Finland 2023

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Foreword

The mission of the International Energy Agency (IEA) is to shape a secure and sustainable energy future for all. We work with countries around the world on strengthening energy security and reaching net zero emissions. Our energy policy reviews are an essential IEA tool for providing insight and advice to governments on how to best achieve their energy and climate goals.

This report commends Finland for the impressive steps that it has taken to improve its energy security and advance its clean energy transition. I had the privilege of meeting with the Prime Minister and other members of the Finnish government in Helsinki in October 2022 to discuss how Finland and Europe can respond to the evolving challenges of the global energy crisis and take advantage of the opportunities of the new global energy economy that is emerging.

Finland has set one of the most ambitious climate targets in the world and the Climate Change Act was updated last year to create a legal obligation to reach carbon neutrality by 2035. It has already made notable progress towards this target, seeing strong growth in onshore wind generation, for example. It has also deployed the first new nuclear reactor in Europe in over 15 years, which started commercial operation in April 2023. Thanks to these and other steps, Finland has one of the lowest levels of reliance on fossil fuels among IEA member countries.

Historically, Russia has been a key source of Finland's energy imports. Following Russia's invasion of Ukraine, Finland has taken several positive steps to end any remaining reliance on Russian energy imports. For example, it has deployed a floating storage and regasification terminal that is capable of covering the natural gas needs of both Finland and Estonia. It has also launched a well-designed consumer awareness campaign that has contributed to a considerable reduction in energy demand.

Despite notable successes, some challenges remain. Imported fossil fuels still account for over one-third of Finland's energy supply, and some areas of the economy, such as transport and key industrial activities, are particularly dependant. Also, land use change and forestry, a sector which has historically offset a significant amount of Finland's greenhouse gas emissions, was a net source of emissions for the first time in 2021. Whether this is a one-off aberration or the start of a long-term trend will have implications for Finland's overall climate and clean energy strategy.

I sincerely hope the recommendations in this report will help Finland achieve carbon neutrality while ensuring energy security.

Dr Fatih Birol

Executive Director

International Energy Agency

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Executive summary

Finland's energy and climate policies are centred on achieving carbon neutrality by 2035 while ensuring energy security, reducing energy import dependency, promoting a sustainable economy and protecting biodiversity. Finland's Climate Change Act was updated in July 2022 with a legal obligation to reach carbon neutrality by 2035. In support of this obligation, the Act sets binding targets to reduce greenhouse gas (GHG) emissions, excluding land use, land-use change and forestry (LULUCF) by 60% by 2030, 80% by 2040 and 90-95% by 2050. The Act also requires the development of several documents defining the specific measures to achieve these targets.

Thanks to its nuclear reactors and large domestic production of renewable energy (mainly forestry solid biomass as well as generation from hydro and wind), Finland has one of the lowest levels of reliance on fossil fuels among IEA member countries. In 2021, fossil fuels covered 36% of Finland's total energy supply (TES), the second-lowest share among IEA countries and much lower than the IEA average of 70%. Finland has no domestic fossil fuel production and all supplies of crude oil, natural gas and coal are imported. The energy intensity of the economy and energy consumption per capita are both very high due to the country's relatively large heavy industry sector and the high heating demand from its cold climate.

The National Climate and Energy Strategy (NCES) is the key document defining the measures by which Finland will meet the European Union's (EU) 2030 energy and climate targets and achieve carbon neutrality by 2035. Finland plans to achieve carbon neutrality by maintaining a high share of nuclear energy, increasing electricity generation and heat production from renewables, improving energy efficiency, and electrifying most energy demand across the economy. There is also a push for the development, commercialisation and cost reduction of new and emerging energy technologies to drive energy transition in hard-to-abate sectors and end uses, especially industry and heavy transport. Bioenergy plays a key role in Finland's climate and energy policy. Forestry biomass is a key source of electricity and heat, and biofuels play a central role in supporting energy transition in the transport sector. Finland's plan to achieve carbon neutrality also relies on increasing carbon removals from LULUCF to offset remaining emissions.

Finland has made notable progress in moving towards carbon neutrality. It deployed the first new nuclear reactor in Europe in over 15 years, which started full operation on 16 April 2023, and has seen strong growth in onshore wind generation. However, notable challenges remain. Imported fossil fuels still account for over a third of Finland's energy supply and some areas of the economy, such as transport and key industrial activities, remain dependant on them. Also, while LULUCF has historically offset a significant amount of GHG emissions, there has been a declining trend in carbon removal from LULUCF since 2010. In 2021, for the first time, the land-use sector was a net source of GHG emissions.

Energy efficiency is a pillar of Finland's strategy to achieve carbon neutrality by 2035, lower energy bills, protect vulnerable consumers and boost energy security. As industry accounts for more than half of energy demand, energy efficiency agreements with specific action plans for industry sectors are expected to achieve the highest amount of savings from 2021 to 2030. In the buildings sector, fuel switching from oil to more efficient heating solutions drove improvements in heating efficiency. Finland is a world leader in heat pump sales. District heating (DH) plays a significant role in the country, and its supply is transitioning away from fossil fuels towards bioenergy and waste heat. Finland is also a world leader in the development of thermal storage solutions, providing flexibility to DH networks but also to the electricity sector, thanks to sector integration. In the transport sector, the performance of passenger cars has improved and the fleet of electric vehicles (EVs) roughly doubled each year from 2012 to 2021. Looking ahead, Finland aims to not increase the energy demand of the industry sector while increasing its value added, strongly raising the share of space heating from non-combustion sources and electrifying the transport fleet with ambitious targets for 2030.

Finland's NCES and other key policy documents indicate that a strong increase in renewable energy is needed to meet the 2035 climate neutrality goal. Much of the growth in renewable electricity generation is expected to come from onshore wind generation, along with the development of Finland's first large-scale offshore farms. Solar PV, so far only a small source of generation, is also expected to rapidly increase deployment. Wood fuels are expected to play a major role in reducing fossil fuel demand in the near future, but in the long term, the government wants to move to heating and cooling systems based on non-combustion technologies (heat pumps, waste heat recovery and geothermal). Increased use of renewable energy by passenger vehicles is driven mainly by a biofuel obligation and, to a smaller extent, EV adoption. The government sees low-emission hydrogen and hydrogen-based fuels as better solutions than direct electrification for heavy road transport, maritime transport and aviation. There is also a notable push to increase biomethane production for use in transport and heating.

Finland is a world-level player in energy technology innovation. In 2020, it ranked fourth among IEA countries for government budget allocations on energy research and development (R&D) as a share of gross domestic product (GDP). The NCES and other key policy documents note that increased innovation is required to support the commercialisation and cost reduction of new and emerging energy technologies that are key to achieving Finland's climate goals. There is a focus on finding solutions for hard-to-abate sectors and on developing new energy technologies and services with the potential for global deployment to maximise climate benefits and promote Finland's economic competitiveness. Within the context of Finland's climate policy, there is an intent to increase Finland's "carbon handprint", or positive global climate impacts, through the export of clean technology.

The government sees critical mineral mining and processing and the battery supply chain as promising areas for delivering strong economic returns while supporting a secure energy transition. Finland has large deposits of cobalt, nickel, lithium, graphite and other critical minerals and is already a major producer of several of these materials. In 2021, Finland refined around 10% of global cobalt output. Finland is home to the only producer outside of the People's Republic of China (hereafter "China") supplying the cobalt for lithium-ion batteries and several Finnish companies are currently expanding the production of nickel, cobalt and lithium. Finland is also active across the battery supply chain, from mining and processing of raw materials to manufacturing batteries and charging

technologies, as well as battery recycling. The government aims to increase Finland's role in the global battery supply chain through increased innovation, with a focus on developing products with higher added value. The National Battery Strategy 2025, published in June 2021, presents a road map for Finland to become a major player in the international battery industry.

Finland aims for the electricity sector to play a major role in achieving the 2035 carbon neutrality target and long-term emissions reductions. The government expects most investment in the electricity sector to be driven by market forces, but it has introduced support measures to encourage investments to reduce the carbon intensity of electricity generation further and increase the electrification of energy demand. Energy taxation has also been adjusted to make investments in low-carbon generation and electrification more attractive. The government is encouraging the transmission and distribution system operators to make significant investments to support increased low-carbon generation and electrification.

Nuclear energy plays a key role in Finland's energy sector and is a central part of the government's plans to achieve carbon neutrality by 2035 and reduce energy import dependence. Nuclear is the largest source of electricity generation in Finland, amounting to 33% of total electricity generation in 2021. This figure is expected to increase to more than 40% following the start of operations of the Olkiluoto 3 reactor on 16 April 2023. As of 2021, Finland had the sixth-highest share of nuclear generation among IEA member countries. It is also a global leader in nuclear waste management and disposal. The Onkalo nuclear waste disposal facility, under construction near the Olkiluoto nuclear power plant, is expected to start operating in 2025 and will be the world's first permanent geological disposal facility for spent nuclear fuel and high-level radioactive waste.

Finland does not have any uranium mining or nuclear fuel enrichment facilities. However, Terrafame, a 70% state-owned mining company, has been working to establish a facility to produce yellow cake uranium at a mine in the Kainuu region that produces nickel and other metals for batteries. In February 2022, the government granted a uranium recovery and refining permit that allows Terrafame to produce up to 250 tonnes of uranium each year. Only minor investments and final approvals are needed before uranium production can start. Once operational, it would be the only site in the European Union mining and processing uranium.

Natural gas plays a small role in Finland (6.4% of TES in 2021) compared to the IEA average of 24%. However, natural gas is a key fuel for some parts of heavy industry. Finland's energy policy is focused on reducing the use the gas, especially following the cut-off of gas supplies from the Russian Federation (hereafter "Russia"), formerly Finland's main supplier. There are efforts to increase industrial electrification and efficiency and boost the production of biogas and low-emission hydrogen to help reduce natural gas demand.

Oil plays a relatively small role in Finland (21% of TES in 2021) compared to the IEA average of 35%. The NCES outlines a variety of measures to further reduce oil consumption in transport by improving efficiency and encouraging the uptake of alternative fuels. Finland's Roadmap to Fossil-Free Transport details measures to support the government's objective to reduce GHG emissions from transport by at least 50% by 2030 (versus 2005) and end fossil fuel consumption in transport entirely by 2045. The government views the use of liquid biofuels as a key interim strategy to limit oil

consumption in transportation. Finland's biofuels blending mandates were among the highest in the world at 19.5% in early 2022. The government plans to significantly increase them to 34% by 2030, including a sub-target of 10% for advanced biofuels. In the longer term, the uptake of EVs is viewed as the principal means of limiting oil consumption and achieving the goal of ending fossil fuel consumption in transportation.

Peat plays a small but notable role in Finland's energy system for electricity generation and heat production. In 2021, peat accounted for 2.7% of TES and 2.9% of electricity generation. Ireland is the only other IEA country were peat plays a notable role in the energy system (2.5% of TES and 1% of electricity generation in 2021). The government aims to reduce the use of peat for energy by at least 50% by 2030. However, it is likely that the use of peat for energy will stop well before 2030, with most large-scale peat-fired plants closing or switching to other fuels between 2023 and 2026.

Starting in late 2021, global energy prices began to increase rapidly, especially in Europe. Price spikes and high volatility are persisting into 2023, driven by Russia's invasion of Ukraine. In February 2022, Finland announced a range of measures to reduce the impact of higher energy prices, particularly for household electricity and heating, and for transportation and agricultural companies. According to the government, these measures will decrease tax revenues by EUR 450 million in 2022 but will not increase government spending. The government is examining how energy transition investment programmes could reduce energy costs and is preparing a loan guarantee programme to support investments by private households and housing companies in energy efficiency measures, renewable heating systems, EV charging infrastructure and the purchase of EVs.

Finland has historically relied on energy imports from Russia. In 2021, Finland spent EUR 10.1 billion on energy imports, with EUR 5.3 billion going to imports from Russia. By share of spending, Russia accounted for 81% of Finland's crude oil net imports, 75% of its natural gas, 52% of its coal and 51% of its electricity net imports. Russia accounted for 25% of wood chips imports for energy use. Finland also imported nuclear fuel from Russia in 2021, accounting for 35% of the total monetary value of the country's nuclear fuel imports. However, following the Russian invasion of Ukraine, Russia unilaterally stopped supplying Finland with most wood products, including wood chips in March 2022, and with electricity and natural gas in May 2022.

Finland is focused on reducing any remaining reliance on Russian energy imports and ensuring secure access to energy by increasing imports from other countries and domestic renewable energy production and by reducing energy demand through energy efficiency. In line with these goals, Finland has taken several strong steps, including securing a ten-year lease on a floating storage and regasification (FSRU) terminal capable of covering Finland's and Estonia's gas demand. The FSRU started commercial operations in December 2022. On the demand side, Finland launched a consumer awareness campaign in August 2022 that aims to progressively increase public understanding on how to reduce energy demand to reduce the impacts of the energy crisis driven by the Russian invasion of Ukraine. The campaign led to significant electricity savings from August to December 2022.

The government of Finland should:

- Develop a contingency plan to achieve the 2035 net zero emissions target in case the LULUCF sector fails to deliver the needed carbon sinks.
- Ensure that temporary measures taken in response to energy price shocks do not undermine signals for long-term clean energy decisions and investments.
- Support increased deployment of energy storage to accelerate the integration of renewable energy and boost the resilience and flexibility of the electricity grid and heating networks.
- Accelerate the uptake of electric vehicles with a clear plan for expanding EV charging infrastructure. Support increasing the vehicle turnover rate with a preference for EVs while encouraging less use and ownership of private vehicles by improving the infrastructure for public transport, walking and cycling.
- Prepare an offshore wind power road map that establishes a clear regulatory regime and ambitious targets and timelines for deployment. Incentives should be considered if needed.
- Assess whether additional measures are needed to reduce oil consumption further to achieve the 2030 target to reduce transport emissions by 50% versus 2005.

1. General energy policy

Key data

(2021)

TES: 1 391 PJ, -5% since 2011

TES by source: bioenergy and waste 33.6%, oil 20.8%, nuclear 18.5%, coal 6.3%, natural gas 6.4%, electricity imports 4.6%, hydro 4.1%, peat 2.7%, wind 2.2%, heat 0.6%

Energy intensity per capita (TES/capita): 251.0 GJ/capita (IEA average: 166.7 GJ/capita); -8% since 2011

Energy intensity per GDP (TES/GDP): 5.44 MJ per 2015 USD PPP (IEA average at 3.7 MJ per USD); -12% change since 2011

TFC: 1 067 PJ; +2% since 2011

TFC by sector: industry 53%, buildings 31%, transport 16%

Source: IEA (2022)

Country overview

Finland is located in Northern Europe, bordering Norway, Sweden and Russia, with coastlines on the Gulf of Bothnia and the Gulf of Finland. Finland has a relatively large land area of 338 000 square kilometres (km^2), which is covered mostly by forests and lakes. In 2022, the population was around 5.6 million, with the majority (over 85%) residing in cities located in the south of the country. Helsinki is the capital and largest city, with a population of around 660 000 in the city limits and 1.5 million in the metropolitan area.

Finland has a cold climate, with a long winter in the north and the interior. While winter is relatively mild along the western and southern coasts, even these regions have several months with sub-freezing temperatures and snowfall. Summer is generally mild and moderately rainy. Finland's cold climate (causing high heating demand) and well-developed economy with high industrial production give it one of the world's highest levels of energy demand per capita.

Finland is a parliamentary republic with a unicameral parliament consisting of 200 seats. Regular elections for all seats are held every four years to support the formation of a government under a Prime Minister. National elections are held every five years to select the President, who is the head of state. Most responsibility for energy and climate policy resides with the national government. Finland has 19 regions. The governments of the 18 mainland regions are composed of delegates from the respective region's municipalities. The 18 regional governments of the mainland have important roles in energy and climate policy, including urban planning and local transportation systems.

Finland's autonomous region of the Åland Islands (population around 30 000 in 2020) has a separate parliament and head of government and greater control over policy making, including for energy policy.

Finland has a well-developed, market-based economy with a GDP of around USD 315 billion in 2021 (44th in the world) and a high GDP per capita of USD 54 682 in 2021 (18th in the world), compared to the OECD average of USD 48 754. The Finnish economy relies mainly on the service sector (69% of GDP in 2021), followed by industry (28%), then agriculture, forestry and fisheries (3%) (OECD, 2023). Finland is competitive in promoting start-ups. Exports account for a large share of GDP (around one-third in 2021), with most exports going to other EU member states. Finland's major exports include forestry products and high-value chemicals and metals. The Finnish economy is dependent on raw materials imports, except for timber and some minerals (OECD, 2020).

The Finnish economy has experienced steady growth in recent years, with GDP growing by 41% between 2010 and 2019. The Covid-19 pandemic resulted in a notable drop in GDP of 2% in 2020. Finland experienced an economic rebound in 2021, with GDP growing by 9%. The OECD estimates that economic growth will slow sharply to 1.1% in 2022 and 0.6% in 2023 owing to the continued disruptions of the pandemic and the Russian invasion of Ukraine.

Energy sector overview

Finland's energy and climate policies are centred on achieving carbon neutrality by 2035 while ensuring energy security, reducing energy import dependency, promoting a sustainable economy and protecting biodiversity. Finland's Climate Change Act was updated in July 2022 with a legal obligation to reach carbon neutrality by 2035. In support of this obligation, the Act sets binding targets to reduce GHG emissions, excluding LULUCF by 60% by 2030, 80% by 2040 and 90-95% by 2050. The Act also requires the development of several documents defining the specific measures to achieve these targets.

Finland's plans to achieve carbon neutrality focus on maintaining a high share of nuclear energy, increasing electricity generation and heat production from renewables, improving energy efficiency, and electrifying most energy demand across the economy. There is also a push for the development, commercialisation and cost-reduction of new and emerging energy technologies to drive energy transition in hard-to-abate sectors and end uses, especially industry and heavy transport. Bioenergy plays a key role in Finland's climate and energy policy. Forestry biomass is a key source of electricity and heat, and biofuels play a key role in supporting energy transition in the transport sector. Finland's plan to achieve carbon neutrality also relies on increasing carbon removals from LULUCF to offset remaining emissions.

Following Russia's invasion of Ukraine, there has been a strong focus on reducing reliance on Russian energy imports by increasing imports from other countries and reducing energy demand through improved energy efficiency and increased use of renewable energy. In 2021, imports from Russia accounted for 81% of Finland's crude oil net imports, 75% of its natural gas net imports and 19% of its electricity net imports (in 2020). In May 2022, Russia unilaterally stopped supplying electricity and gas to Finland.

Finland has made notable progress in moving towards carbon neutrality and reducing its reliance on energy imports from Russia. It has one of the lowest carbon intensities of electricity generation among IEA member countries. It deployed the first new nuclear reactor in Europe in over 15 years, which started full operation on 16 April 2023, and has seen strong growth in onshore wind generation. However, notable challenges remain. Imported fossil fuels still account for over a third of Finland's energy supply and some areas of the economy, such as transport and key industrial activities, remain dependant on fossil fuels. Also, while LULUCF has historically offset a significant amount of GHG emissions, there has been a declining trend in carbon removal from LULUCF since 2010. In 2021, for the first time, the land-use sector was a net source of GHG emissions (see Chapter 2).

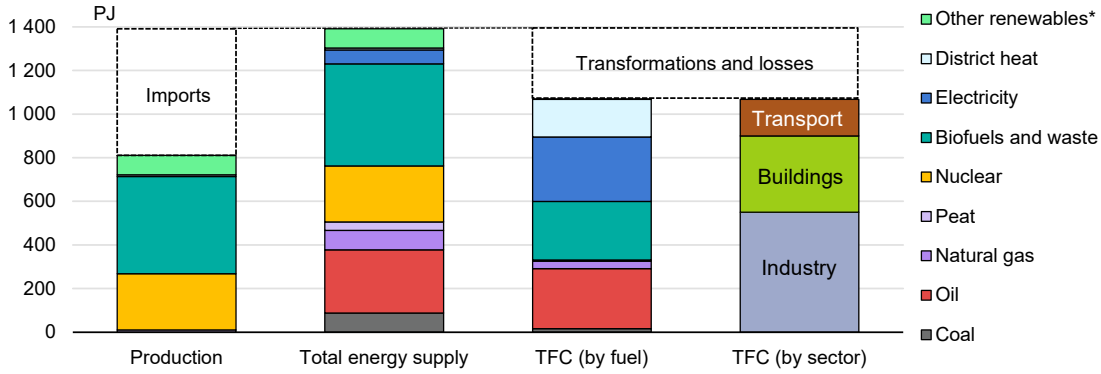
Energy production, supply and demand

Thanks to its nuclear reactors and large domestic production of renewable energy (mostly forestry solid biomass as well as generation from hydro and wind), Finland has one of the lowest levels of reliance on fossil fuels among IEA member countries. In 2021, fossil fuels covered 36% of Finland's TES, compared to the IEA average of 70%. Finland does not have domestic fossil fuel production and all supplies of crude oil, natural gas and coal are imported (Figure 1.1). The energy intensity of the economy and energy consumption per capita are both very high due to the country's relatively large heavy industry sector and the high heating demand due to its cold climate.

Oil plays a relatively smaller role in Finland (21% of TES in 2021) compared to the IEA average of 35%. Natural gas plays a notably smaller role in Finland (6.4% of TES in 2021) compared to the IEA average of 24%. Finland uses only a small amount of coal (6.3% of TES in 2021, compared to the IEA average of 10%). Peat plays a small but notable role in Finland's energy system for electricity generation and heat production. In 2021, peat accounted for 2.7% of TES and 2.9% of electricity generation. Ireland is the only other IEA member country were peat plays a notable role in the energy system (2.5% of TES and 1% of electricity generation in 2021).

Finland has seen a notable shift in the mix of its energy supply (Figure 1.2). From 2011 to 2021, the share of fossil fuels in TES declined from 53% to 36%, with the share in TES falling for all fossil fuels: oil (26% to 21%), natural gas (9.6% to 6.4%) and coal (11% to 6.3%). The share of peat in TES also declined, from 5.8% to 2.7%. These shifts were mainly driven by fuel switching in industry and in electricity and heat generation away from fossil fuels to renewable energy (mainly solid biomass). From 2011 to 2021, bioenergy and waste in TES steadily increased from 23% to 34%. Wind generation also grew significantly, from 0.1% to 2.3% of TES. Over this period, the share of nuclear in TES was relatively stable, averaging 18%, but is expected to increase now that the new Olkiluoto 3 reactor is fully operational.

Figure 1.1 Energy production, supply and demand in Finland, 2021



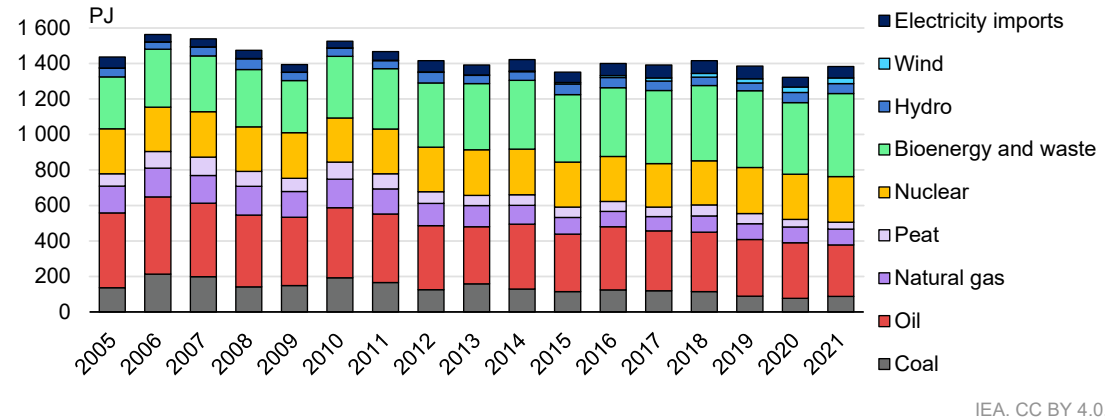
* *Other renewables* include hydro, wind and solar.

Source: IEA (2022).

Finland has experienced a notable decline in fossil fuel demand (Figure 1.2). From 2011 to 2021, the share of fossil fuels in total final consumption (TFC) dropped 36% to 33%, compared to the IEA average of 69% in 2020. The drop in fossil fuel demand was mainly due to reduced oil demand in the transport and industry sectors. There has been overall growth in the direct use of bioenergy, which plays a significant role in Finland's energy system. From 2011 to 2021, the share of bioenergy and waste in TFC grew from 19% to 24%, compared to the IEA average of 6% in 2020. A relatively large share of Finland's energy demand is covered by electricity, but there has been almost no increase in electrification in the last decade. From 2011 to 2021, the share of TFC covered by electricity decreased, from 27.6% to 27.3%, but remained above the IEA average of 23% in 2020. District heat also plays a major role in Finland, covering 15% of TFC in 2021, compared to the IEA average of 2% in 2020. The share of DH peaked in 2010 (when the winter was exceptionally cold) at 17%, then gradually decreased to 15% in 2021.

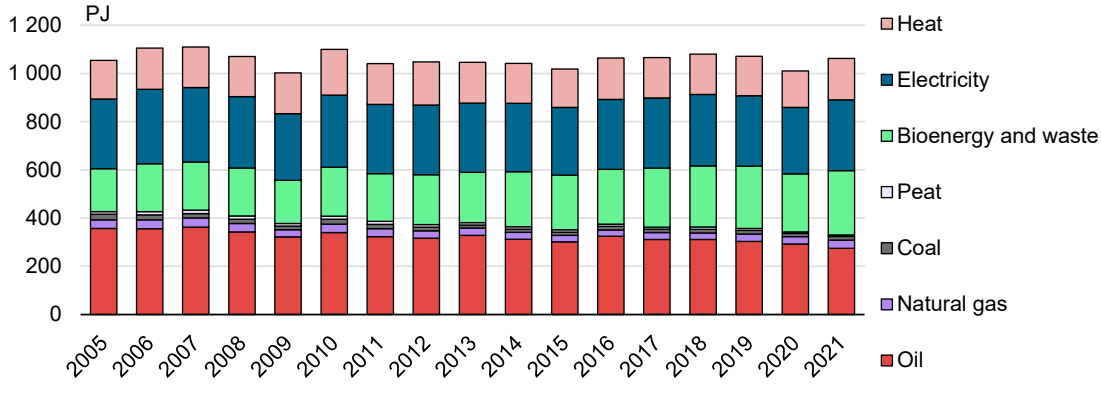
Industry accounts for, by far, the highest share of TFC (52% in 2021, compared to the IEA average of 36% in 2020), followed by buildings (33%) and transport (16%) (Figure 1.3). Industry energy demand is covered by a diverse mix of sources, with notably high shares of bioenergy and waste (33% of industry TFC in 2021, compared to the IEA average of 7% in 2020) and electricity (26% of industry TFC in 2021, compared to the IEA average of 4% in 2020). Finland is notable for having almost no use of natural gas in buildings. In 2021, gas covered just 0.7% of building TFC compared to the IEA average of 35% in 2020. Most building energy demand is covered by electricity (43% of building TFC in 2021, equal to the IEA average of 44%), followed by district heating (34%), bioenergy and waste (17%), and oil (6.1%).

Figure 1.2 Total energy supply by source in Finland, 2005-2021



Source: IEA (2022).

Figure 1.3 Total final consumption by source in Finland, 2005-2021



Source: IEA (2022).

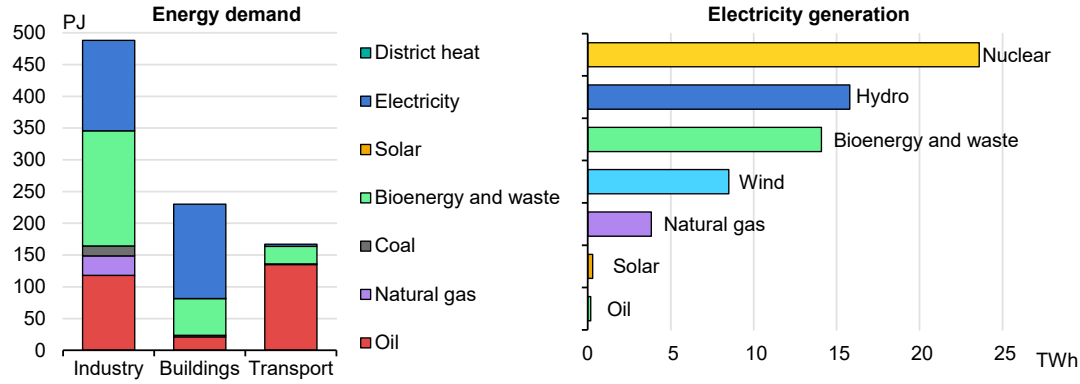
As in most IEA member countries, Finland's transport sector remains almost entirely reliant on oil (81% of transport TFC in 2021), with a growing share (17%) covered by biofuels and a very low share (2.0%) covered by electricity, mainly in rail (the IEA average for the share of electricity in transport is 0.9%). Finland is a leader in the deployment of EVs, which accounted for 3.6% of passenger vehicles in 2021 (versus the EU average of 1.6%) and for 31% of new passenger vehicle sales (versus an EU average of 17.4%).

Thanks to its nuclear reactors and a high share of generation from renewable energy, Finland has one of the lowest carbon intensities of electricity generation among IEA countries (101 grammes of carbon dioxide per kilowatt hour [g CO_2/kWh] in 2021, compared to the IEA average of 321 g CO_2/kWh). The carbon intensity of Finland's generation is expected to continue to decline thanks to increasing generation from nuclear and renewables.

From 2010 to 2021, the share of generation from nuclear energy was relatively steady at around 33% but is expected to grow notably now that the new 1.6 gigawatts (GW) Olkiluoto 3 reactor is fully operational (Figure 1.4). Between 2010 and 2021, the shares of generation from coal (18% to 4%), natural gas (14% to 5%) and peat (8% to 3%) declined, while there was strong growth in wind generation (0.4% to 11.3%). Hydropower is a major

source of generation but experiences notable variations in output based on annual precipitation. From 2010 to 2021, the share of generation from hydro varied between a minimum of 16% and a maximum of 24%. Finland has a high share of generation from bioenergy and waste, which was relatively stable at around 18% of generation from 2010 to 2021, compared to the IEA average of just 4% in 2021.

Figure 1.4 Energy demand per sector and fuel, and electricity generation by fuel in Finland, 2021



Source: IEA (2022).

Key institutions and energy players

The Ministry of Economic Affairs and Employment has the principal responsibility for developing Finland's energy policy. Within the ministry, the Energy Department leads on energy markets, energy efficiency, emissions trading, renewable energy, nuclear energy and fossil fuels. The Energy Department co-ordinates energy environment-related matters between ministries, including the Ministry of the Environment (especially on climate change); the Ministry of Finance (for implementing energy taxation); the Ministry of Agriculture and Forestry (for biomass and LULUCF issues); the Ministry of Transport and Communications (for promotion of low-emission and energy-efficient transport); and the Ministry of Education, Science and Culture (for research and innovation [R&I] policy).

Finland's Energy Authority is the independent regulator responsible for licensing, supervising and promoting the efficient functioning of the electricity and gas markets. The Energy Authority is also the key entity responsible for implementing Finnish and EU energy and climate policy, with a focus on reducing emissions and increasing energy efficiency and the use of renewable energy.

Business Finland is a public organisation responsible for attracting trade, tourism and foreign investment to Finland and providing financial support for R&I. It is supervised by the Ministry of Economic Affairs and Employment and manages several of Finland's key R&I funding programmes. Motiva Oy is a state-owned company that implements government policies on energy conservation and 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 promotes the bioeconomy and sustainable use of natural resources. Luke monitors natural resources, produces data on GHG emissions, supports natural resource policies, and

produces Finland's official food and natural resource statistics. The Radiation and Nuclear Safety Authority is tasked with nuclear safety and radiation monitoring. The National Emergency Supply Agency is a network of ministries and industries that maintains and develops security of supply on the basis of public-private partnership initiatives. Statistics Finland is a government agency responsible for producing most official data (including energy data).

