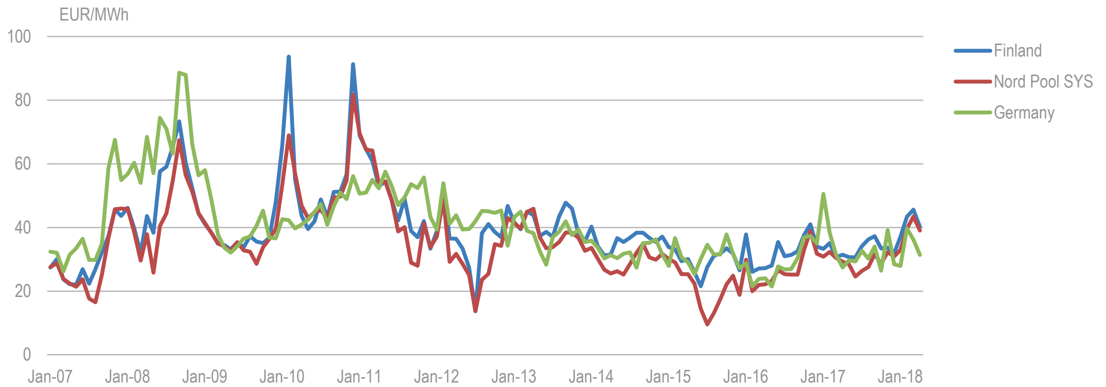
Table 8.3 Net maximum electricity capacity 2017 by ownership (MW)

Owner	Capacity (MW)	Share (%)
Fortum Power and Heat Oyj	2 947	17.8
Teollisuuden Voima	1 761	10.6
Helen	1 141	6.9
Kemijoki Oy	1 122	6.8
Fingrid	948	5.7
Stora Enso Oyj	701	4.2
UPM Energy Oyj	568	3.4
Tuuliwatti Oy	465	2.8
Others	6 923	41.8 %

Wholesale electricity prices

Electricity wholesale prices in the Nordic region have been relatively low for several years, after a decline that began in 2011. The Elspot day-ahead price at the Nord Pool exchange has varied between 20 and 40 EUR/MWh in recent years, in contrast to peak levels around 90 EUR/MWh in 2010 and 2011 (Figure 8.9). General overcapacity in Nord Pool, a high level of renewable generation (wind power) and lower than anticipated demand have led to a decrease in the power prices and this is expected to continue with more wind power capacity coming online across the Nordic market in the next five years.

Figure 8.9 Wholesale electricity prices on Nord Pool day-ahead, January 2007-April 2018



Note: Historical day-ahead (Elspot) monthly average prices on the Nord Pool Exchange and Fraunhofer ISE for German prices: www.energy-charts.de/price_avg.htm?year=all&price=nominal&period=monthly.

Source: Nord Pool (2017), "Historical Market Data", www.nordpoolspot.com/historical-market-data/.

Financial markets

Financial hedging products are traded both in the derivatives exchange, Nasdaq Commodities (NASDAQ OMX), and in the over-the-counter (OTC) market but cleared at the exchange. The hedging power products offered on NASDAQ OMX comprise Nordic, German, Dutch and UK power derivatives. The derivatives are base and peak load futures, Deferred Settlement Futures (DS Futures), options, and Electricity Price Area Differentials (EPAD). However, since the financial crisis of 2008/09, the volume of Nordic derivatives has decreased. Market surveillance is carried out by the Swedish Financial Supervisory Authority (Finansinspektionen) which has granted a licence to clearing-house NASDAQ OMX Stockholm AB.

There are also concerns of limited product spread in the exchange for financial markets and hedging. Market power in the balancing markets remains high. Recently, the Nordic TSOs are working together on a regional balancing market that may reduce these competition concerns in the future.

Retail market

In Finland electricity retail supply does not require any licence or registration from the Energy Authority. In 2016, there were 73 retail suppliers, 55 of which offered their products on the national market. Only 9 electricity retailers are fully independent and ownership-unbundled from electricity network activities; they have no supply obligation. Most of the legally unbundled electricity retailers still belong to the same group of companies as a DSO.

The Energy Authority estimated in 2017 that there were four electricity retailers with a market share above 5%, and the market share of the three largest companies in the retail market for small and medium-sized customers has been estimated to be 35% to 40%. The Herfindahl-Hirschman index (HHI)[21] is low, with a market concentration of around 500 to 700 showing a competitive marketplace.

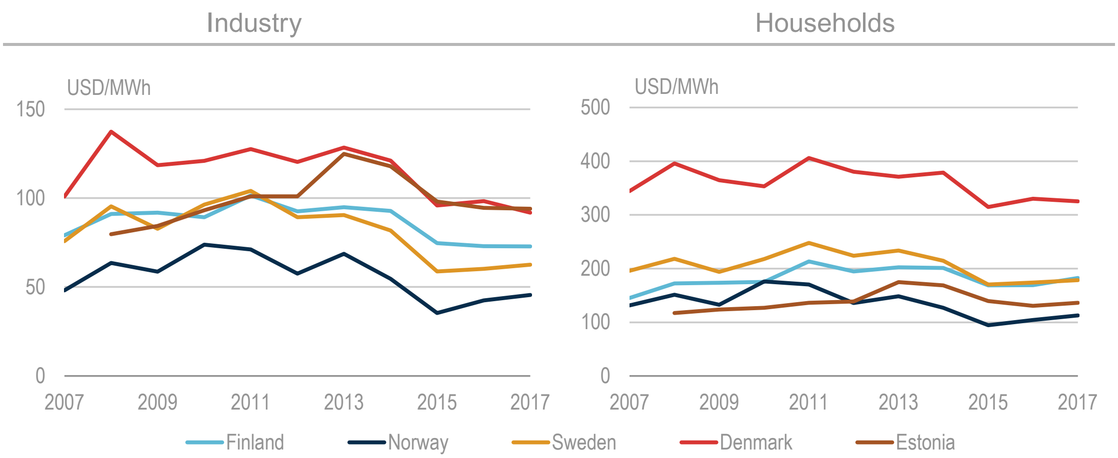
Major players in the retail markets are Fortum Markets Oy (market share of 17% to 20%), Vattenfall Oy (10% to 13 %) and Helen Oy (10% to 13 %). Other players' market share is 5% or less. The market share of all fully independent suppliers together was below 10%. The number of new entrants and fully independent suppliers has increased gradually since 2010. In 2016, there were 9 electricity retailers in the Finnish electricity retail market without obligation to supply. These retailers are also fully independent from the Finnish network companies. At the end of 2016, these retailers had less than 10% of retail customers in Finland.

Electricity retail prices and taxes

Finnish industries pay the fourth-lowest price for electricity among IEA member countries, thanks to the low wholesale prices as well as low taxes (Figure 8.11). In 2017, the industry price was 73 USD/MWh, of which 11% was taxes. Households paid 183 USD/MWh, of which 33% taxes, the median in the IEA.

[21] The Herfindahl-Hirschman Index or HHI is a measure for industry concentration taking into account the size of firms in relation to the industry. It is calculated by adding the sum of the squares of the percentage market shares of each market participant. For example, a market consisting of five competing firms, each with a 20% share of the market would have an HHI score of 2 000 (i.e. 202 x 5). HHI is typically used to help assess the degree of market dominance and potential for market power abuse. Views vary on the interpretation of HHI scores. This study uses the scale developed by the European Union, with scores of 750 to 1 800 considered indicative of moderate concentration; scores of 1 800 to 5000 are indicative of high levels of concentration and scores above 5 000 are indicative of very high concentration, consistent with the presence of substantial potential market power.

Figure 8.10 Retail electricity price trends, 2007-17



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

Figure 8.11 Electricity prices in IEA member countries, 2017

*Tax information not available for the United States.

Note: Data not available for industry in Australia, New Zealand and Italy, and for households in Italy.

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

Smart meters and smart grids

Finland is leading the roll-out of smart meters in the European Union. In 2013, the country completed the roll-out and today, over 99% of all customers have a smart meter. This is revolutionising the grid and system operation in Finland, creating a smart grid, as grid operators no longer use load curves but hourly metered consumption for balance settlement.

Finland is moving towards a centralised information exchange system in retail markets. Since 2015 Fingrid has been developing a data hub, along with other Nordic TSOs, which will contain data from all 3.5 million electricity metering points in Finland. The data hub will bring together all essential electricity end-use information, which will speed up, simplify and improve the supplier switching and the smartness of the grid. The data hub is planned to be operational in 2019. MEAE is currently preparing draft legislation.

A Smart Grid Working Group was created by the MEAE with a two-year mandate. The interim findings of the Group confirmed the need for a market-driven approach for consumer participation and engagement, with storage as part of a competitive service (not regulated service of the DSO) and a positive role for energy communities and aggregators. The Group concluded that there is a need to improve understanding of the impacts of digitalisation, notably next-generation intelligent meters, and to adjust the design of the retail market model as well as building and grid regulation that supports demand-side management. (A final report is expected to be released by the end of October 2018.)

Demand response

At retail level, the full smart meter roll-out has also enabled greater participation of residential consumers in the electricity market, not least thanks to the emergence of dynamic prices. Finland is one of the few countries in the world where customers have wholesale spot price pass through retail electricity prices. By the end of 2016, there were around 10% of customers with hourly prices from wholesale spot price pass-through. However, currently, low wholesale prices in the Nordic market have not created enough incentives to use those price mechanisms in retail prices on a wider basis.

In Finland, demand participates actively in the reserve markets of the TSO Fingrid but its volume is low in the medium-term strategic reserve organised by the EA, which is explained in more detail in the section below on security of electricity supply. Conversely in Sweden, the demand side is included in the strategic reserve.

Supplier switching

According to the Energy Authority, 51% of retail consumers had an open-ended contract with a two-week notice provision. In 2016, supplier-switching rates were at 12% for households and 10% for industry and others, which are relatively high in comparison to European and Nordic switching rates.

Supplier switching procedures are complex given the diverse number of DSOs and their diverse levels of unbundling, regulatory and legal governance. The Electricity Market Act (588/2013) lays out the basic roles and responsibilities of the DSOs and suppliers during supplier switching. The Act sets up the basic principle of using measurement data to settle all customers. The Electricity Market Act also sets an obligation for the TSO to develop a data exchange of electricity trade and settlement, which Fingrid has set up (datahub). A government decree on settlement of electricity delivery and metering (66/2009) has provisions on metering and meter reading during the supplier switching process. The actual information exchange process related to supplier switching is regulated by a Decree of the Ministry of Economic Affairs and Employment on information exchange related to the settlement of electricity delivery (809/2008). The decree allows, however, DSOs in certain conditions to use estimated meter values. The DSO shall send the meter value to the new and old supplier within 10 working days after the supplier switching took place.

To start a switching process, a customer needs to contact only the new supplier for making a new supply contract and terminating the present one. A customer may also wish to contact directly a current supplier in order to terminate the existing supply contract. It is possible to switch supplier on any day. The new supplier sends, without delay, a notification to the DSO informing of the new contract at the latest 14 days before starting the delivery. When there is need for a new metering arrangement, the DSO must be informed 30 days before starting the delivery. When receiving the notification about the new contract, the DSO shall forward this information to the present supplier without any delay and at the latest within two working days after receiving the notification from the new supplier. As indicated, the data hub will significantly simplify this process.

Policies to support renewables and CHP

Combined heat and power (CHP) is subject to both energy/CO_2 and electricity taxation which strongly increased since the 2011 tax reform. To avoid overlaps with the EU wide emissions trading scheme and to promote energy-efficient CHP, the CO_2 tax is halved for CHP, and fuels used for electricity generation are exempt from electricity tax. Today, the CHP tax reduction is however “higher” for coal than for natural gas. Autoconsumption of small-scale electricity producers or consumption during the process of electricity production are also exempted.

Several subsidies are available for CHP and there are two different types of operating aid. The first one concerns only a few biogas and (small) CHP plants using wood-based fuels, which is called the “heat bonus”, paid as a top-up on the electricity feed-in premium. (For biogas plants, the upper limit is 8 MW and for plants using wood fuels the upper limit for aid – 750 000 EUR/year – limits the size of plants.) The other operating aid is meant for existing CHP plants; it compensates the difference between fuel costs of peat and forest chips. Most of the CHP plants using forest chips and/or peat are included in this scheme. In addition, there are CHP plants using gas or coal, but they are not covered by these schemes.

Investment grants are available to companies, municipalities and farmers for installing heat pumps, geothermal, biogas, biomass and solar thermal installations. Finland has amended its support scheme for electricity produced from renewable sources on 23 May 2018 (Government Bill 175/2017). The feed-in premium will be abolished and competitive auctions introduced, in line with technology cost reductions. As part of the ban of coal, the government wants to provide EUR 90 million of support to the faster phase-out of fossil fuel-based CHP. Around EUR 45 million will support a switch to biomass CHP by 2025, with the other half for non-combustion technologies, such as heat pumps (which are used for instance in Denmark at CHP plants to increase performance) or storage.

Security of electricity supply

Legal framework and governance

Under the Electricity Market Act, Fingrid has to maintain the power balance at all times. Distribution system operators have to comply with reliability standards for security and quality of supply.

Finland is a net importer of electricity and has legal provisions under the 2011 *Act on Peak Load Reserves to Ensure Balance between Supply and Demand* (so-called Capacity Reserve Act). The Energy Authority is tasked to evaluate and decide the required size of the peak load reserves and to arrange the tendering process and procurement. The Energy Authority also supervises the profits of the peak load power plants. TSO Fingrid is responsible for making agreements with the selected power plants and Fingrid pays the compensations to the power plants. The peak load reserve system is funded by the fees collected from the Finnish electricity end-users.

The National Emergency Supply Agency, together with Fingrid runs regular exercises on power security, the last one in October 2017 (the national JÄÄTYVÄ 2017 exercise) to practise co-operation between authorities, municipalities and businesses in case of a widespread power outage caused by weather conditions.

Fuel diversity

The Finnish power system relies on capacity from nuclear (33%) and hydro (22%) energy, besides biofuels and waste (18%) and coal 10.0% and natural gas 5%. Wind, biomass and imports have increased with the decline in the importance of fossil fuels. Diversity will be reduced as coal use is being phased out by 2030. Natural gas is hardly used in power generation (5%).

Generation adequacy

Electricity demand is highly seasonal and depends on the weather, but also on industrial production cycles. The record peak demand occurred on 7 January 2016 and reached 15 105 MW. The government estimated annual peak load to be 14 800 MW in 2020 and 15 300 MW in 2030 according to the underlying projections made for the National Energy and Climate Change Strategy for 2030 (MEAE, 2017).

Electricity generation capacity is around 16 GW (including wind and reserves), but only 11.7 GW is available during peak load in the winter periods, and availability and flexibility have worsened in recent years. Even with the new Olkiluoto 3 nuclear plant coming online by 2019, Finland will still remain dependent on electricity imports. Capacity adequacy remains a challenge in Finland, notably during winters (so-called dry years) and/or when interconnector and import capacity can be constrained. As such, Finland is a net electricity importer and cannot rely on its own generation to meet peak demand. It is strongly dependent on imports from the Nordic and Baltic neighbours.

Heat and power demand are closely linked in Finland, given the large role of combined heat and power (CHP). With old CHP plants closing and the future coal phase-out, and delays in the commissioning of new nuclear capacity, there is a challenge in securing electricity supply during peak load hours in winter. The phase-out of coal-fired power generation by 2030, a stated goal of the government, is currently being prepared. MEAE has completed an evaluation of the impacts of security of supply. Estimated available capacity to meet winter peaks until 2019 is around 11 500 MW; around 3 700 MW short of peak consumption. Peak consumption is projected to remain relatively steady to 2020 with modest growth (of the order of 200 MW) by 2030. While additional capacity is scheduled to enter the market in the next five years, the majority will be provided by wind (560 MW) and nuclear (1 612 MW) which do not provide the same level of flexibility as combustible power plants or hydropower. The additional nuclear capacity is due to come online in 2019.

Strategic reserve

In light of these capacity constraints, Fingrid maintains a strategic reserve for 2017-20 of 729 MW (Capacity Reserve Act, 707 MW of power plants and 22 MW of demand response) which is not allowed to participate in the wholesale market (design feature of the energy-only market of the Nordics). The strategic reserve is used to ensure that the balance between supply and demand is achieved if the balance has not been achieved in the commercial market, i.e. in the day-ahead market of Nord Pool. The use of the capacity reserve is rare; last time it was used was in winter 2009/10.

During the peak load season, from December to end of February, power plants in the strategic reserve are in 12-hour readiness. Otherwise, power plants are in one-month readiness mode. The owners of the selected strategic reserve will receive fixed compensation for providing it. The activation of the strategic reserve will happen with the cap price of the markets. When the strategic reserve is activated to balance supply and demand, only actual costs caused by the activation are repaid to the reserve plants.

In 2016, the Energy Authority started preparations for the procurement of strategic reserve capacity for the period of July 2017 to June 2020 by evaluating the needed amount of strategic reserve capacity. After a tendering process in winter 2017, four power plant units and two demand-side flexibility facilities (29 MW) were selected to the strategic reserve. These six units comprise a total reserve capacity of 729 MW.

Flexibility

Finland continues to be an importer of electricity (with a maximum import capacity of 5.2 GW), and relies on flexibility of power supplies from the Nordic and Baltic markets and Russia. In recent years, following the introduction of a capacity market in the Russian price zone and related tariff issues in 2012, Russian power imports decreased by 60%. Power plant flexibility in Finland is very limited for nuclear, but somewhat higher for coal and hydro capacity (accounting together for almost 70% of power generation).