The Finnish Competition and Consumer Authority (FCCA) is an independent authority responsible for ensuring fair and efficient market performance (including energy markets) for the benefit of the national economy and consumers. It has the power to bring legal cases to enforce Finnish and EU laws and regulations on competition and consumer protection. The Consumer Ombudsman, which works in conjunction with the FCCA, enforces compliance with consumer protection legislation, with a particular focus on marketing and contract terms (FCCA, 2023).

Finland has a strong energy industry sector with big players active across the Nordic markets. Fortum is the major electricity producer and the second-largest heat producer in Finland. It also operates in power and heat sales; it is 50.8% government-owned. Fortum owns the Loviisa nuclear power plant 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. It owns the Olkiluoto nuclear power plant. Neste is a state-owned oil company that operates Finland's two oil refineries. Neste is also the largest producer of biodiesel in the world.

Key energy and climate targets

Finland's energy and climate policies are centred on achieving carbon neutrality by 2035 while ensuring energy security, a sustainable economy and biodiversity protection. Finland's Climate Change Act was updated in July 2022 with a legal obligation to reach carbon neutrality by 2035. In support of this obligation, the Act sets binding targets to reduce GHG emissions (excluding LULUCF) by 60% by 2030, 80% by 2040 and 90-95% by 2050. Finland also has a variety of energy and climate targets defined by EU directives (Table 1.1). GHG emissions from Finland's energy-intensive industry and large electricity generation are regulated under the EU Emissions Trading System (ETS). Finland's National Energy and Climate Plan (NECP) defines 2030 targets for non-ETS GHG emissions, renewable energy, energy efficiency and cross-border electricity interconnections that are intended to support the achievement of EU-wide 2030 targets.

Finland achieved its 2020 targets for energy efficiency (primary and final energy consumption); renewables in gross final energy consumption, heating and cooling, and transport; and cross-border electricity interconnection. Finland just missed its target for renewables in electricity. Finland was able to achieve its 2020 GHG emissions reduction target under EU accounting rules that allow credits from years when emissions were below annual Effort Sharing Decision targets to offset for years when emissions exceeded annual targets. In addition, a notable part of the emissions reductions achieved in 2020 resulted from the negative impacts of the Covid-19 pandemic.

Finland is updating its 2030 targets for energy efficiency and renewables to reflect the 2035 carbon neutrality target and increased climate ambitions at the EU level. Finland is pushing the European Union to aim for carbon neutrality by 2035 to 2040, well ahead of the current goal of 2050.

Table 1.1 Finland's 2020 and 2030 energy sector targets and 2020 or 2021 status

Target	Metric	2021 status	2020 targets	2030 targets
Total GHG emissions	**CO_2-eq emissions versus 1990**	-33% (2020)	No target	-60%
Non-ETS GHG emissions	**CO_2-eq emissions versus 2005**	-11% (2020)	-16%	-39%
Energy efficiency	**Primary energy consumption (PJ)**	1 318	1 501	1 458
	Final energy consumption (PJ)	1 041	1 116	1 044
Renewable energy share	**Gross final energy consumption**	43%	38%	51%
	Electricity	39%	41%	53%
	Heating and cooling	53%	54%	61%
	Transport	21%	10%	45%
Cross-border electricity interconnection		29% (2020)	18%	15%

Key energy and climate policies

The Ministerial Working Group on Climate and Energy Policy directs the implementation of policies regarding the carbon neutrality target, strengthening of carbon sinks, and decision-making on climate and energy policy, considering the impacts on social justice and global competitiveness. The group is chaired by the Minister of the Environment and Climate Change and includes the Minister of Economic Affairs and Employment (responsible for energy policy), the Minister of Transport and Communications, the Minister for Development Cooperation and Foreign Trade, the Minister of Agriculture and Forestry, the Minister of Social Affairs and Health, and the Minister for Nordic Cooperation and Equality.

The National Climate and Energy Strategy, adopted in June 2022, is the key document defining the measures by which Finland will meet the European Union's 2030 energy and climate targets and achieve the national targets set in the Climate Change Act for reducing GHG emissions by 60% by 2030 and being carbon neutral by 2035. The strategy focuses on green transition and phasing out imports of Russian fossil energy. To achieve the needed emissions reductions, the strategy defines support measures to increase the use of renewable energy (see Chapter 4), improve energy efficiency (see Chapter 3) and promote innovations that accelerate and reduce the cost of energy transition. Finland provides one of the highest levels of public spending on energy R&I among IEA member countries (see Chapter 5). The strategy also relies on a significant increase in carbon removal through LULUCF to offset remaining emissions (see Chapter 2).

The NCES includes measures to further reduce Finland's already low carbon intensity of electricity generation (including a ban on coal-fired generation by 2029 and goals to reduce peat-fired generation and increase generation from renewables) and to boost the electrification of energy demand in industry, transport, and heating and cooling (see Chapter 6). Nuclear energy plays a key role in Finland's plans to achieve carbon-neutral electricity generation and reduce energy import dependence. Finland's 1.6 GW Olkiluoto 3 is the first reactor deployed in Europe in over 15 years and started full commercial operations 16 April 2023 (see Chapter 7). Natural gas plays a relatively small role in Finland but is a key fuel for the economically important heavy industry sector. Finland is working to diversify and decarbonise its gas supply (see Chapter 8). It also aims to reduce oil demand, especially from transport and buildings (see Chapter 9).

The Climate Change Act mandates the development of four policy plans that provide additional details on Finland's climate and energy policies and supporting measures. The policy plans are the Medium-term Climate Change Policy Plan (defining mitigation measures for non-ETS sectors through 2030, published in July 2022), the National Climate Change Adaptation Plan (defining adaptation measures through 2030, still under development), the Long-term Climate Change Policy Plan (defining policy through 2050, still under development) and the Climate Change Plan for the Land-Use Sector (defining measures to ensure LULUCF continues to act a major emission sink, published in July 2022) (see Chapter 2).

In 2021, the Ministry of Transport and Communications adopted the Roadmap to Fossil-Free Transport, a resolution detailing plans to reduce GHG emissions from the transport sector in line with the 2035 carbon neutrality goal. The roadmap details pathways and measures to reduce GHG emissions from domestic transport by at least 50% by 2030 (versus 2005) and to achieve an entirely fossil fuel-free transport sector by 2045 (see Chapters 3 and 4) (Finland, Ministry of Transport and Communications, 2021).

Finland is working on a legislative road map for a low-carbon construction sector based on life cycle assessments to ensure all areas of construction (renovation, new buildings and transport infrastructure) are compatible with climate targets. Measures to promote wood construction will be continued (see Chapter 3).

The reduction in industrial emissions is mainly based on sectoral low-carbon road maps. The low-carbon road maps will be updated as needed in 2023. The NCES notes that electrification and low-emission hydrogen will play a key role in reducing industrial emissions, noting a particular challenge to quickly increase emissions-free heat production and a need for strongly linking different energy systems (system integration) to phase out industrial use of fossil fuels. To support these efforts and drive low-carbon investments, the government will introduce an electrification subsidy for energy-intensive companies (see Chapters 3 and 4)

As an EU member state, Finland is required to develop several documents detailing how national policies support the achievement of EU-wide climate and energy targets. Finland's NECP, adopted in 2019, details the policies and measures to support 2030 EU climate and energy targets relevant at that time. Finland is updating its NECP to reflect the increased EU ambition for reducing GHG emissions and to account for the national 2035 carbon neutrality obligation. The updated NECP must be submitted to the European Commission in 2023. Finland's National Long-term Strategy, adopted in 2020, details the national policies to support the European Union's goal to achieve carbon neutrality by 2050.

In September 2022, the government announced its budget proposal for 2023; the total of EUR 80.5 billion is EUR 15.6 billion higher than the 2022 Budget. The proposal includes significant funding for green transition and addressing the energy security impacts of the global energy crisis and Russia's invasion of Ukraine. An appropriation of approximately EUR 241 million is proposed for the package concerning security of supply, energy self-sufficiency and clean technologies. These measures include energy investments for biogas, hydrogen, financial support to housing companies for EV charging, subsidies for phasing out oil and gas heating in residential buildings, and subsidies to ensure the availability of domestic wood. The package includes an additional EUR 225 million for

Energy Aid schemes, hydrogen projects and the National Battery Strategy 2025. The budget also includes EUR 2.8 million to support municipalities in drawing up climate plans.

Covid-19 response

In response to the Covid-19 pandemic, the European Union established the Recovery and Resilience Facility, which provides EUR 724 billion to support EU member states' recovery and resilience plans. Finland submitted its plan in May 2021. The European Commission approved the plan in October 2021, authorising EUR 2.1 billion in grant funding (equal to 0.9% of Finland's GDP) for projects and reforms to be completed by 2026. Unlike many other EU member states, Finland did not request any funding as loans. The plan allocated 50.4% of the funding to green transition to support the 2035 carbon neutrality target, including EUR 161 million for renewable energy (offshore wind, solar photovoltaics (PV), biogas, renewable transport fuels, geothermal and heat recovery), EUR 151 million for new energy transmission and distribution infrastructure, EUR 156 million for low-emission hydrogen and carbon capture storage and utilisation (CCUS), EUR 70 million to replace oil boilers with low- or zero-carbon heating systems, and EUR 40 million for private and public EV charging points (EC, 2022a). The Ministerial Working Group on Sustainable Growth in Finland is responsible for implementing the plan.

In June 2022, the European Commission announced that the Recovery and Resilience Facility funding delivered to Finland would decrease from EUR 2.1 billion to EUR 1.8 billion because Finland's economy rebounded better than forecast. The facility allows for such changes to ensure that the limited funding flows to the member states the most impacted by the pandemic. Finland is in the process of developing an updated plan to reflect the lower level of funding and has indicated that reduced EU funding for certain programmes (replacing oil boilers and the deployment of EV charging stations) will be partially replaced with national funding.

The government has created an *ad hoc* programme to distribute Finland's Recovery and Resilience Facility funding for renewable energy and energy infrastructure. The programme will award grants covering a certain share of investment costs of completed projects, with the level of funding depending on the technology and the size of the project. It will be run in a manner similar to the Energy Aid programme, which provides grants covering investment costs in renewable energy and energy efficiency projects (see Chapters 3 and 4).

Measures to address high energy prices

Starting in late 2021, global energy prices began to rapidly increase, especially in Europe. Price spikes and high volatility persist in 2023, driven by the Russian invasion of Ukraine. In February 2022, Finland announced a range of measures to reduce the impact of higher energy prices, particularly for household electricity and heating and for transportation and agricultural companies. According to the government, these measures would decrease tax revenues by EUR 450 million in 2022 but will not increase government spending.

In early 2022, the Electricity Market Act was amended to reduce retail electricity prices by reducing the allowed profits for distribution system operators (DSOs) and the allowed increase in distribution network tariffs. The rate of return for DSOs was reduced from 5.73% to 4%, the lowest level ever. The limit for the maximum annual tariff increases was

reduced from 15% to 8%. These changes are expected to reduce DSO charges to consumers by EUR 350 million (Finland, Ministry of Economic Affairs and Employment, 2021a).

The government is examining how energy transition investment programmes could reduce energy costs and is preparing a loan guarantee programme to support investments made by private households and housing companies in energy efficiency measures, renewable heating systems, EV charging infrastructure and for the purchase of EVs.

The 2023 budget proposal also includes several measures to limit the impact of high electricity and heating costs, especially for low-income families with children. Increased electricity prices can now be taken into consideration when granting social assistance. The government is preparing a fixed-term income tax credit for electricity costs that will be in force for four months (this would reduce tax revenue by an estimated EUR 265 million). The government will also prepare a separate financial support scheme for electricity available to households unable to make full use of the fixed-term income tax credit. This scheme is estimated to increase spending by EUR 85 million. In addition, the government lowered the value-added tax (VAT) on electricity from 24% to 10% from December 2022 to April 2023 (this will decrease tax revenue by an estimated EUR 290 million). The government is also increasing funding available through housing allowances to help cover higher heating costs and to support the renovation of single-family houses. The government estimates this will cost around EUR 6.3 million in 2023.

The government is preparing a windfall profit tax on electricity producers which aims to offset the cost of aid to consumers while ensuring that clean energy investments continue. According to the proposal, the tax would be 30% of the company's net profits exceeding a 10% return on capital in 2023. The law is expected to enter into force at the beginning of 2023 and the tax will be paid in early 2024 (Fortum, 2022a). In addition, the government recommends that energy companies grant longer payment times to consumers with high electricity bills resulting from the energy crisis. The government is preparing amendments to the Electricity Market Act to increase consumer awareness of electricity supply contracts that use spot pricing. In the future, consumers will be required to expressly consent to spot pricing. When offering an electricity supply contract that uses spot pricing, the supplier must provide information on the opportunities, costs and risks of the contract.

To reduce transportation costs, the government temporarily increased the maximum tax deduction for travel expenses related to commuting to work from EUR 7 000 to EUR 8 400 and increased the kilometre allowance for work commuting expenses with a personal car from 0.25 EUR/km to 0.30 EUR/km. These changes were valid for 2022 and are expected to reduce expenses for 570 000 commuters and lower tax revenue by around EUR 142 million. The government budget for 2023 reduced the VAT on passenger transport to zero between January and April 2023 (this would reduce tax revenue by an estimated EUR 60 million) and continued the deduction for commuting expenses at 0.30 EUR/km for 2023 (at a cost of EUR 24 million). In April 2022, the government reduced the biofuels blending obligation for 2022 and 2023, which could reduce transport fuel costs as biofuels are typically more expensive than diesel or gasoline (see Chapter 4). The government is examining the creation of a tax deduction for park-and-ride expenses related to work commuting. It is also working on a commercial diesel tax system to lower the cost of diesel used by professional drivers while taking into account Finland's climate goals.

Response to Russia's invasion of Ukraine

In response to Russia's invasion of Ukraine, Finland and the European Union are aiming to end reliance on Russian energy imports by imposing bans on imports from Russia, increasing imports from other countries, and reducing energy demand through improved energy efficiency and increased use of renewable energy.

Finland has historically relied on energy imports from Russia. In 2021, Finland spent EUR 10.1 billion on energy imports, with EUR 5.3 billion going to imports from Russia. By share of spending, Russia accounted for 81% of Finland's crude oil net imports, 75% of its natural gas, 52% of its coal and 51% of its electricity net imports. Russia accounted for 25% of wood chips imports for energy use. Finland also imported nuclear fuel from Russia in 2021, accounting for 35% of the total monetary value of the country's nuclear fuel imports. However, following the Russian invasion of Ukraine, Russia unilaterally stopped supplying Finland with most wood products, including wood chips in March 2022, and electricity and natural gas in May 2022 (Finland, Ministry of Economic Affairs and Employment, 2022).

In March 2022, the European Union imposed sanctions banning all imports of Russian coal, which came into full effect in August 2022. In June 2022, the European Union imposed sanctions banning seaborne imports of Russian crude oil starting 5 December 2022 and Russian petroleum product imports starting 5 February 2023. Pipeline imports of crude oil and petroleum products are exempt (but Finland does not import Russian oil via pipelines).

In May 2022, the European Commission introduced the REPowerEU plan, which proposes numerous measures intended to end EU reliance on Russian energy imports while supporting energy transition. REPowerEU will provide EUR 210 billion in grant funding to support these efforts. The grants will be awarded through the existing EU Recovery and Resilience Facility. Member states (including Finland) are updating their national recovery and resilience plans with requests for the REPowerEU funds (EC, 2022b).

Under the REPowerEU plan, the European Union adopted a natural gas storage obligation requiring that, in total, EU gas storage facilities be at least 80% full by 5 November 2022 and 90% full by 1 November in subsequent years. Finland does not have natural gas storage but contributes to this gas storage obligation requirement by storing gas in Latvia's underground gas storage facility, which is connected to Finland via the Balticconnector pipeline that links Finland to the gas network of the Baltic states via Estonia. On 5 November 2022, the European Union's total gas storage was 95% full and Latvia's was 58% full. The high level of storage filling contributed, along with mild weather, to lower pressure on gas prices during the winter of 2022/23.

In March 2022, Finland appointed the Ministerial Working Group on Preparedness to guide preparedness activities related to the effects of Russia's invasion of Ukraine. The group is tasked to form a comprehensive picture of the effects of the crisis, assess these effects (particularly in relation to the economy and security of supply, including energy supply), and decide on launching necessary measures and allocating resources.

In May 2022, Finland secured a ten-year lease on a floating storage and regasification terminal that is intended to cover Finland's and Estonia's gas demand. The FSRU can support 5 billion cubic metres (bcm) of natural gas imports per year. In 2021, Finland's gas

demand was 2.6 bcm and Estonia's 0.47 bcm. In December 2022, the FSRU started supplying gas, with full commercial starting in January 2023. The ten-year lease of the FSRU is estimated to cost around EUR 0.45 billion (Fortum, 2022b).

In April 2022, the Ministerial Working Group on Preparedness agreed on a set of urgent measures to ensure affordable energy, including increasing the availability of forest chips and ensuring peat production. In addition, the National Emergency Supply Agency decided to establish an emergency reserve for peat that can cover six months of Finland's peat demand, which comes mainly from large-scale co-generation plants (see Chapter 6).

In September 2022, following Russia's unliteral decision to stop supplying gas via Nord Stream 1, the government offered EUR 10 billion in liquidity guarantees to Finnish electricity companies. This is intended as a last-resort financing option for companies that would otherwise be threatened with insolvency because of ballooning collateral requirements for operation on key energy-trading platforms.

A consumer awareness campaign ("Down a Degree") was launched in August 2022 following the energy crisis due to Russia's invasion of Ukraine. The government will provide regions with funds to support this campaign, with an estimated budget of approximately EUR 1 million per year. The campaign led to significant electricity savings from August to December 2022.

Finland has taken other notable steps in response to Russia's invasion of Ukraine. In May 2022, Finland (and Sweden) applied to become members of the North Atlantic Treaty Organization (NATO). As of September 2022, Finland had supplied at least EUR 92 million in defence and military aid to Ukraine. Finland's budget for 2023 proposes an additional EUR 30 million in aid for Ukraine. The budget also includes an additional EUR 1.0 billion for Finland's Ministry of Defence to boost personnel capacity, increase refresher training and procure defence material. EUR 59 million will go to improving cybersecurity preparedness (including for energy infrastructure). EUR 791 million is proposed to assist the integration of Ukrainians fleeing the war. As of August 2022, 37 000 Ukrainians had filed applications for temporary protection in Finland.

Energy taxation

Finland aims for energy taxation to drive energy transition in a socially fair manner while ensuring a competitive position for domestic industry. Energy taxation comprises a tax based on energy content, a carbon tax based on lifetime CO_2 emissions (77 EUR/tonne for transport fuels and 53 EUR/tonne for heating fuels in 2022) and a security of supply payment (Table 1.2). Revenue from Finland's energy taxes was EUR 4.5 billion in 2020 (Finland, Ministry of Finance, 2022a). VAT is 24% for all energy products.

Table 1.2 Energy tax rates in Finland, 2022

Sector	Fuel/user	Unit	Energy content tax	Carbon tax	Security payment	Total*	EUR/GJ**
Transport	Diesel	EUR/litre	0.3457	0.2456	0.0035	0.5948	16.1
	Gasoline	EUR/litre	0.5379	0.2149	0.0068	0.7596	23.0
Heating and mobile machinery	Heavy fuel oil	EUR/litre	0.1159	0.1867	0.0028	0.3054	7.9
	Light fuel oil	EUR/litre	0.1033	0.169	0.0035	0.2758	7.1
	Natural gas	EUR/MWh	10.33	12.94	0.084	23.354	6.5
	Coal	EUR/tonne	71.45	147.81	1.18	220.44	8.5
Electricity	Household	EUR/MWh	22.4	0	0.13	22.53	6.3
	Industry	EUR/MWh	0.5	0		0.58	0.2

* Excluding value-added tax.

** Estimate based on: fuel oil 0.039 GJ/L, diesel 0.037 GJ/L, gasoline 0.033 GJ/L, coal 26 GJ/tonne.

There are reductions and exemptions on energy taxation depending on the energy product, sector, end use and type of consumer, among other factors. Notable changes were made to energy taxation in 2021 as part of an ongoing process to align taxation with Finland's 2035 carbon neutrality goal and address the impact of high energy prices on economic competitiveness. Finland's energy taxation will likely need to be updated to meet the new requirement under the EU Tax Directive being developed to support the Fit-for-55 package. This includes a potential requirement for the taxation of wood as an energy fuel.

Finland's tax policy aims to encourage the use of bioenergy and discourage the use of fossil fuels. Biogas used in transport and liquid biofuels are subject to the energy content tax and the security of supply payment. Since January 2022, biogas used in heating has been subject to the energy content tax at the same rate as natural gas (10.33 EUR/MWh). As with all other fuels, the carbon tax for biofuels and biogas is based on their lifetime CO_2 emissions, resulting in carbon tax rates that are 50-100% less than those for fossil fuels. Solid biofuels used in heating are exempt from all energy taxation. In line with energy transition goals, rates for all taxed heating fuels were increased at the beginning of 2022.

There are tax exemptions to reduce the energy cost of commercial activities. Fuels used in marine shipping and commercial aviation are exempt from energy taxation (as required under the EU Tax Directive). Electricity used in rail is exempt from energy taxation, diesel used in rail pays the heating fuel rate (lower than the transport rate). For professional agriculture, the energy content tax for light fuel oil, heavy fuel oil and liquid biofuels is refunded.

To encourage the adoption of lower emission vehicles, there are exemptions or lower rates for taxes paid at the purchase and annual registration of battery EVs (BEVs), plug-in hybrid EVs and natural gas vehicles (see Chapter 3). To ensure that increased adoption of low-emission vehicles does not result in a strong drop in tax revenue, these vehicles are charged an annual fee of 0.015 EUR per 100 kilogrammes of vehicle mass for BEVs, 0.005 for plug-in hybrid EVs and 0.031 natural gas vehicles.

Finland's energy-intensive industrial facilities and large electricity and heat generation plants are regulated under the EU ETS and must purchase allowances based on their

GHG emissions (see Chapter 2). In October 2022, the ETS carbon price was around 79 EUR per tonne of CO_2 (t CO_2). Under EU rules, fuels used by electricity generation plants are exempt from national energy taxation. For co-generation plants, a calculation is used to determine what share of fuels contributes to electricity generation and what share contributes to heat production. The share of fuel contributing to electricity is tax-exempt. The share contributing to heating is subject to the energy content tax (but with a reduction of 7.63 EUR/MWh), the carbon tax and the security of supply payment. In 2021, the calculation was updated to increase the taxation of the share of fuels used for heating and ensure that the use of heat pumps used in co-generation would not increase taxation. The lower energy content tax for heating fuels used in co-generation was maintained.

Electricity use is subject to an energy tax and the security of supply payment but exempt from the carbon tax. The energy tax has two brackets for electricity. The first bracket (22.4 EUR/MWh in 2022) applies to households, the service sector, the public sector, forestry and construction. The second bracket gives a lower tax rate to industry, mining, professional greenhouse cultivation and data centres. Agriculture other than greenhouses is subject to the first tax bracket but is refunded the difference between the first and second tax brackets. In 2021, the second bracket was reduced to the lowest rate allowed by the EU Tax Directive (0.5 EUR/MWh). In 2022, several activities were moved to the second bracket, including heat pumps used to support DH or that meet certain efficiency standards, water pumps supporting geothermal power and electric boilers. The second bracket already included data centres with peak demand above 5 megawatts (MW). In 2022, smaller data centres that meet certain efficiency standards or where waste heat is used productively were moved to the second bracket.

Finland provides a refund of 85% of the energy content tax on electricity to certain energy-intensive industrial companies where total energy taxation (other than electricity) exceeds a certain share of the company's value added (1.7% in 2022, 3.7% in 2023). The refund is provided only on energy taxation exceeding EUR 50 000 per year. The refund for energy-intensive companies is being phased out and will end in 2025.

Tax policy is also used to drive investments that support energy transition. To encourage the deployment of small-scale renewable energy projects, electricity generation from these projects is exempt from energy taxation. To encourage the deployment and higher use of energy storage, the double taxation on energy storage was eliminated in 2019 (see Chapter 6). There is an income tax deduction for private households that invest in improved heating systems and home renovations that reduce energy demand. The government is examining the extension of this deduction beyond private households (see Chapter 3). In 2021, the government introduced a 50% tax deduction for companies investing in R&I activities; this deduction was increased to 150% in 2022 (see Chapter 5).

The security of supply payment supports the National Emergency Supply Fund, which funds Finland's National Emergency Supply Agency (NESA). NESA is tasked with planning and operations related to the maintenance and development of Finland's security of supply (energy and other critical materials and services). In the energy sector, NESA's duties relate primarily to Finland's oil stockpiles for emergency response. The revenue from the security of supply payment is around EUR 42.5 million per year. In 2022, the National Emergency Supply Fund held around EUR 2.0 billion, mostly as physical oil stocks (see Chapters 6, 8 and 9) (NESA, 2022).

Fossil fuel subsidies

The government has indicated that it aims to cut environmentally harmful subsidies and redirect these funds to support the clean energy transition. As an EU member state, Finland has committed to eliminate fossil fuel subsidies. The NECP includes a list of environmentally harmful energy subsidies (based on OECD definitions). The NECP does not distinguish fossil fuel subsidies, but the vast majority of environmentally harmful energy subsidies listed in the NECP are tax breaks related to fossil fuel use in industry, transport and agriculture, primarily for oil and natural gas.

Subsidies distributed through the tax system are regularly monitored and reported in the state budget proposal and the government's financial statements. The list of tax subsidies is published annually and submitted to the parliament with the state budget proposal. In addition, annual reporting on tax subsidies is supported by a steering group appointed by the Ministry of Finance, whose tasks include monitoring, evaluating and developing tax subsidy reporting.

Energy poverty

Finland does not have an official definition for energy poverty and no subsidies specifically target energy poverty. The government indicates that energy poverty is addressed through Finland's comprehensive social support system, which guarantees a minimum income for all and includes direct payments that can mitigate energy poverty. These include a housing allowance to reduce housing expenditures and meet basic needs such as energy costs. In addition, households can deduct home renovation costs from their income tax, including investments that could reduce energy poverty, such as insulation and improved heating and cooling systems. Finland also places obligations on electricity suppliers to prevent them from cutting off electricity, especially for households with electric heating.

The most recent data from the EU Energy Poverty Advisory Hub show that energy poverty is a relatively minor problem in Finland, with only 1.9% of the population unable to keep their homes adequately warm in 2019. However, several studies have indicated climate change is increasing the risk of energy poverty in Finland, and that the focus on wintertime heating ignores energy poverty risk related to the inability to keep homes adequately cool in the summer, as most buildings in Finland were designed for a cold climate (Castaño-Rosa et al., 2022). The risk of energy poverty has also increased due to the recent sharp increase in global energy prices.

Critical minerals and batteries

The government sees critical mineral mining and processing and the battery supply chain as promising areas to deliver strong economic returns while supporting a secure energy transition. Finland has large deposits of cobalt, nickel, lithium, graphite and other critical minerals and is already a major producer of several of these. In 2021, Finland refined around 10% of global cobalt output. The Finnish company Freeport Cobalt is the only producer outside China supplying the cobalt for lithium-ion batteries. The Finnish companies Terraframe, Keliber and Nornickel are currently expanding the production of nickel, cobalt and lithium.

Finland is also active across the battery supply chain, from mining and processing raw materials to battery manufacturing, charging technologies and battery recycling. The government aims to increase Finland's role in the global battery supply chain through increased innovation, with a focus on developing higher value-added products. The National Battery Strategy 2025, published in June 2021, presents a road map for Finland to become a major player in the international battery industry (Finland, Ministry of Economic Affairs and Employment, 2021b). The government has budgeted EUR 300 million to support the achievement of the battery strategy's goals. In May 2022, the private company Feyer signed a lease with the municipality of Vaasa for land where it aims to develop a battery production facility with 43 gigawatt hours (GWh) of battery cell capacity by 2025 and up to 83 GWh capacity by 2028. If completed, this would be one of the largest battery cell factories in Europe (FREYR, 2022).

There is also funding for battery projects in Finland from the EU Important Projects of Common European Interest (IPCEI). This strategic financing instrument provides grants to large-scale consortia undertaking projects that support the EU industrial strategy. Funding is awarded by the European Commission based on a competitive process and is expected to leverage large private investments. Finland is involved in two IPCEI projects that support R&D in all segments of the battery value chain (EC, 2022c).

Hydrogen

The government sees a key role for low-emission hydrogen in Finland's hard-to-abate sectors and end uses, especially in certain industrial processes and heavy transport. The government published a National Hydrogen Roadmap in November 2020. The road map provides an overview of the potential for the production and use of low-emission hydrogen in Finland, noting that through 2030 the focus will be on industrial uses. The road map defines qualitative goals relating to low-emission hydrogen production, transport, storage and its use in industry, mobility and other sectors (Laurikko et al., 2020).

The government published a study in May 2022 on the opportunities and limitations of the hydrogen economy in Finland. The study considered five scenarios and estimated that production volumes of low-emission hydrogen would be 3.7-7.9 terawatt hours (TWh) by 2030 and 6.4-132.9 TWh by 2050. The large range results from scenarios that included notable exports of hydrogen and electro-fuels (Finnish Government's Analysis, Assessment and Research Activities, 2022).

The NCES includes a national hydrogen strategy detailing the role hydrogen is expected to play in achieving Finland's climate and energy goals. Priority is placed on developing a domestic hydrogen value chain, with a secondary focus on the potential for hydrogen exports. The strategy defines targets for electrolysis capacity to reach at least 0.2 GW by 2025 and at least 1.0 GW in 2030 (compared to just 9 MW in 2021).

The strategy details measures to promote the production and use of hydrogen and electro-fuels based on hydrogen and indicates that Finland will take a technology-neutral approach that welcomes all emission-free forms of hydrogen production. Support programmes for hydrogen production and use include EUR 156 million for low-emission hydrogen and CCUS projects from the national recovery and resilience plan, an update allowing electro-fuels to contribute to meeting the transport biofuels blending mandate, a target for electro-fuels to cover 3% of transport energy demand by 2030, and support for the development of hydrogen transportation networks and refuelling stations.

The strategy also notes Finland's strong commitment to hydrogen R&D and international co-operation in developing markets, standards and safety rules for hydrogen. Finland will participate in international partnerships for hydrogen, including those through the IEA, the Clean Energy Ministerial and Mission Innovation. In December 2020, Finland signed a hydrogen manifesto with 22 other EU member states to participate in hydrogen IPCEI projects, with the European Union setting a target of producing 10 million tonnes of low-emission hydrogen by 2030.

There are numerous ongoing and planned projects in Finland related to hydrogen (see Annex D). Support for hydrogen projects in Finland comes from the EU Recovery and Resilience Facility, with EUR 156 million for low-emission hydrogen and CCUS, and from the IPCEI. A project being undertaken by the Finnish company Neste for the production and use of low-emission hydrogen at one of its refineries was among the projects approved to receive IPCEI support (Finland, Ministry of Finance, 2022a). This project has already been granted EUR 88 million in funding through the EU Innovation Fund (FuelCellsWorks, 2022).

Gender equality in the energy sector

The NCES notes that gender equality in the energy sector will be promoted in education, career advancement and pay, and the reputation of the energy sector as an equal employer for everyone. In 2018, Finland joined the international Equal by 30 campaign, which aims to ensure equal pay in the energy sector, gender equality in the appointment of management, and uniform opportunities for all to study and choose careers by 2030. The campaign is part of the IEA Technology Collaboration Programme, which promotes the opportunities the clean energy sector provides as an equal working environment.

Assessment

Since the IEA's last in-depth review in 2018, Finland has built upon its energy and climate policy leadership role by establishing a legally binding target, via reform of the Climate Change Act, to achieve carbon neutrality by 2035. This target is to be achieved while also ensuring energy security, reducing energy import dependency, promoting a sustainable economy and protecting biodiversity. Under EU directives and national laws, Finland has 2030 targets for greenhouse gas emissions, renewable energy, energy efficiency and cross-border electricity interconnection capacity, which are intended to support the achievement of EU-wide targets. In December 2020, the 2030 EU-wide GHG emissions reduction target was increased from 40% to 55%. Under the Fit-for-55 package and the REPowerEU plan, the European Union is updating a wide range of energy- and climate-related regulations to reflect the European Union's increased ambitions on energy security and energy transition. Finland is updating its climate and energy policies to reflect the ongoing changes to EU energy and climate policy.