Security of power supply needs to be guaranteed at all times, an increasing challenge in a power system with high shares of wind generation in the Nordic power system. This is exacerbated by the fact that interconnection capacity is limited and availability constrained during dry and cold winters, when hydro or wind power in Sweden and Norway is not available. By 2025, the Nordic region will add around 23 GW of wind power, which will require a much higher flexibility of the Nordic power system, from interconnections, flexible thermal and renewable power plants and grid automation, as well as demand response. Despite ample capacity, peak power availability and rotating mass will be needed to ensure power system stability.

While day-ahead and intra-day markets are run by Nord Pool, the balancing market is a common responsibility of the Nordic TSOs with a merit order established across the Nordic market. Nordic cross-border trading in balancing power and reserve markets is under discussion. For example, the Nordic TSOs have established a joint Nordic market for the automatic frequency-regulating reserve. The 2018 co-operation agreement of the five Nordic TSOs on the development of a new Nordic balancing concept is a milestone achievement in this regard. The co-operation agreement outlines the roles and responsibilities of the TSOs and proposes a common roadmap for implementation of the new balancing concept, common balancing markets and the future development of new market platforms supporting common markets and tasks in the new balancing structure.

Regional security collaboration

The government takes a national approach to electricity security, notably through the strategic reserves, while the wholesale electricity market and power system operation have a regional dimension. Given transmission constraints and the same fuel mix in the Nordic countries (a dry year would affect all countries at the same time) all Nordic countries maintain their own national strategic reserve. A regional approach to electricity security and adequacy is under discussion. Regional co-operation among Nordic TSOs has been the backbone for maintaining day-to-day power security in the Baltic Sea region. The Nordic Regional Security Co-ordinator (RSC) supports the national TSOs in maintaining the operational security of the power systems across Finland, Norway, Sweden and Denmark. In 2018, cross-border short-term power system planning tasks are being transferred to the Nordic RSC, the joint office for the four Nordic electricity TSOs. The RSC is tasked with the following operations:

- Co-ordinated cross-border transmission capacity calculation (CCC).
- Co-ordinated security analysis (CSA) to identify preventive action to the individual TSOs.
- Outage planning co-ordination (OPC) through joint register and streamlined maintenance.
- Short- and medium-term adequacy (SMTA) forecasts for market players.
- Improved individual grid models (IGM) and a common grid model (CGM).

Network adequacy

Transmission networks and interconnectors

At transmission level, Fingrid maintains the grid assets and expands the grid in view of the future needs, including at regional level. In 2017, Fingrid published its latest national ten-year network investment plan, indicating a EUR 1.2 billion investment programme for the years 2017–27 which focuses on both the domestic and the regional transmission grids (Fingrid, 2017b). Fingrid has one of the most comprehensive investment programmes in the Nordic region in terms of volume and upgrades. The national plan reflects grid challenges and needs identified in the Baltic Sea region; it is based on the regional network plan 2017 and the first ever Nordic system development plan prepared in 2017 (Nordic TSOs 2017).

Fingrid's investments focus strongly on renewing ageing transmission lines and substations (which were built in the 1970s). To improve its power security, Fingrid has invested in the strengthening of the internal network, notably by upgrading the oldest power line in Finland (Rautarouva, built in the 1920s) and by constructing a third AC power line to Sweden (800 MW) by 2025. The Fenno-Ska-1 subsea line runs at reduced levels as it reaches the end of its life much earlier than anticipated, by the late 2020s. The cable should be replaced by a link from Vaasa across Kvarken to Sweden by 2027. The new 400-kV cross-border line between northern Sweden and northern Finland and increased electricity production in northern Finland require greater transmission capacity from north to south inside Finland. A new 400-kV connection to Ostrobothnia (the Coastal Line) was completed in 2016, the largest grid investment in the history of Finland, and the next connection from Oulujoki to central Finland (the Forest Line) is being planned. The north-south connection has to be completed before the new Finland-Sweden AC connection comes online to avoid north-south bottlenecks.

Reliability and availability of cross-border capacity have been identified as a challenge in the Baltic Sea region (where most electricity is traded through direct current lines). Finland has increased interconnection capacity to Estland; Fingrid also purchased half the Estlink-1 connection and built reserve power plants in Olkiluoto and Forssa.

Distribution networks

Most interruptions in transmission and distribution occur at the level of the network and are highly weather-induced.

Table 8.4. Interruptions in transmission and distribution networks in 2006-16

	Interruption in minutes lost per customer per year										
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Transmission	2.1	1.5	1.6	2.7	5.0	6.9	1.3	2.3	8.3	2.0	1.4
Distribution	175	110	162	123	287	584	170	332	130	323	97

Source: Energy Authority National Report 2017.

In 2013, new requirements for the allowable interruptions in the distribution networks were set in the Electricity Market Act. Interruptions caused by storm or snow in the urban areas shall not be longer than 6 hours. In rural areas this figure is 36 hours. These standards shall be reached incrementally by the end of year 2028. Because of the requirements, DSOs have made large investments to replace overhead medium- and low-voltage lines with underground cabling. In the first phase, DSOs have invested mostly in medium-voltage lines. It has been estimated that, by 2029, the length of underground cables in medium-voltage networks will more than double their 2013 levels, with a cabling rate increasing from well below 20% in 2013 to almost 50% in 2029.

Assessment

Wholesale electricity market

Finland's electricity supply has a diverse fuel mix with capacity from nuclear power contributing about 33% of total supply, followed by hydro (22%) and coal (10%) and a small share of natural gas (5%). Wind has been progressively increasing, albeit from a low base, to 7%. Net imports, primarily from Sweden and Estonia, play an essential role in meeting demand and peak demand. (Russian imports do not contribute to the peak demand hours in Finland owing to the capacity payments in Russia.)

Since the 2013 in-depth review, Finland's wholesale electricity market has become more and more integrated with the Nordic power market (Norway, Denmark, Sweden) and the Baltics (Estonia, Lithuania and Latvia) into a common market area. More than 70% of electricity consumption in Finland in 2016 was purchased through the Nord Pool market. Integration delivers benefits in the form of lower wholesale prices (through enhanced competition) and a more secure electricity supply to Finnish customers.

Since the 2013 review, Fingrid has strongly improved the security and competitiveness of electricity supply and regional market integration. It expanded considerably the cross-border capacity to Estonia. Interconnection with Sweden and related North-South grid expansion in Finland will be strengthened by 2025 through a new 800 MW AC power line to the north of Sweden, designated by the European Union as a project of common interest. This project will improve import flexibility amid reduced power trade with Russia (following the introduction of its capacity remuneration scheme in 2011) which has historically been the primary source of imports to Finland.

The government has also taken actions to build greater flexibility into the power system. Measures have been introduced to increase competition by reducing barriers for smaller players to participate in the balancing market, including lower minimum bid sizes, electronic automation of bids and increased transparency of balancing power prices. Successful demand response pilot schemes, the full roll-out of smart meters and an increasing share of hourly spot-based retail prices, have leveraged around 500 MW of demand response capacity in the wholesale (primarily day-ahead) market.

However, surplus generation and increasing penetration of renewable resources, overcapacity, and lower fuel prices have led to lower Nord Pool power prices. This is reducing the business case for investment in new capacity in Finland and rendering existing CHP plants less competitive, in spite of some support from government through tax subsidies.

These developments, coupled with the withdrawal of significant thermal generating capacity in recent years – over 2 000 MW of coal and combined cycle gas turbine (CCGT) capacity since 2010 – and plans to phase out coal-based power production by 2030, are leading to increased reliance on imports to meet peak demand in Finland. A significant proportion of imports are coming from hydropower production in other countries, which are affected by climate variations and drought conditions.

To provide insurance against short-term supply shortfalls, the Energy Authority has acquired a strategic reserve capacity of 729 MW for the period of 1 July 2017 to 30 June 2020, with a fixed cost of EUR 13.8 million per year. The new strategic reserve capacity includes 22 MW of demand response. The strategic reserve needs to be evaluated at least every four years, but in practice it has been carried out every two years. Given the dynamic nature of energy markets across Europe and the rapid advancement in new technologies, more regular reviews are necessary, with a wider regional focus.

As the Nordic countries become more interdependent and market integration progresses, greater collaboration between the Nordic TSOs, regulators and energy industry becomes critical, including when designing respective strategic reserves and other security of supply measures. This provides for an opportunity to increase flexibility from interconnectivity, flexible dispatchable power plants, energy storage and demand-side participation.

To date, there are adequacy assessments for different regions under the framework of the European Network of Transmissison Network Operators for Electricity (ENTSO-E). However, there were no periodic assessments undertaken for the Nordic region alone. The Nordic Council of Ministers asked the TSOs to undertake a study in 2017. A milestone in this respect is the common generation adequacy assessment presented together with the Nordic Grid Development Plan in 2017. The new Regional Security Centre (RSC) is a welcome development which will continue to progress on these matters and foster security in the regional power system. The IEA encourages the government of Finland to lead more periodic adequacy assessments, and build upon the current agreement reached in spring 2018 between the TSOs in favour of a Nordic balancing concept and market.

Retail electricity markets and smart grids

In 2016, there were about 73 electricity retail suppliers serving Finland's 3.5 million consumers; 55 of these offered their products nationwide. Annual switching rates are relatively high compared to the rest of Europe, at 12% for households and 10% for industry and others.

Finland is a success story on smart metering deployment, with over 99% coverage for electricity supply and around 10% of consumers have switched to wholesale spot price pass-through dynamic pricing. The Finnish government can be commended for instigating a Smart Grid Working Group to identify barriers and provide concrete actions to facilitate the transition to a smart energy system, in particular enabling consumers to engage with (and reduce bills through) demand response.

In addition, Fingrid is introducing a new data hub in 2021, following some delays, which will contain information from all customers. This will speed up and simplify retail market operations (for example changing suppliers or moving to a new address), support imbalance settlement relating to the distribution network, and reduce barriers to the entry of new, innovative energy services companies.

At a regional level, there is a long-standing ambition to promote a common retail electricity market in the Nordics (promoted by the regulatory collaboration body, NordReg) to support consumer engagement through greater transparency and common standards and products, so that suppliers face no obstacles to operate in the entire Nordic end-user market. The data hub will be an important step into this direction, as the Nordic TSOs advance on common approaches.

The distribution sector in Finland is diverse. There are 77 distribution system operators (DSOs) with varying size and network density. Following a series of severe storms that damaged electricity distribution networks, legislation was introduced in 2013 to ensure greater resilience of the networks against storm or snow through reliability standards: the electricity interruption for the customers must not exceed 6 hours in detailed planned areas and 36 hours in other areas. These time limits must be met gradually over a 15-year time period and fully by the end of the year 2028.

There are a number of areas that the Finnish government can focus on in order to shift to a smarter and more flexible energy system, which involves the electricity retail and distribution sectors.

While Finland's early adoption of smart meters has led to many benefits, it has also resulted in some interoperability issues across DSOs. In order for the country to fully exploit the benefits of aggregation services, demand response and storage, it will need to upgrade its smart meters when the current assets approach the end of their lifetimes in 2025. The government, the Energy Authority and Fingrid should also ensure they are in a position to maximise benefits of the data hub; by utilising the wealth of information, it could improve policies and regulation of the energy system. This can help in assessing retail market competition, the uptake in flexibility services, and the comparative energy efficiency of different sectors.

The government should also review barriers to smart and flexible energy services in the regulatory and tax regimes. For example, it needs to ensure that innovative and new technologies, such as storage and network-connected electric vehicles, do not face double charging of energy taxes, VAT or network costs.

The government should also put in place appropriate consumer protection policies to ensure that the transition to a smarter and more decentralised energy system reaches all consumers – and not just those who can afford the latest technology (for example smart appliances, smart heating, small-scale storage and electric vehicles).

Tighter regulation and oversight of electricity distribution are required in order to support the transition of the sector to new business models and a smarter system. The government has already taken an approach to ensure better quality of supply but further regulatory measures should be considered.

First, it will be important to ensure that these new services are effectively unbundled to encourage competition in energy services and in line with European legislation. Today, around 30 DSOs pursue both retail and distribution activities.

Secondly, traditionally network companies have focused on the "poles-and-wires" aspects of their businesses. However, in a future smart energy system, they should be taking an output-based approach – for example facilitating storage, demand response or energy efficiency where this is more cost-effective than reinforcing their networks. This transition can be difficult for some DSOs, who are locked in methods of the traditional model, and also want to keep expanding their asset base. The definition of concrete output targets could be an opportunity to foster quality of supply, and not necessarily investment in physical grid, leaving a greater choice for DSOs to choose between capital and operational expenditures.

Thirdly, the current regulatory framework for distribution networks is comparatively light touch and DSOs are free to set the tariffs, in line with the methodology of Energy Authority. Depending on the network, there is significant variability between DSOs in terms of the size of the fixed and variable costs. The tariff structure may present a barrier to entry for third parties, e.g. aggregators who want to offer demand-response services through distribution networks, or direct to consumers. It also means that some consumers, where distribution costs are fixed, have lower incentives to pursue energy efficiency or demand response and have less ability to reduce energy bills. Conversely, where demand for distributed electricity decreases, with the emergence of new smart-system services (storage, distributed generation, EVs, etc.), the fixed component risks undercoverage. The government should explore greater consistency and the harmonisation of distribution tariff methodologies.

Overall, ensuring unbundling and the competitive offering of services and the appropriateness of cost recovery require greater oversight. The Energy Authority should be equipped with the powers to audit investment costs of all DSOs, regardless of their size and scope. The tighter regulation and requirements to increase services will encourage DSOs to seek efficiencies, either within their own businesses or through consolidation.

Sector coupling with co-generation

Combined generation of heat and power, and related district heating and cooling, remain the best ways to improve energy efficiency, help renewables and link heating with electricity for flexibility. Finland has a large potential for aligning energy efficiency and renewable energy policies, linking heating with electricity for flexibility and integrating more renewables in both heating and electricity (project in Åland), and utilise waste heat and waste cold. Having in mind the benefits from greater sector coupling through electrification as the energy system decarbonises, the heating/cooling sector is critical and the use of more renewable sources and low-emission fuels can be encouraged.

As electricity prices are expected to stay low with higher shares of renewable energy coming online by 2030 in the Nordic region, the business case for combined heat and power is changing. Heat produced from renewable energy sources is supported through operating aid allocated to some combined heat and power plants working on biogas or woodchips. However, taxation does not encourage environmentally sustainable CHP. There is a need to rethink the current support and taxation system. Energy taxation could be brought in line with the CO_2 content, and the CO_2 tax reduction for CHP should be made available to those plants that use low-emission fuels.

The existing subsidies for electricity generated from woodchips and lower tax for peat use should be revisited in this context as they distort the market and may present barriers to entry for lower-cost and cleaner alternatives. In 2018, the feed-in tariff support scheme has been replaced by technology-neutral tendering processes in 2018-20 (for a production totalling a modest 1.4 TWh), while subsidies are redirected to support biomass CHP and new technologies. CHP will need to phase out coal use by 2029, as part of the Finland's commitment to the Powering Past Coal Alliance. The government adopted a EUR 90 million incentive package to support the early switch to biomass-fired CHP and non-combustion technologies (EUR 45 million), such as heat pumps (which are used for instance in Denmark at CHP plants to increase performance) or storage. This is a welcome approach, as thermal energy storage is an enabler of flexibility, renewable energy and energy efficiency (hourly/seasonal; pilots under planning). Smart systems (building automation and control, heating appliances and networks) are enablers of energy efficiency, consumer engagement and demand response.

Recommendations

The government of Finland should:

☐ Progressively reform the tax regime (including for coal and peat) and subsidies to support low-emission combined heat and power in line with CO_2 content, in support of the goal to phase out coal use in power and heat generation.

- Continue to support cross-border integration of intra-day and reserve markets (balancing and imbalance power), including demand-side participation in the Finnish system to reward resources that provide flexibility and reliability to the power system, and promote innovation, competition and address peak capacity needs.
- Carry out an annual in-depth assessment of the electricity adequacy in the regional context to estimate the needed investment in large-scale domestic supply, interconnections and related network investment as well as the amount of the needed strategic reserve capacity, including demand response.
- Run regional electricity security preparedness assessments to encourage greater collaboration of the energy authorities, transmission system operators and stakeholders participating in the Nordic Market. Assess long-term climate change implications for the availability of renewables, such as biomass and hydropower; also assess unusual events that can affect distribution and transmission infrastructure (e.g. storms, fires).
- Improve oversight of the performance of the distribution network companies by considering options, such as:
  - effective unbundling of distribution system operators to remove barriers for third-party participation in energy services and ensure that they become neutral facilitators of the retail market;
  - moving to output-based regulation that encourages distribution system operators to adopt the full array of options for maintaining and upgrading their networks and local balancing, including storage, demand-side response and energy efficiency;
  - ensuring greater consistency and harmonisation of distribution tariff methodologies for the recovery of costs from consumers;
  - auditing the effectiveness of the distribution system operations and tightening regulation where appropriate in order to increase efficiencies and service.
- Remove barriers to the development of a smart energy system (aggregation, storage and demand response), including ending double charging of storage and electric vehicles, setting minimum requirements for the next generation of smart meters, and ensure that low-income households are not “left behind” in the transition.
- Adopt a comprehensive digitalisation agenda and complete the creation of the data hub in order to speed up supplier switching, and improve visibility of energy performance from specific sectors and tariffs to stimulate system flexibility, notably from demand response.

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9. Nuclear

Key data

(2017 Provisional)

Number of reactors: Four reactors - two in Loviisa (Fortum) and two in Olkiluoto (TVO)

Installed capacity: 2.8 GW (1.0 GW in Loviisa and 1.8 GW in Olkiluoto)

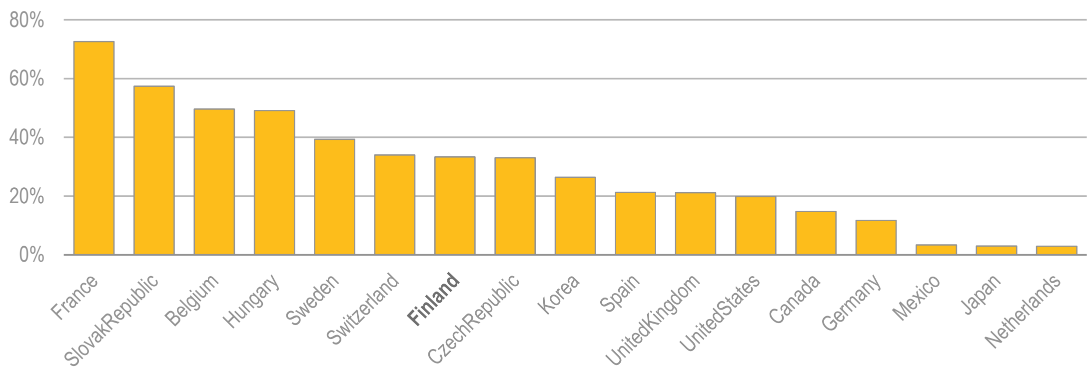
Electricity generation: 22.5 TWh, -4.1% since 2007

Share of nuclear: 17.0% of TPES, 32.1% of domestic energy production, 33.3% of electricity generation

Overview

Nuclear energy is a crucial part of Finland's energy system, as the largest source of electricity and the second-largest source of domestic energy production after biofuels. Nuclear power accounts for a third of total electricity generation, the seventh-highest share in the IEA (see Figure 9.1).

Figure 9.1 Share of nuclear in electricity generation in IEA member countries, 2017

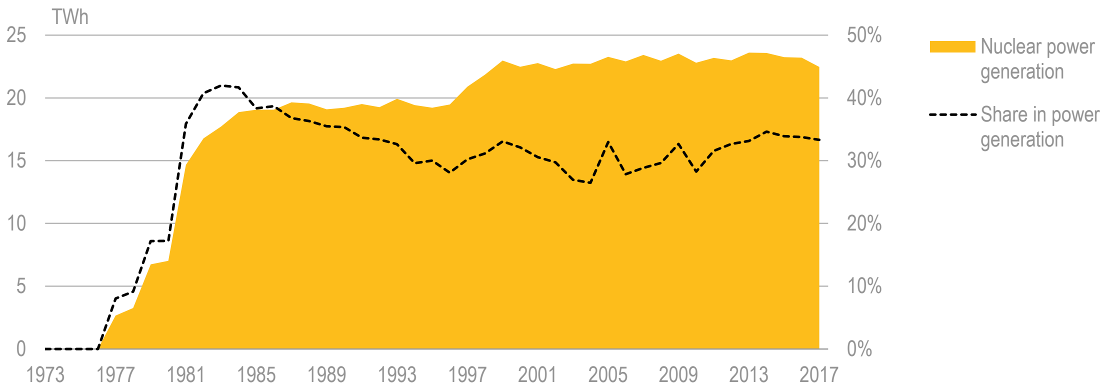


Note: Data are provisional.

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

In 2017, nuclear power generation was 22.5 terawatt-hours (TWh), and the electricity generation has been stable around 23 TWh per year since 1999 (see Figure 9.2). With an installed capacity of 2.8 gigawatts (GW), the nuclear fleet had a capacity factor of 96%, and is one of the most efficient in the world. Nuclear power accounted for over 40% of total electricity generation in the early 1980s but has since fallen to around 30%, as other power sources have increased along with increased demand in the country. One new reactor is under construction and one new reactor project is waiting for the construction licence. Nuclear energy production continues to support the goals of Finland's National Energy and Climate Strategy for 2030 fostering decarbonisation and security of supply. Its underlying modelling assumes the share of nuclear in power generation to double in 2030 compared to 2010.

Figure 9.2 Nuclear power generation and share in electricity generation, 1973-2017



Note: Data for 2017are provisional.

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

Institutional governance

The **Ministry of Economic Affairs and Employment (MEAE)** is responsible for the overall supervision of the use of nuclear energy. The main tasks of ministry in this respect include drafting of legislation, supervision of planning and implementation of nuclear waste management, administration of the State Nuclear Waste Management Fund, and supervision of research and development (R&D) works in the nuclear area. MEAE also prepares decisions in principle on new nuclear facilities as well as construction, operating and decommissioning licences for the government approval process.

The **Radiation and Nuclear Safety Authority (STUK),** the regulator, plays an important role in ensuring the safe operation of nuclear power plants. STUK issues regulatory requirements and supervises their implementation through an extensive approval and inspection programme. It is an independent body.

Although responsible for setting the overall institutional framework necessary for the safe operation of nuclear reactors, the Finnish state is not involved in the investment decisions taken by the utilities, nor does it provide subsidies. The decisions to invest in nuclear power are taken by the utilities. The *Mankala* principle, which allows investment risks to be shared by the utility co-owners, can be seen as an effective way to address the challenge of financing the large capital investment costs that characterise nuclear new build. This co-operative model is a unique funding mechanism that has been and continues to be used in Finland, and is being studied by other countries.

Nuclear power plants

There are currently four nuclear reactors in operation at two sites in Finland; two in Loviisa in the south of Finland and two in Olkiluoto on the west coast (see Figure 9.3). All four reactors were commissioned in the four-year period 1977-80 (see Table 9.1).

The Loviisa reactors are pressurised water reactors (PWR) of modified Russian VVER-440 design and operated by Fortum, a listed public company with the Finnish government as major shareholder (50.8%). The units were uprated from 445 megawatts (MW) net power to 507 MW and, in July 2007, the government granted Fortum a new 20-year operating licence, which allows for operation until 2027 for Loviisa 1 and 2030 for Loviisa 2. Fortum is now considering the future of its plants and could apply for further extensions of the operating licences.

The two reactors in Olkiluoto are Swedish boiling water reactors (BWR) design operated by Teollisuuden Voima Oy (TVO), a non-listed public company owned by a consortium of energy and industry companies. The reactors started up in 1978 and 1980 at 660 MW each and were later upgraded to 880 MW. Current licences will expire at the end of 2018, and in January 2017 TVO applied for a new 20-year operating licence for its Olkiluoto 1 and 2 units, which would allow for operation until 2038.

In 2000, TVO submitted an application for a decision in principle to build a new nuclear power reactor and, two years later, the government took the decision to allow for a fifth reactor. The construction licence for the new reactor was approved in 2005 by the French-German consortium AREVA NP and Siemens as suppliers of a 1.6 GW European pressurised water reactor (EPR). The construction began in 2005 and the project was initially set to be finalised in 2009, but has been delayed by approximately a decade. Olkiluoto 3 is now expected to enter commercial operation in 2019.

In June 2007, a new company, Fennovoima Oy, initiated a nuclear new build project (Hanhikivi 1). The company was created by a consortium of industry and energy companies with the aim of constructing a new nuclear power plant (NPP) in Finland that could be operational by 2024. The government decision-in-principle was taken in 2010 and further completed in 2014. In December 2013, Fennovoima signed a turnkey plant supply contract for the AES-2006-type VVER reactor at the Pyhäjoki site with Rosatom Overseas. In June 2015, Fennovoima submitted the construction licence application to MEAE. The reactor could be operational by 2024 according to the Rosatom schedule.

Table 9.1 Nuclear reactors in Finland

Reactors	Capacity (MW)	Commissioning	Expected close-down
Loviisa 1	507	1977	2027
Loviisa 2	502	1980	2030
Olkiluoto 1	880	1978	**2018***/2038
Olkiluoto 2	880	1980	**2018***/2038
Olkiluoto 3	1 600	2018/19**	
Hanhikivi 1	1 200	planned	

* The present operating licence will expire end of 2018 for Olkiluoto 1 and 2.

**Expected start-up.

Sources: IAEA *PRIS* database; NEA (2017) “Nuclear Energy Data 2017”.

Figure 9.3 Nuclear power plants in Finland

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.

New build: current and planned

According to the Climate and Energy Strategy for 2030 adopted by Finland, nuclear power is an option, but the initiatives must come from industry. As stipulated in the Nuclear Energy Act, an environmental impact assessment (EIA) process must be completed before an application for a decision-in-principle (DIP) can be submitted to the government. In 2002, the government made a favourable DIP for a fifth NPP unit (Olkiluoto 3). In May 2010, the government took positive decisions-in-principles for the construction of two further units (Olkiluoto 4 and Hanhikivi 1 units).

Reactors under construction

The start of the construction of the Olkiluoto 3 reactor (OL3) in 2005 under a turnkey contract between the operator TVO and a consortium led by AREVA and Siemens companies, represented the first Generation-III new build project to be launched in OECD Europe. The construction has suffered numerous delays and cost overruns. In March 2018, TVO informed that it signed a settlement agreement with AREVA and Siemens concerning the OL3 EPR project. The agreement covers several issues, including ensuring that there are adequate technical, human and financial resources to complete the project, and the international arbitration process at the International Chamber of Commerce (ICC) is settled by a payment to TVO of EUR 450 million (Euros). At the time of writing, OL3 is expected to start producing electricity in May 2019. In April 2016, TVO filed an application for the OL3 operating licence. Simulator training for the operating personnel commenced in early 2017. In February 2018, nuclear fuel assemblies have been inspected and transferred inside OL3. Hot functional tests have been completed in June 2018 at the unit.

Lessons learned from first-of-a-kind projects, like the OL3 EPR, are beneficial to subsequent projects, whether in the same country or in others. And as another new build project is to go ahead in Finland, it is therefore essential that lessons learned from the OL3 project are taken into account by the different stakeholders.

Reactors planned

In May 2010, the government took positive decisions-in-principle (DIPs) for the construction of two further units, TVO's Olkiluoto 4 unit, and a unit, called Hanhikivi 1, to be operated by a newcomer on the market, Fennovoima. On the other hand, the proposal of Fortum to build a third unit in Loviisa was turned down. The Parliament ratified these decisions in July 2010. Arguments stated by the government to support these decisions included climate and energy strategy targets, such as an overall reduction of greenhouse gas (GHG) emissions and self-sufficiency in electricity production, and the improved competitiveness of Finnish industry, which is highly energy-intensive (the forest industry alone represented 22% of the electricity consumption in 2016).

TVO's Olkiluoto 4 nuclear power unit project proceeded to the bidding phase. However, in 2014, the government rejected TVO's applications to extend the validity of the DIP and set a new deadline to submit the construction licence application. TVO stopped the project in spring 2015.

Fennovoima signed a turnkey plant supply contract for the AES-2006-type VVER reactor with Rosatom Overseas in December 2013. A shareholders agreement was signed to sell 34% of Fennovoima's shares to Rosatom Overseas. As Rosatom was not mentioned as an alternative in the original DIP application, Fennovoima started a new environment impact assessment (EIA) process in autumn 2013 that was approved in 2014. In 2016, Fennovoima started the third EIA process, concentrating on final disposal sites for its spent nuclear fuel, since there is no specific plan in this regard. Fennovoima submitted the construction licence application to MEAE at the end of June 2015. The preparatory works have started at the Pyhäjoki site.

TVO and Fennovoima are power companies which operate under the so-called Mankala principle, namely the production of electricity at cost for its shareholders, which include industry companies, and regional and local power companies (supplying municipalities). The Mankala principle is a widely used business model in Finland, and notably in the electricity sector, whereby a company operates like a zero-profit-making co-operative for the benefit of its shareholders. The costs are distributed in proportion to each shareholder's stake in the company, and ownership gives each shareholder a proportional share of the electricity produced.

Nuclear safety

Following the Fukushima accident, the MEAE requested STUK to prepare a report on how Finnish NPPs could withstand extreme flooding and loss of external power and ultimate heat sink. STUK reported that no immediate safety improvements were necessary at the plants, but recommended that investigations be carried out to improve the preparation for certain exceptional natural conditions. Stress tests were also carried out within the framework set by the European Nuclear Safety Regulators Group (ENSREG). The Finnish stress-test report was sent to the European Commission in December 2011, and international peer reviews were also completed. The EU framework led in 2014 to an amendment of the Nuclear Safety Directive and Finland will implement this into the national legislation, with a law that will come into force in 2018.

Safety improvements have been implemented continuously in Finnish NPPs, with lessons learned from international operational experience being taken into account. Power uprates were also applied to both Loviisa and Olkiluoto plants resulting in increased power output. At the same time, Finland's reactors have been operating with very high load factors. Both the utilities and the government recognise that ensuring the highest levels of safety has also resulted in the best economic performance.

Since 2016, STUK established a commercial company (STUK International Ltd) which is offering its services to international customers. STUK International Ltd will provide expert services to promote safety in the use of nuclear energy and radiation, and engages in R&D in the field.

Nuclear waste is defined as radioactive waste in the form of spent nuclear fuel or some other form generated in connection with or as a result of the use of nuclear energy. In Finland, producers of nuclear waste are responsible for all nuclear waste management activities and their associated costs. The Nuclear Energy Act states that the nuclear waste generated in Finland shall be handled, stored and permanently disposed of in Finland (except for spent fuel from the research reactor).

Nuclear waste management

The spent fuel policy was set up several decades ago, with the decision by the government in 1983 to consider deep geological disposal as the final solution for high-level radioactive waste management. According to the Nuclear Energy Act of 1987, decisions-in-principle regarding nuclear energy activity should be made taking into account the energy needs of the country, the suitability of sites and environmental impacts associated with the activity, and the existence of a nuclear fuel and waste management plan.

The Posiva Company was set up in 1995 as a subsidiary of the country's two nuclear operators, TVO (60%) and Fortum (40%), to manage the spent fuel from the existing four reactors. A final solution to spent fuel management was seen as a key factor enabling the DIP regarding the Olkiluoto 3 project. The current plan for the deep repository (over 450 metres below sea level) being built in Olkiluoto, addresses the needs of Olkiluoto units 1 to 3 and Loviisa 1 and 2, as included in the actual licensing. An underground rock characterisation facility called ONKALO has been under construction in Olkiluoto since 2004 by Posiva, and its excavation was completed in 2016. ONKALO research facility made it possible to collect the data necessary for ensuring safety and suitability of the site for the disposal of spent nuclear fuel. The construction licence of Posiva disposal facility was granted by the government in 2015 and the construction was started in 2016 to expand the ONKALO facility to a full-scale repository. The ONKALO research activities are still ongoing in parallel with the construction of the repository tunnels and facilities.

The application for the construction licence was made in 2012, with the disposal of spent fuel to start in 2020. The government decided to grant a construction licence, in November 2015, for spent fuel consisting of 6 500 tonnes of uranium (tU). This is the first construction licence in the world granted to a final disposal facility for spent fuel. The construction of the encapsulation plant and the final disposal tunnels started after STUK's final decision. When operational in 2020, the repository will be the world's first deep geological disposal for high-level waste. Posiva Solutions Oy, a subsidiary of Posiva, was established in 2016; it focuses on the sales of the know-how and technologies the company has accumulated from its design, research and development activities in the final disposal facility.

From a technical point of view, cost-sharing co-operation with the Swedish waste company SKB has been beneficial to improve the knowledge and technology associated with deep geological disposal of nuclear waste. A large share of Finland's nuclear energy research was also devoted to waste management. Posiva is also involved in EU research initiatives such as the Euratom Nuclear Fission Research Programme, the OECD Nuclear Energy Agency's expert group works and the International Atomic Energy Agency programmes.

As mentioned above, a positive DIP was made in 2010 concerning a new reactor unit to be operated by Fennovoima, which has since chosen the site of Pyhäjoki. The government decided in 2010 that Fennovoima should continue carrying out studies on the development of a joint repository with current NPPs, as well as studies on its own repository for spent fuel. Posiva Solutions and the newcomer Fennovoima signed a service agreement in 2016 to plan the future spent fuel solution for Hanhikivi 1 NPP. In 2016, Fennovoima also started an Environmental Impact Assessment (EIA) of its spent fuel disposal in case it has to start a new site.

Nuclear power companies in Finland contribute to the State Nuclear Waste Management Fund. The fees cover all the waste handling, storage and final disposal costs of spent fuel and other radioactive waste, as well as the decommissioning of the nuclear facilities. The annual cost of nuclear waste management and decommissioning amounts to about 5% to 10% of the total electricity production cost. The Nuclear Waste Management Fund as from 2017 amounted to around EUR 2.5 billion in total.

Uranium mining

All the uranium used in Finland's nuclear reactors is imported in the form of manufactured fuel assemblies. The Russian Federation[22] supplies VVER fuel for the Loviisa nuclear power plant and Western companies manufacture the boiling water reactor (BWR) fuel for the Olkiluoto 1 and 2 units, with uranium originating from major producing countries – notably Canada and Australia – and enriched in Russia or in Western Europe.

From 2004, several companies have been interested in the uranium potential contained in the Finnish bedrock. Some uranium exploration companies have shown an interest in Northern and Eastern Finland and several exploration licence applications have been filed with the then-Ministry of Economic Affairs and Employment (today MEAE).

At the end of October 2017, multi-metal mining company Terrafame applied for a new permit to recover uranium as a by-product from the Sotkamo nickel and zinc mine. The uranium content in the ore is very low (15 to 20 parts per million) but the bioleaching process makes the recovery possible. In 2015, the company acquired the business operations and assets of Talvivaara Sotkamo Ltd, which had invested to start uranium extraction at the mine in north-eastern Finland. Terrafame estimates that it could produce up to 250 tonnes of uranium metal per year. In addition to acquiring the government's permission to start uranium recovery, Terrafame also required approval from the Radiation and Nuclear Safety Authority for a pilot-scale recovery testing that was granted in 2018. Moreover, Terrafame needs an uranium sales permit from the Ministry of Foreign Affairs and a permit from the European Atomic Energy Community (Euratom) to transport uranium abroad for processing.