The NCES is the key document defining the measures by which Finland aims to meet the national and EU targets, achieve carbon neutrality by 2035, and reduce reliance on Russian energy. The Climate Change Act requires the development of additional climate change policy documents focused on the medium term, the long term (2050), climate adaptation and the land-use sector. The government has adopted the medium-term and land-use sector plans. The adaptation and long-term policies remains under development.

Finland's plans to achieve carbon neutrality focus on maintaining a high share of nuclear energy, increasing the use of renewables, reducing the use of fossil fuels and peat, improving energy efficiency, and increasing the electrification of energy demand across the economy. Finland plans to further expand its energy and climate policy leadership role by driving the development, commercialisation and cost-reduction of new and emerging technologies to drive the energy transition in hard-to-abate sectors and end uses, especially industry and heavy transport. Olkiluoto 3 is Europe's first nuclear reactor in over 15 years. Finland wishes to develop the nuclear sector by facilitating small modular reactors. The IEA review team noted that a reform of the Nuclear Energy Act is required to fully facilitate the potential of small modular reactors in Finland.

The sustainable use of bioenergy is central to Finland's energy policy. Forestry biomass is a key source of electricity and heat, and biofuels play a major role in supporting energy transition in the transport sector. Finland's plan to achieve carbon neutrality by 2035 relies heavily on increasing carbon removal through LULUCF to 21 million tonnes carbon dioxide (Mt CO_2) per year. LULUCF has historically offset a significant amount of GHG emissions, averaging 18.6 million tonnes of CO_2-equivalent (Mt CO_2-eq) in net GHG emissions reductions per year from 1990 to 2020. However, there has been a declining trend in carbon removal through LULUCF since 2010, and in 2021, the land-use sector was a net source of GHG emissions for the first time. The dependency on the LULUCF sector represents a clear risk to Finland's 2035 ambition. Should the LULUCF sector underperform, additional measures will likely be required in the energy sector to achieve the net zero by 2035 ambition.

Finland expects that most of the investments needed to support the energy transition will be made by the private sector based on market forces. Finland has numerous programmes that direct national and EU funding to support the energy transition. Finland is moving away from providing operational subsidies towards an enabling framework system that includes limited investment subsidies for emerging technologies and small projects, with the aim to drive private investment.

Finland has experienced a rapid deployment of renewables, dominated by onshore wind but more recently supplemented by solar. Since the closure of support schemes in 2018, the vast majority of onshore wind deployment has been on a market basis, with no investment or operational aid. Finland expects onshore wind to continue to grow, despite spatial limitations in the east, where turbines can interfere with the operation of military radar. A review has been commissioned to examine potential solutions to this issue. Offshore wind is also expected to grow significantly; however, some investment support is envisaged for a demonstration project, and regulatory clarity is required to develop offshore wind in the Finnish exclusive economic zone.

The government has indicated that it is working on eliminating environmentally harmful subsidies, but there is no full inventory of fossil fuel subsidies or any legally binding targets to phase them out.

The most recent data from the EU Energy Poverty Advisory Hub show that energy poverty in Finland is currently a relatively minor problem, with only 1.9% of the population unable to keep their homes adequately warm in 2019 due in part to energy cost allowances provided to low-income groups. However, Finland has no official definition of energy poverty. The risk of energy poverty has increased due to the recent sharp increase in global energy prices.

Finland's high-quality education system supports the development of R&I skills and attracts foreign talent. The National Roadmap for Research, Development and Innovation notes that the learning outcomes of Finland's education system are good by international standards but have deteriorated in recent years, with significantly fewer young adults completing a higher education degree than in peer countries. The IEA review team notes that there are shortages in several sectors in the skills and expertise required to deliver the clean energy transition.

In 2018, Finland joined the international Equal by 30 campaign, which aims to ensure equal pay in the energy sector, gender equality in the appointment of management, and uniform opportunities for all to study and choose careers by 2030. The NCES notes that gender equality in the energy sector will be promoted in education, career advancement and pay.

In response to energy price increases driven by Russia's invasion of Ukraine, Finland has introduced a range of measures to reduce the impact of higher energy prices. These measures include lower electricity network tariffs; reduced biofuel obligations; and several programmes that reduce the cost of electricity, heating and transport. There is also additional support for energy efficiency measures. The government continues to monitor energy prices and has indicated it will take additional measures as needed to protect consumers from high prices.

Also as a result of Russia's invasion of Ukraine, Finland has dramatically reduced its reliance on Russian energy imports. In 2021, imports from Russia accounted for 34% of total energy consumption, comprised of 81% of Finland's crude oil net imports, 75% of its natural gas, 52% of coal and 51% of its electricity net imports. Finland also imported nuclear fuel from Russia in 2021, accounting for 35% of the total monetary value of its nuclear fuel imports. In March 2022, Russia unilaterally stopped supplying biomass to Finland and in May 2022 it stopped supplying electricity and gas. Finland and the European Union are taking strong steps to completely end reliance on Russian energy through the REPowerEU plan and national measures that aim to increase imports from other countries, increase renewable energy and reduce energy demand.

Finland operates a lean government; however, the IEA review team notes long lead times for the development of critical legislation to facilitate private investment in the clean energy transition. It was also noted that there can be significant delays and resource shortages in the public authorities responsible for issuing the requisite permits for clean energy projects and supporting infrastructure. This conflicts with the REPowerEU goal of limiting permitting times to accelerate the deployment of renewables.

Numerous experiences worldwide demonstrate that close co-operation between all levels of government and civil society generates long-lasting support for clean energy transitions, including for the related infrastructure deployment. To achieve its energy and climate policy targets in a cost-efficient manner, Finland could gain from further aligning efforts at the national, regional and local levels where municipalities are best placed to ensure engagement with citizens.

Key recommendations

The government of Finland should:

- Develop a contingency plan to achieve the 2035 net zero emissions target in case the land use, land-use change and forestry sector fails to deliver the needed carbon sinks.
- Ensure that temporary measures taken in response to energy price shocks do not undermine signals for long-term clean energy decisions and investments.
- Ensure that relevant ministries, agencies and other public bodies are adequately resourced to expeditiously develop legislation, implement reforms, and facilitate accelerated and streamlined permitting of clean energy projects and supporting infrastructure.
- Strengthen co-operation between national, regional and municipal authorities on energy and climate planning.

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2. Energy and climate change

Key data

(2021)

GHG emissions with LULUCF:* 49.0 Mt CO_2-eq; +1% since 2005, -13% since 1990

GHG emissions without LULUCF:* 48.0 Mt CO_2-eq; -32% since 2005, -33% since 1990

Energy-related GHG emissions from fuel combustion: 37.6 Mt CO_2-eq; -33% since 2005

Energy-related GHG emissions by sector: electricity and heat generation 35%, industry 32%, transport 27%, buildings 6%

Energy-related GHG emissions per GDP: 0.141 kg CO_2/USD
(IEA average 0.186 kg CO_2/USD)

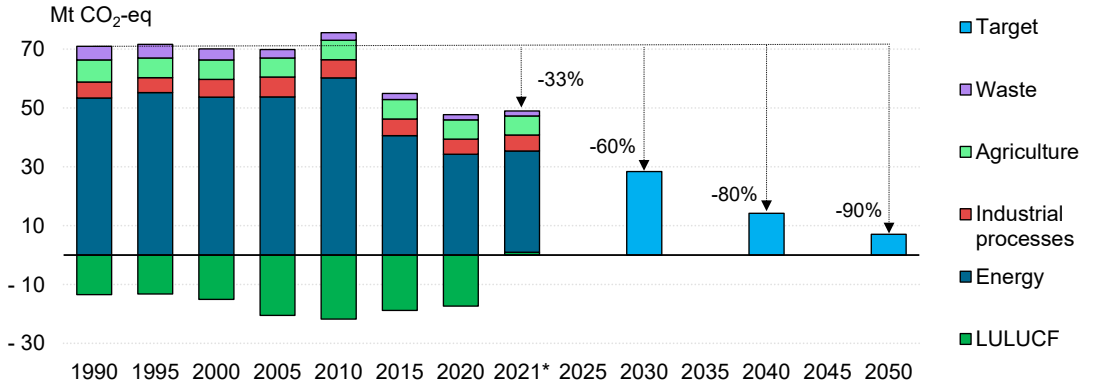
Energy-related GHG emissions per capita: 6.48 t CO_2/capita
(IEA average 8.28 t CO_2/capita)

* 2021 greenhouse gas emissions data are from Statistics Finland.

Overview

Finland has set an ambitious and legally binding target to achieve carbon neutrality by 2035, with binding targets to reduce GHG emissions (excluding LULUCF) by 60% by 2030, 80% by 2040 and by at least 90% (with an aim for 95%) by 2050 versus 1990 (Figure 2.1). From 1990 to 2021, Finland's GHG emissions excluding LULUCF fell by 33%, from 71 Mt CO_2-eq to 48 Mt CO_2-eq, mainly due to a strong reduction in energy-related emissions (Figure 2.1). In 2021, 71% of GHG emissions were energy-related, followed by 14% from agriculture, 11% from non-energy related industrial processes (such as emissions from cement production or the use of fossil fuels as feedstocks) and waste (3.5%).

Figure 2.1 Greenhouse gas emissions by sector in Finland, 1990-2021 and targets



Sources: IEA based on data from UNFCCC (2022); 2021 data from Statistics Finland.

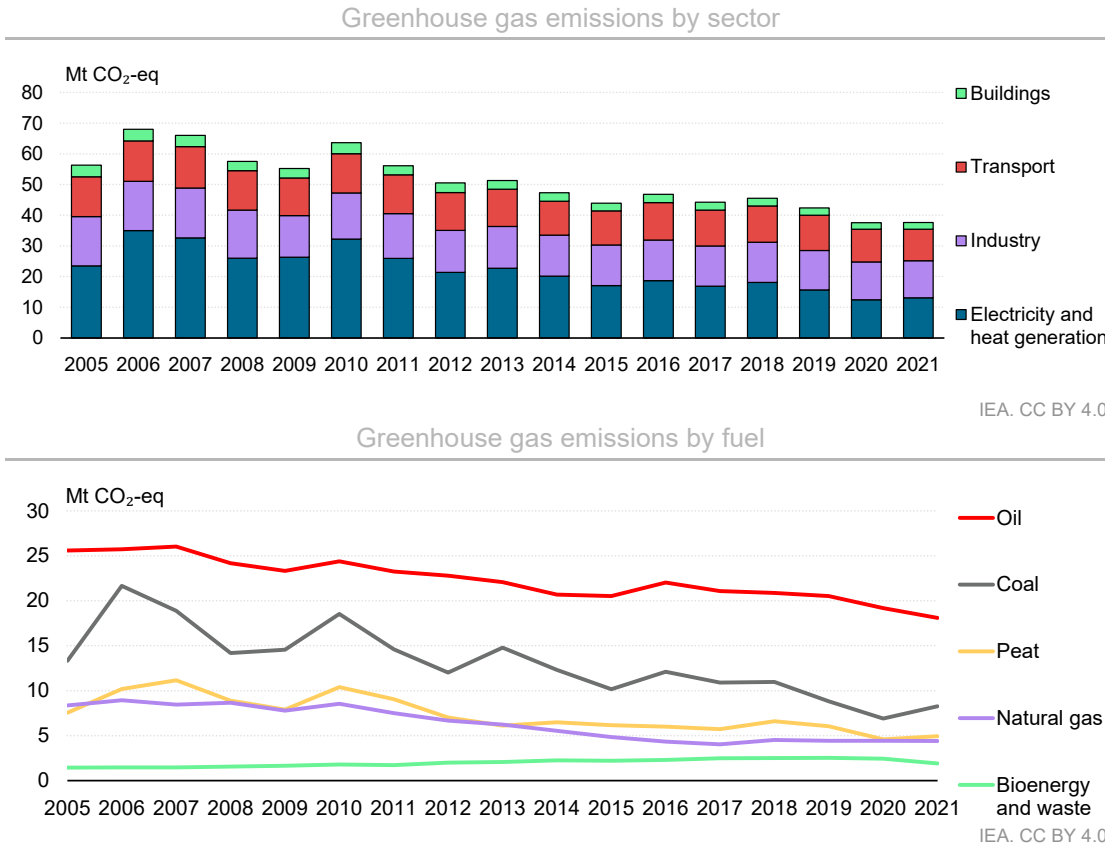
Finland's plans to achieve carbon neutrality focus on maintaining a high share of nuclear and biomass generation, increasing electricity generation and heat production from renewables, improved energy efficiency and electrification of most energy demand across the economy. There is also a push for commercialisation and cost-reduction of new and emerging energy technologies to drive energy transition in hard-to-abate sectors and end uses, especially industry and heavy transport.

Finland's carbon neutrality target also relies on maintaining a high level of carbon removal through LULUCF. LULUCF has historically offset a significant amount of GHG emissions, averaging 18.6 Mt CO_2-eq in net GHG emissions reductions per year from 1990 to 2020. However, there has been a declining trend in carbon removal through LULUCF since 2010, and in 2021 the land-use sector was a net source of GHG emissions for the first time (Statistics Finland, 2022a). The main reasons for this were an increase in the total roundwood removals, which reached a record of 76.3 million cubic metres (mcm) in 2021 (11% higher than in 2020), and lower than expected forest growth. In addition, there was a trend of rising emissions from drained peat bogs. Most roundwood is used for industrial purposes.

Energy-related greenhouse gas emissions

From 2011 to 2021, Finland's energy-related GHG emissions experienced a significant overall decline from 56.1 Mt CO_2-eq to 37.6 Mt CO_2-eq (Figure 2.2).

Figure 2.2 Energy-related greenhouse gas emissions by sector and fuel in Finland, 2005-2021



Source: IEA (2023).

The reduction in energy-related emissions was driven by a strong drop in the carbon intensity of the energy supply, resulting from lower generation based on coal, natural gas and peat and increased generation from wind and higher electricity imports. Emissions from oil have also decreased due to decreased use of oil heating in buildings, the increasing efficiency of vehicles and a rising share of biofuels. A notable part of the emissions reduction in 2020 was linked to the impacts of the Covid-19 pandemic and a record-warm winter; however, total emissions did not increase significantly in 2021.

In 2021, electricity and heat generation accounted for 35% of energy-related GHG emissions, followed by industry (32%), transport (27%) and buildings (6%). That year, energy-related emissions came mostly from oil (48%), followed by coal (22%), peat (13%), natural gas (12%), and bioenergy and waste (5.1%). From 2011 to 2021, emissions dropped for oil (-22% to 18.1 Mt CO_2-eq), coal (-43% to 8.3 Mt CO_2-eq) peat (-45% to 4.9 Mt CO_2-eq) and natural gas (-41% to 4.4 Mt CO_2-eq).

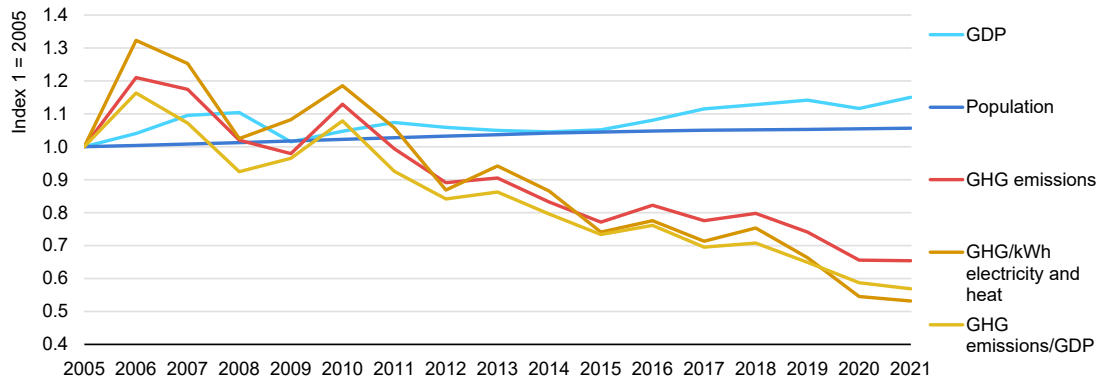
The transition away from generation based on coal, peat and natural gas led to a strong reduction in emissions from electricity and heat generation, which dropped from 26 Mt CO_2-eq to 13 Mt CO_2-eq between 2011 and 2021. Over the same period, there was a smaller overall decline in GHG emissions from transport, from 13 Mt CO_2-eq to 20 Mt CO_2-eq, driven by improvements in the efficiency of passenger vehicles and an increasing share of biofuels. From 2011 to 2021, industry GHG emissions declined from 15 Mt CO_2-eq to 12 Mt CO_2-eq, driven by increasing energy efficiency in the industry sector and fuel switching from oil and coal to bioenergy.

Finland's building sector has relatively low emissions (5.9% of energy-related emissions in 2021, compared to the IEA average of 13.4% in 2020). Building sector emissions are mainly driven by seasonal heating demand, as space heating accounts for most building emissions (63% in 2020). Unusually cold temperatures caused building GHG emissions to peak in 2010 at 3.6 Mt CO_2-eq. Thanks to a reduction in oil-fired heat and increased efficiency of space heating, GHG emissions from the buildings sector have declined to 2.2 Mt CO_2-eq in 2021.

Emissions drivers and carbon intensity

Since recovering from the impacts of the 2008 financial crisis, Finland is showing clear signs of decoupling of GHG emissions from economic and population growth. From 2010 to 2021, energy-related GHG emissions declined by 41%, GDP increased by 10% and population grew by 3.3%. This decoupling is supported by a strong reduction in the carbon intensity of electricity generation, which fell from 195 g CO_2-eq/kWh to 79 g CO_2-eq/kWh from 2010 to 2021, coupled with a continued increase in the direct use of bioenergy in industry and buildings and a high level of electrification.

Figure 2.3 Energy-related greenhouse gas emissions and main drivers in Finland, 2005-2021



Source: IEA (2023).

Climate targets

Finland's national Climate Change Act was updated in July 2022 with a legal obligation to reach carbon neutrality by 2035. In support of this obligation, the Act sets binding targets to reduce total GHG emissions (excluding LULUCF) by 60% by 2030, 80% by 2040 and 90-95% by 2050. Finland's plan to achieve carbon neutrality relies on strong reductions in emissions across the economy as well as on a significant increase in carbon removal through LULUCF. The Climate Change Act includes an unspecified goal to increase LULUCF carbon removals.

GHG emissions in Finland are also subject to reduction targets defined by EU directives. Emissions of CO_2, nitrous oxide and perfluorocarbons from Finland's large electricity plants, energy-intensive industrial facilities and domestic aviation are regulated under the EU ETS, which uses tradable emissions allowances to drive emissions reductions at regulated facilities in the European Union, Iceland, Liechtenstein and Norway. The ETS sets targets to reduce emissions from regulated facilities by 21% by 2020 and 43% by 2030 (both versus 2005 levels). In 2020, EU-wide ETS emissions had declined by 42.3% compared to 2005, highlighting the low ambition of the 2020 and 2030 targets. The European Union is considering increasing the 2030 target to a 62% reduction. In 2021, 43% of Finland's GHG emissions fell under the ETS and came primarily from industrial processes (59%) and fuel combustion (41%).

Finland's non-ETS emissions (transport, buildings, agriculture, waste and non-energy intensive industry) are subject to a 2020 target under the EU Effort Sharing Decision (ESD) and a 2030 target under the EU Effort Sharing Regulation (ESR). In combination, the ETS, ESD and ESR aim for a 20% reduction in EU-wide GHG emissions by 2020 and a 55% reduction by 2030 (both versus 1990 levels). In 2021, 57% of Finland's GHG emissions were from non-ETS sources. In 2019, the largest shares of non-ETS emissions came from transport (38%), buildings (10%), agriculture (22%) and industry (8%).

Under the ESD, Finland was required to reduce non-ETS emissions by 16% by 2020 compared to 2005. Finland was able to achieve its 2020 ESD target under EU accounting rules that allow credits from years when emissions were below annual ESD targets to offset for years when emissions exceeded annual targets (Table 2.1). (Statistics Finland, 2022b). Finland's non-ETS emissions dropped to 27.6 Mt CO_2-eq in 2021.

Table 2.1 Finland's non-ETS annual greenhouse gas targets and emissions, 2013-2020

Non-ETS emissions (Mt CO_2-eq)	2013	2014	2015	2016	2017	2018	2019	2020
ESD target	31.8	31.3	30.8	30.3	30.2	29.6	29.1	28.5
ESD emissions	31.6	30.1	29.9	31.4	30.1	29.9	29.6	28.1
Cumulative credits	-0.2	-1.1	-0.9	1.0	0.1	-0.3	0.6	-0.4

Finland's NECP sets a target to reduce non-ETS GHG emissions by 39% by 2030 compared to 2005 levels. This target is in line with the contribution to EU-wide emissions reductions expected under the ESR. In December 2020, the 2030 EU-wide GHG emissions reduction target was increased from 40% to 55%. Under the Fit-for-55 package, the European Union is updating a wide range of energy- and climate-related regulations to address the increased ambition of the 55% target. This includes setting stronger targets for renewable energy, energy efficiency and notable updates to the ETS. Finland is updating its NECP to reflect the EU-wide 55% target and the national goal for carbon neutrality by 2035. The draft of the updated NECP must be submitted to the European Commission in June 2023.

The ESR includes a flexibility mechanism allowing nine EU member states, including Finland, to use a limited amount of ETS allowances to contribute to meeting ESR emissions reduction targets from 2021 to 2030. This mechanism is only applicable to EU member states that did not allocate free ETS allowances to industry or member states with national emissions reduction targets that are significantly above the average of EU member states' reduction target and significantly higher than the country's cost-effective reduction potential (Finland qualifies under the second option). The mechanism limits the use of ETS allowances to meet the ESR target to a maximum of 2% of a country's ESR emissions in 2005. Finland has notified the European Commission that it plans to use the maximum level available under this mechanism (EC, 2022a).

Climate policy and key mitigation measures

The NCES is the key document defining the measures for Finland to achieve its EU 2030 energy and climate targets and the national targets to reduce GHG emissions by 60% by 2030, achieve carbon neutrality by 2035 and phase out imports of Russian energy. The strategy defines a range of measures to drive strong emissions reductions across the economy but assumes that carbon removal from LULUCF will notably increase to offset the remaining emissions.

The NCES GHG emissions reduction measures focus on increasing the use of renewable energy (especially wind, sustainable biomass, advanced biofuels and biogas) (see Chapter 4), improving energy efficiency in all sectors (see Chapter 3), promoting innovation to accelerate and reduce the cost of energy transition (see Chapter 5), boosting electrification of energy demand (especially in passenger vehicles, building heating and industry), phasing out coal generation by 2030 (see Chapter 6), maintaining a high share of nuclear generation (see Chapter 7), reducing gas demand and decarbonising gas supply (see Chapter 8), and reducing oil demand (see Chapter 9). The NCES also sees a role for hydrogen in hard-to-abate sectors and end uses. In addition, the Roadmap to Fossil-Free Transport details plans to reduce GHG emissions from the transport sector in line with the 2035 carbon-neutrality goal.

The Climate Change Act mandates the development of four policy plans that provide additional details on Finland's climate policy. The policy plans are the Medium-term Climate Change Policy Plan (defining mitigation measures to meet the 2030 ESR target), the National Climate Change Adaptation Plan (defining adaptation measures through 2030), the Long-term Climate Change Policy Plan (defining policy through 2050) and the Climate Plan for the Land Use Sector (defining measures to ensure LULUCF continues to act as a major carbon sink). The Climate Change Act requires the government to submit an Annual Climate Report to parliament each calendar year. The report contains information on GHG emissions trends, progress on achieving emissions reduction targets and suggestions on any additional measures required to meet targets.

The NCES notes that the land-use sector will be increasingly integrated into the planning and implementation of national climate and energy policy. To support this effort, the Climate Plan for the Land Use Sector specifies the means by which climate emissions from the land-use sector can be reduced and carbon sinks and storages strengthened. The plan aims for additional climate measures in the land-use sector to support a net annual emissions reduction of at least 3 Mt CO_2-eq per year by 2035. These additional measures will be taken in a frontloaded manner to ensure that Finland can maximise the use of the LULUCF flexibility mechanism to help meet its ESR emissions targets.

Some climate measures were already implemented during the preparation of the Climate Plan for the Land Use Sector. To help boost LULUCF emissions removals, the government created a new subsidy for afforestation on idle land available from 2021 to 2024. In addition, the government amended the Act on the Financing of Sustainable Forestry to increase support from existing mechanisms, for example fertilisation of forests with wood ash. In addition, the ownership policy guidelines of Metsähallitus (a state-owned company responsible for Finland's public lands) were updated to require a target for increasing carbon sinks and stocks for the first time. The targets apply to areas managed by both businesses and public services. A key measure is fertilisation and planting new trees. In 2021, Metsähallitus significantly increased fertilisation and planted around 17 million saplings (Metsähallitus, 2022).

The Climate Plan for the Land Use Sector also includes measures targeting land-use changes, the prevention of deforestation, carbon dioxide emissions from agricultural land, climate-resilient use of peatland fields, the management of peatland forests and the promotion of carbon markets. It is particularly important to prevent forest damages, as climate change increases the risk of damage to insects and storms. Despite these efforts, LULUCF emissions removals have continued to decline, and in 2021, the land-use sector was a net source of GHG emissions for the first time. The main reasons for this were an increase in the total roundwood removals, which reached a record of 76.3 mcm in 2021 (11% higher than in 2020), and lower than expected forest growth. In addition, there was a trend of rising emissions from drained peat bogs.

Carbon pricing

Finland was the first country in the world to introduce a carbon tax (in 1990) and has undertaken several major reforms to ensure that overall energy taxation is aligned with its sustainability and energy transition goals (see Chapter 1). As part of these efforts, the carbon tax has been increased for transportation and heating fuels several times and expanded to cover additional sectors. The carbon tax covers most fuels used for transportation as well as heat production. The carbon tax rate is based on lifetime

emissions. In 2022, it was 77 EUR/t CO_2 for transportation fuels and 53 EUR/t CO_2 for fuels used in heat production (one of the highest nominal CO_2 tax rates in the world).

In addition to the national carbon tax, Finland's energy-intensive industrial facilities, large-scale electricity generation plants and domestic aviation are subject to carbon pricing through the EU ETS. Entities covered by the ETS must have ETS allowances for their emissions, with most allowances purchased through auctions. Some allowances are free, but the number of free allowances is steadily decreasing. Revenues from the allowance auctions are delivered to countries participating in the ETS based on the total value of allowances purchased by ETS-regulated entities operating inside their borders.

From the start of the ETS in 2013 to 2017, allowance prices were relatively stable, around 4-8 EUR/t CO_2. ETS prices began to rise in 2018 as a result of ETS reforms and market forces, with a rapid increase starting in late 2020 when the price exceeded 30 EUR/t CO_2 for the first time. In August 2022, the ETS price reached an all-time high of 98 EUR/t CO_2. The price has remained at historically high levels and was around 97 EUR/t CO_2 in January 2023. The rapid increase in ETS prices resulted in strong growth in Finland's ETS auction revenues (Table 2.2). From 2013 to 2021, Finland's annual ETS revenues increased from EUR 67 million to EUR 409 million. As of September 2022, Finland had received a total of EUR 1.84 billion in ETS revenues since the programme began in 2013 (Energiavirasto, 2022a).

Table 2.2 Emissions Trading System revenues in Finland, 2013-2022

ETS revenues		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
General		67.0	62.7	91.6	70.6	94.6	249.8	217.4	218.2		
Aviation	EUR million	0	0.8	2.1	0.6	0.6	2.0	2.6	2.4		
Total		67.0	63.5	93.8	71.2	95.3	251.8	220.0	220.6	409.0	345.0
Share spent on climate and energy		3%	49%	100%	100%	10%	100%	100%	100%	100%	100%

Note: 2022 values include revenues only through September 2022. No breakdown available for 2021 or 2022.

ETS rules require that funding equal to at least 50% of ETS allowance revenues delivered to each member state be spent on climate and energy measures to modernise the energy system and reduce GHG emissions. Finland does not earmark ETS revenues, but in most years, its spending on qualifying climate and energy projects exceeds 100% of its ETS revenues.

ETS rules also allow EU member states to provide financial support to compensate certain industrial facilities for increased electricity costs resulting from the ETS (electricity suppliers pass the cost of required ETS allowances on to all consumers). The support aims to reduce the risk of carbon leakage (EU companies relocating production to countries with less ambitious climate policies resulting in increased GHG emissions in those countries). In 2016, the European Commission approved Finland's ETS compensation system for industry with a budget of EUR 149 million available to reduce costs incurred from 2017 to 2021. This system did not require companies receiving the funds to take any steps to support energy transition (Energiavirasto , 2022b).

In August 2022, the European Commission approved Finland's updated ETS compensation system, which has a budget of EUR 687 million to reduce costs incurred from 2021 to 2025. The updated compensation system covers 25% of electricity cost resulting from ETS prices, up to a maximum of EUR 150 million per year. At least 50% of the support must be spent on measures that reduce emissions, electrify processes, or increase energy efficiency or the use of renewable energy. These measures must be undertaken between July 2022 and December 2028. Companies must submit regular reports to the Energy Authority to verify that support is being spent on approved measures (EC, 2022b).

Under the updated compensation system, eligible industries include certain branches of forestry; metals; chemicals; refined petroleum products; leather clothing; and manufacturing of certain industrial gases, glass fibres and plastics. There are additional requirements to qualify, including completing an energy audit (or being exempt from energy audits under EU rules), covering at least 30% of annual electricity demand with carbon-free generation (generated on site or demonstrated with guarantees of origin) and having GHG emissions significantly below the level that entitles a company to receive free EU ETS emissions allowances (Energiavirasto, 2023).

Reduction of peat for energy use

Peat is a notable energy source in Finland, used primarily to fuel co-generation plants and heat-only boilers in rural areas. While GHG emissions from peat use in energy generation have been steadily declining, they are still significant. In 2020, such emissions were around 5 Mt CO_2-eq, higher than emissions from natural gas. Peat extraction also has a high environmental and climate impact, reducing natural habitat and removing carbon stocks. Finland has set a non-binding goal to reduce the use of peat for energy by at least 50% by 2030. A peat floor price mechanism is in place to ensure reduced use of peat even if the ETS prices significantly decline.

However, because of high ETS prices and other factors reducing the competitiveness of peat, the use of peat for energy may end before 2030. Three private companies that are the largest users of peat for energy in Finland have announced plans to stop using peat by 2022-24 and have already moved significant heat and electricity generation to plants powered with forestry biomass and/or waste (Pledge Times, 2023).

The government indicates that the reduction in peat energy use should take place in a fair manner, both regionally and socially, and should not jeopardise the security of electricity and heat supply. In 2021, a working group on peat, appointed by the Ministry of Economic Affairs and Employment, submitted a report proposing measures to ensure a just and secure transition away from peat. The group indicated that the fastest and most effective measure to improve the situation of peat industry operators would be a one-off package supporting the closure of their operations.

The group also proposed measures to transition peat companies to new business activities. These included retraining programmes, an aid scheme for new peat-based products with higher added value and other options to attract new economic activity to peat regions. The group notes that funding for such efforts could come from the European Union's Just Transition Fund. The group also proposed measures to maintain the possibility of producing peat energy during the transition period to prevent risks to the security of electricity and heat supply. At the beginning of 2022, the government introduced

a scheme that compensated entrepreneurs for scrapping their peat extraction equipment. The scheme proved popular and the allocated budget was used up in the first quarter of 2022.