Nuclear research, human resources, and education

To support the development of nuclear energy, continuous efforts in R&D are needed in all areas of the sector, from new build to operational safety and to waste management and decommissioning. Today, Finland's research effort (EUR 75 million) is largely funded by the power companies, and is essentially dedicated to applied research in waste management and reactor safety. Responding to the Fukushima Daiichi accident, the Finnish research stakeholders have decided to focus more research efforts on beyond-design accidents. Funding for basic research as well as for advanced nuclear technologies, such as fusion, but also for small and medium-sized reactors (SMRs) and Generation-IV fission systems has been more limited.

[22] Hereafter, "Russia".

The financing of both national nuclear research programmes SAFIR2018 (about EUR 14 million/year on reactor safety) and KYT2018 (about EUR 4 million per year –on nuclear waste research) is based on the nuclear waste management fund and gives the utilities the mandatorily largest share of financing as defined by the Nuclear Energy Act (2004). The Technical Research Centre of Finland VTT, has built the new Centre for Nuclear Safety Research (CNS) at the Otaniemi Espoo, with 150 researchers and six hot cells. The CNS facility will be commissioned in 2018. The cost of the whole project is about EUR 50 million. The Lappeenranta University of Technology's thermo-hydraulic testing facilities and instrumentation have also been modernised.

Finland's only research reactor, a 250-kW Triga Mark II reactor in Otaniemi Espoo, has been used for boron neutron capture, therapy, research, education and isotope production since it started in 1961. In June 2015, VTT ended the operation of the reactor and applied for a decommissioning licence in 2017, which is in process at MEAE.

The current activities and the planned expansion of nuclear power in Finland will require significant human resources. Universities offering educational programmes in the area of nuclear energy, such as the Lappeenranta University of Technology, are confident that the growing nuclear power sector and the promise of jobs it offers will attract large numbers of students to programmes of nuclear energy-related courses.

Assessment

Finland has a long tradition in nuclear energy dating back to 1977. Nuclear power plays a major role in the country's energy sector as the largest low-carbon source of energy in power production (nuclear provided 34% of the domestic electricity generation in 2016). Finland has dedicated a lot of attention to education and public acceptance, which has ensured the long-term role which nuclear has been playing in the country's energy mix.

In mid-2018, four units are operated at two sites, Loviisa and Olkiluoto for a total net capacity of about 2.8 GW_e. Nuclear power plants have been operated very effectively in Finland, with load factors of about 96%, well above the OECD countries' average. Finnish reactors have regularly been upgraded in terms of safety features to reflect the latest requirements. A new 20-year operating licence application for Olkiluoto 1 and 2 units was submitted in 2017 to continue the operation beyond 2018. For the Loviisa 1 and 2 units, the licence renewal will become topical by 2027-30. A fifth unit is under construction, Olkiluoto 3 (OL3), and is now expected to enter commercial operation in 2019.

The long-term future for nuclear power in Finland has been clarified with Parliament's positive decision-in-principle concerning the construction of one additional reactor (Hanhikivi 1). Licensing for the construction of Hanhikivi 1 is in progress. Since the last in-depth review of Finland, the OL4 project has been cancelled. The two new reactors (OL3 and Hanhikivi 1) could raise the share of nuclear electricity to about 40% by 2025-30, and contribute to maintain nuclear power in line with decarbonisation and security of supply objectives. In Finland, a unique investment framework is in place, whereby nuclear initiatives come from industry users who become shareholders in the project. Although responsible for setting the overall framework for the safe operation of nuclear reactors, the government does not intervene directly in investment decisions, nor does it provide subsidies.

The regulator, the Radiation and Nuclear Safety Authority (STUK), plays an important role in ensuring all safety-related activities, from the design of the plants to their operation and decommissioning. The high safety standards promulgated by the regulator are internationally recognised. Since the last in-depth review in 2013, STUK established a commercial company (STUK International) which is offering its services to international customers.

The operators of nuclear facilities in Finland contribute to the State Nuclear Waste Management Fund which covers the spent fuel waste management and operates waste management as well as the decommissioning of the plants. The spent fuel policy was set up several decades ago, with the decision by the government to consider deep geological disposal as the solution for high-level radioactive waste management. The historical nuclear operators, TVO and Fortum, have worked together through their subsidiary Posiva to fund the R&D efforts and to construct the world's first geological repository for high-level waste. Since the last in-depth review, the government granted the construction licence for the disposal facility in November 2015. This is the first construction licence in the world granted to a final repository of spent fuel. The facility is planned to begin operations in the early 2020s. The current plan for the deep repository to be built in Olkiluoto addresses the needs of Olkiluoto units 1 to 3 and Loviisa 1 and 2, as included in the actual licensing. The newcomer, Fennovoima, is studying the possibility for a new repository site and signed a service agreement in 2016 with Posiva Solutions. Before the start of operation of Hanhikivi 1, there should be either a contract with Posiva or a solid plan for a new repository as, today, the nuclear actors have not yet agreed on a common plan.

In the nuclear fuel cycle area, multi-metal mining company Terrafame applied at end of October 2017 to the Finnish government for a new licence to recover uranium as a by-product from the Sotkamo nickel mine. Handling of this application is ongoing.

Today, Finland's research effort in the nuclear sector (about EUR 75 million) is largely funded by the industry and is essentially dedicated to applied research in reactors safety and waste management, in line with the Nuclear Research Strategy of 2014. Since the last review, the new Centre for Nuclear Safety Research was built by the Technical Research Centre of Finland, and will be commissioned in 2018. Finland has also operated a research reactor Triga Mark since 1961, which has been under preparation for decommissioning since 2015.

Recommendations

The government of Finland should:

- Ensure that a final plan is agreed among the Finnish nuclear industry actors regarding the spent fuel management for the future nuclear reactor (Hanhikivi 1) and ensure the safe management of the spent fuel from the Triga Mark research reactor under preparation for decommissioning.
- Encourage active participation in the multinational efforts to progress the international harmonisation of nuclear safety standards and licensing frameworks of new reactor designs, to leverage the resources and knowledge of national regulators.

- Enhance public support for research and development in areas that are needed to maintain and develop a broad competence base in the Finnish nuclear sector. Foster the development of adequate skills, education and training in the nuclear energy sectors from the design of the plants to their decommissioning.
- Continue to promote uranium recovery by-products from domestic mining in line with international best practices in mining, processing and environmental management.

References

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

NEA (Nuclear Energy Agency) (2017), *Nuclear Energy Data 2017*, OECD/NEA, Paris.

10. Fossil fuels

Key data

(2017 provisional)

Oil:

Crude oil imports: 12.4 Mt, +0.6% since 2007

Oil product net exports: 2.8 Mt (5.8 Mt imported, 8.6 Mt exported)

Share of oil: 26.3% of TPES and 0.3% of electricity generation

Consumption by sector (2016): 8.7 Mtoe (transport 46.0%, industry 33.9%, commercial 9.8%, residential 3.8%, heat and power generation 3.4%, other energy 3.1%)

Natural gas:

Natural gas imports: 2.3 bcm, -50% since 2007

Share of natural gas: 5.6% of TPES and 5.0% of electricity generation

Consumption by sector (2016): 2.1 Mtoe (power and heat generation 51.9%, industry 27.4%, other energy 17.5%, commercial 1.4%, residential 1.3%, transport 0.4%)

Coal and peat:

Peat production: 3.1 Mt, -30.1% since 2007

Coal imports: 4.2 Mt, -36.9% since 2006

Share of coal and peat: 12.0% of TPES and 14.0% of electricity generation

Consumption by sector (2016): 4.5 Mtoe (power and heat generation 70.7%, other energy 16.2%, industry 11.9%, commercial 1.1%, residential 0.1%)

Overview

The share of fossil fuels in Finland's energy system has been declining for several decades, after introducing more renewable energy sources (see Figure 10.1). In 2017, fossil fuels accounted for 44% of total primary energy supply (TPES). The share of coal/peat and natural gas has fallen very rapidly, while oil has retained its role in supply. Natural gas and coal are used in the cities along the south of Finland, while peat and biomass are used in the more isolated centre and north of the country. Finland has targets to further reduce fossil fuel consumption under its climate targets towards the Paris Agreement, notably in heat and power generation. However, other aspects need to be taken into account when reducing fossil fuel consumption, including the effects on energy security and employment.

Institutions

The **Energy Department of the Ministry of Economic Affairs and Employment (MEAE)** is responsible for preparing legislation on fossil fuels and related security of energy supply and emergency situations, including acts and decrees for the security stockpiling of imported fuels (coal, crude oil and petroleum products) and of domestic peat.

Stocks are maintained and managed by the **National Emergency Supply Agency (NESA),** supported by several committees (see below section on security of supply), looking after the various fuels and sectors, including district heating.

The **Energy Authority** regulates natural gas networks and supervises natural gas wholesale and retail supply activities, as Finland does not have a competitive gas market.

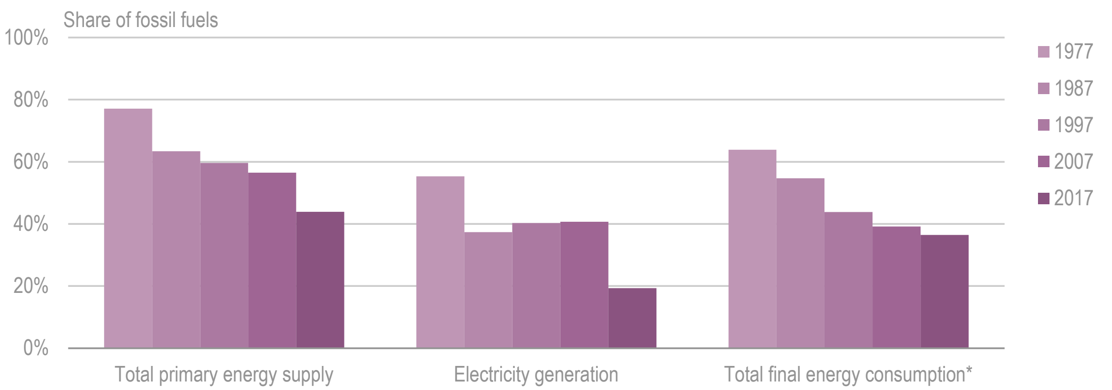
State-owned gas company **Gasum Oy** is responsible for the imports, transmission and wholesale of gas.

Supply and demand of fossil fuels

Finland has no production of crude oil, natural gas or coal, and is dependent on imports. Most fossil fuel imports come from the Russian Federation.[23] However, thanks to its two refineries, Finland is a net exporter of oil products. Oil is the largest fossil fuel, accounting for over half of fossil fuels in TPES and nearly 90% of fossil fuels in TFC. Whereas natural gas, coal and peat dominantly are used for heat and power generation, oil is consumed largely in the transport and industry sectors.

Finland has domestic production of peat, and is the second largest peat consumer in the International Energy Agency (IEA), after Ireland.

Figure 10.1 Share of fossil fuels in different energy supplies, 1977-2017



*Latest consumption data are from 2016.

Notes: Data are provisional for 2017.

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

[23] Hereafter, "Russia".

Fossil fuel consumption

In 2017, TPES of all fossil fuels was 15.1 Mtoe, a decline by 28% since 2007. Oil accounted for 60% of the fossil fuel supply, followed by coal, natural gas and peat. Power and heat generation is the largest consumer of natural gas, coal and peat, whereas oil is consumed across all sectors (see Figure 10.2).

Oil demand has been on a small but steady decline for several decades, since 2005 when oil accounted for 10.7 Mtoe of Finland's TPES to 9.0 Mtoe in 2017. The transport sector accounts for nearly half of total oil consumption and industry for another third. Transport consumption has been relatively stable around 4 Mtoe over the last decade. Industry consumption in 2016 was 2.9 Mtoe, of which half was consumed for non-energy purposes in process industries. The residential sector was a large oil consumer for heating in the 1970-80's, but consumption has shifted towards biofuels, electricity and district heating. Around 190 000 Finnish one-family houses are heated with oil.

Natural gas consumption has declined by nearly half since 2007, notably in the power sector. Gas demand dropped in the combined heat and power generation because of low electricity prices and increased taxes on gas used in co-generation plants since 2011 tax reforms. In that reform, the tax relief for natural gas use in CHP-production was abolished. Natural gas has the same energy and carbon dioxide (CO_2) component in energy taxation as other fossil fuels (excluding motor gasoline and diesel oil).

In 2016, power and heat generation accounted for just over half of total gas demand, with the remaining gas consumed mostly in industry (forest, chemical industry) and refineries. Finland has a very small household market for natural gas (in 2017, around 21 000 customers); these are households using gas for cooking, and the residential and commercial sectors accounted for only a few per cent of total consumption.

Coal and peat consumption is similar to that of natural gas, with the power and heat sector accounting for the largest share, followed by industry and coke ovens. Consumption in the heat and power sector varies annually – it increases in years of high electricity demand and low availability of hydro power.

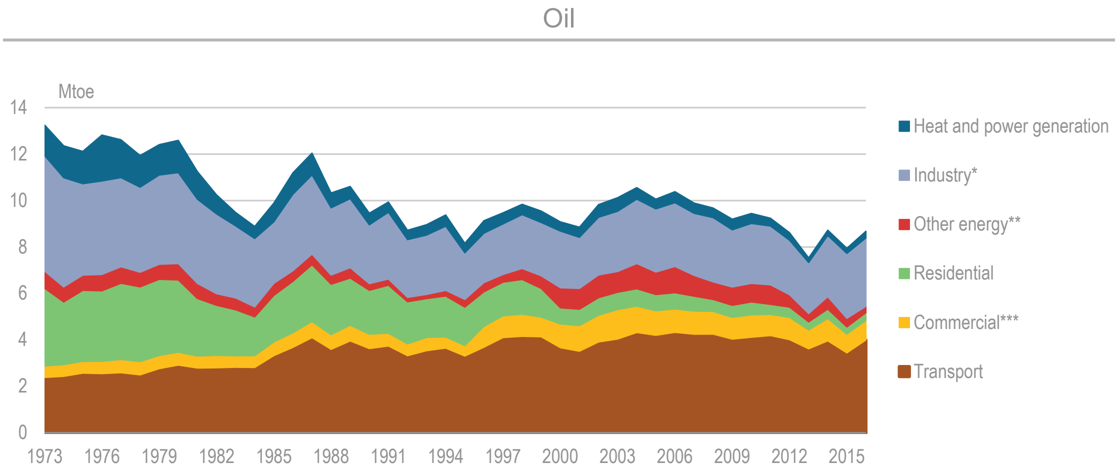
Coal and natural gas are mainly used along the coast, at locations close to harbours, while inland Finland uses peat and biomass as main CHP fuels (see Figure 10.3).

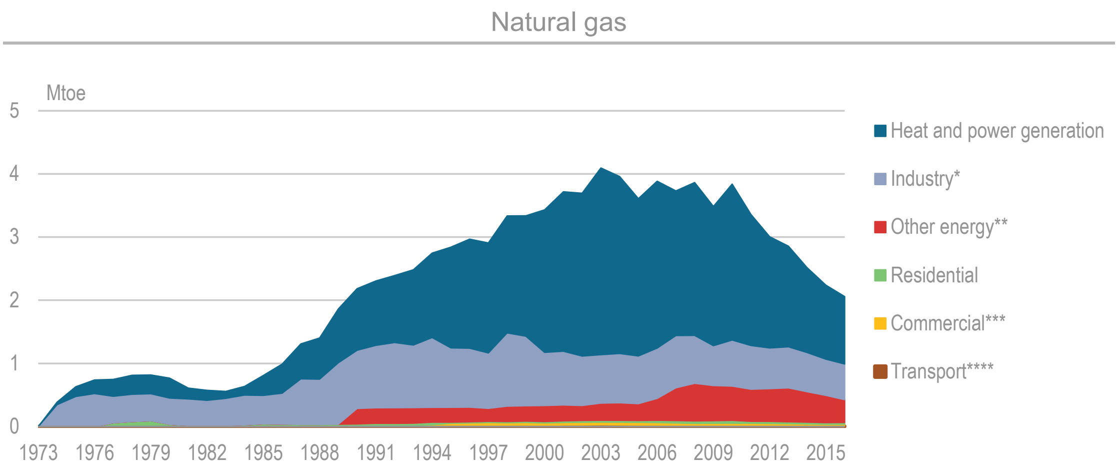
Alternative fuels

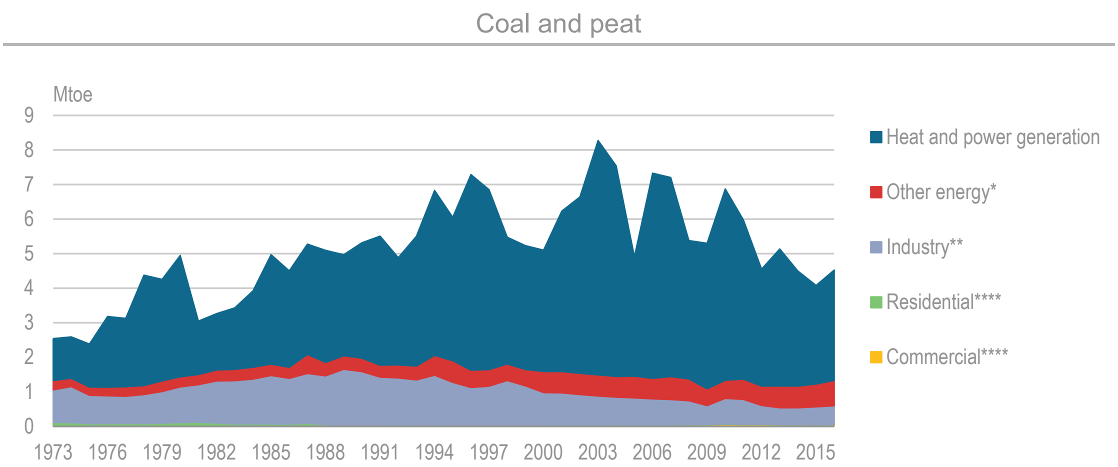
Finland has five biogas plants connected to the gas network and many filling stations. The government targets 50 000 gas-fuelled vehicles by 2030. Today, Finland has in place a negotiated third-party access of biogas to the grid. By 2020, under the new Natural Gas Market Act, Finland will introduce regulated TPA and adapt its quality norms for biogas to new EU standards. The share of biofuels has been on the rise, thanks to the blending mandate requiring fuel distribution companies to increase the share of biofuels in the total energy content of petrol, diesel oil and fuel oil gradually to at least 6% in 2011-2014, 8% in 2015, 10% in 2016, 12% in 2017, 15% in 2018, 18% in 2019 and 20% in 2020.

Security of supply in Finland is based on such alternative fuels, including air-propane mix (or LNG) for households and other gas specific users, heating oil, LPG, electricity etc.

Figure 10.2 Fossil fuels consumption by fuel and consuming sector, 1973-2016







*Other energy includes the energy sector's own consumption and losses in oil and gas production and refineries.

**Industry includes non-energy consumption.

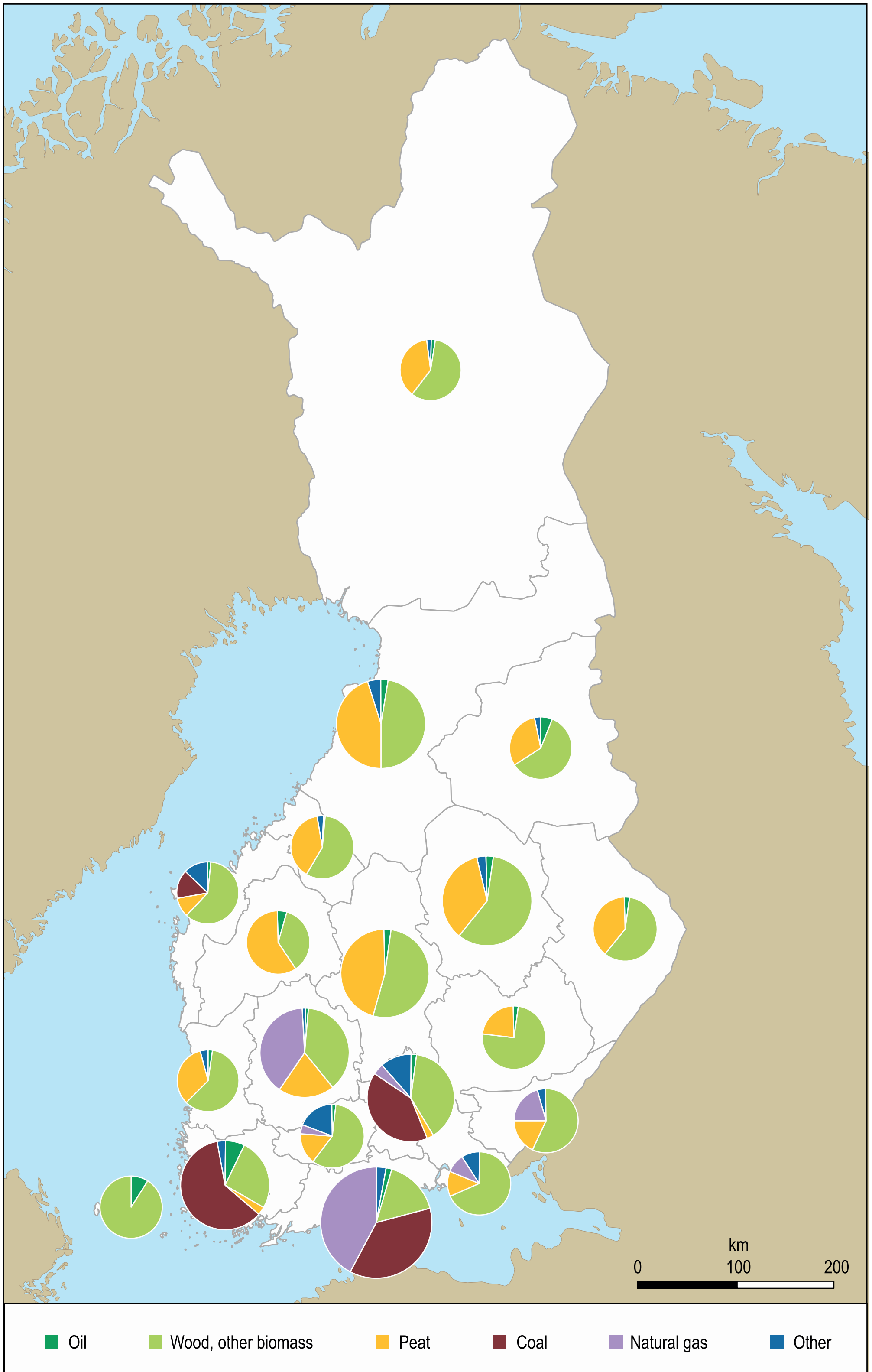
***Commercial includes commercial and public services, agriculture and forestry.

****Negligible.

Note: TPES by consuming sector.

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

Figure 10.3 Fossil fuels used in district heat production and CHP production, 2015

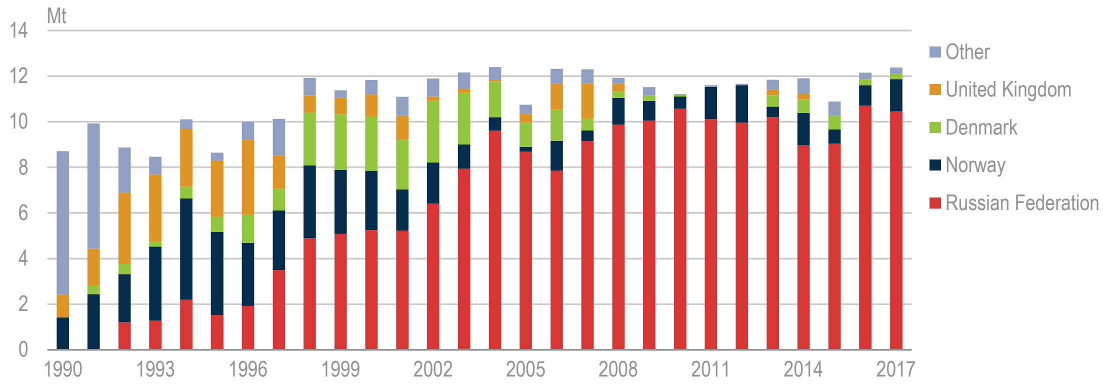


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Oil supply

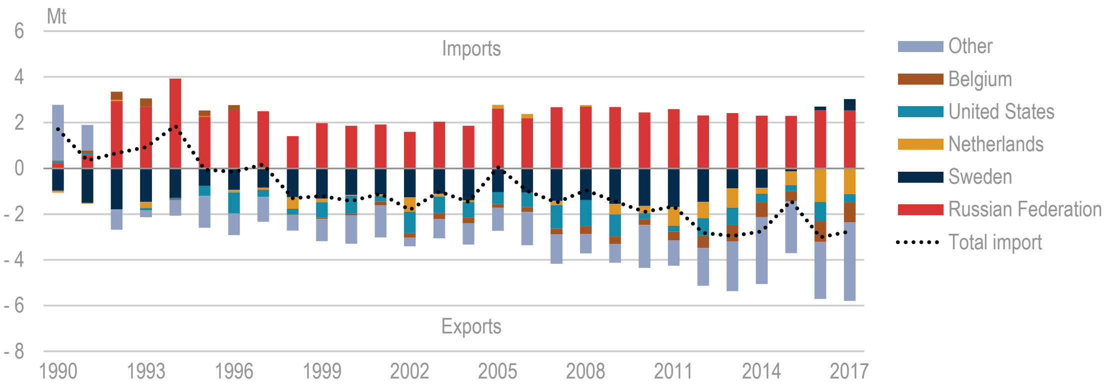
Crude oil supply has been stable around 12 million tonnes (Mt) per year for nearly two decades. Without domestic production, all crude oil is imported to Finland. A previously diverse mix of oil imports from three to four countries has narrowed to supply dominated by oil imported from Russia (see Figure 10.4). In 2017, Russian oil accounted for 84% of the total crude oil imports of 12.4 Mt.

Figure 10.4 Crude oil imports by country, 1990-2017



Sources: IEA (2018b), *Oil information 2018*, www.iea.org/statistics/.

Figure 10.5 Oil product imports and export by country, 1990-2017

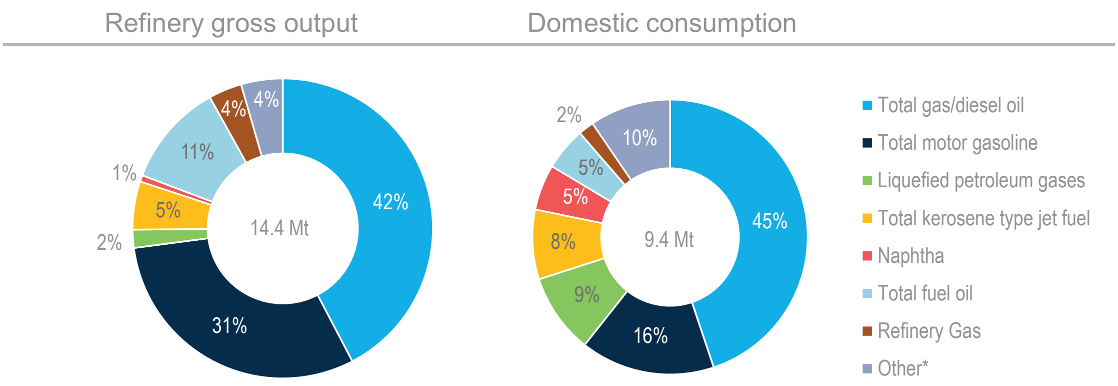


Sources: IEA (2018b), *Oil information 2018*, www.iea.org/statistics/.

The large oil product production in Finland's two refineries makes the country a net exporter of oil products, despite significant volumes of imports. In 2017, total net exports were 2.8 Mt, mainly exported to other northern European countries (see Figure 10.5). The Netherlands was the largest net importer of Finnish oil products, with 1.1 Mt.

In 2017, total gross refinery output was 14.4 Mt oil products. Diesel oil accounted for the largest share at 42% of the product mix, followed by motor gasoline at 31% and fuel oil at 11%. Production differs slightly from the domestic consumption mix, which has a smaller share of gasoline and fuel oil and more liquefied petroleum gases and naphta (see Figure 10.6).

Figure 10.6 Refinery gross output and domestic consumption by product, 2017



**Other products* includes petroleum coke, other kerosene, aviation gasoline and other non-specified products.
Sources: IEA (2018b), *Oil information 2018*, www.iea.org/statistics/.

Oil market in Finland

Finland has a strong refining sector, producing mainly for export markets besides domestic demand. Finland has two refineries, both owned by the company Neste and specialised in refining Russian heavy crude from the Urals region. The oil refineries are located in large ports in Porvoo and Naantali. Finland has six main oil import terminals, two for crude, located at the oil refineries, and four for oil products (see Figure 10.7). Finland has a total oil storage capacity of 63 million barrels (mb), mainly in 25 coastal and major inland storage facilities. The large storage facilities are owned by the industry; the public stockholding agency NESA owns half of the storage capacity to cover public stocks.

Partly state-owned Neste Corporation is the key player in the domestic market and the only crude oil importer. There are several retail companies active in Finland, including Neste, Teboil, ABC, St1 and others. In the Finnish retail market Neste's market share has increased to 48% in 2016, followed by Teboil 22% and St1 with 15% as third largest.

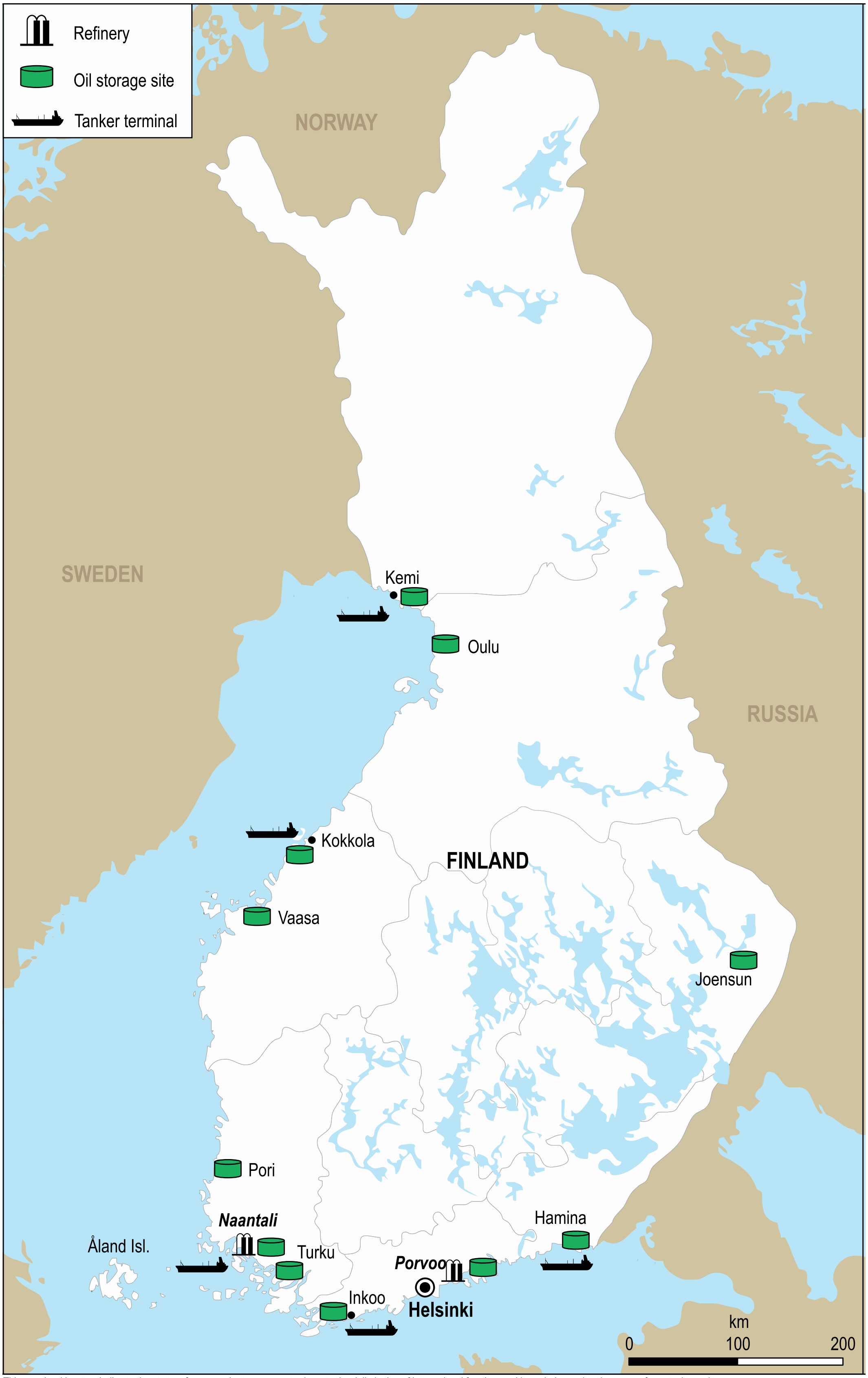
Oil product prices

Finnish consumers pay relatively high fuel prices by international comparison across the IEA member countries, mainly due to high taxes (see Figure 10.8). In the third quarter of 2017, Finland had the sixth highest price for diesel fuel, the seventh highest price for gasoline and the sixth highest price for light fuel oil.

Security of oil supply

In line with EU rules (Directive 2009/119/EC) to maintain minimum stocks of crude oil and/or petroleum products and to fulfil Finland's obligations as a member of the International Energy Agency (IEA), the country maintains oil reserves equivalent to at least 90 days of net imports. As of May 2018, Finland held 42.1 million barrels of stocks (23.9 industry and 18.2 public), which equated to 240 days of 2017 net-imports, much beyond the minimum of 90 days required. Under Finland's NESA, the Oil Pool is responsible for emergency preparedness planning on oil and natural gas, and for maintaining emergency response arrangements for petroleum product transports.