In 2021, the tax on peat used for energy increased from 3.0 EUR/MWh to 5.7 EUR/MWh (in line with an increase of 2.7 EUR/MWh in energy taxation for all heating fuels). Before 2021, small-scale facilities using less than 5 000 MWh/year of peat were fully exempt from the energy tax on peat. In 2021, this tax exemption was granted to all facilities using peat for energy regardless of their size, with the tax-free use of peat for energy set at up to 10 000 MWh/year from 2022 to 2026 and up to 8 000 MWh/year from 2027 to 2029. Starting in 2030, only small-scale facilities using less than 5 000 MWh/year will be exempt from the energy tax on peat. This change is intended to prevent a sudden end to peat energy production. Following Russia's invasion of Ukraine, the National Emergency Supply Agency decided to establish an emergency reserve for peat, equal to approximately 20% of annual peat consumption in 2021.

When peat production ends, the government wants peat production areas to switch to new forms of use through afforestation, restoration by wetting, and establishing bird wetlands or new types of biomass production. Several studies and projects have been launched since 2021 to assess the impacts of new forms of land use on carbon sequestration in peat production areas. The projects also produce tools and operating models for planning the further use of peat production areas. In addition, an information package on options for further use was prepared for landowners.

Methane emissions

In 2021, methane accounted for 8% of Finland's total GHG emissions, mainly from the waste and agriculture sectors. From 1990 to 2021, methane emissions decreased by 44%, mainly due to improvements in waste treatment and a reduction in animal husbandry in the agriculture sector. The government expects existing policies to reduce methane emissions by 12% by 2030. Finland's energy sector accounts for around 5% of total methane emissions.

CO_2 is the main GHG emitted by the energy sector in Finland (95.4% of emissions in 2021), followed by methane (2.3%) and nitrous oxide (2.3%). In 2021, methane emissions from the energy sector were 863 kilotonnes of carbon dioxide equivalent (kt CO_2-eq), most of which came from the residential sector (406 kt CO_2-eq), followed by fuel combustion in industry (201 kt CO_2-eq), and electricity and heat (122 kt CO_2-eq), fugitive emissions for oil and gas (22 kt CO_2-eq), and other small sources. From 2005 to 2021, Finland's energy sector methane emissions decreased by 24%, mainly due to decreased emissions in industry and electricity generation and decreased fugitive emissions from the natural gas system.

Finland has not adopted national targets for reducing methane emissions. However, it has regulation requiring the monitoring and reporting of methane emissions and supports various international efforts to reduce methane emissions. Monitoring methane emissions from the natural gas transmission network is required under the Environmental Protection Act. The Finnish Safety and Chemicals Agency also monitors methane emissions. Statistics Finland reports on them.

Finland signed the Global Methane Pledge in November 2021 at COP 26. Countries joining the pledge agreed to take voluntary actions to reduce global methane emissions by at least 30% by 2030 (versus 2020) and to move towards using best available methodologies to quantify methane emissions (Global Methane Pledge, 2021). Finland is also a member of the Global Methane Initiative, a public-private partnership where members exchange information and technical resources to advance methane mitigation in three key sectors: 1) oil and gas; 2) biogas; and 3) coal mines (Global Methane Initiative, 2022).

Methane emissions in Finland will soon be regulated under new EU rules. The EU Methane Strategy (adopted in 2020) aims to reduce methane emissions by 35-37% by 2030 (versus 2005 levels) to support the recently adopted EU target to reduce total GHG gases by 55% by 2030. Current EU policies are projected to reduce methane emissions by only 29% by 2030. An EU Methane Regulation is under preparation on monitoring and reporting energy sector methane emissions. Finland supports this new regulation.

Carbon capture, utilisation and storage

Finland's energy policy sees a limited but potentially impactful role for CCUS in meeting long-term GHG emissions reduction targets, especially for hard-to-abate end uses. The NCES indicates that GHG emissions reductions from CCUS in Finland will only be significant from 2040 onwards and that the total GHG emissions reduction from CCUS could amount to around 9 Mt CO_2-eq by 2050. The NCES also notes that large-scale use of CCUS in Finland will require cost-effective solutions for marine shipping of CO_2, as Finland does not have geological CO_2 storage sites.

The Geological Survey for Finland conducted studies showing that geological conditions in Finland do not enable permanent storage of captured CO_2 (Teir et al., 2011). In addition, the Act on the Recovery and Storage of Carbon Dioxide bans the storage of CO_2 in Finland (except volumes up to 100 000 t for R&I purposes). The Act also sets requirements for ensuring the safe capture and transportation of CO_2. In 2017, Finland ratified an amendment to the London Protocol regarding the export of CO_2 for disposal in sub-seabed geological formations. Finland is exploring issues related to bilateral agreements with other countries on CO_2 storage and taking other steps required under the London Protocol to allow for exporting CO_2.

In the near term, Finland's efforts on CCUS focus on supporting R&I for technology demonstration and cost reduction. Finland's national recovery and resilience plan includes EUR 156 million for low-carbon hydrogen and CCU projects (there are no storage options). CCUS projects are also eligible for support through several of Finland's R&I programmes. The NCES notes qualitative goals to accelerate the development and use of CCUS, pilot CCUS on waste incineration, and promote an EU legislative framework for CCUS regulation. It does not, however, provide details on how these goals will be met.

Finnish companies and R&I entities have been awarded numerous patents related to CCUS and are undertaking or planning at least 20 CCUS-related commercialisation and pilot projects. There are also a large number of R&I projects looking at CCUS application for power to gas/fuels.

Climate change impacts and adaptation

IEA analysis notes that Finland is at risk of notable impacts from climate change. Finland's average annual temperature has risen more than 1°C in the past 150 years and is projected to continue increasing more rapidly than the global average in the coming decades. It is estimated that by the end of the century, Finland's average temperature could increase by 2-6°C degrees above the 1981 to 2010 average. Warmer temperatures are likely to reduce energy demand for heating and increase demand for cooling and could affect electricity supply by reducing output from thermal power plants, therefore lowering the transmission capacity of the electricity grid.

Finland's precipitation has been highly variable, making it difficult to analyse long-term trends. However, climate projections indicate an increasing precipitation trend. Heavy precipitation events could become more frequent in the summer, resulting in more flooding. Winters could be cloudier. These changes may affect renewable energy sources, for instance, by making greater hydropower generation possible and reducing solar energy potential in the winter. There could also be unpredictable impacts on the available level of forestry biomass. Increasing rainfall and a longer growing season might increase forest biomass production, but changing climatic conditions might impact the health of forests due to disease and pest risks, reducing the availability of timber.

The frequency of strong winds is projected to increase, especially in coastal regions. Severe winter and summer storms can negatively impact the energy system, damaging electricity lines, poles and transformers, causing power outages. Indeed, long-lasting power outages in the last few years have brought the operational security of Finland's electric grid into public discussion. For instance, storms left 94 000 homes without electricity in 2019 and 60 000 dwellings were affected in 2020. Severe storms also pose a risk to wind generation (damage to turbines, reduced generation at very high wind speeds). Wind generation is a key part of Finland's plans for climate neutrality.

Finland is a global leader in climate adaptation policy. It was the first European country to develop a National Strategy for Adaptation to Climate Change (in 2005). The current national adaptation policy framework, outlined in a government resolution based on the National Climate Change Adaptation Plan 2022 (adopted in 2014), demonstrated a continuing commitment to climate resilience, with general objectives such as implementing adaptation actions by integrating them into each sector's planning, decision making and activities. Finland has also conducted numerous detailed studies on climate risks.

Based on this extensive research, Finland has identified measures to adapt to climate change in the energy sector. Its Seventh National Communication under the United Nations Framework Convention on Climate Change describes ongoing and planned adaptation measures, such as dam safety improvement through flood management and the construction of intelligent electricity networks. Finland's nuclear power plants were designed with consideration for the impacts of drought on cooling capacity. The Electricity Market Act ensures that distribution network design, construction and maintenance are resilient to extreme weather events. Climate resilience is also referred to in national energy policies, establishing links between energy and climate plans (UNFCCC, 2017).

The Climate Change Act introduced a process for developing and updating a National Climate Change Adaptation Plan every ten years. The first plan was adopted in December 2022 and defines 24 goals related to preparedness and adaptation and the policy

measures to implement them. The plan is based on a risk and vulnerability analysis. Adaptation needs are examined both by the administrative sector and across their borders as well as from a regional perspective. The goal is also to develop a monitoring system to evaluate the progress and effectiveness of actions.

The plan's key targets are to: carry out climate change adaptation cost-effectively by making adaptation part of the normal planning and decision-making processes in different sectors; ensure that those involved will have access to the necessary climate risk assessment and management methods; and increase adaptive capacity in society, innovative solutions and awareness of climate change adaptation through research and development, communication, and education. The plan will define new policies to strengthen the risk management of climate impacts in the energy and industrial sectors and support investments in developing a weatherproof infrastructure.

A mid-term evaluation supporting the development of the plan was published in 2019. The evaluation was co-ordinated by the Finnish Environment Institute (SYKE) and Natural Resources Institute Finland (Luke) and included broad stakeholder engagement, including the energy sector. The most important needs the review identified relate to increasing awareness of weather- and climate-related risks and the options to adapt to them, clarifying the roles and responsibilities related to adaptation, and ensuring well-functioning co-ordination. The review also noted the importance of developing sector-specific guidance, along with tools and instructions that regional and local operators, in particular, can use to strengthen their adaptive capacity at their own initiative (Finland, Ministry of Agriculture and Forestry, 2022).

Finland is also supporting climate adaptation at the EU level. A new EU Climate Change Adaptation Strategy was adopted in February 2021. It focuses on issues such as investments in the climate resilience of infrastructure, particularly critical infrastructure such as electricity networks. Finland's National Climate Change Adaptation Plan will contribute to implementing the EU Adaptation Strategy in the national context (Climate Adapt, 2021).

Assessment

Finland's Climate Change Act sets a legal obligation to reach carbon neutrality by 2035 and binding targets to reduce GHG emissions (excluding LULUCF) by 60% by 2030, 80% by 2040 and 90-95% by 2050. Finland also has 2030 targets to reduce non-ETS emissions by 39% by 2030. These high ambitions will pose a true challenge in the coming years. The government needs to identify efficient and politically acceptable measures with reasonable costs that will drive strong emissions reductions in a socially just manner. In the energy sector, GHG emissions stem mostly from the use of fossil fuels, which should be reduced. Emissions from industrial processes and the agriculture and land-use sectors pose a notable challenge.

The pace of the envisaged transition is very ambitious. Instruments and incentives will have to be in place in a timely manner to achieve the required emissions reductions. There are notable bottlenecks to achieving the climate neutrality goal by 2035. The government needs to move quickly to finalise several pieces of energy legislation required to define key regulations and support programmes. Finland also faces notable challenges in the availability of the highly skilled personnel needed in government and key private sector positions, e.g. for permitting and deploying energy projects.

A large amount of EU funding supporting emissions reductions comes from the Recovery and Resilience Facility to accelerate energy transition, but this funding is temporary and must be allocated by 2026. This funding can help achieve the carbon neutrality target and the government needs to develop and incentivise sustainable and predictable funding streams that will maintain the momentum gained from the temporary boost in EU funding.

The Climate Change Act provides a coherent climate policy framework with legally binding targets, four policy plans with clear areas of coverage, and a regular process for reporting on progress and updating plans. However, the main policy document appears to be the NCES. The NCES covers the key climate and energy policy measures as well as issues like energy security and energy markets, but it does not have a clear relationship with the policy framework created under the Climate Change Act. The government should ensure coherence between the NCES and the various plans required under the Climate Change Act to provide consistent signals on climate policy.

Land-use sector and biomass

Current plans for achieving carbon neutrality rely on large and increasing annual emissions removals from land use, land-use change and forestry that must reach a net sink of around 21 Mt CO_2-eq per year in 2035 compared to around 17 Mt CO_2-eq per year in 2020. Much greater reliance may need to be placed on emissions reductions in the energy sector and much stronger measures may be required to ensure that LULUCF can act as a growing carbon sink. Finland has vast knowledge about sustainable forest management and ways to achieve optimal carbon sinks. However, current measures, for example afforestation, will take a long time to become effective. Additional measures to increase the carbon sink capacity should be taken as soon as possible.

The net land sector emissions in 2021 place a large uncertainty on Finland's reliance on carbon sinks to become climate-neutral by 2035. In addition, OECD analysis from 2021 notes that Finland's future demands for biomass given in key sectoral road maps does not support the carbon absorption capacity needed to meet the 2035 carbon neutrality target (OECD, 2021). The IEA advises the government to assess the robustness of its strong reliance on LULUCF carbon sinks to meet the 2035 target. The government should develop a clear quantitative estimate of what level of logging can be allowed while still achieving the forest carbon sinks needed to support carbon neutrality and protect biodiversity. This estimate should also examine other key LULUCF sources and sinks beyond forest harvesting, including restoring drained peatlands and reducing emissions from agriculture, which have risen over the past two decades. A sustainable level of logging/land use could constrain the high reliance on wood for energy production, further increasing the need for emissions reductions from the energy sector and requiring adjustments to support measures for energy transition.

Peat

Due to the prevailing energy crisis in 2022, Finland created a requirement for peat stockpiling. But both the government and industry acknowledge that the peat industry is no longer attractive from an environmental and commercial perspective. The government set a goal to reduce the use of peat by at least 50% by 2030. The use of peat for energy will likely stop well before 2030, with most large-scale peat-fired plants closing or switching to other fuels between 2023 and 2026.

The government aims to limit the economic impact on areas where peat production is a key activity. A government working group has suggested actions to support these areas; the government has already adopted several of these measures. In addition, the European Commission has approved Finland's plan to use the EU Just Transition Fund to support transition in peat-producing areas.

The government should adopt a legal end date for commercial use of peat for energy production and take measures to accelerate a sustainable transition of the peatlands. Extra attention is needed in the transition of the former peatlands, as peatlands can potentially become large emissions sources if not managed well. Specifically, customised measures per peatland area should be taken (depending on the current state of the peatland) and, if needed, the government should provide subsidies to ensure a sustainable transition.

Carbon leakage

In August 2022, the European Commission approved Finland's updated ETS compensation system, which has a budget of EUR 687 million to reduce costs incurred from 2021 to 2025. The updated compensation system covers 25% of the increased electricity costs resulting from ETS prices, up to a maximum of EUR 150 million per year. The programme is available to a wide range of industrial companies and while it is primarily intended to prevent carbon leakage, it also includes requirements intended to drive energy transition. To qualify for compensation, all beneficiaries will have to either demonstrate that GHG emissions from their installations are below the applicable benchmark used for the free allocation of ETS allowances or that at least 30% of their electricity demand is covered by carbon-free sources (through on-site or near-site renewable energy generation facilities, carbon-free power purchase agreements or guarantees of origin). Companies receiving support must make investments that promote carbon neutrality equal to at least 50% of the received aid. This investment must be completed between July 2022 and December 2028. The maximum aid intensity is set at 25% (granted aid can only cover 25% of eligible investment costs). Companies must submit regular reports to the Energy Authority to verify that support is being spent on approved measures.

Climate adaptation

Finland likely faces negative impacts from climate change. Higher summertime temperatures could increase demand for cooling and affect electricity supply by reducing output from thermal power plants and lowering electricity transmission. Increased precipitation could increase hydropower generation but also the risk of flooding. Impacts on the availability of forestry biomass are uncertain, but there are risks that forest growth could be negatively impacted.

Finland is a global leader in climate adaptation policy. It was the first European country to develop a National Strategy for Adaptation to Climate Change (2005). The Climate Change Act introduced a process for developing and updating a National Climate Change Adaptation Plan every ten years. The plan defines adaptation measures through 2030 and was adopted at the end of 2022.

An evaluation supporting the development of the plan was published in 2019. The evaluation was conducted with broad stakeholder engagement, including the energy sector. The most important needs the evaluation identified relate to increasing awareness of weather- and climate-related risks and the options to adapt to them, clarifying the roles and responsibilities related to adaptation, and ensuring well-functioning co-ordination. The evaluation also noted the importance of developing sector-specific guidance, along with

tools and instructions that regional and local operators, in particular, can use to strengthen their adaptive capacity at their own initiative.

The evaluation also noted that climate change increases the risks for Finland through cross-border impacts. Finland must, therefore, also prepare for spill-over effects from the rest of the world in addition to the impacts and consequences from within its own borders. Climate change can affect, for example, global and regional raw material supplies and energy production, as well as supply chains and, through them, security of energy supply.

Recommendations

The government of Finland should:

- ☐ Assess the robustness of its climate strategy regarding the potential conflict between logging (including for bioenergy) and forest sinks, and consider additional measures to ensure reaching the 2035 climate neutrality goal.
- ☐ Adopt an end date for the commercial use of peat for energy production and take measures to accelerate a sustainable transition of peat-producing regions.

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3. Energy efficiency

Key data
(2021)

TFC: 1 067 PJ, +2% since 2011

TFC by source: electricity 28%, oil 26%, bioenergy and waste 25%, district heating 16%, natural gas 3.2%, coal 1.5%, peat 0.5%

TFC by sector: industry 52%, buildings 33%, transport 16%

TFC per capita: 193 GJ/capita (IEA average in 2020: 112.8 GJ/capita), -1% since 2011

TFC per GDP: 4.19 MJ/USD (IEA average in 2020: 2.66 MJ/USD), -5% since 2011

Overview

Improving energy efficiency is a pillar of Finland's plans for achieving carbon neutrality by 2035. Energy efficiency became even more central in 2022, with the global energy crisis continuing to drive surging energy prices and fuel supply disruptions. In Finland, increased energy prices led the average annual household expenditure for energy to increase by 33% from 2019 to 2022. Improved energy efficiency leads to energy savings, lower energy bills and higher comfort and protects vulnerable households. At the same time, energy efficiency measures are key to lowering emissions and boosting energy security.

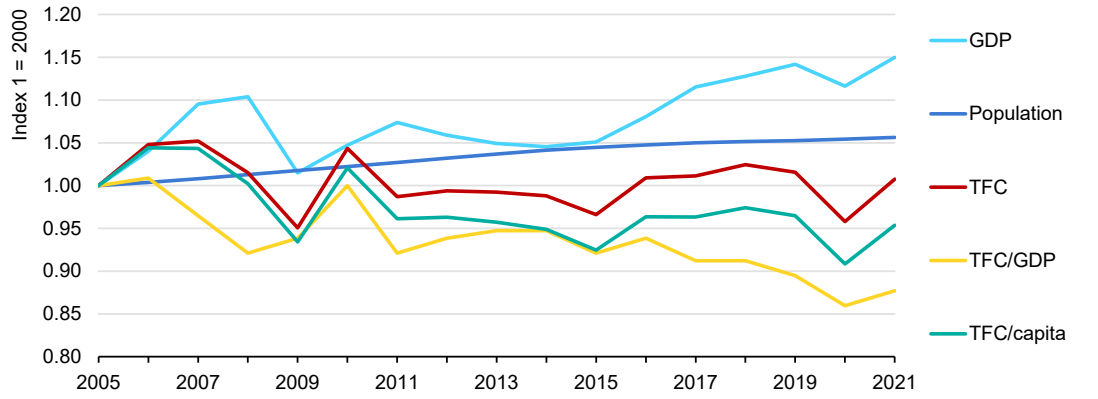
From 2005 to 2021, Finland's energy demand fluctuated between 1 007 PJ and 1 114 PJ, with annual variations driven by changes in industrial energy demand linked to global economic conditions and weather, affecting energy demand for heating. Finland has shown clear signs of decoupling energy demand from economic growth, especially since 2013 (Figure 3.1). Energy savings were achieved mainly in the industry sector thanks to switching to more efficient heating systems and in transport thanks to the improved efficiency of passenger vehicles.

Finland has set energy efficiency targets in its NECP. Targets include a maximum level of energy use (primary and final energy consumption) in 2020 and 2030 and annual energy savings obligations. Finland achieved its 2020 energy consumption and energy savings targets. Looking ahead to 2030, more ambitious targets are expected following a revised EU directive that requires a greater effort on energy efficiency.

As industry accounts for more than half of Finland's TFC, energy efficiency agreements with industrial players are Finland's main energy efficiency measure. Energy audits are mandatory for large enterprises. The audits are optional for small and medium-sized enterprises (SMEs), but the government provides financial support. In buildings, increased minimum standards for the building code and support for replacing heating systems are

expected to increase energy savings. The road map for fossil-free transport aims to halve transport emissions by 2030 and achieve net zero emissions by 2045. The achievement of these targets is supported through numerous measures to increase energy efficiency, including subsidies and tax incentives for EVs; vehicle scrapping schemes; increased biofuel requirements; and measures to encourage public transport, walking and cycling.

Figure 3.1 Energy consumption and drivers in Finland, 2005-2021

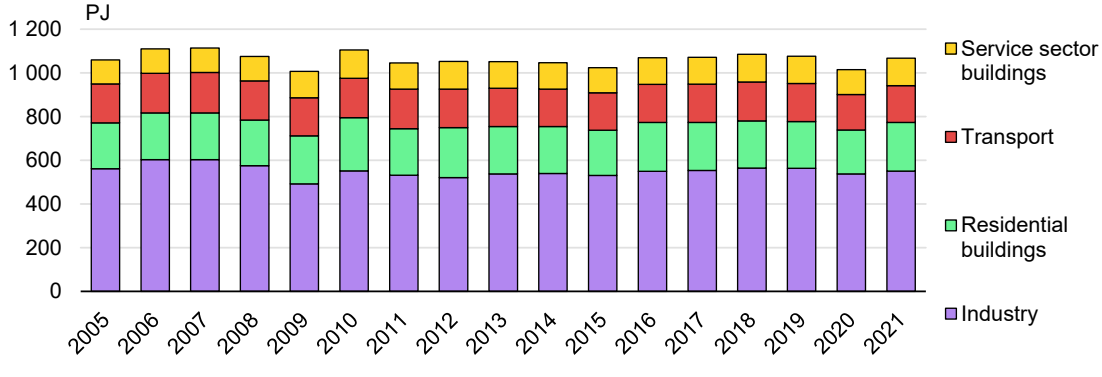


Source: IEA (2023a).

Energy demand

From 2005 to 2021, Finland's energy demand (TFC) fluctuated between 1 007 PJ and 1 114 PJ, driven by variations in industrial energy demand (492 PJ to 603 PJ) linked to global economic trends, fluctuations in building energy demand (314 PJ to 373 PJ) linked to variations in heating demand mainly caused by weather, and changes in transport energy demand (162 PJ to 185 PJ) linked to economic trends and since 2013 increasing vehicle efficiency (Figure 3.2). In 2021, industry accounted for 52% of TFC, followed by buildings (33%, with 21% from residential and 12% from service sector) and transport (16%).

Figure 3.2 Total final consumption by sector in Finland, 2005-2021



Source: IEA (2023a).

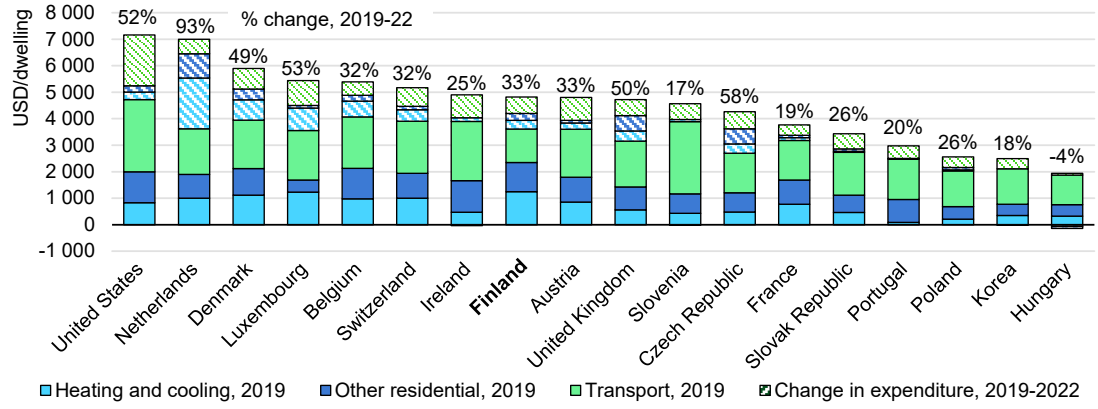
Energy efficiency and the energy crisis

The global energy crisis following Russia's invasion of Ukraine has further increased the value of energy efficiency actions. Energy efficiency is a key tool for governments to lower consumers' energy bills. IEA analysis shows that past efficiency actions delivered energy savings for around USD 680 billion across IEA member countries in 2022, or around 15% of total energy expenditure (IEA, 2022).

In Finland, the global energy crisis led to a 27% increase in retail energy prices, which is lower than the average of IEA member countries, also thanks to the very low share of natural gas – the fuel at the centre of the crisis – in Finland's energy system. However, the price increase was felt by Finnish consumers, with a 33% increase in energy bills between 2019 and 2022. This is higher than in other countries, where higher state expenditure was used to lower energy bills (Figure 3.3). The transport sector experienced the highest price increases, with a 49% rise in transport costs, as gasoline prices rose by 68% from April 2019 to April 2022 and diesel prices by 85%.

Higher energy and expenditure savings in transport could be achieved by replacing vehicles with more efficient, smaller and electric vehicles. Thanks to new European fuel economy standards, the higher efficiency of newer vehicle models with respect to those 10 years old in the same category translates into savings of USD 850 per year for a medium-sized car and USD 780 for a compact car. Potential annual savings of more than USD 1 000 are possible for drivers replacing a 10-year-old SUV with a similar new and more efficient one. EVs could enable additional savings of at least USD 1 000 per year compared to internal combustion vehicles.

Figure 3.3 Average household annual energy expenditure, selected countries, 2022 versus 2019



Source: IEA (2022).

Energy efficiency targets

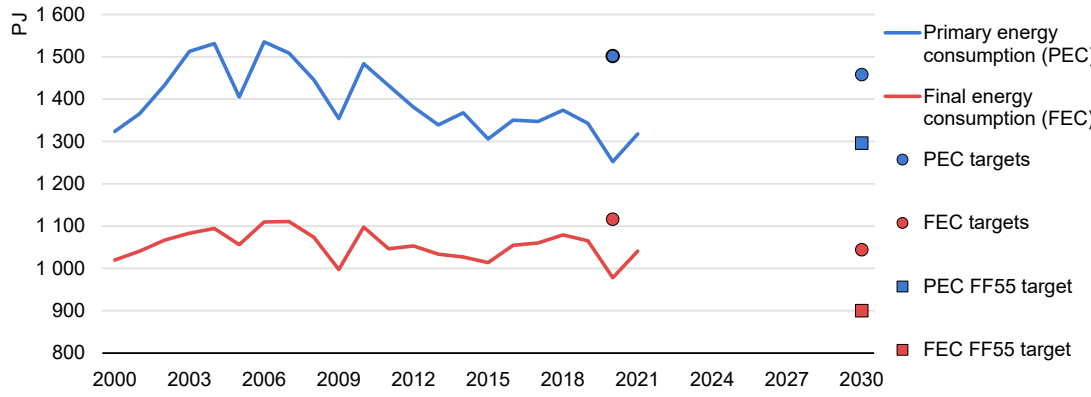
Under the EU Energy Efficiency Directive (EED), each EU member state has national energy efficiency targets for 2020 and 2030 that contribute to achieving EU-wide targets to reduce energy demand by 20% by 2020 and 32.5% by 2030 (compared to a business-as-usual projection). The national targets are defined as reductions in primary energy consumption (PEC) and final energy consumption (FEC). Finland's 2020 targets are set in

its National Energy Efficiency Action Plan. Finland's 2030 targets are set in its NECP, adopted in 2019. Finland achieved its 2020 targets for PEC and FEC well ahead of schedule (Figure 3.4). The European Commission's review of Finland's NECP conducted in October 2020 noted that the 2030 targets for PEC and FEC are not ambitious enough.

In 2020, the 2030 EU-wide GHG emissions reduction target was increased from 40% to 55%. The European Union is revising energy legislation through the Fit-for-55 package to support the increased target. This includes a significant revision of the EED, with a proposal to increase the 2030 target for EU-wide energy demand reduction from 32.5% to 36% for FEC and from 32.5% to 39% for PEC, or 9% lower than the 2020 reference scenario projections. Given the increased EU ambitions for energy savings and the European Commission's indication that Finland's existing 2030 targets are of low to moderate ambition, it is likely that Finland will need to increase its 2030 energy efficiency targets and enhance supporting measures. The government has indicated that the updated targets would be 1 296 PJ for PEC and 900 PJ for FEC. Additionally, the proposal contains several new obligations as well as increased data collection, reporting and monitoring.

In May 2022, the European Commission issued a new communication, REPowerEU, that proposes further tightening the 2030 energy efficiency target for member states, with a reduction of 13% from the 2020 reference scenario projections (EC, 2019). The government indicates that these changes would require Finland's FEC to decrease to 860 PJ. The government has not provided further clarity as to how the PEC target would be updated to comply with REPowerEU, and negotiations on the final targets at the EU level were ongoing at the time of writing (February 2023).

Figure 3.4 Finland's 2020 and 2030 energy efficiency targets and status 2005-2021



	2020 status	2021 status	2020 targets	2030 targets	2030 targets Fit-for-55
Primary energy consumption	1 252 PJ	1 318	1 501 PJ	1 458 PJ	1 296
Final energy consumption	978 PJ	1 040	1 116 PJ	1 044 PJ	900

Note: FF55 = Fit-for-55.

Source: EC (2019).

Institutions

Finland's Ministry of Economic Affairs and Employment has overall responsibility for formulating energy efficiency policy and co-ordinates its implementation across ministries and other institutions. It manages the transposition of EU energy efficiency legislation into Finnish law alongside the development and periodic review of Finland's National Climate and Energy Strategy.

The Finnish Energy Authority is responsible for the practical implementation of certain measures to promote energy efficiency. It is involved in implementing energy efficiency agreements, energy audits, consumer guidance in energy-related matters, the eco-design requirements and energy labelling of products.

Motiva ltd (Motiva Oy) is a state-owned company (since 2000), set up originally in 1993 as Finland's national energy agency. It is responsible for assisting the ministries and the Energy Authority in implementing energy efficiency programmes 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.

Efficiency policy and measures

According to its National Climate and Energy Strategy and Carbon Neutral Finland 2035, Finland aims to promote energy efficiency involving the entire energy system, in accordance with the energy efficiency first principle. Current policies include energy efficiency agreements (including financial support for investments and development projects), energy audits and energy advice. Table 3.1 lists the main measures expected to provide energy savings by 2030.

Table 3.1 Main measures and expected energy savings under the National Climate and Energy Strategy

Industry	PJ/year by 2030
Energy efficiency agreements	100.9
Renewable energy in agriculture	14.0
Energy audits	11.7
Surplus heat	5.8
Land consolidation	1.0
Energy efficiency investments by farms	0.4
Buildings	
Building codes	47.3
Heat pumps for single-family and terraced houses	43.0
Ecodesign Directive	25.5
Transport	
European Union's binding CO_2 limits for cars	34.4
Economic steering improving transport performance (e.g. fuel taxation)	4.4
Mass and dimensional changes heavy good vehicles	0.07

Source: Finland, Ministry of Economic Affairs and Employment (2022).

Energy savings under EU EED Article 7

Article 7 of the EU EED requires each member state to achieve an annual reduction of 1.5% in national energy sales from 2014 to 2020. For Finland, this corresponds to cumulated energy savings of 176 PJ between 2014 and 2020. Finland notified the European Commission in December 2018 that it had already achieved the target for 2014-20.

A new cycle of energy savings is expected under the EED for EU countries from 2021 to 2030. Finland expects to achieve cumulative energy savings of 551 PJ by the end of this period. Finland plans to cover the largest part of these savings (54%) with energy efficiency agreements (see the section on "Industry energy efficiency policy"), followed by the installation of heat pumps (13%) (Table 3.2).

Table 3.2 Energy savings expected in Finland under Article 7 of the Energy Efficiency Directive

	Cumulative savings in 2021-30 (PJ)
Energy efficiency agreements	296.7
Heat pumps for single houses	73.4
Transport fuel taxation/car traffic	55.3
Energy audit programme – small and medium-sized enterprises and municipalities	41.1
Energy efficiency in agriculture	41.0
Energy efficiency agreements/customer advice	39.5
Mass and measure modifications in truck transport	3.9
Total	**551.2**

Source: EC (2022).