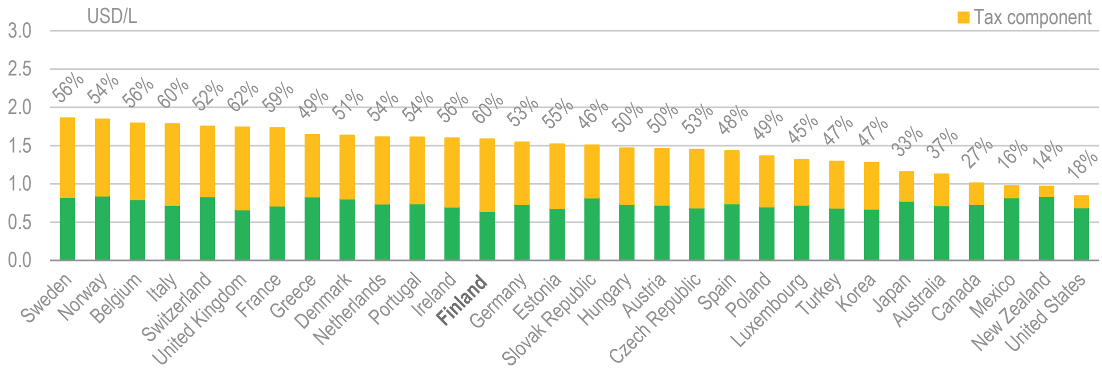
Figure 10.7 Oil infrastructure in Finland



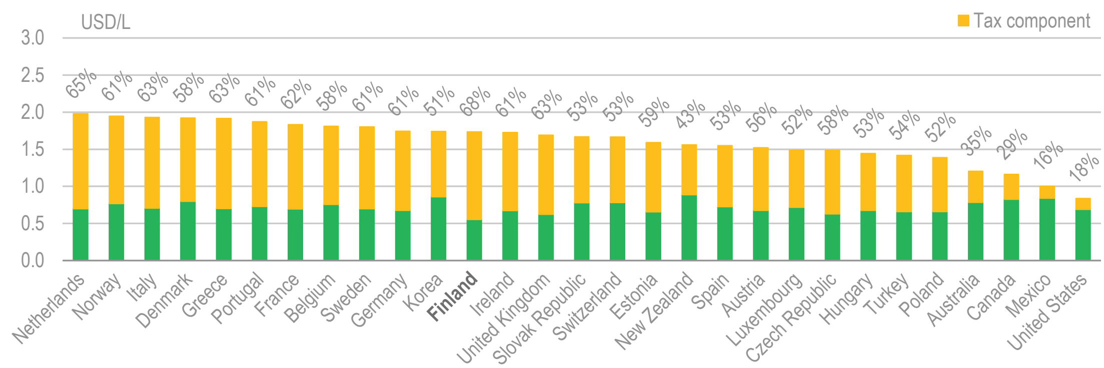
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 10.8 Oil product prices in IEA member countries, Q2 2018

Automotive diesel fuel

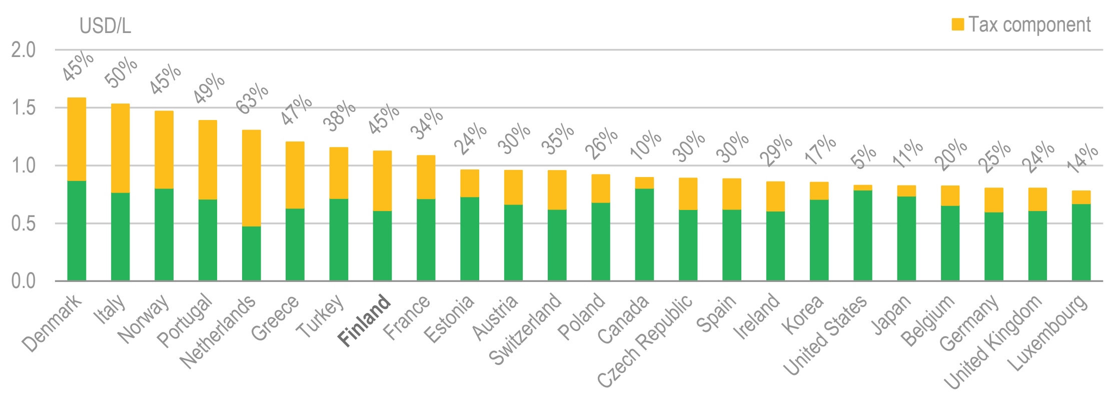


Premium unleaded gasoline (95 RON)



Note: Data are not available for Japan.

Light fuel oil



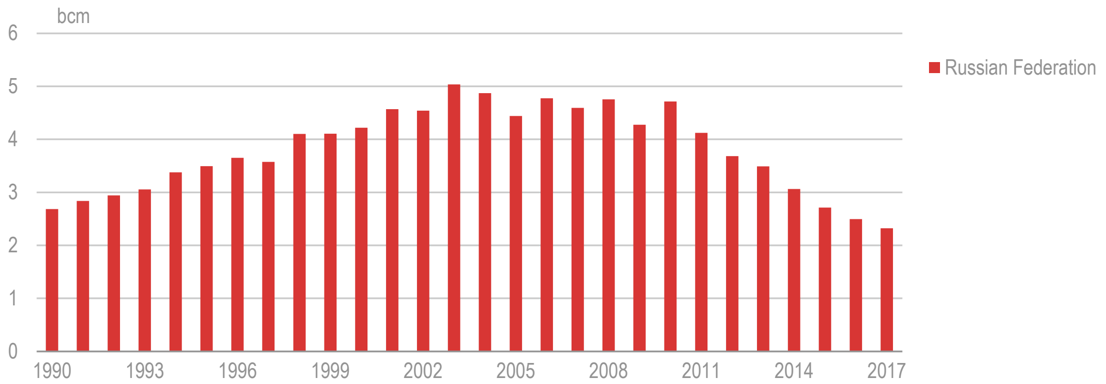
Note: Data are not available for Australia, Greece, Hungary, Mexico, New Zealand, Slovak Republic and Sweden.

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

Natural gas supply

Finland has no domestic natural gas production, and all gas is imported via pipelines from Russia. After a period of continuous growth throughout the 1990's, gas supply flattened and began to rapidly decline in 2010 (see Figure 10.9). In 2017, natural gas supply had fallen to 2.3 bcm, a reduction by more than half since 2010. This reflects decreasing demand for natural gas from 5.0 bcm in 2003.

Figure 10.9 Natural gas imports by country, 1990-2017



Sources: IEA (2018d), *Natural Gas Information 2018*, www.iea.org/statistics/.

Natural gas infrastructure

Finland imports gas from Russia through a twin pipeline through one interconnection point Imatra with a total capacity of 22 mcm/d.

In recent years, LNG terminals have flourished, mainly serving local industrial users and maritime uses of LNG. In 2016, Finland's first onshore LNG import terminal (in Pori) was commissioned besides one liquefaction plant (in Porvoo, refinery location) and there is an LNG terminal for industrial use in northern Finland (Tornio). Another terminal at the south coast of Finland (Hamina) is in the construction phase in 2018.

Finnish Baltic Connector Oy and Estonian Elering AS are building the Balticconnector gas pipeline (with a capacity of 3 GWh/h) between Finland and Estonia which will link the Klaipeda LNG regasification and storage terminal in Lithuania and the Baltic gas storage in Latvia (underground gas storage in Inčukalns) with Finland by late 2019. The state-owned project company Baltic Connector Oy was established in 2015, following the final investment decision taken in October 2016 by Finnish Baltic Connector Oy and Estonian Elering AS. As a project of common interest, Balticconnector received 75% funding from the EU Connecting Europe Facility (EUR 187 million [Euros]).

Policy and regulation

Finland has a small and isolated gas sector. It has a derogation for isolated markets under the EU Gas Directive 2009/73/EC and does not apply EU rules on unbundling and third party access regulation of pipeline gas and LNG. To date, the Finnish market is not open for competition.

State-owned Gasum is the vertically integrated sole importer, transporter and supplier of gas (it has however sold its retail business in 2017). All natural gas suppliers have an obligation to supply gas at "reasonable prices"; suppliers set the prices without ex-ante approval by the regulator. Gasum has to supply gas to all gas customers, as there is no competition. There is no supplier switching, as all suppliers hold a monopoly in their network area. There are no market structures for trading and settlement in place.

There are 24 local distribution network companies, mainly owned by municipalities, which are involved in retail supply. Some DSOs are owned by industrial users of natural gas. Gasum Oy owns and operates the transmission network of around 1 300 km of pipelines. Networks are regulated by the Energy Authority for a four-year regulatory period.

Since 1 January 2018 Finland has been implementing gas market opening, which will be completed by 2020, on the basis of the new Natural Gas Market Act. The gas market will be opened as of 1 January 2020, when Finland gives up the derogations from the EU Gas Directive and introduces third party access to pipeline gas and LNG (including off-grid), following the commissioning of the Balticconnector pipeline. In 2018, the government needs to develop the rules for market participants, secondary legislation in 2017-2019, and prepare the effective unbundling of the transmission system operator by 31 Dec 2019. Finland will implement EU rules for the internal gas market and market places by 1 January 2020, and abandon price regulation of gas. The government aims at a common gas market area with the Baltic states, however conditional on the outcome for market design, which requires clarifications of how the Balticconnector pipeline and the Russian gas imports can be operated and regulated in the Finnish gas system.

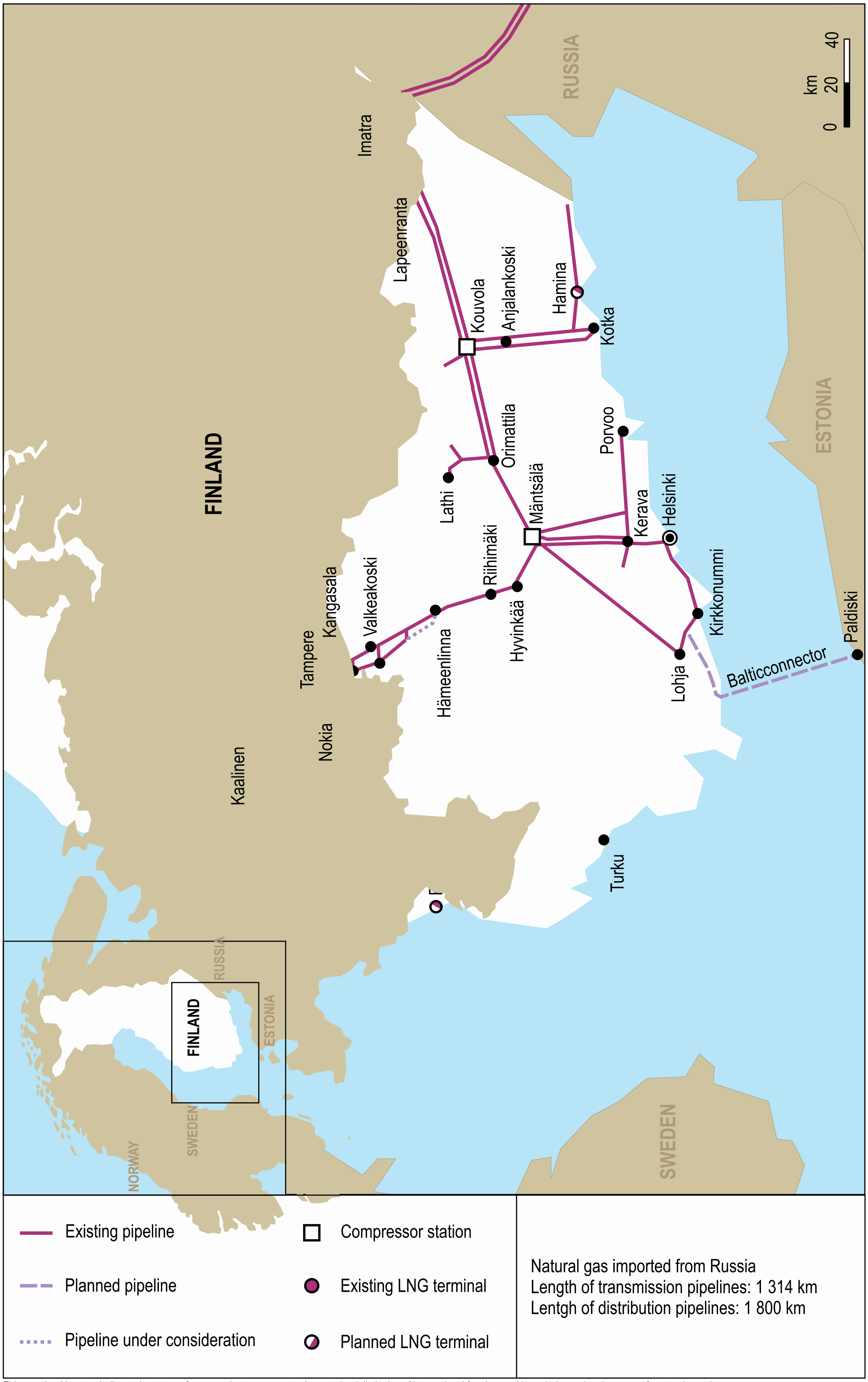
Security of gas supply

There has been no historic disruption of gas supplies from Russia. The capacity margin of the Finnish gas system is satisfactory, with 9.5 GW import capacity over 7.8 GWh/h peak load (historic peak load in 2016, but winter peak load in 2016/17 was lower at 6.87 GW/h). Finland has some gas storage at the LNG terminal which however is not connected to the grid. The gas system cannot fully compensate the failure of the major gas import pipeline from Russia. The question of solidarity will be topical when Balticconnector between Finland and Estonia will be introduced and more analysis is required concerning rules of implementation of solidarity with the neighbouring countries.

As main emergency measures at the national level Finland uses fuel switching and demand restraint, with a large role played by stockpiling of alternative fuels to cover any gas supply shortages.

Natural gas plant owners and Gasum (not industrial users) are obliged to maintain compulsory stockpiles equivalent to three months' average natural gas consumption at their own cost by stockpiling oil, coal or other back-up fuel. For protected customers also air-propane mixture could be used. In the event of a supply disruption, the majority of natural gas consumption in combined heat and power production can be replaced by coal and/or light or heavy fuel oil. If the supply disruption goes on for a longer period (i.e. weeks), transport of compensating fuel may become bottlenecked, especially during the winter period. On the other hand, state strategic oil stocks include oil products, which can be used as alternative fuel in gas burning plants in gas supply disruptions.

Figure 10.10 Natural gas infrastructure

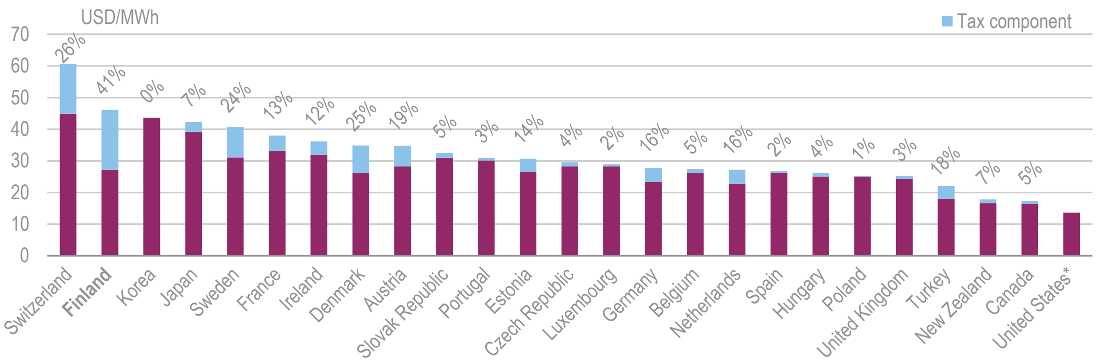


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Natural gas prices

In 2017, Finnish industries paid the second highest price for natural gas among all IEA member countries, due to the highest taxes by international comparison (see Figure 10.11). Unlike price falls in neighbouring countries, Finland has gone from prices below other Nordic countries to the highest prices in the region (see Figure 10.12). In 2017, Finnish industries paid 46 USD/MWh, slightly above the Swedish price level and significantly higher than in Denmark and Estonia. In Finland, the energy component of the gas price has increased since 2015, as it is indexed to the price of heavy fuel oil, the price of imported coal and a domestic energy index (EA, 2017).

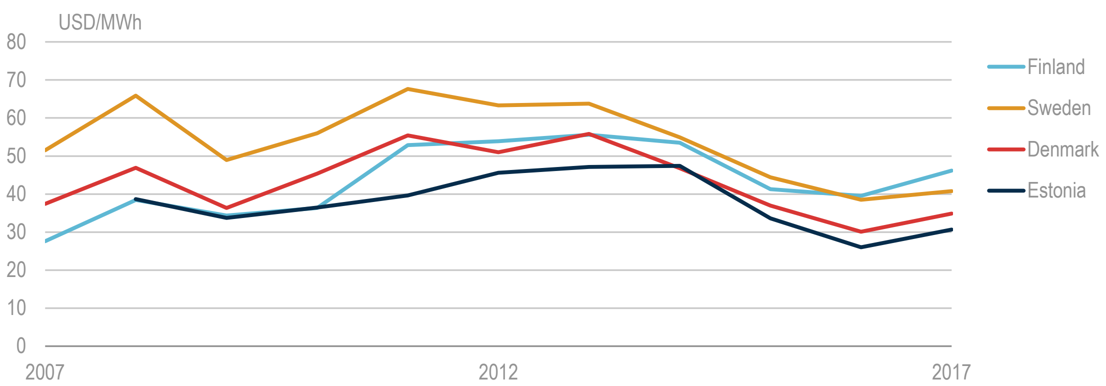
Figure 10.11 Natural gas prices in industries in IEA member countries, 2016



*Tax information not available for the United States. Note: Data are not available for Australia, Greece, Italy, Mexico and Norway.

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

Figure 10.12 Natural gas prices in industries in selected countries, 2008-17



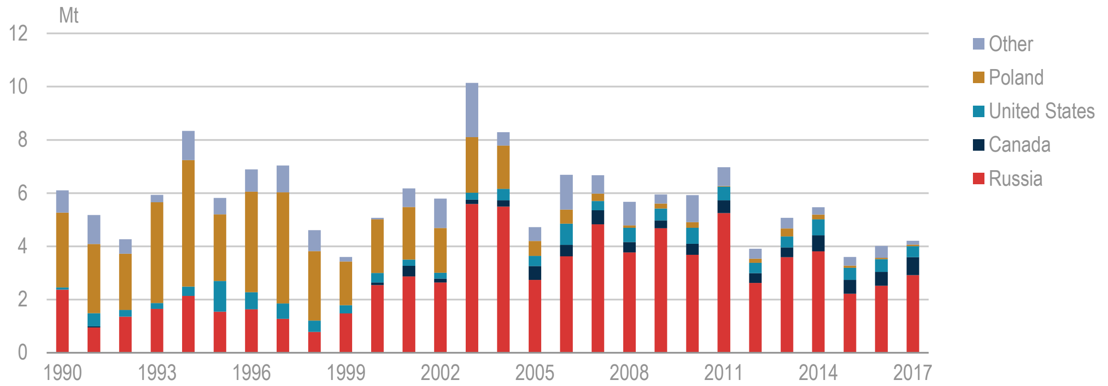
Source: IEA (2018c), *Energy Prices and taxes, Second Quarter 2018*, www.iea.org/statistics/.

Coal and peat supply

As with crude oil and natural gas, Finland has no domestic coal production and relies on imports of hard coal to cover its demand. In 2016, Finland imported 3.9 Mt hard coal, two-thirds coming from Russia (see Figure 10.13).

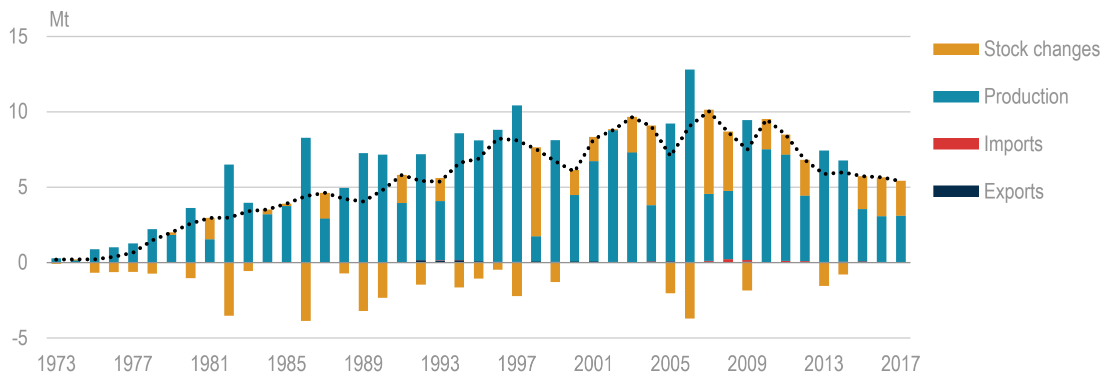
Finland has large wetland areas with vast resources of peat that can be used for energy production. In 2017, peat production was 3.1 Mt, and another 2.3 Mt was supplied by stocks from previous years (see Figure 10.14). Total peat supply has nearly halved in the last decade, from 10.0 Mt in 2007 to 5.4 Mt in 2017 and allocating new land areas for peat production is difficult amid permitting and environmental concerns. Total energy content of Finnish peat resources is estimated to 12 800 terawatt hours (TWh) (WEC, 2018), compared to annual peat consumption of around 15-25 TWh.

Figure 10.13. Coal imports by country, 1990-2017



Sources: IEA (2018e), *Coal information 2018*, www.iea.org/statistics/.

Figure 10.14. Peat supply by source, 1973-2017



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

Coal and peat policies

Hard coal is used in CHP plants in large cities, particularly in regions with a harbour. Eight cities have large coal-fired units, accounting for 90% of the coal used in energy production in Finland. The largest are the cities of Helsinki, Naantali, Espoo, Vantaa, Vaasa and Lahti.

The only large coal-fired condensing plant (500MW) is located at Pori and plays an important role to cover peak demand during the winter. Coal is also used in some multi-fuel power plants along biomass and peat, whereby coal works locally as a security of supply fuel.

The government of Finland has decided to phase out the use of coal for energy generation by 2030. According to the National Energy and Climate Strategy 2030 the government will define a transitional period for phasing out coal power by 2030 during this government term. The Ministry of Economic Affairs and Employment commissioned a study by Pöyry, which found that a ban of coal in 2030 would have some minor impacts, while banning coal already in 2025 would require significant investments and have serious economic impacts especially in Helsinki, Vaasa, Espoo and Vantaa, as coal would be replaced by biomass and to a significant degree by natural gas. The study assumes costs of EUR 200 million in 2024–2033 for phasing out coal by 2025. A natural reduction of coal use in energy is expected, as plants retire, reducing coal use from 22 TWh in 2016 to around 5–7 TWh by 2025 and to 3.5 TWh by 2030, while the coal-fired district heat capacity will decrease from 2 055 MW to 1 100 MW by 2025 and to 480 MW by 2030.

In April 2018, the government decided that the use of coal in energy production will be prohibited by law in 2029. The government presented an incentives package, amounting to EUR 90 million, for district heating companies that commit to a faster phase out of coal use by 2025. The package will be financed by lowering the required annual production level, proposed for the tendering scheme for renewable electricity, from 2 TWh to 1.4 TWh and shifting subsidies from renewable electricity to heat. The Law will go to Parliament in the fall 2018.

Finland is one of the few countries (Sweden, Ireland) that uses a significant proportion of peat, mostly co-fired with biomass. Taxation is used to ensure that peat, which is not more competitive than forest chips or forest-industry by- products, can compete with coal and other imported fossil fuels. The taxation of peat is a key steering instrument, especially in separate heat production. According to theNational Energy and Climate Strategy for 2030, energy peat use is expected to go down from 20 TWh to 15 TWh by 2030. However, there is no plan for peat to be phased-out.

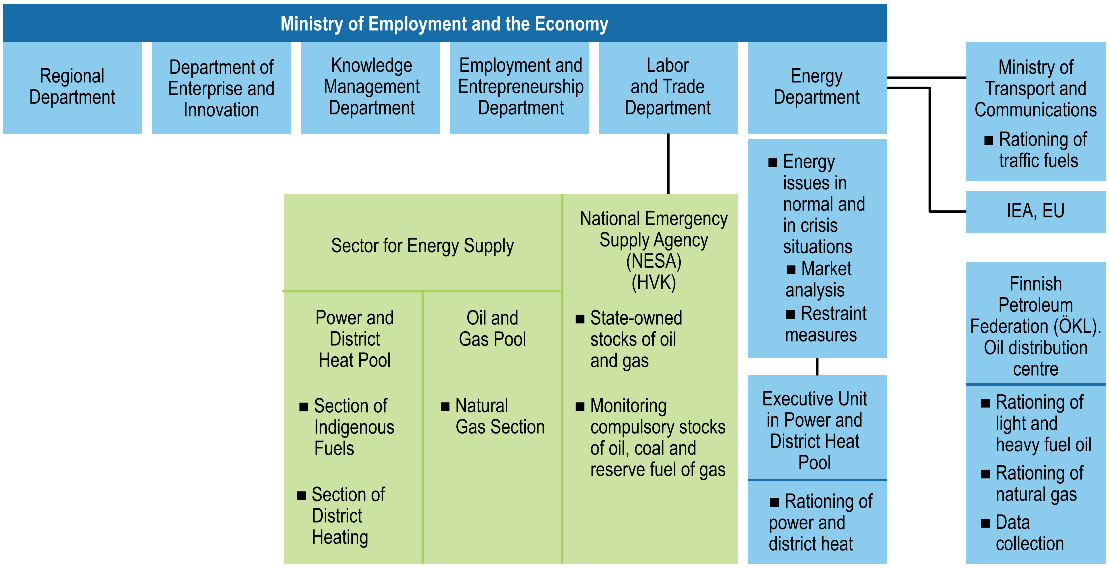
Security of supply of fossil fuels

Finland maintains stocks of imported fuels at a level of 5 months' average consumption, in line with Government Decision on the security of supply goals (5sth December 2013) to secure fuel supplies in cases of import disruptions and to fulfil international contractual and legal obligations to the International Energy Agency and the European Union.

The National Emergency Supply Agency (NESA), founded in 1993 is the national stockholding agency of Finland. NESA is responsible for the development and maintenance of security of supply based on the Security of Supply Act. NESA maintains state strategic stocks of various basic materials including oil. NESA is the competent national authority for compulsory stockpiling of imported fuels and the competent authority in the meaning of the Regulation (EU) No 994/2010 concerning measures to safeguard security of gas supply.

The Energy Department in the Ministry of Economic Affairs and Employment and the NESA are two important parts of the Finnish energy NESO that are shown in Figure 10.15. Within NESA, the Energy Supply Sector is responsible for preparedness planning concerning emergencies and major disruptions. The Power Supply Pool ensures preparedness to secure the supply of electricity and district heating in emergency conditions. Nuclear power plant sites store enough nuclear fuel to ensure the production of electricity for several months or even more than a year. Finland stockpiles peat to have reserve stocks covering six months' use at the beginning of the peat production season.

Figure 10.15. Finland's Emergency Organisation



Assessment

Oil

Finland has no production of crude oil; the country imports crude mainly from Russia, which accounted for 88% of crude imports in 2016. For oil products however, Finland has increased its production and can be considered a relatively large net exporter, with 3 Mt net exports in 2016.

The transport sector accounts for the largest oil product consumption, but the industry is also a large consumer. Neste owns the country's two refineries, which are specialised in refining Russian heavy Urals crude.

Finland maintains high levels of oil security in line with European and international rules, including the IEA stockholding obligations. As of May 2018, Finland held 42.1 million barrels of stocks (23.9 industry and 18.2 public), which equated to 240 days of 2017 net-imports.

In the National Energy and Climate Strategy for 2030, Finland envisages reducing domestic oil use by 50% compared to 2005. Between 2005 and 2015 oil demand decreased from 10.9 to 7.9 Mtoe. To achieve its goal, Finland has to produce a steep reduction by 2030 through measures, such as improved energy efficiency of the transport system, the accelerated vehicle stock renewal, a targeted 250 000 electric vehicles and 50 000 gas fuelled vehicles in 2030, the increased share of biofuel of all fuels sold to road transport to 30% by 2030 and a 10% mandatory blending of bio liquids into light fuel oil for space heating by 2030.

These measures need to be detailed and implemented in national legislation, and assessments are required to determine both the impact and the costs and benefits.

Natural gas

Natural gas accounted for 6% of TPES and 5% of electricity generation in 2016. Natural gas consumption almost halved since 2006 and amounted to 2.6 bcm in 2015, with main uses in power and heat generation. Finland has no domestic production of natural gas, and has imported its entire consumption from Russia for decades. Natural gas is mainly used by industry, in heat and power generation, and in other energy (oil refineries). Gas consumption in heat and power generation (CHP) has fallen rapidly and is not competitive with other fossil fuels, more so after the end of the tax relief on gas use in CHP. Electricity production from CHP was compensated for by increased imports and renewable energy sources (mainly biofuels, some wind). The residential gas market is rather small; there are only 29 000 gas customers that use gas mainly for cooking.

State-owned Gasum is vertically integrated: it acts as the TSO in Finland and has a monopoly on gas pipeline imports and transmission. Given the isoloation of the gas market from the EU gas market and international LNG markets, Finland has a derogation from the EU Natural Gas Directive and did not implement unbundling and EU gas market rules. The capacity margin of the Finnish gas system is satisfactory, with 9.5 GWh/h import capacity over 7.8 GWh/h peak load, and has now access to LNG.

Until recently, Finland imported only gas from Russia, by pipeline. This dependency will change by 2020. Finland has a new LNG import terminal in Pori and two more under construction for industry use (with investment support by the state of Finland). A third new LNG import terminal will be connected to the grid and will support the local distribution network. Furthermore, Finland decided to create the Balticconnector gas pipeline between Finland and Estonia. The EU declared this project to be a project of common interest, and provides 75% of the EUR 250 million investment. Gasum saw no business case for this pipeline. The Baltic Connector will link Finland to Baltic gas storages, LNG terminals and further to Europe once the Baltic countries are connected to Europe by the GIPL pipeline. The Connector is projected to come online by end of 2019, with a capacity of 2.6 bcm/y, enough to supply all of Finland, although not on peak demand days. The Connector can also operate in bidirectional mode.

The phase-out of coal in energy generation by 2030 is expected to increase the flexibility needs of the power system. Besides facilitating investments in gas consuming industries, the government is interested to interconnect to the EU internal gas market, notably to the Baltic grid and Poland (GIPL pipeline) and diversify supplies. As soon as the Baltic Connector is operational, the government will open the gas market in 2020 for third parties and effectively unbundle Gasum in a TSO and gas trader. The government has no clear indication whether other gas companies have an appetite to enter a market that lost almost half of its volume, and is projected to remain stable for the coming decade. Future growth is expected from natural gas use in industry.

There are few biogas installations, many of them run by Gasum. There is negotiated TPA for biogas – regulated TPA and quality standards for biogas are forthcoming under the New Natural Gas Market Act by 2020. Both regulations are envisaged to be part of the regulatory package to open the gas market in Finland.

Coal and peat

Coal accounted for 9% of TPES and 11% of electricity generation in 2016. Finland has no domestic coal production, and Russia accounts for around two-thirds of total coal imports, mainly thanks to its competitively priced hard coal. Coal consumption has seasonal variability, due to its use in CHP, but also strong variability over the years, as coal-fired power generation tends to compensate for hydro production in dry years. In general coal consumption is on a declining trend, as the use of biomass has increased.

Coal is used in CHP plants in larger cities. The only large coal-fired condensing plant (500MW) is at Pori and it plays an important role to cover peak demand during the winter. The government has decided to phase out the use of coal for energy generation by 2030. Once the existing pulverised fuel combustion plants will be decommissioned, coal will be used only as a back-up fuel in exceptional situations, and as coking coal in metal production.

Finland is one of the few countries in the IEA that use a significant proportion of peat for heating and electricity production; peat represents 4% of TPES, around 10% of heat production and some 3% of electricity generation. Many of the CHP plants and heat boilers that use woodchips or forest by-products as their main fuel require a minimum amount of peat to be co-fired to avoid corrosion of the installation. Taxation is used to ensure that peat is more cost-effective than imported fossil fuels (coal, gas, oil), resulting in greater use than is technically required. The taxation of peat is a key steering instrument, especially in separate heat production.

CO_2 emissions from burning peat are 106 g/MJ; from coal 95 g/MJ and from natural gas 56g/MJ. The respective shares in TPES are: peat 4%; coal 9% and natural gas 6%. According to the government, total CO_2 emissions from fossil fuels are 43 Mt, which would imply that the respective CO_2 emissions are: from peat 5.2 Mt, coal 10.8 Mt and natural gas 4.3 Mt. Phasing out peat could thus substantially contribute to the CO_2 emissions reduction target of 2030.

On the other hand, for Finland, peat is a domestically sourced fuel, while all coal and gas have to be imported. Peat production comes with employment in rural areas. According to the current National Energy and Climate Strategy, energy peat use is expected to go down from 20 TWh to 15 TWh by 2030. There is no plan for peat to be phased-out. Peat can have a role in isolated inland Finland and as emergency stocks, securing the diversity of the energy supply.

Recommendations

The government of Finland should:

Oil

- ☐ Assess and clarify the measures that will be used to implement the targeted reduction in domestic oil end-use by 2030, to provide certainty for industry and consumers alike for their future investment decisions.

Natural gas

- Review the tax levels for natural gas and peat when used in CHP and heat production, and create a level playing field based on their CO_2 emissions.
- Develop timely and clear market rules ahead of the opening of the gas market in 2020 to encourage third parties entering the market, and ensure strict monitoring of the market behaviour by Gasum to avoid abuse of market power.
- Ahead of the opening of the Baltic Connector create clear rules for its use, and together with Estonia and other Baltic countries create a single Baltic gas market design.
- Encourage the development of biogas by clarifying the technical rules across Finland and the Nordics under which this gas can be accepted by the TSO, and arrange for non-discriminatory access to the gas grid.

Coal

- Clarify which measures will be used to phase out coal consumption by 2030, including which actions will be taken to remove the allowances equivalent to the emissions of the installations that will be closed.
- Evaluate under which circumstances coal-fired power generation capacity can be part of the strategic reserve of electricity, also after 2030.

Peat

- Assess the cost and benefits of an early phase out of use of peat vis-à-vis other emission reduction options and if appropriate develop a roadmap for the peat phase-out.
- Evaluate the need for government subsidies to peat producers for holding emergency stocks; compare this subsidy system with a system in which the consumers of peat themselves are responsible for ensuring continued peat supply.

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Review criteria

The Shared Goals, which were adopted by the IEA Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews (IDRs) conducted by the IEA. The Shared Goals are presented in Annex C.

Review team and preparation of the report

The review team visited Finland from 27 November to 1 December 2017, met with government officials, regulators, stakeholders in the public and private sectors as well as other organisations and interest groups. The discussions helped the team identify the key challenges facing energy-policy makers in Finland. The report was drafted on the basis of these meetings, the government's initial submission to the IEA energy policy questionnaire and several updates since the review visit.

The IEA and the peer review team are grateful for the co-operation and assistance of the many people it met throughout the visit. The review team wishes to express its gratitude to the hosts at the Ministry of Economic Affairs and Employment, to: Mr Riku Huttunen, Director General of the Energy Department and Mr Petteri Kuuva, Head of Unit. Special thanks for the organisation of the review on the government side go to Ms Katja Tuokko for her support and excellent management of the programme and the logistics throughout the review week.