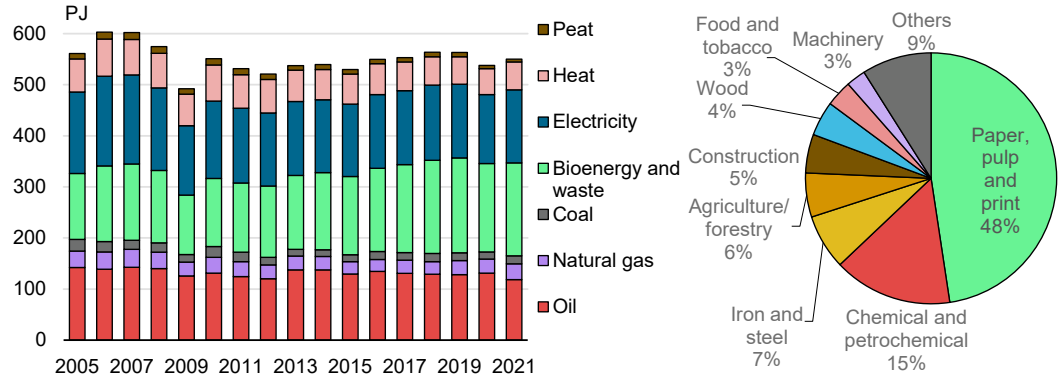
Industry

Finland's industry sector has, by far, the largest share of energy demand (52% TFC in 2021 compared to the IEA average of 36% in 2020). Industry sector energy demand has fluctuated in line with economic activity (Figure 3.5). Between 2011 and 2021, there was a progressive decrease in the shares of electricity (27% to 26%), oil (24% to 22%), district heat (13% to 10%), coal (3.8% to 2.1%) and peat (2.3% to 1.0%). At the same time, the share of bioenergy and waste increased (24% to 33%). Finland is notable for the relatively low use of natural gas, just 5.6% of industry TFC in 2021, compared to the IEA average of 25% in 2020.

The largest industrial energy-consuming sector in 2021 was pulp and paper, accounting for 48% of industry TFC. The other main sectors in terms of energy demand were chemical and petrochemical (15%), iron and steel (7%), agriculture/forestry (6%), construction (6%), wood (4%), and food and tobacco (3%). Energy efficiency in the manufacturing sector has improved, as its energy intensity per value added decreased from 13.6 MJ/USD in 2015 to 12.2 MJ/USD in 2020. Finland has the highest energy intensity per value added of the manufacturing sector among IEA countries with available data and much higher than the IEA average (4.4 MJ/USD in 2020). However, this is also linked to the high share of pulp

production in Finland, which uses more energy per paper tonne than any other country only using recycled fibres or imported market pulp. Finland and Sweden are the largest producers and exporters of pulp in Europe.

Figure 3.5 Total final consumption in industry by source in Finland, 2005-2021 and energy use by subsector, 2021



Source: IEA (2023a).

Industry energy efficiency policy

Even though its GDP is projected to grow, as is industrial production (especially in the paper, pulp and print sector), Finland aims to not increase the energy demand of the industry sector by improving energy efficiency. The government aims to increase electrification and the use of waste or ambient heat, which will also support the achievement of carbon neutrality by 2035.

Voluntary energy efficiency agreements first started in Finland in 1997. They consist of framework contracts between the government and industry associations or local governments on the efficient use of energy, following specific action plans for each sector. Parties join the energy efficiency agreements by signing an accession document, committing themselves to improve their energy efficiency in accordance with the actions and targets presented in the action plan of their own industrial branch. Action plans have been created for several industry subsectors (energy-intensive industry, food and drink, chemical, wood products, energy production, energy services, motor trades and repairs, commerce, hotels, and restaurants). Companies that do not identify themselves in these sectors can also join more generic action plans. Additional action plans exist for the municipal sector, targeting local and regional authorities, and for the property sector, including action plans for rental housing properties and commercial properties. Lastly, HÖYLÄ IV energy efficiency agreements cover the distribution of liquid heating fuels.

Companies that join energy efficiency agreements receive support and incentives for achieving the targets within the action plans in the form of funding for energy-saving measures (under the Energy Aid scheme) and technical assistance. Companies also benefit from improved energy efficiency and lower energy costs. The Energy Authority manages the energy efficiency agreements and has commissioned Motiva Oy for their implementation, communication, reporting and monitoring.

The current third agreement period started in 2017 and will end in 2025 and involves 728 companies, nearly 7 300 industrial sites and 134 municipalities. Between 2017 and 2021, companies implemented and reported around 19 000 improvement measures, with energy savings of 37 PJ/year. Savings were achieved mainly by energy-intensive industries (18.4 PJ/year), followed by the energy sector (8.5 PJ/year). The total mobilised private investment was around EUR 1 billion, leading to annual cost savings of EUR 431 million. The government estimates that the total savings under the agreements between 2017 and 2020 correspond to an emissions reduction of 2 Mt CO_2. In the NCES, the government announced that energy efficiency agreements will be ensured even after the current agreement period (2017-25).

The government provides financial support (Energy Aid) for innovative energy efficiency and renewable energy projects to companies, municipalities and other organisations based on an assessment of the Ministry of Economic Affairs and Employment (see Chapter 4 for renewable projects). Energy efficiency investments eligible for support include demonstration projects for new technologies and energy service company projects. The main goal of Energy Aid is to support renewables and energy efficiency projects that involve new technologies and that would not be implemented without the aid. For this reason, before the decision to grant the aid is taken, the beneficiary should avoid any binding investment decision or acquisition. In addition, companies and municipalities under energy efficiency agreements are eligible for support for energy efficiency investments with conventional technology.

A special Energy Aid grant for new technologies and large-scale demonstration projects is available for investments over EUR 5 million taking forward future energy technologies. Additionally, aid is granted to projects that enable the substitution of coal with renewable alternatives before the end of 2025.

Energy audits are mandatory for large companies under Article 8 of the EED, and there are no subsidies from the government for these obliged companies. However, energy efficiency agreements can include energy audits for a broader set of companies and municipalities. Contracting parties to these agreements can apply for Energy Aid to support the energy audit and implement energy efficiency measures, especially when involving new technologies, including flexibility capacity and intelligence.

To support carbon neutrality in the industrial sector, Finland introduced a support scheme in 2022 that provides payments to offset increased electricity costs resulting from ETS prices. The payments can cover 25% of ETS-related electricity costs up to a maximum of EUR 150 million per year (Energiavirasto, 2023). Any company receiving the payments must use at least half of the subsidy for activities to reduce emissions, improve energy efficiency and increase the use of renewables. Industries across most sectors are eligible for the support, but they must demonstrate that they have performed an energy audit or that they are exempt from conducting one and that at least 30% of their energy consumption is electricity produced from carbon-free sources. The investments must be completed by the end of 2028.

To improve the efficiency of electricity and heat generation, industrial companies need to perform a cost-benefit analysis to evaluate the costs and benefits of co-production of electricity and heat when designing or performing a major renovation of an electricity generation facility, a new industrial plant generating surplus heat, or an energy production facility that is close to a district heating or cooling network (Energiavirasto, 2015).

In supporting the goal to achieve carbon neutrality by 2035, in 2019 the government announced its intention to prepare sectoral low-carbon road maps for key industrial energy sectors in co-operation with companies and organisations in each sector (Finland, Ministry of Economic Affairs and Employment, 2021a). By 2021, 13 industrial sectors had prepared their road map, supported by the ministry. These road maps provide the government with estimates of anticipated sectoral development, include GHG emissions and energy consumption, and indicate the investment needs of various sectors. The main conclusions from these road maps include a recognised need for investments in research and new technologies, including energy and materials efficiency; alternative energy sources (biofuels, hydrogen and electrification); the increased exploitation of waste heat; and the implementation of CCUS (Finland, Ministry of Economic Affairs and Employment, 2021b). The government used these road maps to prepare its NCES; identify sustainable recovery measures, including in the recovery and resilience plan; and as a guide for the allocation of RD&D investments (see Chapter 5). The government is committed to updating the road maps in key industrial sectors in 2024.

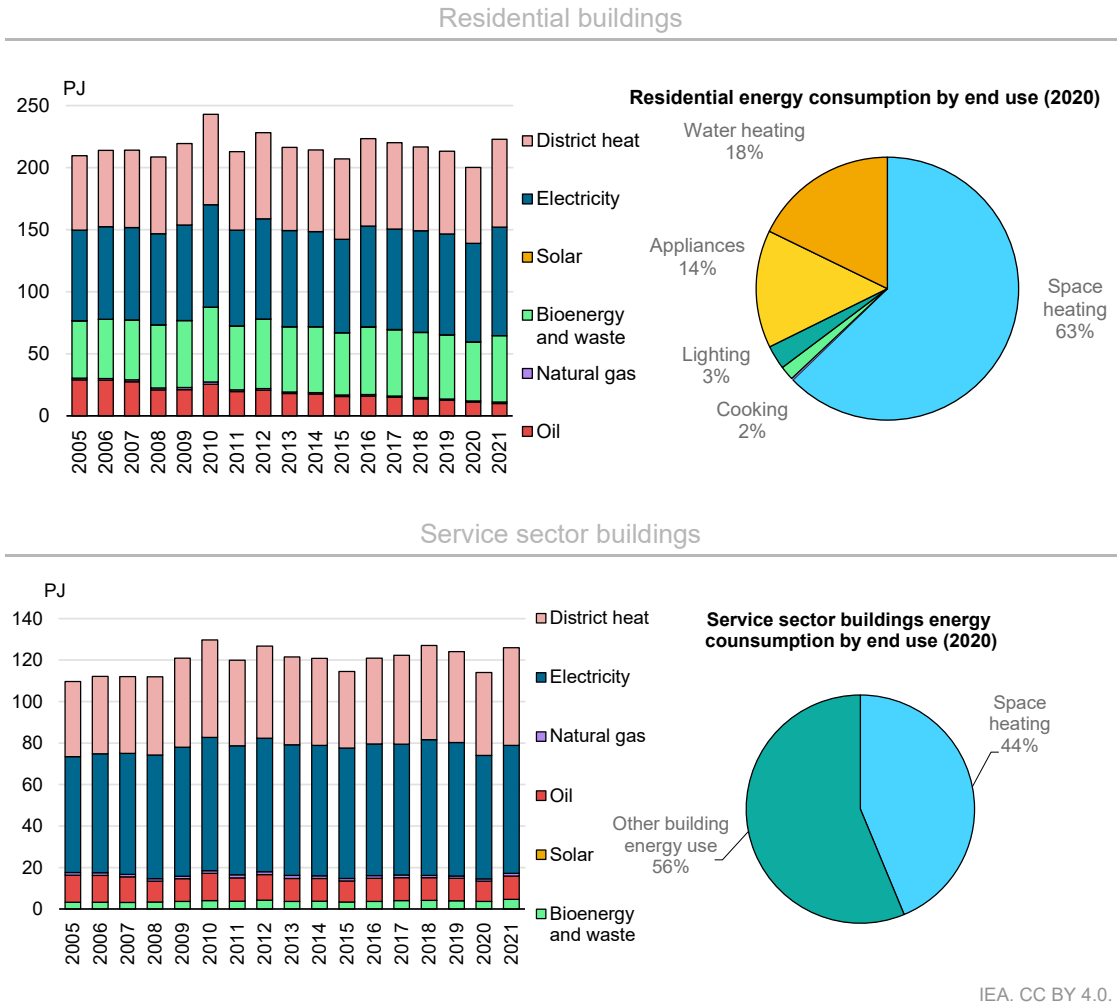
Buildings

Buildings account for the second-highest share of energy demand in Finland (one-third of TFC in 2021); 64% of this demand is from residential buildings and 36% from service sector buildings. Finland is an outlier among IEA member countries, as natural gas plays a marginal role, covering just 0.6% of building energy demand in 2020, compared to the IEA average of 35%.

Most residential building energy demand comes from space heating (63% in 2020). This drives strong annual variations in total residential building energy demand and ranged from 243 PJ in the exceptionally cold year of 2010 to 200 PJ in 2020 (Figure 3.6). In 2020, there were around 3 million dwellings in Finland; residential buildings accounted for around 68% of total floor area. Among all residential buildings, 54% were single-family houses and 46% were multi-dwelling buildings. The total floor area of residential buildings was 166 million m^2, 26% of which was built before 1959 and 35% after 1990. Buildings built after 2010 have an average heating energy consumption of 85 kWh/m^2, just one-third of those built before 1959 (EC, 2020).

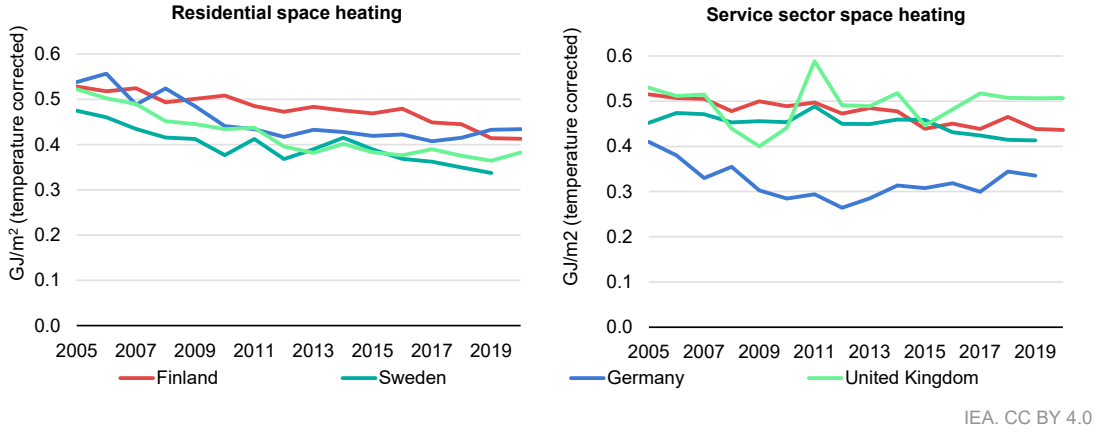
There has been a notable shift in the mix of energy sources for residential buildings. From 2011 to 2021, the share of oil decreased (10% to 6%) as electrification increased (39% to 43%). Residential buildings have benefitted from increased efficiency, as the energy intensity per dwelling and per square metre has decreased since 2005. However, the energy intensity per square metre (0.64 GJ/m^2) is still higher than the IEA average (0.53 GJ/m^2) and that of other countries in the region, such as Sweden (0.60 GJ/m^2) (Figure 3.7).

Figure 3.6 Total final consumption in the building sector by source in Finland, 2005-2021, and by end use in 2020



Sources: IEA (2023a; 2023b).

Figure 3.7 Energy intensity of space heating in Finland, 2005-2020



Source: IEA (2023b).

Most service sector building energy demand also comes from space heating (44% in 2020), with annual temperature variations having a major impact. Contrary to residential buildings, the energy mix of service sector buildings has been relatively stable in Finland. In 2020, most service sector energy demand was provided by electricity (53%), followed by DH (35%), oil (9%), and bioenergy and waste (3%).

Buildings' energy efficiency policy

Article 5 of the EU EED requires member countries to achieve an annual renovation rate of 3% for public buildings. Finland is following an "alternative approach" and is committing to achieve an amount of energy savings in the period at least equivalent to the renovation rate of 3%. The corresponding cumulative energy savings to be achieved for the whole period from 2021 to 2030 is 17 312 MWh (62.3 terajoules [TJ]).

Building codes

The current energy efficiency requirements for new buildings entered into force in 2018. They are in line with the European Union's Energy Performance of Buildings Directive and aim for the cost-optimal level of energy performance, leading to the lowest cost during the estimated lifecycle of buildings. The government provides information to the European Commission on the fulfilment of the Energy Performance of Buildings Directive every five years and aims to review the need for amendments to energy efficiency requirements for new and renovated buildings in 2023.

In line with the Energy Performance of Buildings Directive, energy performance certificates were introduced in 2008 and updated in 2018. They are required for new buildings and when buildings or parts of buildings are sold or rented. As of 2021, around 215 000 energy performance certificates had been issued. Around half of these were released at the construction of buildings; the other half were issued when buildings were sold or rented. Around half of buildings have an energy performance certificate class C or higher. The building stock has become gradually more energy efficient as building energy performance requirements, the prospect of reduced energy costs and the demand for better living comfort have encouraged the adoption of energy-efficient solutions in a cold climate.

Finland is one of the leaders in Europe and the world for the roll-out of smart meters. Since 2014, nearly all of the country's 3.7 million metering points have been upgraded with smart meters. Since 2021, companies have been installing new-generation smart meters, which allow readings with a frequency of 15 minutes instead of one hour. Finland aims to upgrade all electricity meters by 2025. The data from the new generation smart meters are collected on a nationwide data hub (see Chapter 6). The government considers smart solutions and digitalisation as key tools for improving the energy efficiency of buildings and has asked Motiva to examine opportunities for launching a test phase using the smart readiness indicator defined by EC directives to assess the readiness of buildings for smart solutions.

Policies to increase the energy efficiency of appliances, equipment and lighting are mainly based on the EU Ecodesign Directive. As the public sector is a major purchaser of goods and services, with public procurement contracts valued at about EUR 47 billion a year, the Act on Public Contracts encourages authorities to include energy efficiency as a procurement criterion.

Investment and consumer awareness programmes

Since June 2020, a grant programme provides subsidies for replacing oil boilers with heating systems that do not use fossil fuels (Centre for Economic Development, Transport and the Environment, 2022). The subsidy is available to eligible owners of single-family houses or apartments in semi-detached houses that are the main residence. The grant amounts to EUR 4 000 when switching to a geothermal heat pump, air-water heat pump or district heating and to EUR 2 500 when switching to other non-fossil heating systems. The programme's entire budget was used in 2020 (EUR 28.5 million) and 2021 (EUR 9.4 million); EUR 40 million was available in 2022. An additional EUR 60 million is allocated to the programme from the EU Recovery and Resilience Facility. As of September 2022, the subsidy had been granted for 14 639 applications, corresponding to a total budget of EUR 56.5 million. The government estimates that the programme's total budget is sufficient to replace around 36 000 oil heating systems, or less than one-quarter of all oil-fired heating systems in Finland (Sankelo et al., 2022).

The Housing Finance and Development Centre (ARA) provides grants for renovation projects improving the energy efficiency of residential buildings between 2020 and 2023. The grants cover 10-50% of the total investment, depending on the type of measure, with a maximum of EUR 4 000, or EUR 6 000 if aiming at almost zero energy consumption. The maximum cover is granted for interventions replacing oil heating boilers and on the building envelope (Housing Finance and Development Centre 2022).

A nationwide programme that started in 2018 supports consumer awareness through regional energy advisory services to provide consumers with independent and updated information about energy efficiency and renewable energy solutions. A consumer awareness campaign (Down a Degree, 2023) was launched in August 2022 following the energy crisis linked to Russia's invasion of Ukraine. The government will provide regions with funds to support this campaign; the estimated budget is approximately EUR 1 million per year. The campaign led to significant electricity savings from August to December 2022 (Fingrid, 2023).

National Long-Term Renovation Strategy for 2050

The Finnish National Long-Term Renovation Strategy 2020-2050 (EC, 2020) was published in 2020. It aims at reducing the energy consumption and emissions of the building stock by 90% by 2050 in relation to 2020 levels. It revolves around three pillars: 1) building loss and space utilisation efficiency; 2) maintenance and renovations; and 3) decarbonising heating. The first pillar aims to accompany the ongoing long-term domestic migration concentrating the Finnish population in large urban areas: energy efficiency is more easily achieved in the denser urban areas, combined with the demolition of older buildings in rural zones. Policies support this strategy through demolition subsidies and spatial planning. As part of the second pillar, property owners are encouraged to prepare a property-specific strategy or a strategy for the entire building stock on repair actions over the next 15-20 years, involving a gradual improvement of buildings towards the nearly zero-energy level, or preparation for demolition. With respect to heating, the third pillar of the strategy includes a target to phase out fossil oil by 2030. Fossil oil will be phased out in state-owned buildings by 2024, and a subsidy for phasing out oil heating from family houses has been in place since 2020 (see above).

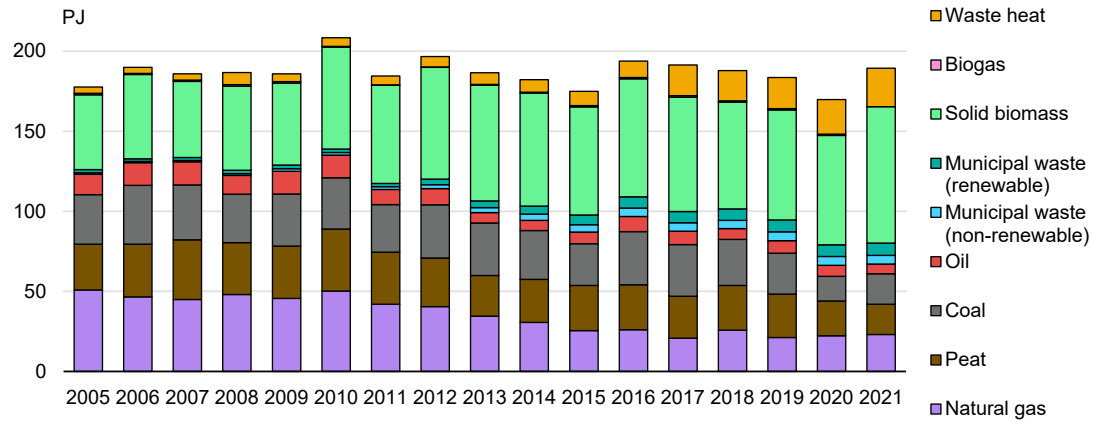
District heating and cooling

Finland has the third-highest share of district heat (DH) in total final consumption (15%) among IEA member countries, after Denmark (19%) and Estonia (16%). District heat is mainly used in the building sector (101 PJ) – where it is the first source of space heating and covers 32% of the sector's TFC and 45% of space heating – and in industry (51 PJ, 10%). Around 60% of DH is produced in co-generation plants with combined heat and power production; the remainder is produced from heat-only facilities. DH is widely used in densely populated urban areas. The total length of Finland's DH network is 15 570 km.

Since 2005, annual DH production has fluctuated between a minimum of 172 PJ in 2020 and a maximum of 211 PJ in 2010 (Figure 3.8). The fuel mix of heat generation has experienced an increasing share of bioenergy and decreasing shares of fossil fuels. In 2021, solid biomass covered 44% of heat generation, a considerable increase from 30% in 2010. The same year, natural gas accounted for 12%, half the share in 2010. Heating from waste heat has increased considerably in recent years and accounted for 12% of total heat production in 2021. Coal and peat follow, with 10% each, and have also been decreasing since 2010. The government plans to phase out the use of coal for district heat by 2029, with most of it effectively disappearing by 2025. Meanwhile, the share of biomass is expected to increase.

In 2021, around 1.2 PJ of district cooling was also produced, mainly from heat pumps (69%). The most important project is the Katri Vala heating and cooling plant in Helsinki, a flagship project using heat pumps for district energy (Helen, 2019).

Figure 3.8 District heat supply by source in Finland, 2005-2021



Source: IEA (2023a).

District heating energy efficiency policy

Finland sees carbon-neutral heating, including district heating and cooling, as a key component for reducing GHG emissions. Looking ahead, geothermal heat and other non-combustion solutions are preferred over solid biomass, as the availability of sustainably produced biomass is limited. The government plans to promote new non-combustion DH production and storage, as well as continue to support the growing

use of waste heat from industrial facilities. Finland is a pioneer in the utilisation of thermal storage, and several new projects recently started operations or have been planned (Box 3.1).

Box 3.1 Thermal storage

Thermal storage is a relatively simple technology that provides flexibility to the district network systems and the electricity network due to sector integration.

Finland is one of the most advanced countries in the world for the adoption of thermal storage, with a few projects from private companies using different technologies.

In Helsinki, the municipality-owned energy company Helen repurposed an old oil security storage in Mustikkamaa to become the country's largest thermal storage connected to the city's DH network (Helen, 2018a). The caves are filled with warm water from the local district heating network in autumn and heat exchangers can later transfer the thermal power to the DH system. The cave can store up to 260 thousand cubic metres of water, with a charging and discharging power of 120 megawatts (MW), and a total storage capacity of 41.8 terajoules (TJ), enough to heat more than 500 homes for one year. Helen also has heat storage facilities at the Vuosaari and Salmisaari power plants and is planning another thermal storage facility in Kruunuvuorenranta, with a capacity even higher than that in Mustikkamaa, to provide seasonal energy storage in combination with solar thermal for water heating during the summer and use the stored thermal energy in the winter (Helen, 2018b).

Other companies are investing in thermal storage projects. Polar Night Energy is developing smaller high-temperature thermal storage solutions based on sand. The company offers heat storage systems with 2 MW of heating power and a capacity of 200 megawatt hours (MWh) (0.7 gigajoules [GJ]) or 10 MW of heating power with a capacity of 1 000 MWh (3.6 GJ) (Polar Night Energy, 2021). Elstor obtained public funding from the state-owned Climate Fund to develop modular thermal storage converting electricity into stored thermal energy to be used for DH but also by industrial companies, for example in the food sector (Pesu, 2021). Similarly, Fortum has invested in a 100 MW electric boiler which can use electricity during off-peak hours to charge an 800 MWh (2.88 TJ) thermal storage connected to the DH system to cover demand during heating peak hours (Caruna, 2022).

Sources: Helen (2018a; 2018b); Polar Night Energy (2021); Pesu (2021); Caruna (2022).

In recent years, competition in the heating market has not been favourable for district heating. The cost of fuels for DH has increased, and the added cost of emissions allowances has increased interest among consumers for their own carbon-neutral heating source with more predictable costs.

DH prices in Finland are not regulated, but the dominant market position of DH operators requires pricing to be on equal terms for all consumers. The competition authority can initiate investigations if it suspects abuse of the dominant market position. There is no general obligation to connect to a DH network, with some local exceptions. District heating

customers also have the right to disconnect without any extra fee. The DH network is owned by heating suppliers, and the use by third parties is guaranteed by law and based on bilateral agreements.

The government and associations are co-operating to increase the efficiency of DH systems. In 2021, Finnish Energy, the association for the Finnish energy industry sector, updated the requirements for the design, installation and equipment of district heating, and reduced the inlet water temperature from 115°C to 90°C, aiming to increase the overall efficiency of the networks and decrease losses. In 2022, the government started to develop a model contract for heat trade to facilitate agreements on the purchase and sale of waste heat.

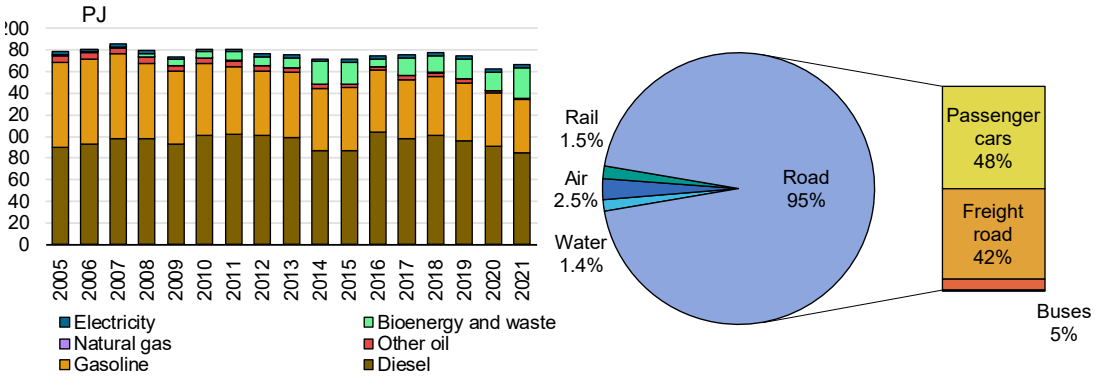
Transport

The transport sector accounts for the smallest share of energy demand in Finland (16% of TFC in 2021, compared to the IEA average of 31.3% in 2020). From 2010 to 2019, transport energy demand was relatively stable, ranging between 172 PJ and 181 PJ (Figure 3.9). In 2020, the impacts of the Covid-19 pandemic caused a 7% drop in transport energy demand compared to 2019, and demand rebounded by 3% in 2021, still 4% lower than in 2019. The transport sector fuel mix has undergone a small shift towards renewable energy. From 2011 to 2021, there was a decline in the share of gasoline (34% to 30%); a more than tripling of the share of biofuels (5% to 17%); and a small increase in the share covered by electricity (1.5% to 2.0%), mostly for rail, but with growing demand from EVs. Over the same period, the share of diesel fluctuated from a minimum of 50% in 2021 to a maximum of 59% in 2016.

Most transport sector energy demand comes from road transport (94% in 2020), with a high share (50%) from passenger vehicles and 39% from freight road transport (Figure 3.8). Small shares of transport demand come from domestic marine navigation (3%), rail (2.1%) and domestic aviation (0.7%). Road transportation relies mostly on diesel and gasoline, with a mandated blending of biofuels and a small but growing share of EVs. Finland's rail system is largely electrified (electricity covers 74% of rail energy demand).

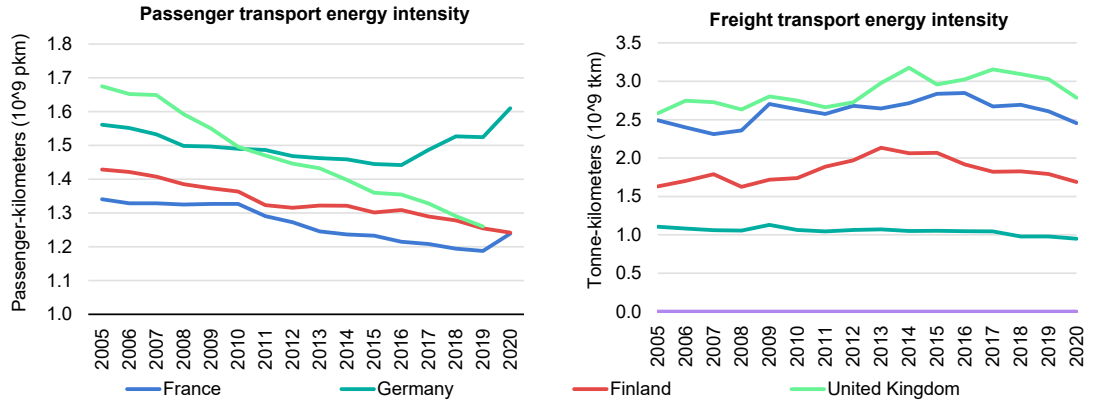
The energy efficiency of Finland's passenger car fleet has steadily improved (Figure 3.10). From 2005 to 2020, it declined from 1.46 megajoule per passenger-kilometre (MJ/pkm) to 1.25 MJ/pkm, lower than the IEA average of 1.8 MJ/pkm. In comparison, there has been limited progress in improving the energy efficiency of Finland's freight transport fleet. From 2005 to 2013, the energy intensity of freight transport increased notably from 1.63 megajoules per tonne-kilometre (MJ/tkm) to 2.14 MJ/tkm. Since 2013, the energy intensity of freight transport has been declining, but in 2020 it was 1.68 MJ/tkm, still slightly above the level in 2005 but lower than the IEA average (2.5 MJ/tkm).

Figure 3.9 Total final consumption in transport by fuel, 2005-2021, and by mode in 2020



Notes: Other oil = kerosene jet fuel, fuel oil and aviation gasoline.
Sources: IEA (2023a; 2023b).

Figure 3.10 Transport energy intensity in select IEA countries, 2005-2020



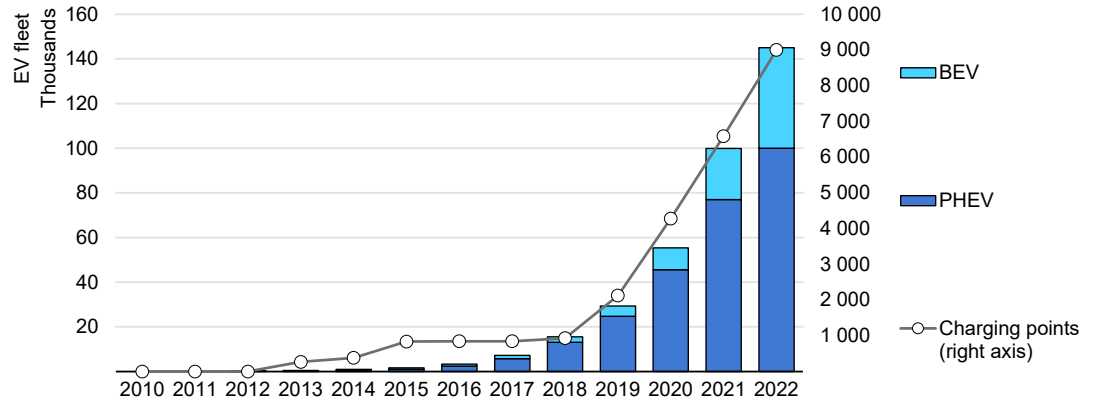
Source: IEA (2023b).

Finland is making strong progress in the adoption of EVs, but still lags behind other Northern European countries such as Norway, Sweden, Iceland and Denmark. From 2012 to 2021, the number of registered EVs grew from just 237 to almost 100 000 (Figure 3.11), with most of this growth taking place since 2018. Finland has targeted 880 000 EVs by 2030, covering approximately one-quarter of the passenger vehicle stock. In 2021, EVs accounted for 3.6% of passenger vehicles in Finland (versus the EU average of 1.6%) and 31% of new passenger vehicle registrations (versus the EU average of 17.5%). Finland's EV fleet is composed mostly of plug-in hybrid electric vehicles, 77% of total EVs in 2021, compared to 23% for battery electric vehicles. However, the share of BEVs has been steadily increasing.

Deployment of public charging points greatly accelerated in 2019 to reach more than 9 000 in 2022. In 2021 and 2022, the amount of public fast-charging stations (>22 kilowatts [kW]) increased rapidly (E-mobility, 2023). The EU Alternative Fuel Infrastructure Directive recommends the installation of 1 public charger for 10 EVs (0.1 charger/EV ratio). As of June 2022, the ratio in Finland was 0.06, while the EU average is 0.09. Some countries have higher deployment; the

Netherlands, for example, has achieved a ratio of 0.22. As for fast charges, Finland has set a target of 1 public fast charger for 100 BEVs. As of June 2022, the ratio was 3.2 fast chargers per 100 BEVs (Jääskeläinen, 2022). The building of infrastructure for alternative fuels has been supported in Finland by subsidiaries since 2018.

Figure 3.11 Registered electric vehicles and public charging points in Finland, 2012-2021



Source: IEA (2023c).

Transport energy efficiency policy

The Finnish government aims to improve both the energy efficiency of vehicles and the wider transport system.

The Roadmap for Fossil-Free Transport (Finland, Ministry of Transport and Communications, 2021) aims to halve transport emissions by 2030 and achieve a fossil-free transport sector by 2045. The road map includes three phases. In the first phase, subsidies and tax incentives promote low- and zero-emission transport, including biofuels, EVs, walking, cycling and public transport. In the second phase, the mandatory shares of biofuels are set to increase, while demand for transport will decrease because of modal shift, remote work, optimised freight transport through high-capacity transport and improved efficiency of operations, including by digitalisation of logistics. Finally, in the third phase, the government will assess the impact of the measures in the previous phases and decide on the need for additional measures.

Finland aims to have 880 000 electric passenger vehicles (27% of total stock), 36 000 electric vans and 6 600 electric heavy-duty vehicles in 2030. At least half of electric cars and vans would be fully electric. Finland also aims to have 130 000 gas-fuelled vehicles on the road in 2030. With a view to increase the efficiency of the whole sector, Finland has a goal to stop the increase of passenger vehicle-km, decrease the need for transport by private vehicles in urban areas, and reduce the growth of vehicle-km of freight vehicles, transporting goods more efficiently also by increasing digitalisation of logistics and encouraging full-load driving.

Until the beginning of 2023, the purchase of BEVs was supported with a EUR 2 000 subsidy for vehicles with a value lower than EUR 50 000. Subsidies ranging between EUR 2 000 and EUR 6 000 were also available for purchasing electric vans, and between

EUR 6 000 and EUR 50 000 for electric heavy-duty vehicles, depending on the size of the vehicle. The subsidiary programme for electric vans and heavy-duty vehicles is applicable until the end of 2024.

A successful scrapping programme was in place in 2020-21, offering a scrapping premium for exchanging an old gasoline or diesel car and purchasing a new car, electric bike or public transport ticket. The campaign had a EUR 8 million budget. The scrapping premium was used to replace over 6 500 old cars. The premium was EUR 2 000 for a new car and EUR 1 000 for a bicycle or a seasonal public transport ticket. According to the Roadmap for Fossil-Free Transport, the scrapping premium campaign will take place from time to time. Previous campaigns were held in 2015 and 2018.

EVs also benefit from tax discounts. BEVs are exempted from first registration car tax. Additionally, the tax value of company BEV cars is reduced by EUR 170 per month and the charging of EVs at the workplace is exempted from income tax.

In an effort to move away from oil-based fuels, subsidies were also given for converting private vehicles from oil to ethanol (EUR 200) and to gas (EUR 1 000) until the beginning of 2023. In addition, the purchase of compressed gas vans is supported by a subsidy of EUR 2 000 and up to EUR 6 000 for heavy-duty vehicles. The subsidy for liquefied gas trucks is EUR 14 000. Applications to receive subsidies for gas-fuelled vans and heavy-duty vehicles must be submitted by the end of 2024. Since 2018, Finland has budgeted a total of EUR 50.5 million to subsidise the purchase of an electric or gas-fuelled vehicle or to convert a vehicle to run on alternative fuel.

Financial support via tenders is also available for improving the charging infrastructure for EVs, biogas- and hydrogen-fuelled vehicles. The tenders provide support for high-power charging and local public transport charging points for EVs, pressurised and liquified biogas, and hydrogen filling stations. A total of EUR 34 million will be reserved to support EV charging infrastructure. Of this, EUR 22 million will focus on the construction of fast chargers for passenger vehicles and EUR 12 million for the construction of charging infrastructure for heavy-duty vehicles. This will allow adding 1 400 fast chargers, up from the current 300. The Fintraffic website provides an updated map of Finland's electric and gas distribution points. Finland is planning to update its alternative fuels' infrastructure programme for road transport to 2035 by the end of 2023. It also aims to perform railway track kilometres almost entirely by electricity in 2050.

Finland has also planned investments to promote a modal shift to walking, cycling, public transport and car-pooling. In the Roadmap for Fossil-Free Transport, between 2022 and 2024, a budget of EUR 30 million per year was proposed to be allocated for investments in improving municipalities' walking and cycling infrastructure. In addition, EUR 10 million per year is allocated for maintenance works of walking and cycling infrastructure. A budget of EUR 43 million per year was planned for enhancing public transport and EUR 7.5 million for other measures that aim to promote behavioural changes through communication campaigns, mobility planning and digitalised services to encourage car-pooling. After 2024, decisions on walking and cycling infrastructure and public transport subsidies will be part of a national 12-year National Transport System Plan.

Assessment

The global energy crisis has increased the focus on energy costs and energy efficiency, and all parts of Finnish society are now asked to save energy. Official campaign activities to inform about needed behavioural changes were launched in Finland and Europe in the second half of 2022. The government should take advantage of this public focus and get the population actively involved with improving the availability of information, regulatory changes and financial support.

Finland has EU targets that set the maximum levels of energy use (primary and final energy consumption) in 2020 and 2030 and annual energy savings obligations. Finland achieved its 2020 energy consumption and energy savings targets. The current 2030 targets are expected to be corrected upwards with the approval of updated EU directives, requiring greater efforts on energy efficiency improvements.

There is broad recognition of the impact that rising energy prices have on customers, especially from low-income households. Finland manages this problem through social support with direct economic transfers. The IEA notes that challenges stemming from energy poverty are best addressed with the implementation of energy efficiency solutions, as that will provide a sustained reduction in energy costs while also improving quality of life.

As Finland is aiming for climate neutrality in 2035, it is important to continuously focus on energy efficiency to minimise system costs, like expanding the grid to accommodate rising demand and variability of supply, which will be a significant task in Finland in the coming years.

Industry

Energy intensity in the industrial sector is high compared to international metrics. This is mainly due to the high share of export-oriented energy-intensive industries, especially the pulp and paper industry, which accounts for almost half of industry energy demand.

Even though GDP is projected to grow, as is industrial production, Finland aims to avoid an increase in the energy demand of the industry sector by improving energy efficiency. The government aims to increase electrification of the industry sector, which would also help achieve carbon neutrality by 2035 if coupled with higher shares of carbon-free electricity generation.

The framework of voluntary energy efficiency agreements and audits is the cornerstone of Finnish energy efficiency policy for industry and has been in place since 1997. It is a highly effective alternative to regulatory steering of the commercial and industrial sector, with more than 700 companies having signed an agreement with the government. Most sectors are well underway to reach the savings target for the 2017-25 period. The IEA notes that there might be room for a more ambitious target to push sectors for further improvements.

The voluntary energy efficiency agreements support companies of all sizes and sectors. Financial support is granted for performing energy audits under the agreements but not to companies obligated to conduct audits under the Energy Efficiency Act. Implementing the measures is not mandatory, but action is needed to fulfil the reduction target stipulated in the agreement, and funding to support the implementation of the actions might be available through the Energy Aid programme if they fulfil the programme's requirements. The

government should consider prioritising industrial electrification, for example, by providing a targeted increased financial support to electrification measures included in energy efficiency agreements or identified by energy audits. According to the government's plans, energy efficiency agreements will be ensured even after the current agreement period ends in 2025.

Buildings

Finland has a cold climate, with the highest number of heating-degree days in the European Union. This is a strong incentive for developing energy-efficient buildings and high-performance heating solutions, making Finland's buildings very energy efficient.

The current energy efficiency requirements for new buildings entered into force in 2018, and the government aims to examine the need to review energy efficiency requirements for new buildings and buildings undergoing renovation or alteration in 2023. Energy performance certificates are required for new buildings and when buildings or parts of buildings are sold or rented. As of 2021, around 215 000 energy performance certificates had been issued, covering around 10% of the total building stock. Around half of these were released when the buildings were constructed and the other half when buildings were sold. Around half of the buildings have an energy performance certificate of class C or higher.

The government plans to improve the energy efficiency of buildings with investment programmes. Since June 2020, a grant programme has provided subsidies for replacing oil and gas boilers with heating systems that do not use fossil fuels. The current programme will have funds to support the replacement of 36 000 boilers out of the approximate national stock of 150 000. Data on heat pump sales for 2022 are very encouraging, as around 200 000 heat pumps were sold that year, a 52% increase since 2021 and the highest number of heat pumps sold in the European Union per 1 000 people. However, as the long-term renovation strategy includes a target to phase out oil and gas by 2030 in all buildings, the government should consider continuing with a support scheme, as replacing all oil and gas boilers will be more challenging without support. The scheme should be revised regularly to ensure a suitable level of support.

Another programme is also available for residential buildings; it's managed by the Housing Finance and Development Centre. The programme provided grants for renovation projects to improve the energy efficiency of residential buildings between 2020 and 2022. The government could also consider extending the time and resources for this programme.

Finland has one of the highest shares of smart electricity meters in households in the world, and the smart meters are about to be replaced by upgraded ones that have the possibility of measuring use every 15 minutes. This resource is not utilised to its full extent. A project or analysis should be initiated to assess the potential for using the metered information to optimise energy use within the household, as well as opportunities to detect the potential for demand response.

The government acknowledges that the lowest income households cannot afford the co-financing required to access most subsidy schemes. Finland is encouraged to analyse the possibility of establishing loan options for these households through, for example, access to government-guaranteed loans. This option should be available to all types of housing, including housing companies.

There is a general understanding of the difficulty that low-income households in Finland face when energy prices increase. As it is difficult to focus support schemes without a clear idea of the target group, it is important for Finland to develop a definition of energy poverty.

District heating and cooling

There are 108 district heating providers in Finland, with a customer base of 5.9 GWh/year. Some networks supply just 20-30 houses. While co-operation already takes place among DH providers, the sector as such could benefit from co-ordinated action, as they have many tasks in common. Areas of common interest could be principles for the use of waste heat and how to address challenges coming with lower temperature DH, also considering customers' interests. The sector would benefit from a separate district heat climate road map for carbon neutrality. This could support a co-ordinated and cost-effective development.

The government should also consider increased support for thermal storage for DH on top of what is already provided through Energy Aid. These investments would help to decarbonise DH and support more flexible and cost-effective operation of DH. Thermal storage can also function as notable demand side response assets, creating another potential revenue stream for DH operators while also allowing them to support electricity system flexibility and security. Despite these operational cost advantages, these storage systems have notable capital costs. Many DH operators, especially smaller scale ones, will not be able to afford them or will need to increase their prices. Support from the government in this area could help to ensure DH remains a low-cost and low-carbon option.

Increased efficiency of DH can also come from lowering temperatures in DH networks. Lower temperatures have a number of advantages, including decreasing operational losses; supporting electrification, as it increases the potential use of heat pumps; and opening to increased waste heat recovery.

Finland is commendably an active member of the IEA Technology Collaboration Programme on district heating and cooling, and the Finnish VTT Technical Research Centre leads a project on the optimisation of low-temperature and low-carbon district heating systems, which is active from 2020 to 2023. Project partners are the Swedish Environmental Research Institute, the Technical University of Denmark and the Flemish Institute for Technological Research.

Transport

The energy efficiency of Finland's passenger car fleet has steadily improved, but not at a pace sufficient enough to meet Finland's climate ambition. There has been limited progress in improving the energy efficiency of Finland's freight transport fleet. After peaking in 2013, the energy intensity of freight transport has been declining, and in 2020 was still above the level in 2005 but lower than the IEA average.

Finland is making strong progress on the adoption of EVs, but still lags behind other Northern European countries. In 2021, there were around 100 000 registered EVs, accounting for 3.6% of passenger vehicles in Finland. Finland aims for EVs to cover approximately 27% of passenger vehicles in 2030, with 880 000 electric cars. In that year, Finland aims to have 36 000 electric vans and 6 600 electric heavy-duty vehicles on the

road. Finland was also one of the first countries in the world to use electric ferries, both hybrid and full electric, now providing regular service to the public.

Finland offers a subsidy for the purchase of new EVs; however, the scheme for electric passenger cars will end at the beginning of 2023. Finland ran a successful scrapping programme in 2020-21, with a subsidy provided for exchanging a gasoline or diesel car for an EV or electric bike. A scrapping scheme helps to address the very low vehicle turnover rate. Finland has one of the oldest vehicle fleets in Europe and some of the longest driving distances. To reach the target of 750 000 EVs in 2030 and taking into account the low replacement rate of the vehicle fleet in Finland, a new scheme is planned to come into effect in the 2020s; such a scheme must be reliable, targeted and with a known time frame.

Financial support via tenders is available for EV charging. There is also support for EV charging infrastructure in housing co-operatives and workplaces. There should be a clear plan for the development of infrastructure and progress should be monitored.

Through its Roadmap to Fossil-Free Transport, Finland aims to halve emissions from transport by 2030 and achieve a fossil-free transport sector by 2045. The road map includes targets for increasing the number of walkers and bikers, with a goal of increasing by 30% trips made by bicycle by 2030. Between 2022 and 2024, the government has allocated a budget for investments in improving walking and cycling infrastructure, public transport, and other measures to promote behavioural changes. Progress should be monitored and sufficient resources allocated to carry out the actions, with the goal to reduce the use and ownership of private vehicles.

Recommendations

The government of Finland should:

- ☐ Increase incentives for electrification of industry in the voluntary energy agreement scheme.
- ☐ Ensure that the financial support schemes for replacing oil and gas boilers in households have sufficient funding to accelerate the replacement of these systems.
- ☐ Explore options to support energy renovation for lower income households, including by offering government-guaranteed loans.
- ☐ Work with industry to create a separate district heat climate road map for carbon neutrality that supports co-ordinated and cost-effective development of the sector.
- ☐ Promote electrification and thermal storage in district heat systems, also by encouraging lower temperatures in district heating networks.
- ☐ Accelerate the uptake of electric vehicles with a clear plan for expanding EV charging infrastructure, and support increasing the vehicle turnover rate with a preference for EVs while encouraging decreased use and ownership of private vehicles by improving infrastructure for public transport, walking and cycling.

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4. Renewable energy

Key data

(2021)

Renewables in TFEC: 507.6 PJ/47.6% of TFEC (bioenergy 406.7 PJ, hydro 64.7 PJ, wind 34.8 PJ, solar 1.33 PJ)

Renewables in electricity generation: 38 TWh or 53% of electricity generation (bioenergy 13.6 TWh, hydro 15.8 TWh, wind 8.5 TWh, solar 0.3 TWh)

Renewables by sector:[1] gross final energy consumption 43.1%, electricity 39.5%, heating and cooling 52.6%, transport 20.5%

Overview

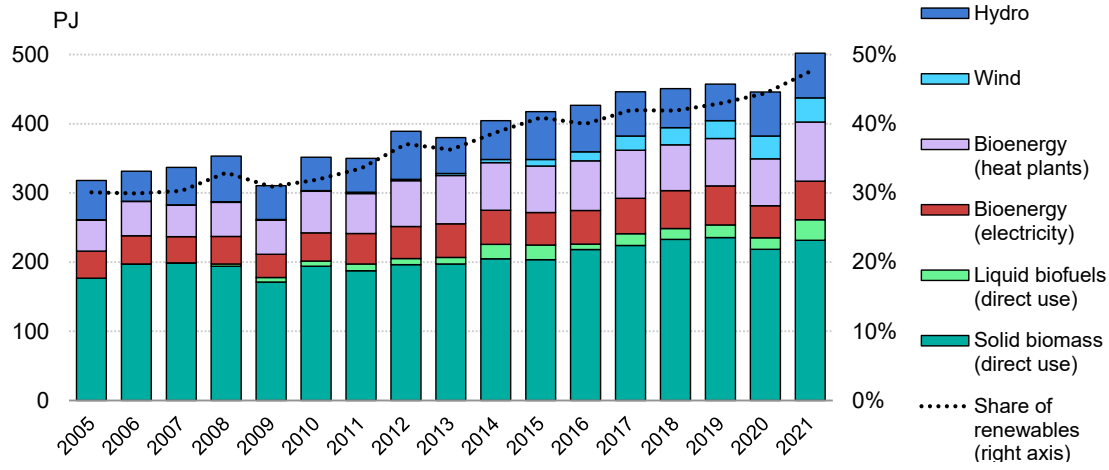
From 2011 to 2021, the share of renewable energy in Finland's total final energy consumption (TFEC) increased steadily from 34% to 48%, driven mainly by increases in bioenergy (29% to 38% of TFEC), hydro (4.7% to 6.1%) and wind (0.2% to 3.3%) (Figure 4.1). In 2020, Finland's share of renewables in TFEC ranked the third highest among IEA member countries. In 2021, renewables covered 43.1% of Finland's gross final energy consumption, 39.5% of electricity generation, 52.6% of heating and cooling, and 20.5% of transport (Figure 4.2).

Finland's energy policy aims to greatly increase the use of renewable energy in all sectors. There are targets to increase the share of renewable electricity generation (mainly from onshore and offshore wind) and to boost electrification of energy demand so renewable electricity can support the decarbonisation of industry, buildings and transport. Sustainable bioenergy is a key aspect of meeting the climate neutrality target. This includes notable use of forestry biomass in industry and building heating (co-generation, district heating and individual heating systems) and biofuels in transport. The government is also pushing for increased production and use of biomethane and hydrogen produced from renewable electricity.

Finland is transitioning its renewable support scheme away from operational subsidies paid for the delivery of renewable energy to investment subsidies that mainly target commercialisation and cost reduction of new technologies and deployment of small-scale distributed renewable energy projects.

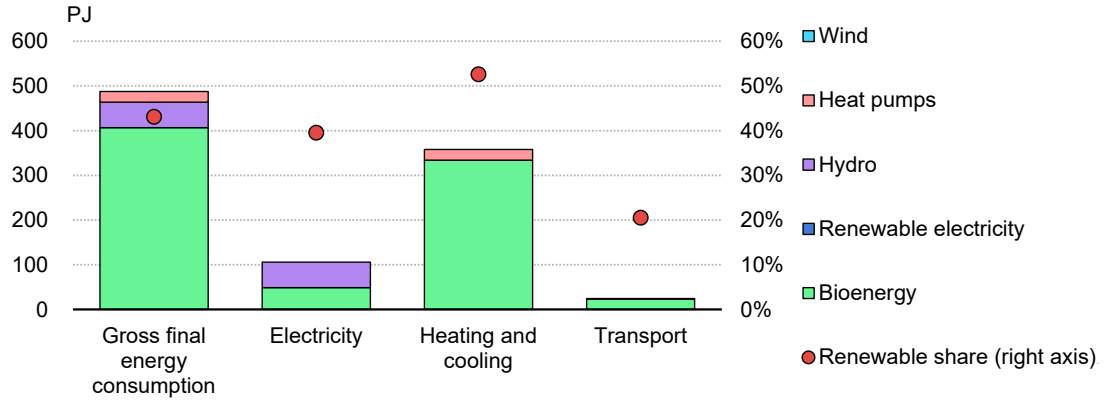
[1] Shares are based on Eurostat methodologies used to track progress on renewable energy targets and are different from the IEA methodology. Eurostat applies formulas to normalise fluctuations in wind and hydro generation and uses multiplication factors that give higher shares to advanced transportation biofuels and renewable electricity in transport.

Figure 4.1 Renewable energy in total final consumption in Finland, 2005-2021



Source: IEA (2022).

Figure 4.2 Renewable energy in key metrics in Finland, 2021

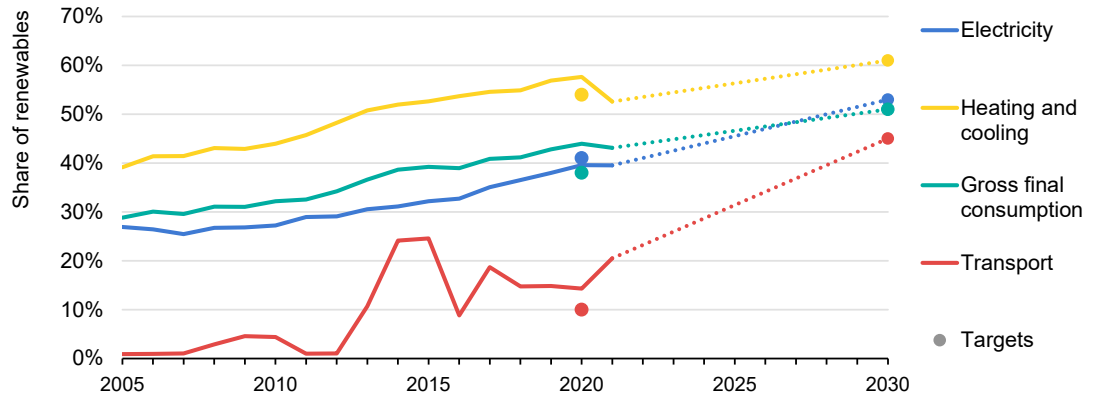


Source: IEA based on data from EC (2022).

Renewable energy targets

Under the EU Renewable Energy Directive (RED), all EU member states, including Finland, have 2020 and 2030 targets for renewables in gross final energy consumption and must provide indicative trajectories for renewable energy in electricity generation, heating and cooling, and transport (Figure 4.3). These targets and trajectories aim to support the achievement of EU-wide targets for renewable energy to cover 20% of gross final consumption by 2020 and 32% by 2030 (the 2030 target is likely to be increased to 45%).

Figure 4.3 Finland's renewable energy targets, trajectories and status, 2005-2030



	Status	Targets and trajectories	
Renewable energy share	**2021**	**2020**	**2030**
Gross final energy consumption	43%	38%	51%
Electricity	39%	41%	53%
Heating and cooling	53%*	54%	61%
Transport	20%	10%	45%

* The drop of the share of renewables in heating and cooling in 2021 is related to updated sustainability criteria for solid biomass and difficulties to obtain information on the sustainability of imported biomass.

Source: IEA based on data from EC (2022).

Finland exceeded its 2020 targets for renewable energy in gross final energy consumption, heating and cooling, and transport but was slightly below the target for renewables in electricity generation. Finland also has a non-binding national target to reach a 20% share of renewables in transport linked to the biofuels obligation; this target was met. The target allows credits for years when the share exceeded the annual target to cover for years when the share was below the target. Fuel sales were notably lower in 2020 because of the impact of the Covid-19 pandemic, so credits from previous years were used to cover the gap from the 13% actual sales to the 20% target.

Finland's actual share of renewables in gross final consumption was 44.6% in 2020. Because Finland exceeded the 2020 target, it was allowed to sell statistical transfers of renewable energy to EU member states that did not achieve their 2020 targets. In March 2021, Finland agreed to sell Belgium a statistical transfer of 1 376.5 GWh of renewable energy for EUR 18.6 million (Finland, Ministry of Economic Affairs and Employment, 2021). After this transfer, Finland's share of renewables in gross final energy consumption was 43.8%, still well above its 2020 target of 38%.

In December 2020, the 2030 EU-wide GHG emissions reduction target was increased from 40% to 55%. To support the increased target and the REPowerEU efforts to end reliance on Russian energy, the European Union is updating numerous policies through the Fit-for-55 package. This includes significant changes to the RED, with a proposal to increase the EU-wide 2030 target for renewable energy in gross final energy consumption from 32% to 45%. Finland is updating its NECP to reflect the increased EU climate ambition and the national 2035 carbon neutrality target and will likely need to increase its already ambitious 2030 renewable energy targets.

As part of the RED update, in September 2022, the European Parliament voted to cap the amount of primary woody biomass that can count towards meeting the 2030 renewables target or received subsidies. Most wood biomass used for energy in Finland is waste and residues from the forest industry, which would not be affected by the cap. However, the cap on the use of primary woody biomass for energy production could have an impact on Finland, as the government estimates that primary woody biomass accounted for around 11% of renewable energy in 2022.

Renewable energy policy and support measures

Finland's NCES and other key policy documents indicate that most of the increase in renewable energy needed to meet the 2035 climate neutrality target will come from wood fuels, wind generation and heat pumps powered with renewable electricity. Wind generation, including offshore wind, is seen as the key technology for increasing renewable electricity generation. Wood fuels are expected to play an increasing role, as the use of coal and peat for heating is reduced. However, in the long term, the government wants to move to heating and cooling systems based on non-combustion technologies (heat pumps, waste heat recovery and geothermal). Increased use of renewable energy by passenger vehicles is driven mainly by a biofuel obligation and, to a lesser extent, EV adoption. The government sees low-emission hydrogen and hydrogen-based fuels as better solutions than direct electrification for heavy road transport, maritime transport and aviation. There is also a notable push to increase biomethane production for use in transport and heating.

Finland's overall support system for renewables is transitioning away from operation subsidies paid based on the amount of renewable energy generated to investment subsidies paid on successful completion of projects that focus on commercialisation and cost reduction of new technologies and small-scale distributed renewable energy projects. Finland's feed-in tariff (FIT) for renewable electricity and heat production was closed for new projects between 2017 and 2021 (depending on the technology). One auction awarding a feed-in premium (FIP) for renewable generation was conducted in 2018, with all subsidies going to onshore wind projects. No additional auctions awarding FIP support will be conducted, as the government indicates that market forces are driving sufficient renewables deployment.

Going forward, the government expects that most projects based on mature technologies will be developed on a market basis and aims to provide a supportive market environment encouraging the needed investments. The government is investigating options to expand existing financing solutions, such as commercial instruments minimising risk, and to create new financial instruments. A new Government Decree on General Terms of Granting Energy Aid reflecting the focus on investment subsidies for new technologies came into effect in early 2023. EUR 200 million in 2023 and a planned total of EUR 150 from 2024 to 2025 will be allocated to demonstration projects for new technologies, with additional funding at a lower level for small-scale renewable energy projects based on mature technologies and for energy efficiency projects.

Energy Aid is the main programme delivering investment subsidies. It provides grants to projects for renewable energy (electricity, heat and fuels), energy efficiency, research and commercialisation of new technologies, and implementation of voluntary energy audits. Priority is given to projects involving new technologies that so far have limited deployment in Finland and that can play an important role in achieving long-term energy and climate

goals. To qualify for aid, a project must have a cost of at least EUR 10 000 and be undertaken by a community or a company that is not a farm, is not active in fisheries or aquaculture, is not a housing company or residential property, and does not receive other funding from the state budget (Business Finland, 2023).

The share of investment costs covered by the Energy Aid grant for conventional technologies ranges from 10% to 25% for renewable energy and energy efficiency projects and 40-50% for energy audits. Up to 40% of the costs may be covered for investment projects involving new technologies. Grants are available for renewable energy projects using biogas (25% of project costs); solar thermal and small wind power (20%); solar PV, heat pumps, landfill gas and small co-generation (15%); and wood fuel heating (10%). Projects must become operational to receive the grant funding.

Aid applications are primarily processed by Business Finland. Since 2019, funding has been available for large-scale projects (eligible costs exceeding EUR 5 million for mature technologies and EUR 1 million for new technologies). Funding for large-scale projects is awarded by the Ministry of Economic Affairs and Employment based on a competitive process that assesses demonstration value, feasibility, energy impacts and cost-effectiveness. From 2018 to 2021, Energy Aid provided a total of EUR 365 million in grants (EUR 217 million for renewables, EUR 102 million for energy efficiency and EUR 45 million for energy storage), which equalled around 18% of Finland's public funding for energy investments (Table 4.1). From 2018 to 2021, the largest amount of support went to biomethane in transport (EUR 40.2 million), hydrogen (EUR 40.2 million), solar PV (EUR 37.5 million), transport biofuels (EUR 34 million) and heat pumps (EUR 24.4 million). The Energy Aid programme has a total budget of EUR 200 million for 2022-26.

In 2022, Finland introduced an *ad hoc* aid scheme that will award grant funding to projects that support Finland's pandemic recovery and resilience plan. This scheme will award investment grants using an award system similar to that of the Energy Aid programme but with funding from the EU Recovery and Resilience Facility. Finland's recovery and resilience plan will provide at least EUR 154 million for new energy technology (offshore wind, solar PV, biogas, renewable transport fuels, geothermal and heat recovery), EUR 154 million for new energy infrastructure such as transmission and distribution infrastructure (including waste heat), EUR 47.5 million for electrification and decarbonisation of industry, and EUR 127 million for low-emission hydrogen and CCUS. Significant additional funding for renewables will be awarded through the *ad hoc* scheme once the EUR 210 billion in REPowerEU funding has been allocated between EU member states (see Chapter 1).

REPowerEU also focuses on rapidly scaling up the production of biomethane and low-emission hydrogen to reduce reliance on Russian natural gas. Finland's NCES places a strong emphasis on scaling up the production of hydrogen (see Chapter 5) and biomethane (mainly to increase the share of renewable energy in transport).