The members of the team were:

IEA member countries and observers

Mr. Lars Georg Jensen, Denmark (team leader)

Mr. Anton Eliston, Norway

Mr. Will Broad, United Kingdom

Ms Joanne Bright, Australia

Mr. Joan Canton, European Commission

Ms Luminita Grancea, OECD Nuclear Energy Agency

Mr. Javier Bustos, Chile

International Energy Agency

Mr. Aad van Bohemen

Ms Sylvia Beyer

Mr. Pierpaolo Cazzola

Organisations visited

- Ministry of Economic Affairs and Employment
- Ministry of Agriculture and Forestry
- Ministry of the Environment
- Ministry of Finance
- Ministry of Transport and Communications
- Association of Finnish Peat Industries
- Baltic Connector Oy
- Bioenergy Association of Finland
- Central Union of Agricultural Producers and Forest Owners
- Climate Leadership Council
- Confederation of Finnish Industry and Employers
- Energy Authority
- ELFI
- Finnish Association for Nature Conservation
- Federation of Finnish Technology Industries
- Fennovoima
- Fingrid Oyj
- Finnish Association for Nature Conservation
- Finnish Competition and Consumer Authority
- Finnish Climate Change Panel
- Finnish Clean Energy Association
- Finnish Energy Industries
- Finnish Forest Industries Federation
- Finnish Home Owners' Association
- Finnish Oil and Gas Federation
- Finnish Petroleum Federation
- Finnish Wind Power Association
- Fortum
- Gasum
- METLA, Finnish Forest Research Institute
- Motiva Oy
- NESA (National Emergency Supply Agency)
- NESTE
- Posiva Oy
- ST1
- STUK, Radiation and Nuclear Safety Authority
- Tekes, Finnish Funding Agency for Technology and Innovation
- TVO
- UPM
- VTT, Technical Research Centre of Finland

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2015	2016	2017E
TOTAL PRODUCTION		**4.9**	**12.1**	**14.9**	**17.5**	**17.8**	**17.8**	**18.2**
Coal		-	-	-	-	-	-	-
Peat		0.1	1.8	1.1	1.8	0.8	0.7	0.7
Oil		-	-	0.1	0.1	0.1	0.1	0.1
Natural gas		-	-	-	-	-	-	-
Biofuels and waste[1]		3.9	4.3	6.5	8.4	9.0	9.2	9.7
Nuclear		-	5.0	5.9	5.9	6.1	6.0	5.9
Hydro		0.9	0.9	1.3	1.1	1.4	1.4	1.3
Wind		-	-	0.0	0.0	0.2	0.3	0.4
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	0.1	0.1	0.2	0.2	0.2
TOTAL NET IMPORTS[3]		**16.2**	**16.9**	**17.5**	**17.3**	**15.0**	**14.9**	**15.3**
Coal	Exports	0.0	0.0	0.0	0.0	0.1	0.1	0.1
	Imports	2.4	4.4	3.6	4.0	2.6	2.8	2.9
	Net imports	2.4	4.4	3.5	4.0	2.5	2.7	2.8
Oil	Exports	0.2	1.7	5.1	6.9	6.9	9.1	8.8
	Imports	13.8	12.0	15.6	16.3	16.6	18.4	18.5
	Int'l marine and aviation bunkers	-0.2	-0.9	-1.0	-0.7	-0.9	-0.9	-1.0
	Net imports	13.4	9.5	9.5	8.7	8.7	8.4	8.8
Natural Gas	Exports	-	-	-	-	-	-	0.0
	Imports	-	2.2	3.4	3.8	2.2	2.1	1.9
	Net imports	-	2.2	3.4	3.8	2.2	2.1	1.9
Electricity	Exports	0.0	0.0	0.0	0.4	0.4	0.3	0.2
	Imports	0.4	0.9	1.1	1.4	1.8	1.9	1.9
	Net imports	0.4	0.9	1.0	0.9	1.4	1.6	1.8
TOTAL STOCK CHANGES		**-0.1**	**-0.6**	**-0.0**	**1.8**	**-0.1**	**1.3**	**0.8**
TOTAL SUPPLY (TPES)[4]		**21.0**	**28.4**	**32.4**	**36.6**	**32.6**	**34.0**	**34.4**
Coal		2.5	4.1	3.6	4.6	2.7	3.2	2.8
Peat		0.0	1.2	1.5	2.3	1.4	1.3	1.3
Oil		13.3	9.5	9.1	9.5	8.0	8.7	9.0
Natural gas		-	2.2	3.4	3.8	2.2	2.1	1.9
Biofuels and waste[1]		3.9	4.6	6.5	8.4	9.1	9.3	9.8
Nuclear		-	5.0	5.9	5.9	6.1	6.0	5.9
Hydro		0.9	0.9	1.3	1.1	1.4	1.4	1.3
Wind		-	-	0.0	0.0	0.2	0.3	0.4
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	0.1	0.1	0.2	0.2	0.2
Electricity trade[5]		0.4	0.9	1.0	0.9	1.4	1.6	1.8
Shares in TPES (%)								
Coal		*12.0*	*14.4*	*11.2*	*12.5*	*8.3*	*9.4*	*8.3*
Peat		*0.2*	*4.3*	*4.6*	*6.3*	*4.2*	*3.9*	*3.7*
Oil		*63.0*	*33.3*	*28.1*	*25.8*	*24.4*	*25.5*	*26.3*
Natural gas		-	*7.7*	*10.6*	*10.5*	*6.9*	*6.1*	*5.6*
Biofuels and waste[1]		*18.7*	*16.1*	*20.2*	*22.8*	*27.9*	*27.2*	*28.5*
Nuclear		-	*17.6*	*18.1*	*16.2*	*18.6*	*17.8*	*17.0*
Hydro		*4.3*	*3.3*	*3.9*	*3.0*	*4.4*	*4.0*	*3.7*
Wind		-	-	-	*0.1*	*0.6*	*0.8*	*1.2*
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	*0.2*	*0.3*	*0.5*	*0.6*	*0.6*
Electricity trade[5]		*1.8*	*3.2*	*3.2*	*2.5*	*4.3*	*4.8*	*5.1*

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**	**2017E**
TFC	**19.2**	**22.4**	**24.5**	**26.5**	**24.9**	**26.0**	**..**
Coal	1.0	1.2	0.7	0.5	0.3	0.4	..
Peat	0.0	0.4	0.3	0.3	0.2	0.2	..
Oil	11.3	9.4	8.3	8.2	7.7	8.3	..
Natural gas	-	1.0	0.9	0.8	0.6	0.6	..
Biofuels and waste[1]	3.9	3.5	4.5	4.9	5.4	5.4	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	0.0	0.0	0.0	..
Electricity	2.3	5.1	6.5	7.2	6.7	7.0	..
Heat	0.6	1.9	3.3	4.6	3.8	4.1	..
Shares in TFC (%)							
Coal	*5.4*	*5.2*	*2.7*	*1.9*	*1.3*	*1.5*	..
Peat	*0.1*	*1.8*	*1.3*	*1.2*	*0.9*	*0.8*	..
Oil	*58.7*	*41.8*	*33.9*	*31.0*	*30.9*	*31.8*	..
Natural gas	-	*4.3*	*3.7*	*3.1*	*2.6*	*2.4*	..
Biofuels and waste[1]	*20.5*	*15.7*	*18.4*	*18.6*	*21.9*	*20.9*	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	*0.0*	*0.0*	*0.0*	..
Electricity	*12.1*	*22.6*	*26.6*	*27.1*	*27.1*	*26.7*	..
Heat	*3.1*	*8.6*	*13.3*	*17.2*	*15.4*	*15.9*	..
TOTAL INDUSTRY[6]	**7.6**	**10.6**	**12.7**	**12.1**	**12.0**	**12.4**	**..**
Coal	0.9	1.2	0.6	0.5	0.3	0.4	..
Peat	0.0	0.4	0.3	0.2	0.2	0.2	..
Oil	5.0	2.7	2.6	2.6	2.9	3.0	..
Natural gas	-	0.9	0.8	0.7	0.6	0.6	..
Biofuels and waste[1]	-	2.5	3.4	3.0	3.5	3.7	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	1.6	2.8	3.7	3.5	3.3	3.3	..
Heat	0.1	0.2	1.2	1.6	1.3	1.3	..
Shares in total industry (%)							
Coal	*12.2*	*10.9*	*5.1*	*4.1*	*2.7*	*3.0*	..
Peat	*0.2*	*3.6*	*2.3*	*2.0*	*1.5*	*1.3*	..
Oil	*66.0*	*25.7*	*20.4*	*21.3*	*24.3*	*24.1*	..
Natural gas	-	*8.7*	*6.6*	*6.0*	*4.8*	*4.5*	..
Biofuels and waste[1]	-	*23.1*	*26.8*	*24.9*	*29.2*	*29.9*	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	*20.5*	*26.3*	*29.0*	*28.6*	*27.1*	*26.6*	..
Heat	*1.0*	*1.6*	*9.7*	*13.0*	*10.5*	*10.5*	..
TRANSPORT[4]	**2.4**	**4.0**	**4.0**	**4.3**	**4.2**	**4.3**	**..**
OTHER[7]	**9.2**	**7.8**	**7.8**	**10.1**	**8.7**	**9.2**	**..**
Coal	0.1	0.0	0.0	0.0	0.0	0.0	..
Peat	0.0	0.0	0.0	0.1	0.0	0.1	..
Oil	3.9	2.7	1.8	1.5	1.2	1.2	..
Natural gas	-	0.0	0.1	0.1	0.1	0.1	..
Biofuels and waste[1]	3.9	1.1	1.1	1.8	1.4	1.5	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	0.0	0.0	0.0	..
Electricity	0.8	2.2	2.8	3.6	3.4	3.6	..
Heat	0.5	1.7	2.0	3.0	2.6	2.8	..
Shares in other (%)							
Coal	*1.1*	*0.1*	*0.1*	-	-	-	..
Peat	*0.1*	*0.2*	*0.4*	*0.6*	*0.5*	*0.6*	..
Oil	*42.0*	*34.6*	*23.3*	*15.1*	*13.4*	*13.0*	..
Natural gas	-	*0.5*	*0.8*	*0.8*	*0.6*	*0.6*	..
Biofuels and waste[1]	*42.8*	*13.7*	*14.0*	*17.6*	*16.5*	*16.7*	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	*8.2*	*28.6*	*35.4*	*36.2*	*39.4*	*38.7*	..
Heat	*5.7*	*22.3*	*26.0*	*29.6*	*29.5*	*30.5*	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	3.4	11.8	15.4	18.9	15.5	15.9	..
Output (Mtoe)	2.2	4.7	6.0	6.9	5.9	5.9	5.8
Output (TWh)	26.1	54.4	70.0	80.7	68.6	68.8	67.4
Output Shares (%)							
Coal	*18.7*	*18.5*	*13.1*	*18.8*	*8.3*	*11.1*	*9.9*
Peat	*9.4*	*5.1*	*5.7*	*7.8*	*4.5*	*4.2*	*4.1*
Oil	*31.6*	*3.1*	*0.8*	*0.6*	*0.3*	*0.3*	*0.3*
Natural gas	-	*8.6*	*14.5*	*14.0*	*7.6*	*5.4*	*5.0*
Biofuels and waste[1]	-	*9.5*	*12.4*	*13.9*	*17.2*	*17.4*	*17.9*
Nuclear	-	*35.3*	*32.1*	*28.3*	*33.9*	*33.7*	*33.3*
Hydro	*40.3*	*20.0*	*21.0*	*16.0*	*24.4*	*23.0*	*21.9*
Wind	-	-	*0.1*	*0.4*	*3.4*	*4.5*	*7.1*
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	-	-	*0.1*	-	-	*0.1*
TOTAL LOSSES	**1.9**	**6.7**	**8.5**	**10.1**	**7.9**	**8.1**	**..**
of which:							
Electricity and heat generation[9]	0.6	5.1	5.9	7.1	5.6	5.6	..
Other transformation	0.5	0.2	0.8	0.7	0.4	0.4	..
Own use and transmission/distribution losses[10]	0.9	1.4	1.8	2.3	2.0	2.1	..
Statistical Differences	**-0.1**	**-0.7**	**-0.6**	**0.0**	**-0.2**	**-0.1**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
GDP (billion 2010 USD)	99.85	167.12	209.38	247.80	247.41	252.69	259.35
Population (millions)	4.67	4.99	5.18	5.36	5.48	5.50	5.51
TPES/GDP (toe/1000 USD)[11]	0.21	0.17	0.15	0.15	0.13	0.13	0.13
Energy production/TPES	0.23	0.43	0.46	0.48	0.54	0.52	0.53
Per capita TPES (toe/capita)	4.51	5.69	6.26	6.82	5.95	6.19	6.24
Oil supply/GDP (toe/1000 USD)[11]	0.13	0.06	0.04	0.04	0.03	0.03	0.03
TFC/GDP (toe/1000 USD)[11]	0.19	0.13	0.12	0.11	0.10	0.10	..
Per capita TFC (toe/capita)	4.11	4.49	4.73	4.94	4.54	4.73	..
CO_2 emissions from fuel combustion ($MtCO_2$)[12]	47.9	53.8	54.6	62.0	42.4	45.5	..
CO_2 emissions from bunkers ($MtCO_2$)[12]	0.5	2.8	3.2	2.3	2.8	2.8	..
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-14**	**14-15**	**15-16**	**16-17**
TPES	1.8	1.3	1.2	-1.7	-4.4	4.3	1.0
Coal	2.9	-1.2	2.4	-9.6	-11.9	17.8	-10.9
Peat	22.6	2.0	4.4	-11.2	-3.4	-	-
Oil	-2.0	-0.4	0.4	-2.0	-8.9	9.2	4.1
Natural gas	-	4.6	1.1	-10.0	-11.0	-7.9	-7.1
Biofuels and waste[1]	0.9	3.7	2.5	2.7	-2.2	1.9	5.7
Nuclear	-	1.6	0.1	0.8	-1.4	-0.2	-3.2
Hydro	0.2	3.0	-1.3	0.9	25.2	-5.8	-6.4
Wind	-	-	13.6	39.6	110.5	32.0	56.4
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	-	3.2	9.5	10.4	18.9	4.2
TFC	0.9	0.9	0.8	-1.8	0.8	4.5	..
Electricity consumption	4.7	2.5	1.0	-1.3	-0.9	3.0	..
Energy production	5.5	2.1	1.6	1.1	-3.0	0.3	2.4
Net oil imports	-2.0	0.1	-0.9	-0.5	2.6	-3.6	4.1
GDP	3.1	2.3	1.7	-0.1	0.1	2.1	2.6
TPES/GDP	-1.3	-0.9	-0.5	-1.7	-4.5	2.1	-1.6
TFC/GDP	-2.1	-1.3	-0.9	-1.7	0.6	2.3	..

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.

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, total net imports also include peat, biofuels and trade of electricity.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
9. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear and 100% for hydro, wind and solar photovoltaic.
10. Data on “losses” for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Toe per thousand US dollars at 2010 prices and exchange rates.
12. “CO_2 emissions from fuel combustion” have been 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.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency and flexibility within the energy sector are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

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

ANNEX D: Glossary and list of abbreviations

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

Acronyms and abbreviations

AC	alternating current
AFI	alternative fuels infrastructure
BECCS	bioenergy with carbon capture and storage
BEV	battery electric vehicles
BTL	biomass-to-liquids
BWR	boiling water reactor
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CCU	carbon capture and utilisation
CEM	Clean Energy Ministerial
CHP	combined heat and power
CNS	Centre for Nuclear Safety
CSA	co-ordinated security analysis
DH	district heating
DIP	decision-in-principle
DS	deferred settlement
DSO	distribution system operator
EA	Energy Authority
EPBD	Energy Performance of Buildings Directive
EC	European Commission
ECA	Export Credit Agency
EED	Energy Efficiency Directive
EIA	environmental impact assessment
ENSREG	European Nuclear Safety Regulators Group
EPAD	Electricity Price Area Differentials
EPR	European pressurised water reactor
ESD	Effort Sharing Decision
ETS	Emissions Trading Scheme
EU	European Union
EUR	euro
EV	electric vehicle
EVSE	electric vehicle supply equipment
FCA	Finnish Competition Authority

FQD	Fuel Quality Directive
GDP	gross domestic product
HHI	Herfindahl-Hirschman Index
ICC	International Chamber of Commerce
ICE	internal combustion engine
IGM	individual grid models
ILUC	indirect land use change
IPCC	Intergovernmental Panel on Climate Change
LULUCF	land use, land-use change and forestry
MaaS	mobility as a service
MCCP	Medium-term Climate Change Policy Plan
MCPP	Medium-term Climate Policy Plan
MEAE	Ministry of Economic Affairs and Employment
NEEAP	National Energy Efficiency Action Plan
NESA	National Emergency Supply Agency
NPP	nuclear power plant
OPC	Outage Planning Co-ordination
PCI	project of common interest
PHEV	plug-in hybrid electric vehicle
PWR	pressurised water reactors
RAKLI	Association of Building Owners and Construction Clients
RDD	research, development and demonstration
RED	Renewable Energy Directive
RSC	Regional Security Co-ordinator
SF	Statistics Finland
SMTA	Short- and Medium-Term Adequacy
SRC	Strategic Research Council
TFC	total final consumption
TPA	third-party access
TPES	total primary energy supply
TSO	transmission system operator
TVO	Teollisuuden Voima Oy
UNFCCC	United Nations Framework Convention on Climate Change
UPM	United Paper Mills
US	United States
VAT	value-added tax
WEC	World Energy Council

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ENERGY POLICIES OF IEA COUNTRIES

Finland

2018 Review

Since 2016, the International Energy Agency's (IEA) in-depth country policy reviews focus on key energy security challenges in fast-changing global energy markets as well as on the transition to clean-energy systems. This latest update on Finland's energy policies therefore offers insights into three special focus areas – bioenergy, transportation, and combined heat and power (CHP) production.

With abundant forest resources, Finland is a global leader in developing second-generation biofuels. This report examines the impacts of greater biofuel use on sustainability and the country's carbon sink, and it offers perspectives for Finland's potential for innovation in heavy duty, aviation and maritime transport.

The country has aligned its climate and energy policies within a robust policy framework and set ambitious climate targets for 2030, such as cutting oil consumption in half and achieving 30% of renewables in transport by 2030. As the power sector is largely decarbonised, transport is a key sector for the country's ambitious national climate targets.

Finland has been a leader among IEA countries in public and private spending on energy research, development and demonstration. A longer-term policy framework for 2050 will be pivotal to guide investments in clean energy technology innovation, a critical factor for reaching decarbonisation goals.

The report looks at the challenges Finland faces and provides recommendations for further policy improvements. It is intended to help guide the country towards a more secure and sustainable energy future.