Table 4.1 Energy Aid grant funding, 2018-2021

Grants (EUR million)	2018	2019	2020	2021	Total
Renewable heating	**6.9**	**11.1**	**13.4**	**22.2**	**53.6**
- Biomass heating plants	2.3	1.6	0.4	0.3	**4.6**
- Heat pumps	0.9	1.0	4.6	17.9	**24.4**
- Biogas	0	5.2	2.0	3.4	**10.6**
- Solar thermal	1.3	0	0	0	**1.3**
- Geothermal	0	0	6.4	0.6	**7.0**
- Other	2.4	3.3	0	0	**5.7**
Renewable electricity	**9.0**	**16.1**	**6.6**	**18.1**	**49.8**
- Hydropower	0	2.9	0	0	**2.9**
- Wind (including offshore)	0	0	0	0.02	**0.02**
- Biogas	0	0	0	0.2	**0.2**
- Landfill gas	0.7	0	0	0	**0.7**
- Solar photovoltaics	8.3	13.2	6.6	9.4	**37.5**
- Other	0	0	0	8	**8.4**
Renewable fuels	**17.1**	**6.9**	**50.2**	**39.9**	**114.1**
- Biomethane (transport)	17.1	6.9	16.2	0	**40.2**
- Biofuels	0	0	34.0	0	**34.0**
- Hydrogen	0	0	0	39.9	**39.9**
Renewable energy total	**33.1**	**34.1**	**70.3**	**80.2**	**217.5**
Energy efficiency total	**20.3**	**18.0**	**32.5**	**31**	**102.0**
Energy storage total	0	0	0	45.3	**45.3**
Energy Aid total	**53.3**	**52.0**	**102.8**	**156.8**	**364.9**

The government is also working to ensure a transparent and timely permitting process for new renewable energy investments and sees this as key to meeting the carbon neutrality target. In June 2021, Finland implemented RED rules that require final permitting decisions in less than two years for electricity projects of at least 150 kW and one year for smaller projects (the maximum duration may be extended by one year under extraordinary circumstances). Finland's NCES aims for licensing processes of priority investments to have a maximum duration of one year and has taken several steps to support this goal. In 2021, Finland established a "one-stop shop" for environmental permits, designated a contact point to guide developers of renewable energy projects and published a manual of administrative procedures for developers. It has also dedicated some funding from the EU Recovery and Resiliency Facility to provide more resources to national permitting authorities, municipalities and regional councils to speed up permit and planning procedures.

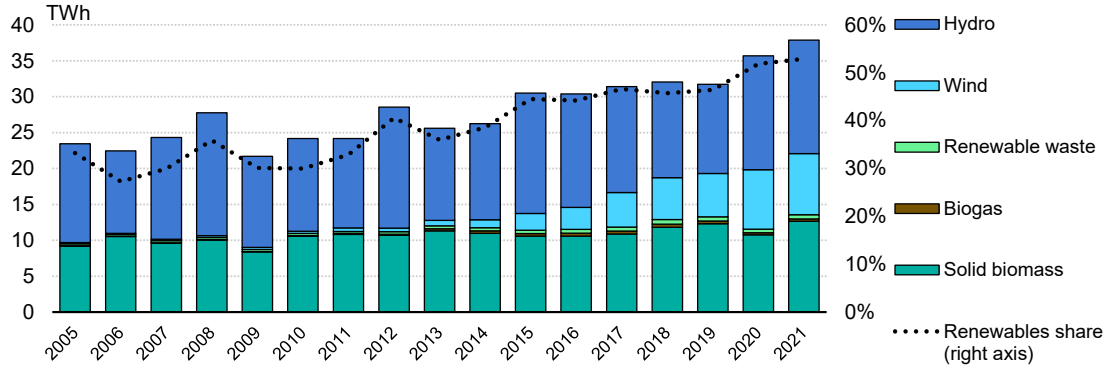
Renewable energy is also supported through a guarantee of origin system. Guarantees of origin are required to show compliance with renewable energy targets, to receive subsidies and for companies to market energy products as renewable. The programme aims to encourage consumers to choose suppliers sourcing their electricity, heating and cooling, and gas from renewable energy. Electricity products generated entirely with renewable

energy are marked with a green leaf in the Energy Authority's online tool, allowing consumers to compare different retail electricity offers. Guarantees of origin are granted for electricity generated with renewables, nuclear power and efficient co-generation, and renewable gasses (biomethane, hydrogen, electro-fuels), and for heat and cooling produced with renewables or waste energy. Finextra, owned by the electricity transmission system operator (TSO) Fingrid, is responsible for the electricity guarantee of origin register. The gas TSO Gasgrid Finland Oy is responsible for the gas and hydrogen guarantee of origin register. The Energy Authority acts as the administrator of the guarantee of origin register for heating and cooling and supervises compliance with the Guarantee of Origin Act (Energiavirasto, 2022a).

Renewables in electricity

From 2011 to 2021, Finland experienced a relatively steady increase in renewable electricity generation, which grew from 24 TWh to 38 TWh, and from 33% to 53% of total generation (Figure 4.4). Most of this growth came from increased wind generation (0.5 TWh to 8.5 TWh). Hydro generation is generally the largest source of renewable generation but varies notably depending on water availability. From 2011 to 2021, hydro generation ranged from a minimum of 12.4 TWh in 2019 to a maximum of 16.9 TWh in 2012. Generation from bioenergy (mainly forestry biomass, with small shares of biogas and renewable waste) is the second-largest source of renewable generation and also experienced notable annual variations but increased overall from 11 TWh in 2011 to 14 TWh in 2021. The share of generation from bioenergy was 19% in 2021, compared to an IEA average of 3% in 2020. Finland has very little generation from solar PV, just 0.3 TWh in 2021.

Figure 4.4 Renewable energy in electricity generation in Finland, 2005-2021



Source: IEA (2022).

Finland is pushing for much higher generation from renewables, mainly from wind and solar PV. The NCES estimates that wind capacity will grow to at least 6.8 GW by 2030 (compared to 3.6 GW in 2022) and that PV capacity will reach at least 5.3 GW by 2030 (compared to around 1 GW in 2022). The government expects most of the capacity to be deployed on a market basis. Investment subsidies are available mainly for projects demonstrating new technologies or deploying small-scale distributed renewables. Finland is still providing operational subsidies to renewable electricity projects through a FIT and FIP, but these subsidies are no longer available for new projects.

Finland stopped offering the FIT for wind generation projects commissioned after 1 November 2017, for biogas and wood fuel power plants commissioned after 1 January 2019, and for wood chip power plants commissioned after 15 March 2021. The FIT will be paid to qualifying projects commissioned before these dates for 12 years from the date the project was cleared by the Energy Authority. The FIT provides payments in addition to the market revenue generators earn from electricity sales. Projects receiving other subsidies are not eligible for the FIT.

The FIT payment is equal to a target price (83.50 EUR/MWh) minus the three-month average of the hourly electricity price in the joint Nordic electricity market (Elspot price). If the electricity price three-month average is less than 30 EUR/MWh, the FIT is set at 53.50 EUR/MWh (the target price minus 30 EUR/MWh). Co-generation plants that are connected to the electricity grid and meet certain requirements for efficiency and sourcing of biomass can receive a heat bonus in addition to the FIT of 50 EUR/MWh for biogas and 20 EUR/MWh for forestry biomass. The FIT is funded directly from the state budget (Energiavirasto, 2022b). From 2019 to 2021, FIT payments totalled EUR 754 million, with almost 98% going to wind generation (Table 4.2). Because of high electricity costs, FIT payments in 2022 were very low, with just EUR 2.4 million appropriated. For 2023, the combined budget for the FIT and FIP is EUR 135 million (almost all of this is expected to go to the FIT).

Table 4.2 Feed-in tariff payments in Finland, 2019-2021

Payments (EUR million)	2019	2020	2021	Total
Wind generation	214	322	198	734
Wood chips	12	0.3	0.2	12.5
Wood fuels	0.1	0.1	0.1	0.3
Biogas	2.2	1.9	2.8	6.9
Total	229	324	201	754

One auction awarding a FIP for renewable generation was conducted in 2018. No additional FIP auctions will be conducted. The 2018 auction offered support for 1.4 TWh of generation from wind, solar, biomass, biogas and wave power projects. In 2019, support was awarded to seven onshore wind projects for 1.36 TWh of generation (no other technologies were selected). The FIP bids from the winning projects ranged from 1.27 EUR/MWh to 3.97 EUR /MWh. The FIP is paid for 12 years on top of market revenue. If the three-month market price of electricity exceeds 30 EUR/MWh, the FIP is reduced on a sliding scale. The FIP is not paid when the market price is higher than 30 EUR/MWh plus the project's FIP bid. The FIP is funded directly from the state budget. Under these rules, no FIP payments were made in 2019 or 2020 and were just EUR 20 000 in 2021. No FIP payments were made for 2022 because of high electricity prices. The government has estimated that the FIP will cost a total of EUR 42 million over 12 years (or less, depending on market prices).

With the removal of operation subsidies, long-term power purchase agreements (PPAs) are becoming a driver for new renewable energy projects in Finland. The first announcement of a merchant project without any subsidy support was made in May 2018. This project used a PPA to support a 21 MW wind project. Since then, the use of PPAs to support renewable projects has accelerated and they are being used by private companies

and municipal energy utilities. The number of signed PPAs reached a record level in 2022 and is expected to expand. However, larger wind farm project developers have stated that investment decisions are no longer fully dependent on a long-term PPA but that many projects can be profitable by selling on the open market (Chambers and Partners, 2022).

The government is promoting the deployment of wind generation by allocating additional funding for national wind power surveys, studies to speed up planning, and permitting by municipalities and regional councils. In 2022, an additional EUR 1.5 million in funding was provided to support these efforts. A property tax must be paid to the municipality where the wind project is located. Wind projects deployed in the Perämeri area (approximately 2 425 km^2 located in the municipalities of Hailuoto, Lumijoki, Raahe, Siikajoki and Pyhäjoki) must pay a radar compensation fee as well, which funds radar upgrades to offset the impact of the wind turbines.

Wind generation projects deployed anywhere in Finland require approval from Finland's Defence Forces to ensure that they do not interfere with military radar systems. Historically, the Defences Forces rejected around 20% of submitted projects; however, very few projects are approved in eastern or southern Finland near the Russian border (Finnish Wind Power Association, 2021). As a result, most wind generation is in western Finland. This has resulted in concerns about grid constraints on wind generation. Municipalities outside of western Finland have also noted that they are excluded from the notable property tax revenue charged to wind generation. The government has indicated it is developing a plan to ensure wind power development can continue at the desired rate. However, since the Russian invasion of Ukraine, the Defence Forces have been rejecting a higher share (around 33%) of submitted wind projects (YLE, 2022).

Finland aims for offshore wind to play a major role in achieving its climate goals. However, there has been only limited deployment of offshore wind. Finland's only offshore wind farm (Tahkoluoto) started operations in 2017. It only has a capacity of 44 MW. Since 2017, no other offshore wind projects have been deployed. In July 2022, the government authorised Metsähallitus to lease two areas for offshore wind development. Metsähallitus is a state-owned company responsible for Finland's public lands and waters. One lease aims to expand the existing Tahkoluoto offshore wind farm to a total capacity of 500-900 MW. The second lease is for the new Korsnäs offshore wind project. In December 2022, Metsähallitus announced that it would partner with Vattenfall to develop the project aiming for a capacity of 1.3 GW generating around 5 TWh per year. The project is expected to be operational in the early 2030s and will cost between EUR 2 billion and EUR 3 billion (Vattenfall, 2022). Going forward, all new leases in public waters will be allocated through the auction system.

In December 2021, the government approved a competitive auction process to lease areas for offshore wind projects in the public waters controlled by Metsähallitus. The first auctions are expected to take place in 2023 or 2024. Metsähallitus is responsible for determining which areas will be leased based on a balance of wind resource quality, environmental impacts and competing uses. The government has the right to approve the areas to be leased and the terms and conditions of the auction, including the option to set a minimum lease price. The winner of an auction is given exclusive rights to develop a specific area and must pay the agreed lease price, the cost of subsea cables and other offshore infrastructure to connect offshore wind farms to the onshore grid and the standard grid

connection fee charged to all generators based on the voltage of the connection. The electricity TSO is responsible for any costs needed to upgrade the onshore grid to receive offshore wind generation.

The auction will not offer any financial support and the NCES notes that the government does not consider it appropriate to grant extensive aid for offshore wind projects. It does, however, expect growth based on market conditions. The NCES notes that aid is considered necessary for the first offshore wind demonstration projects, but no details are given on what is considered a demonstration project. In Mach 2022, EUR 30 million in investment subsidies from Finland's recovery and resilience plan were awarded to an offshore wind demonstration project in Tahkoluoto with a capacity of around 30 MW. The government also aims to reduce the property tax for offshore wind turbines compared to onshore turbines.

The government also wants offshore wind generation deployed in the Finnish exclusive economic zone, which is located outside Finland's public waters managed by Metsähallitus. Developing wind generation in the exclusive economic zone would require legislative amendments. Current legislation does not adequately consider the special characteristics of offshore wind. Most significantly, it does not provide solutions in a situation where more than one operator is interested in the same sea area. The government is already taking steps to promote offshore wind projects in the exclusive economic zone. In January 2022, two private companies (OX2 and Wpd, currently Skyborn Renewables) received exploration permits for offshore wind projects in the Gulf of Bothnia's exclusive economic zone. The permits enable more extensive seabed exploration (Baltic Wind, 2021). In December 2022, the government granted the private company Eolus research permits to conduct environmental impact assessments and seabed investigations for the two offshore wind projects in the Finnish Bothnian Sea that aim for a total capacity of 3.5 GW generating 14-16 TWh per year. The research work is expected to start in 2023 (Maritime Executive, 2022). At the same time, the government granted research permits to the private company Ilmatar Energy for two offshore wind projects within the Finnish exclusive economic zone.

There is only limited deployment of solar PV in Finland, with the potential limited by the strong seasonality of the solar resource. The government does, however, support increased solar PV deployment. Solar PV received one of the highest levels of funding from the Energy Aid programme, with a total of EUR 37.5 million from 2018 to 2021. In addition, the government's efforts to boost small-scale distributed generation will help to support PV deployment. Support in this area includes a tax exemption for small-scale electricity generation and a tax credit for household expenses for installing electricity generation systems in detached houses. There are indications that the development of large-scale solar projects is starting. An international consortium is working to finalise permitting for a 500 MW solar project in southern Finland (Bellini, 2021). The Energy Authority's most recent market report shows that from 2018 to 2021, the number of household consumers with a network service contract that includes partial self-generation has increased from 13 200 to 37 100.

Support for energy communities will also likely boost solar PV deployment. In 2020, the government adopted a decree that enables sharing electricity generation in energy communities and the introduction of hourly net metering. An amendment to the Electricity Market Act adopted in August 2021 allows for energy communities that cross property

boundaries. The government also aims to support distributed generation by making it easier for SMEs to sign PPAs, with solar PV being one of the attractive options for such PPAs.

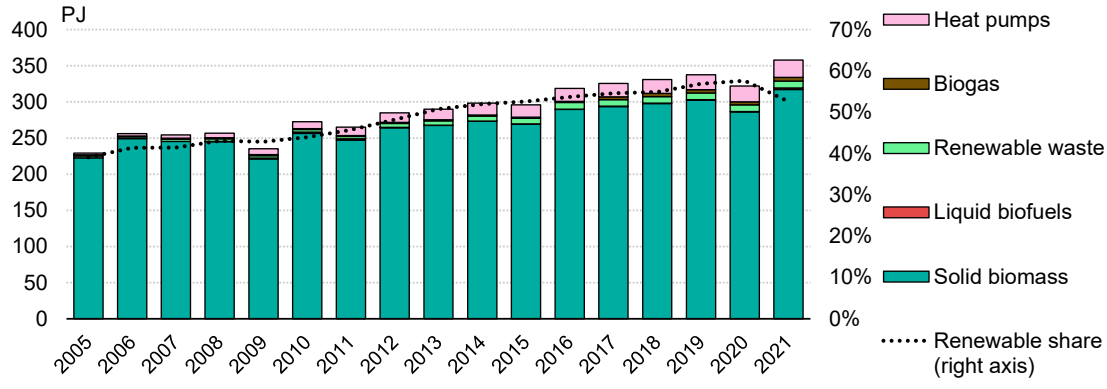
In 2021, Business Finland published a Solar Cluster Study, which concluded that Finland is an attractive market for solar PV, with strong local technological solutions and service providers. However, it noted a need to form a more collaborative solar cluster to stimulate investment in large-scale solar PV installations (Business Finland, 2021).

Finland is also taking steps to expand the capacity and increase the flexibility of its electricity grid to ensure that it can support the desired rapid expansion of renewable generation. This includes investments in new lines and substations and support for rolling out smart meters and deploying energy storage. There are also efforts to ensure the electricity market regulations provide a clear business case driving investments in renewable generation (see Chapter 6).

Renewable heating and cooling

From 2011 to 2021, renewable heating and cooling increased from 265 PJ to 358 PJ and from 46% to 58% of total heating and cooling demand (Figure 4.5). This growth was mainly driven by increased heating from forestry solid biomass (247 PJ to 317 PJ) and some increase in heating from heat pumps (12 PJ to 24 PJ), renewable waste (3.6 PJ to 9.6 PJ) and biogas (1.1 PJ to 5.0 PJ). Finland has one of the highest uses of solid biomass for heating in the IEA. Solid biomass is used extensively for heating in buildings and industry. In 2021, solid biomass accounted for 89% of total renewable heating demand. The solid biomass used for energy in Finland comes mainly from wastes and residues generated by commercial forestry operations. This biomass is primarily burned in co-generation plants that provide heat to industrial sites and buildings through large district heating networks. In 2021, biomass covered 44% of district heat production (see Chapter 3).

Figure 4.5 Renewable energy in heating and cooling in Finland, 2005-2021



Source: IEA based on data from EC (2022).

As with electricity generation, the government sees market forces as the main driver for investments in renewable heating and cooling and has phased out operational subsidies for new renewable heating and cooling projects. Investment subsidies for renewable heating and cooling projects are available through the Energy Aid programme, with a focus

on new technologies and distributed systems. Some financing programmes targeting energy efficiency improvement can also support investments in renewable heating and cooling (see Chapter 3).

Finland has a programme to replace oil-fired heating in residential buildings (in 2020, oil covered 6% of total building energy demand). It provides grants of EUR 4 000 per household to switch to heat pumps (air, ground sourced or water) or district heating and EUR 2 500 to switch to other renewable heating systems. No grants are available for switching to heating systems based on coal, natural gas or peat. The grant is awarded once the heating system has been installed. The programme started in June 2020 and has a total budget of EUR 143 million, which the government estimates is sufficient to replace around 33 000 oil heating systems (Centre for Economic Development, Transport and the Environment, 2022).

In 2021, Finland introduced a biofuel obligation for light fuel oil used in building heating, construction equipment and stationary engines. This obligation applies to retail suppliers selling over 1 million litres of light fuel oil per year, with the obligated share set at 3% for 2021 and increasing each year to reach 10% by 2028. Biofuels produced from food or animal feed only count toward meeting 2.6 percentage points of the obligated share. In July 2022, the government started a public consultation on a proposed amendment to increase the obligated share to 30% by 2030. The proposed increase is estimated to reduce emissions by an additional 0.5 Mt CO_2 (Finland, Ministry of Economic Affairs and Employment, 2022).

Fiscal policy is also used to support renewable heating and cooling. Homeowners can deduct the cost of investments in certain renewable heating and cooling systems from their income taxes. National energy taxation and the EU ETS aim to drive investments in renewable heating by increasing the cost of heating based on fossil fuels and peat compared to heating based on renewable energy (see Chapter 1). In 2022, the government lowered tax rates on electricity consumed by pumps in geothermal heating plants, and certain heat pumps and electric boilers, with the aim to further increase the attractiveness of investing in renewable heating.

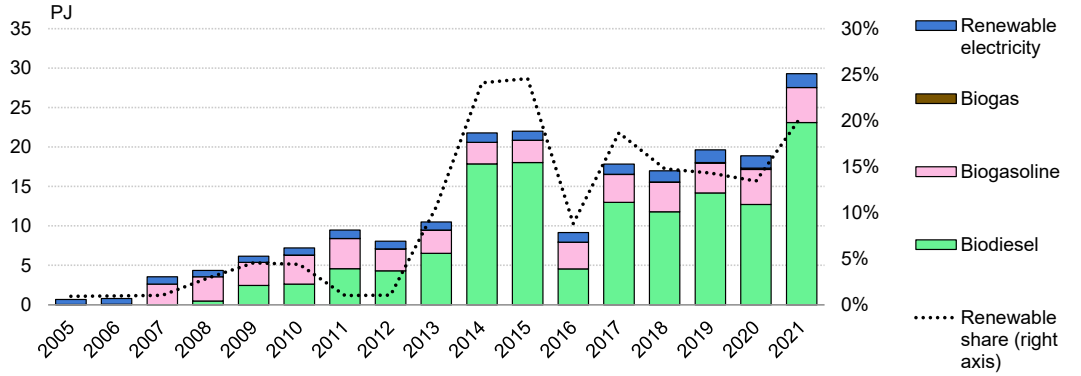
The NCES indicates that the government wants to increase the use of geothermal energy, including low-temperature geothermal for heat pumps and high-temperature geothermal for heat production. However, the NCES notes that there is little knowledge on geothermal resources or potential production volumes in Finland. The NCES also notes that the deep drilling required for resource assessment and potential use of geothermal energy requires further development of permitting and other administrative procedures, and the evaluation of risks such as earthquakes.

Renewables in transport

The share of renewables in transport has undergone substantial variations (Figure 4.6). The sharp drop in the level of biofuels in 2015 is a result of the rules of Finland's biofuels obligation. In 2015, companies notably exceeded the obligation and were able to use this as credit for the 2016 obligation, allowing them to sell a notably lower amount of biodiesel while still meeting the obligation. The share increased notably in 2021 to reach 20%. Most renewable energy in transport is covered by liquid biofuels, primarily biodiesel (83% of renewables in transport in 2021). Most transport biodiesel in Finland is hydrotreated

vegetable oil renewable diesel, but there is also a blending of some first-generation fatty acid methyl ester (FAME) biodiesel. Renewables in transport also include biogasoline[2] (16%) and small shares from renewable electricity (6.4%) – mainly for rail – and biogas (0.8%).

Figure 4.6 Renewable energy in transport in Finland, 2005-2021



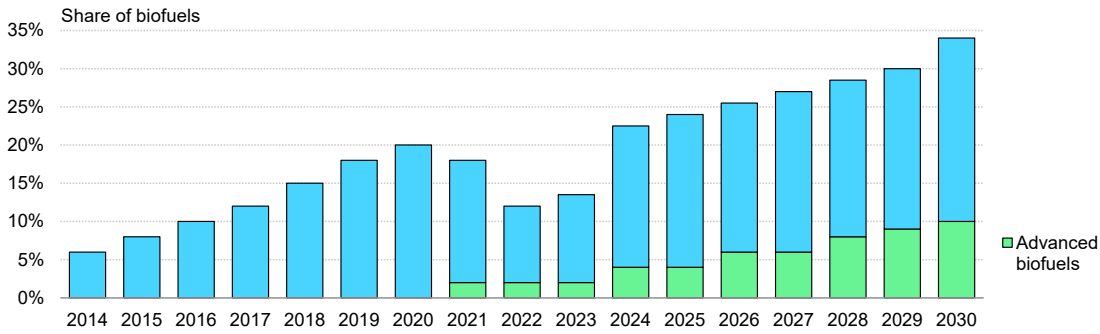
Source: IEA based on data from EC (2022).

The policies and measures to support renewables in transport are defined in the NCES and the Roadmap to Fossil-Free Transport. Together these documents indicate that liquid biofuels will continue to play a key role in reducing transport oil demand through at least 2030. In the longer term, Finland aims for a transport system where passenger vehicles and rail are almost entirely electrified, while heavy road transport, marine transport and aviation are powered by a mix of liquid and gaseous biofuels, hydrogen, electro-fuels, and some electrification. Finland's main measure supporting renewables in transport is a biofuel obligation. There is also support for the electrification of transport (see Chapter 3) and the introduction of renewable hydrogen (see Chapter 5) and biomethane.

The biofuel obligation requires retail suppliers of gasoline and diesel transport fuels to reach a share of biofuels by energy content in their annual sales (Figure 4.7). If a supplier exceeds the obligated level of sale in a certain year, then the excess sales (up to 30% of the obligation for that year) can count towards meeting the obligation for the following year. Suppliers are subject to a fine of 0.04 EUR/MJ if they fail to meet the overall obligated share and a fine of 0.03 EUR/MJ if they fail to meet the obligated share for advanced biofuels. The biofuels obligation requires that the obligated share reach 20% by 2020 (this was achieved using credits from 2019). In 2019, the obligation was updated with a requirement that the obligated share reach 30% by 2030 and a sub-requirement that the obligated share of advanced biofuels reach 10% by 2030. These are among the most ambitious biofuels targets in the IEA.

[2] Biogasoline includes bioethanol, biomethanol, bioETBE and bioMTBE that are blended into gasoline.

Figure 4.7 Obligated share of biofuels in annual transport fuel sales in Finland, 2014-2030



Source: EC (2022).

Under EU and national rules, the energy content of advanced biofuels (produced from waste, residues, or inedible cellulose or lignocelluloses) is counted as double in relation to the obligated share. Since 1 January 2021, biofuels produced from food or animal feed can only count toward meeting 2.6 percentage points of the obligated share. The biofuel obligation can also be covered with biomethane (since 1 January 2022) and electro-fuels (since 1 January 2023).

In April 2022, the government announced a package of measures intended to reduce the high energy costs resulting from Russia's invasion of Ukraine. This included a reduction in the biofuels obligation for 2022 and 2023 (biofuels are typically more expensive than gasoline and diesel). To ensure the obligation is still in line with Finland's energy transition goals, the obligated share for 2030 was increased to 34% (the 2030 obligated share of 10% for advanced biofuels was not changed) (McGarrity, 2022).

Finland also supports renewables in transport through a range of measures to increase the adoption of EVs in combination with measures to increase electricity generated by renewable energy. These include a target for approximately 25% of the passenger vehicle fleet to be EVs by 2030, purchase subsidies and reduced taxes and fees to lower the cost of EVs, and investment subsidies for the deployment of EV charging infrastructure. There are also targets for full electrification of Finland's rail network (see Chapter 3).

Finland is pushing to increase the use of biogas in the transport sector. The Roadmap to Fossil-Free Transport indicates that Finland has resources to support 16 TWh per year of biogas production and includes goals for the use of 2.5 TWh of biogas in transport by 2030 and 5-6 TWh by 2045. The road map estimates that 2.5 TWh of biogas would enable 100 000-130 000 passenger vehicles and 6 000 heavy-duty vehicles to be powered with 100% biogas (in 2021, there were around 3.2 million vehicles in Finland) (Statistics Finland, 2023). Support for increased use of biogas in transport includes the addition of biogas in the biofuel mandate and investment aid for agriculture and rural enterprises related to biogas plants. From 2018 to 2021, the largest amount of support granted by the Energy Aid programme went to projects related to biomethane in transport (EUR 40.2 million).

There are also subsidies for compressed natural gas (CNG) and liquefied natural gas (LNG) vehicles and refuelling stations, which are intended to both reduce reliance onimported oil and encourage the purchase of CNG and LNG vehicles that could be powered with biogas. In the near term, such vehicles would likely be powered mostly by imported natural gas (see Chapter 8).

Assessment

Finland's energy policy aims to significantly increase the use of renewable energy in all sectors. The NCES sets a 2030 target and supporting measures for the share of renewable energy in gross final energy consumption (51%), electricity generation (53%), heating and cooling (61%), and transport (45%). Achieving these targets requires accelerating the pace and scale of renewable energy project deployment. While the current permitting granting processes appear relativity transparent and efficient, many projects still face long delays. The longest delays come from appeals that seek to block the issuing of permits in combination with a lack of resources and staff at the courts and government agencies that process these appeals. Renewable projects can also require permitting of associated infrastructure (electricity, roads, water supply, etc.), which can also cause notable delays.

The government prioritises establishing a faster permitting process and has dedicated some funding from the Recovery and Resilience Facility and the national budget to key entities involved in approving projects and processing appeals. However, the Recovery and Resilience Facility is temporary and the total funding, including national funding, does not reflect the desired scale of deployment of renewable projects.

The government should ensure that permitting authorities at all levels have adequate staffing and capacity to ensure timely processing of permits and should establish a one-stop shop for all approval and appeal processes. It should also facilitate consultation (ahead of permitting processes) and arbitration as an alternative to legal challenges.

The government expects most renewable projects to be deployed on a market basis. Between 2019 and 2021, Finland stopped providing operational subsidies to new renewable projects. Investment subsidies are available mainly for projects demonstrating new technologies or deploying small-scale distributed renewables. The government should closely monitor whether this approach is delivering fair competition and lower costs, and driving the desired level of deployment. The government may need to examine options for new financing instruments to ensure renewable project developers have access to sufficient capital at attractive rates.

Renewables in electricity

Onshore wind is the fastest-growing source of renewable generation. The TSO will need to ensure that the grid is developed rapidly enough to accommodate the growing number of wind projects. This requires timely permitting by several layers of government. The demands on the grid could be reduced by expanding wind generation in eastern Finland, where it is currently limited by constraints related to military radar. Finland has appointed an expert to develop solutions that would allow wind farm deployment in the east without impacting radar capabilities. The government could learn from Baltic and Nordic neighbours on solutions for onshore wind power compatibility with military radar. For

example, Finland can look to the recent experience in Estonia, which has found a solution to deploy new radar systems that maintain security while removing restrictions to wind power on 20% of its land area.

Finland aims for offshore wind to play a major role in achieving its climate goals. Thus far, Finland has only one small (44 MW) offshore wind farm, which started operations in 2017. Finland is developing a competitive tender process to lease areas for offshore wind projects in territorial waters. The auction will not offer any financial support, and developers must cover the cost of offshore infrastructure to connect projects to the onshore grid. The TSO will cover any costs needed to strengthen the onshore grid to enable the connection.

The government also wants offshore wind generation deployed in the exclusive economic zone outside Finland's territorial waters. This requires legislative amendments. In January 2022, the government granted permits that enable more seabed exploration as a first step in the potential development of offshore wind farms in the exclusive economic zone.

Notable challenges remain to large-scale offshore wind deployment. To address these challenges, the government needs to prepare an offshore wind power road map that establishes a clear regulatory regime and ambitious targets and timelines for deployment. Incentives should be considered if needed.

As part of this process, the government needs to quickly amend legislation to define the permitting and leasing authority and allow granting of exclusive rights for offshore wind projects in the exclusive economic zone. In addition, the role of Metsähallitus needs to be clarified; there seems to be a conflict of interest, with it acting as a project developer while also being responsible for offshore wind leases. It would be preferable for Metsähallitus to focus on issuing leases promptly and transparently, which could require increased staffing and capacity and leave project development to private companies. The government should also consider selecting a single permitting and leasing authority for all of Finland's waters, including territorial waters and the exclusive economic zone.

In addition, the offshore leasing process should be updated to reflect Finland's strong climate ambitions. The government should set an ambitious GW target for the medium and long term and develop a competitive tender system with a clear timetable, transparent and timely posting of auction requirements and processing of auction bids. The leasing process can focus on deployment areas identified in the Maritime Spatial Plan 2030. The auctions should include measures to speed up permitting, such as the government conducting basic environmental assessments of the areas to be auctioned.

The government has indicated that subsidies may be needed for the first offshore wind demonstration projects and some funding for offshore wind was made available through the Recovery and Resilience Facility. However, it remains unclear if any additional funding will be given to offshore wind and under what conditions. The government should engage with offshore wind experts to determine if subsidies or other incentives (e.g. development of offshore grid by the TSO) are needed to kickstart offshore wind development in Finland. For example, the icing in Finland's seas has been noted as a potential technical challenge, but Finland's only offshore wind farm and several farms in Sweden can offer insights on how to address issues posed by sea ice. If demonstration-scale projects are needed to test challenges to conditions specific to Finland, these projects should be undertaken as soon as possible to avoid long delays in moving to commercial-scale deployment.

Given the very limited offshore wind deployment to date, some level of support may be needed. For example, Sweden has been able to progress much faster in deploying offshore wind by covering the cost of the offshore grid infrastructure. Poland, which is developing its first offshore wind farms, offers subsidies to encourage the first projects to come online sooner. The government needs to clarify whether financial or other support is needed in early auctions and how it will be offered.

The government should also start developing an Offshore Wind Industrial Strategy that supports the development of ports, local supply chains and the labour force needed to ensure sustained large-scale deployment and maximise the domestic economic benefits. This strategy has been highly successful in Denmark and the United Kingdom and is being implemented in Poland.

In addition, Finland should engage with neighbouring countries on the potential for developing linked and meshed offshore electricity grids that can support both an increase in offshore wind deployment and interconnection capacity.

The government aims to increase Finland's limited deployment of solar PV. Solar PV received one of the highest levels of funding from the Energy Aid programme. The government has also adjusted a variety of regulations to encourage the deployment of distributed solar PV.

Solar PV deployment has been doubling in the last few years and is expected to increase at least fivefold between 2022 and 2030. High electricity prices are currently driving residential and industrial sectors to increase their investments in solar energy. However, challenges remain to large-scale deployment. Solar is a relatively new sector for Finland, and the government needs to step up efforts to ensure there are enough trained installers and that robust supply chains are in place for panels and other system components. Also, the government needs to ensure that the capacity for approving and permitting projects at a variety of scales (rooftop residential to utility scale) is in place. Deployment of solar has especially a promising potential in eastern Finland, where defence radar concerns limit the deployment of wind power.

PPAs have been playing a prominent role in driving the deployment of renewable electricity projects but have mainly been used by large companies. The government should examine if there are notable barriers to SMEs taking advantage of PPAs and develop tools to help overcome them, for example with information campaigns and PPA templates.

Finland is taking steps to expand the capacity and increase the flexibility of its electricity grid to ensure it can support the rapid expansion of renewable generation. However, there is still only a limited role for energy storage and distributed demand-side response (DSR). Given Finland's full roll-out of smart meters, the government should consider amending its support scheme for distributed small-scale PV to focus on solar PV plus battery storage systems. This would reduce the burden on the distribution grid while driving the potential for DSR. In addition, legal and regulatory changes are needed to allow aggregators and energy service companies to encourage distributed generation and storage and to use these systems to their full potential.

Revenue sharing and better co-operation with local communities would help increase the social acceptance of renewable energy projects and supporting infrastructure, helping to speed up the permitting and approval process.

Renewables in heating and cooling

The government sees market forces along with the EU ETS and national energy taxation as the main drivers for investments in renewable heating and cooling and has phased out operational subsidies for new renewable heating and cooling projects. Investment subsidies and other funding are available for new projects.

In the near term, Finland sees forest biomass as the key fuel to meet heating demand while reducing the use of fossil fuels and peat for heating. Most heating from biomass currently comes from forestry industry waste used in high-efficiency co-generation plants. There is relatively little use of high-value wood for energy. Finland has large forest resources and places a focus on the sustainable use of wood that allows forests to serve as large carbon sinks. Strong efforts are needed to ensure that biomass use remains sustainable and accounts for climate impacts on forests. This is especially critical given that Russia is no longer exporting wood chips to Finland and because increased use of forestry biomass is needed to offset the rapid decline in the use of peat for heating.

There is also notable direct use of biomass for heating in individual residential systems and saunas. The government needs to ensure this heating is provided through efficient modern stoves that limit local air pollution. It should also take steps to limit the use of individual biomass heating systems, with a focus on replacing them with heat pumps and electrification.

In the longer term, Finland aims to transition most heating demand to non-combustible options for both district heating and individual systems. Finland has already made notable progress on the electrification of heating and has recently taken steps to accelerate this trend. The tax rate of electricity used in large-scale heat pumps and electric boilers has been reduced to the lowest level allowed under EU regulations, and support has been provided to deploy thermal energy storage projects. Finland should keep building on its leadership in these areas and see what steps can be taken to accelerate non-combustible heating options, especially thermal storage, which can play a critical role in reducing peak heating demand and supporting more flexible and cost-effective operation of both district heating networks and the electricity system.

Renewables in transport

The government indicates that liquid biofuels will continue to play a key role in reducing transport oil demand through at least 2030. Finland's main measure supporting renewables in transport is a biofuel distribution obligation. In addition, biofuels are taxed at a lower rate than fossil fuels to encourage their use.

Finland also supports renewables in transport through a range of measures to increase the adoption of EVs. These include a target for 25% of the passenger vehicle fleet to be EVs by 2030, purchase subsidies (procurement subsidy for electric passenger cars ending from the beginning of 2023), reduced taxes and fees to lower the cost of EVs, and investment subsidies for the deployment of EV charging infrastructure. Finland also aims for rail transport vehicle-kilometres to be performed in 2050 almost 100% by electricity.

Given Finland's low-carbon electricity generation, the government should increase the priority for electrifying transport. The EU Recovery and Resilience Facility provides a large but short-term boost in financing EV charging infrastructure. The government should have a long-term vision on building out EV charging infrastructure that is backed with stable

funding. In addition, more effort is needed to encourage smart charging so that EVs are charged at times that limit peak demand and maximise the uptake of low-carbon generation. Increased electrification of passenger transit would also allow biofuels to be directed to harder-to-abate areas like freight trucks.

In the longer term, Finland aims for a transport system where heavy road transport, marine transport and aviation are powered by a mix of liquid and gaseous biofuels, hydrogen, electro-fuels, and some electrification. In line with this, Finland is pushing to increase the use of biogas in the road transport sector. The Roadmap to Fossil-Free Transport indicates that Finland has resources to support 16 TWh per year of biogas production and includes goals for the use of 2.5 TWh of biogas in transport by 2030 and 5-6 TWh by 2045. The government should closely monitor the development of the biogas sector and take steps as needed to see that it develops in a rapid and sustainable manner.

Marine transport and aviation are two important subsectors of transport in which CO_2 emissions are difficult to reduce. Regarding marine transport, Finland has the longest sea-route to global markets among European countries. In aviation, pilot studies are conducted for biofuel mixing, but cost-efficiency constitutes a problem. Therefore, there is a need in the medium and long term to support the use of cleaner fuels in those transport modes. This could best be achieved by pilot projects by the private sector and replication of the results. The government can play a co-ordinating role.

Recommendations

The government of Finland should:

- ☐ Prepare an offshore wind power road map that establishes a clear regulatory regime and ambitious targets and timelines for deployment. Incentives should be considered if needed.
- ☐ Shorten the duration of permitting renewable energy projects and supporting infrastructure.
- ☐ Support increased deployment of energy storage to accelerate the integration of renewable energy and boost the resilience and flexibility of the electricity grid and heating networks.
- ☐ Increase the priority for electrification of transport and focus biofuels towards hard-to-abate end uses like freight transport.
- ☐ Explore solutions for wind power compatibility with military radar.

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5. Energy research and innovation

Key data

(2020)

Government energy research and development (R&D) budget: EUR 176.6 million

Energy RD&D budget as a share of GDP: 0.062% of GDP (IEA average:* 0.032%)

Energy RD&D budget per capita: 32.6 EUR/capita (IEA average: 13.5 EUR/capita)

* Average of 28 IEA member countries for which 2020 data were available.

Overview

Finland is a world-level player in energy technology innovation. In 2020, Finland ranked fourth among IEA member countries for government budget allocations on energy R&D as a share of GDP. Finland's key areas of expertise include smart grids, bioenergy (especially advanced liquid biofuels), batteries and nuclear energy (including power plants and waste management). Finland is home to several world-class research facilities and its public and private sector research entities are highly active in international co-operation on energy innovation.

The 2022 European Innovation Scoreboard[3] indicated that Finland had the second-highest performance on innovation among EU member states, with relative strengths in public-private co-publications, lifelong learning, innovative SMEs collaborating with others, information and communications technology (ICT) specialists, and enterprises providing ICT training (EC, 2022a). In 2021, Finland ranked second in the EU Eco-innovation Index, which measures EU member states' environmental innovation performance (EC, 2022b).

The government sees energy technology innovation as a key part of achieving the 2035 climate neutrality target and long-term emissions reduction targets. The NCES and other key policy documents note that increased innovation is required to support commercialisation and cost reduction of new and emerging energy technologies that are key to achieving Finland's climate goals. There is a focus on finding solutions for hard-to-abate sectors and on developing new energy technologies and services with the potential for global deployment to maximise climate benefits and promote Finland's economic competitiveness. The main goal of innovation policy in Finland is to encourage companies to renew and create sustainable and internationally competitive business with high value

[3] The European Union conducts an annual European Innovation Scoreboard to assess the research and innovation performance of EU member states and the relative strengths and weaknesses of their research and innovation systems.

added. Within the context of Finland's climate policy, there is an intent to increase Finland's "carbon handprint", or positive global climate impacts, through the export of clean technology.

The private sector accounts for most of Finland's R&D expenditure, around two-thirds in 2020, with the public funding accounting for the remainder. Most public R&D funding goes to higher education (around 66%), followed by public and private non-profit R&D entities (around 20%), and private companies (around 14%) (Finland, Ministry of Education and Culture, 2020). Government funding for overall R&D has been steadily declining since 2010. However, in 2021, Finland set a goal to increase total spending on R&D (public and private) to 4% of GDP by 2030 (versus 3% of GDP in 2021). The R&D Funding Act, which entered into force at the start of 2023, set increasing levels of annual government R&D funding to ensure that government R&D funding reaches 1.2% of GDP by 2030; this is intended to drive increased private sector R&D funding to reach the 4% goal.

Key energy technology innovation actors

The Research and Innovation Council co-ordinates the development of Finland's innovation system. It is chaired by the Prime Minister; the Ministers of Science and Culture and of Economic Affairs and Employment are vice-chairs. It also includes the Ministers of Education, Justice and the Interior, along with members from universities, public research centres and the private sector (Finland, Ministry of Transport and Communications, 2021a). The Ministry of Economic Affairs and Employment is responsible for preparing and implementing Finland's innovation policy and is a major source of public R&D funding.

The Ministry of Education, Science and Culture ensures the overall functioning of higher education and science in Finland. It plans and implements higher education and science policy and prepares related statutes, national budget proposals and government decisions. The Finnish higher education system consists of 13 universities and 22 universities of applied sciences that operate under the Ministry of Education, Science and Culture (Research Finland, 2020).

Business Finland is a public organisation established in 2018 to promote exports and the internationalisation of businesses to attract tourism, foreign investment and talent to Finland and provide financial support for innovation. It is supervised by the Ministry of Economic Affairs and Employment and manages several of Finland's key funding programmes. It provides grant and loan funding for research, product development and other business development needs, especially for SMEs. Business Finland also supports R&D undertaken by large companies in co-operation with SMEs or research institutions. It is the main source of public funding for activities aimed at demonstrating and commercialising new and emerging technologies and services (Business Finland, 2021).

The Academy of Finland is a government agency within the Ministry of Education, Science and Culture. It provides grant funding in competitive calls for scientific research, researcher training and improving framework conditions for research. It is the main source of public funding for basic research. It also provides expertise to Finnish and international scientific collaborative networks and collects and analyses data on science and scientific research. It serves the government as an expert in science policy issues. Within the Academy of Finland, the Finnish Research Infrastructure Committee is responsible for monitoring and

developing research infrastructure activities, submitting proposals on long-term research infrastructure plans, selecting infrastructure projects to be funded, and monitoring projects (Academy of Finland, 2021).

VTT is a state-owned non-profit research centre supervised by the Ministry of Economic Affairs and Employment. VTT's activities are divided into three business areas: 1) carbon-neutral solutions; 2) future products and materials; and 3) digital technologies. VTT provides innovation services (including R&D support and information) to domestic and international customers in the private and public sectors. It has several relevant facilities, including the Bioruukki, the largest bioeconomy R&D facility in the Nordic countries, and the Centre for Nuclear Safety, Finland's main public research centre for nuclear energy. VTT also has partnerships with universities. In 2021, VTT's budget was EUR 245 million (VTT Technical Research Centre, 2021).

There are 11 other public research institutes, whose mandates vary from research (both basic and applied) to additional responsibilities, such as monitoring, data collection and management, certification, and inspection. In addition, Finland's private sector plays a major role, providing the majority of technology innovation spending. Companies are also key research partners for higher education and research institutions.

Energy innovation priorities and guiding documents

Finland has strong overarching ambitions for innovation, which the NCES translates into priorities and measures for the energy sector. Finland's policy priorities for overall technology innovation are increasing the level and quality of innovation and ensuring it is aligned with the country's climate and economic development goals. A strong emphasis is placed on reversing the trend of declining R&D funding, with a goal for combined public and private R&D expenditures to reach 4% of GDP by 2030 (versus 3% in 2021). The government has indicated that this would require government R&D funding to increase from around EUR 2.5 billion (0.91% of GDP) in 2022 to EUR 4.3 billion (1.2% of GDP) in 2030, with the remaining expenditures to reach the 4% target coming from the private sector.

The National Roadmap for Research, Development and Innovation (adopted in 2020 and updated in 2021) is the main document guiding overall technology innovation policy. It details the measures to boost funding to reach the 4% goal. The road map notes that encouraging increased innovation (especially in the private sector) requires a credible long-term commitment to public funding. It also notes that the unpredictability of public funding is a weakness of Finland's innovation system. The road map introduces a new partnership model to facilitate better co-ordination between the public and private sectors through the development of innovation ecosystems and new operating models for testing, piloting and scaling innovations. The partnership model will also better group national programme financing with EU and other international funding, ensure that funding targets key growth areas and ecosystems, and is awarded on a competitive basis (Finland, Ministry of Economic Affairs and Employment, 2022).

The road map details measures to improve the quality of innovation by strengthening R&D centres and ecosystems, increasing co-operation between actors and diversifying the role of the public sector as a driver and user of innovation, and improving the international attractiveness of Finland's technology innovation environment. The road map is updated periodically to account for changes in the R&D environment and feedback from R&D actors

and other stakeholders. The first update was co-ordinated by the Ministry of Education and Culture and the Ministry of Economic Affairs and Employment in consultation with the Research and Innovation Council. The government approved the updated road map in December 2021. Implementation of the road map will be monitored and reported to the Ministerial Working Group on Competence, Education, Culture and Innovation (Government of Finland, 2022).

In line with the road map, several measures have recently been adopted or are under development to increase and ensure the transparency and long-term stability of public R&D support (with a priority on leveraging private investment) and to make private sector R&D investment more attractive, for example through an increased tax deduction.

The Strategy for National Research Infrastructures in Finland 2020-2030 (adopted in 2019) sets goals for promoting the development of Finland's research infrastructures in line with the National Roadmap for Research, Development and Innovation. Under the strategy, the Finnish Research Infrastructure Committee opens road map and funding calls for research infrastructures. The first call was completed in December 2020 and defined 29 research infrastructures as strategically significant to Finland's innovation goals over the next 10-15 years. Five of the selected infrastructures conduct energy-related R&D (Tampere University, 2020).

The NCES sets overall priorities for energy technology innovation. There is a clear focus on directing support to new and emerging technologies and services with the potential to drive emissions reductions in hard-to-abate sectors. The NCES indicates that Finland will take a technology-neutral approach to funding energy R&D with a focus on cost-effective emissions reductions and the ability to scale globally for the highest climate impact. However, there is also a focus on supporting certain technology areas where Finland has established expertise and for which there are opportunities to contribute to Finland's economic competitiveness. The NCES also notes that new legislation enabling testing environments should be examined, especially for energy markets, which are heavily regulated, limiting opportunities for R&D.

Nuclear energy is a clear technology priority and is supported by two dedicated funds that are separate from the state budget: one for nuclear energy R&D and one for nuclear waste R&D. Finland has conducted extensive R&D on nuclear fuel management and disposal and is in the process of opening the world's first deep geological repository for final disposal of spent nuclear fuel (see Chapter 7).

Bioenergy is also a priority, and several funding programmes include support for bioenergy innovation. Finland's strengths include forestry biomass and advanced biofuels. There is a focus on increasing the sustainability of bioenergy. The National Battery Strategy 2025 presents a road map for Finland to become a major player in the international battery industry. Finland has several funding mechanisms that direct money towards battery projects. Finland is also participating in EU-funded projects supporting battery technology innovation.

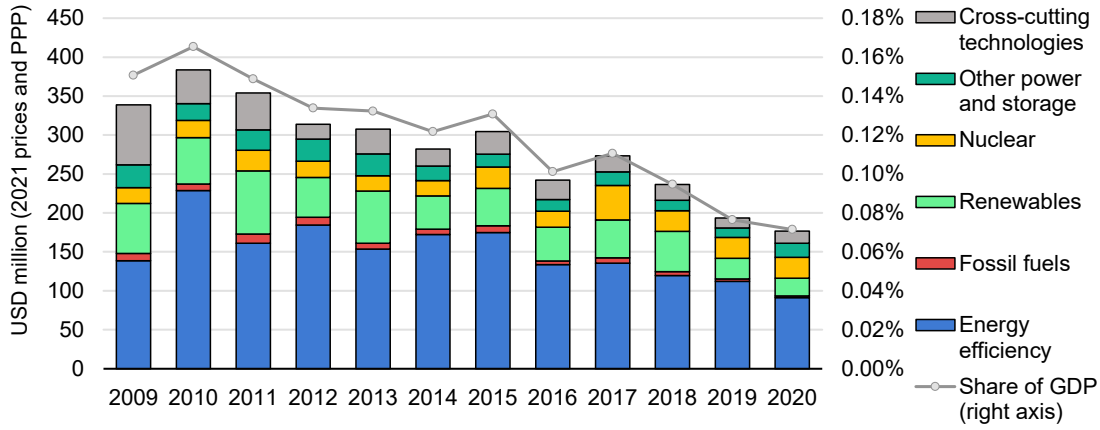
The government sees a key role for hydrogen in Finland's hard-to-decarbonise sectors and end uses, especially in certain industrial processes and heavy transport. Priority is placed on developing a domestic hydrogen value chain, with a secondary focus on the potential for hydrogen exports. The government is directing support to hydrogen research and pilot projects, with funding also from EU sources (see Chapter 1).

Resource push

Public support for energy R&D

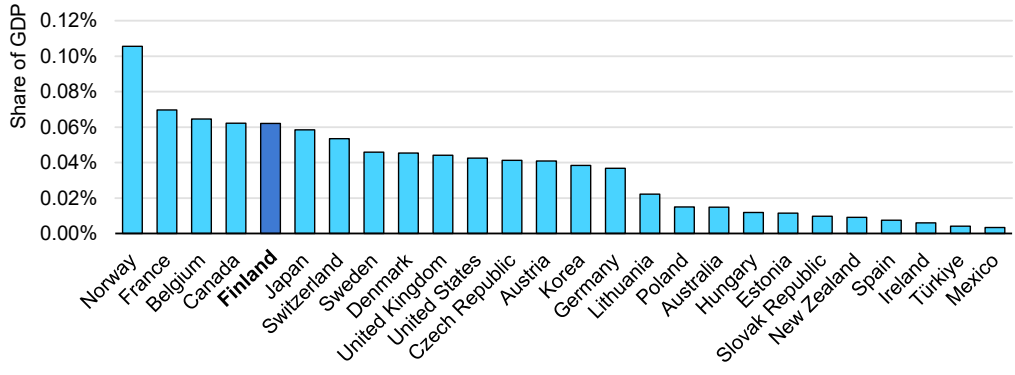
From 2010 to 2020, Finland's public budget for energy R&D declined significantly from USD 383 million to USD 177 million and from 0.17% to 0.07% of GDP (Figure 5.1). The decline resulted mostly from lower spending on R&D for energy efficiency, which dropped from USD 229 million to UD 91 million, and for renewables, which fell from USD 60 million to USD 23 million. The decrease also reduced Finland's ranking among IEA member countries for public budget dedicated to energy R&D by GDP from second in 2019 to fourth in 2020 (Figure 5.2).

Figure 5.1 Energy-related R&D public budget by sector in Finland, 2009-2020



Source: IEA (2022).

Figure 5.2 Energy-related public R&D funding per GDP in IEA countries, 2020



Note: Data for Greece, Italy and Luxembourg are not available for 2020.
Source: IEA (2022).

In 2021, Finland set a goal to increase total spending on R&D (public and private) to 4% of GDP by 2030 (versus 3% of GDP in 2021). Finland is also committed to supporting a target for EU-wide spending on R&D to reach 3% of EU-wide GDP by 2030 (versus 2.2% in 2018). The R&D Funding Act, which entered into force at the start of 2023, set increasing levels of annual government R&D funding to ensure that government R&D funding reaches

1.2% of GDP by 2030. This is intended to drive increased private sector R&D funding to reach the 4% goal. The R&D Funding Act does not require specific allocations to energy R&D, but the government is committed to reaching carbon neutrality by 2035 and sees a major role for R&D in driving the green energy transition. To complement the R&D Funding Act, a parliamentary working group on R&D and innovation is drafting a long-term plan to set the main guidelines for allocating public R&D funding, but it will not decide on allocations for different themes or sectors. A more detailed plan will be prepared as part of the next government programme in 2023.

Other steps are also being taken to boost overall spending on R&D. A law prepared by the Ministry of Finance on a new R&D tax incentive entered into force at the beginning of 2023. It aims to encourage SMEs, in particular, to increase or expand their R&D activities. The government also aims to increase Finland's use of R&D funding available from the European Union. Actions have been taken to encourage and support research units and companies to apply for EU R&D funding.

Grant funding is available to companies that invest in energy demonstration projects through the Energy Aid programme, which prioritises projects involving new technologies that have limited deployment in Finland and that can play an important role in achieving long-term energy and climate goals. From 2018 to 2021, Energy Aid provided a total of EUR 365 million in grants, with some of the largest amounts of funding going to emerging technology and demonstration projects, including energy storage (EUR 45.3 million, with most of this going to two projects, one for pumped hydro storage and one for thermal energy storage), biomethane in transport (EUR 40.2 million), hydrogen (EUR 40.2 million) and transport biofuels (EUR 34 million). The Energy Aid programme has a total budget of EUR 200 million for 2022-26 (Business Finland, 2023). Business Finland awards the smaller grants, while the funding decisions for large projects are taken by the Ministry of Economic Affairs and Employment (see Chapter 4).

Business Finland provides innovation support to companies through several other programmes, including: a grant and loan programme dedicated to SMEs, a grant and loan programme for large companies (which requires co-operation with an SME or research centre), a loan programme open to SMEs and large companies undertaking pilot projects, and innovation vouchers for SMEs. Business Finland supports the government in obtaining innovative solutions for services obtained through public procurement (Business Finland, 2021). In addition, Business Finland launched challenge competitions in 2020, 2021 and 2023 that offered financial support to international companies to resolve significant future challenges and increase their research, development and innovation investments in Finland. Business Finland also supports the Veturi or locomotive model for innovation, under which a major anchor firm leads large-scale industrial innovation projects. Funding is provided to support the project, as well as networks and clusters of supporting actors, including universities, research institutions, foreign firms and SMEs (Business Finland, 2022).

Finland is a major supporter of R&D for nuclear energy. In 2020, Finland ranked sixth among IEA member countries for public budget dedicated to nuclear energy R&D by GDP. While public funding for overall energy R&D declined significantly from 2010 to 2020, public funding for nuclear energy R&D experienced an overall increase. Nuclear energy R&D is focused on safety and the operational performance of nuclear power plants and the management and disposal of waste. It is supported by two dedicated funds that are separate from the state budget: one for nuclear energy and one for nuclear waste. From

2010 to 2020, Finland dedicated EUR 218 million in public support to nuclear energy R&D, with the majority (EUR 114 million) going to plant safety and integrity, followed by nuclear fission supporting technologies (EUR 46 million), nuclear fission fuel cycle (EUR 37 million), and nuclear fusion (EUR 20 million). Finland has unique experience in relation to nuclear waste management and has undertaken extensive R&D activities leading to the start of construction on the world's first deep geological repository for final disposal of spent nuclear fuel (see Chapter 7).

The government aims to increase Finland's role in the global battery supply chain through increased innovation, with a focus on developing products with higher added value. The National Battery Strategy 2025, published in June 2021, presents a road map for Finland to become a major player in the international battery industry. Several areas of the strategy focus on increasing R&D on batteries (Finland, Ministry of Economic Affairs and Employment of Finland, 2021). Finland is also participating in EU-funded projects supporting battery innovation.

Finland's Climate Fund is a state-owned special-assignment company focused on combatting climate change, boosting low-carbon industry and promoting digitalisation through investments in companies. Capital loans are the primary funding instrument. Investing in funds and expansion into other debt or equity instruments can be considered in certain cases, but the Climate Fund does not award grants or subsidies. The Climate Fund typically invests in scaling up climate solutions for facilities, infrastructure or in digital climate solutions. The selection of funding targets is guided by the fund's funding criteria, which emphasise climate and environmental impacts. The fund's annual financing volume is around EUR 130 million. The fund's average project size ranges from EUR 4 million to EUR 40 million; investments of over EUR 20 million must also be supported by the Ministerial Committee on Economic Policy (Finnish Climate Fund, 2021).

In 2020, the government introduced a 50% deduction on certain R&D expenditures undertaken from 1 January 2021 through 2025. In 2021, this deduction was increased and extended and now provides a deduction of 150% for certain R&D expenditures undertaken from 1 January 2022 through 2027. The deduction is only relevant for R&D subcontracting expenditures paid by a business or agricultural entity to a qualifying research and information dissemination organisation. No deduction may be granted for R&D work for which the entity has already received public aid. The qualifying expenditures must be at least EUR 5 000 per year and the maximum tax deduction is EUR 500 000 per year (Finnish Tax Administration, 2022).

EU funding

In addition to national funding, energy technology innovation in Finland is supported by EU funding, including through the EU Framework Programme for Research and Innovation, the European Union's main mechanism for directing innovation funding to member states. Horizon 2020, the framework programme from 2014 to 2020, provided EUR 80 billion for R&D through a competitive process open to all EU public and private entities and designed to increase public-private partnerships and international co-operation. Horizon 2020 provided a total of EUR 1.52 billion of funding to Finland, with around EUR 0.4 billion going to energy and climate projects, including EUR 126 million for secure, clean and efficient energy; EUR 112 million for climate action, environment, resource efficiency and raw materials; EUR 77 million for smart, green, integrated transport; EUR 75 million for advanced manufacturing and processing; and EUR 8 million for nuclear energy (EC, 2022c).

Horizon Europe is the EU Framework Programme for Research and Innovation for 2021-27. It was launched in February 2021, aims to provide EUR 95.5 billion in innovation funding, will continue to support energy-related technology innovation and sets goals to increase international R&D co-operation (EC, 2021). Business Finland hosts the national liaison office for Horizon Europe in Finland, which offers free services to support Finnish R&D actors in applying for Horizon Europe funding.

The EU Innovation Fund commercial demonstration of innovative low-carbon technologies is funded by ETS revenues. A project being undertaken by the Finnish company Neste for the production and use of low-carbon hydrogen at one of its refineries received EUR 88 million in funding through the EU Innovation Fund (FuelCellsWorks, 2022).

In 2022, Finland introduced the Energy Investment Aid scheme to award funding from the EU Recovery and Resilience Facility, using a method similar to the Energy Aid programme. The scheme will provide around EUR 490 million in funding for energy investments, including energy infrastructure, the deployment of new energy technology, hydrogen, CCU and electrification of industries.

Although not specifically dedicated to clean energy, Sitra, the Finnish Innovation Fund, is noteworthy for its focus on equity investing (among other tools). This independent foundation, which reports directly to the Finnish parliament and can make policy interventions without a government mandate, has placed the ecological reconstruction of society at the top of its list of five goals for 2021-24. In addition to being a think tank and promoter of experiments and operating models, it invests in Finnish start-ups and other SMEs, mainly through venture capital funds. Committed to the ownership and development of portfolio companies for an average period of four to ten years, it is a longer term investor than most venture capital funds. Twelve per cent of its portfolio is currently allocated to venture capital and private equity, with this capital coming from annual returns on capital investments of its initial government endowment. It does not provide grants or concessional financing but works with VTT and Business Finland.

Private sector R&D

The government sees private sector investment in energy R&D as essential to achieving climate neutrality and maintaining Finland's economic competitiveness. The government aims to strengthen co-operation between companies and public research entities by directing public R&D funding to strategic partnerships, internationally significant projects, and shared R&D environments. Several of Finland's measures to encourage R&D aim to drive private sector investments (tax breaks, grants and loans, etc.). Most of Finland's R&D and innovation funding programmes are open to private sector projects and aim to use public funding to leverage increased private sector R&D spending.

Finland has extensive data on private sector R&D spending, but there is no breakdown of expenditures for energy R&D. Statistics Finland (the government agency responsible for producing most of Finland's official statistics) conducts an innovation survey covering private sector innovation activities every two years. Data from the most recent innovation surveys show that the private sector accounts for most of Finland's R&D spending (around two-thirds in 2020) and that most private sector R&D spending came from a limited number of large companies.

In 2021, businesses with more than 500 employees accounted for 53% of private sector R&D spending. That year, almost half of businesses with more than 500 employees

engaged in R&D activities, compared with around just 12% of SMEs (10-249 employees). Private sector R&D spending consistently declined until 2016 but increased by 32% from 2016 to 2021. In 2021, three sectors accounted for 60% of private sector R&D spending: 1) electronics, computers and electrical equipment (32%); 2) information and communication (19%); and 3) other machinery and equipment (13%).

The innovation survey for 2018 to 2020 does not provide a breakdown of investment amounts. The survey, covering 2016-18, noted that total private sector expenditures on innovation increased by EUR 760 million to reach EUR 6.8 billion and that 29% of companies undertaking innovation activities used public financial support (Statistics Finland, 2020).

Education and skills

The National Roadmap for Research, Development and Innovation notes that Finland has a high-quality education system that supports the development of R&D and other innovation skills and attracts foreign talent. However, the road map also points to weaknesses and indicates that more work is needed to ensure Finland has the highly skilled academic and labour force needed to support its ambitious policy.

The road map notes that learning outcomes of Finland's education system are good by international standards but have deteriorated in recent years, with significantly fewer young adults (aged 25-34) completing a higher education degree than in peer countries. The road map notes that the publishing activities of researchers in Finland are of good quality and quantity by European standards. However, Finland's top-level expertise is concentrated in a few areas (bioenergy, batteries, nuclear, smart grids) and Finland lags behind the world's leading countries in the number of most cited publications. The road map also notes the number of international students and R&D professionals settling in Finland does not meet the level needed to achieve innovation policy goals. It points out that fragmentation and unpredictability of research funding reduce the attractiveness of a research career in Finland. For example, 72% of researchers had to use two or more funding sources while doing their doctoral thesis.

To address these challenges, the road map indicates that more effort is needed to boost domestic talent and attract international talent. In support of this, the government set a goal that at least half of young adults will complete a higher education degree by 2030. It is also introducing public R&D funding mechanisms that aim to provide higher funding levels over a sustained period to improve transparency and consistency in funding availability to universities and researchers.

Knowledge management

International co-operation

Finland's public and private R&D and innovation entities are highly active in international co-operation on energy topics. This includes co-operation through EU initiatives and international organisations. The Ministry of Economic Affairs and Employment co-ordinates Finnish participation in the global energy fora, including the IEA technology collaboration programmes (TCPs), Mission Innovation and the Clean Energy Ministerial. The NCES notes that the government's focus areas for international R&D advocacy and co-operation include energy system integration, hydrogen and circular economy.

The IEA TCPs are multilateral mechanisms that support global collaboration to advance co-operation on research and the use of specific energy technologies. The TCPs are composed of thousands of experts across government, academia and industry in 55 countries that co-operate on 39 technology-specific programmes. Experts can be officially appointed by governments or join privately from industry and research entities.

As of October 2022, 10 Finnish entities (the Ministry of Economic Affairs and Employment, Business Finland, VTT, Finnish Energy Industries, the Finnish Heat Pump Association, Tampere University of Technology, Aalto University, Åbo Akademi Process, Kemijoki Oy, and Lappeenranta University of Technology) were participating in 22 TCPs (equality in energy transitions, energy technology systems analysis, buildings and communities, district heating and cooling, energy storage, heat pumping technologies, user-centred energy systems, smart grids, high-temperature superconductivity, industrial technologies and systems, advanced fuel cells, advanced motor fuels, advanced materials for transportation, clean and efficient combustion, hybrid and electric vehicles, fluidised bed conversion, GHG programme, bioenergy, hydrogen, hydropower, PV power systems, wind energy). The Finnish government sponsors participation in two TCPs (industrial technologies and systems and advanced fuel cells) (IEA, 2021).

Mission Innovation is a global partnership of 23 countries and the European Commission launched at COP21 in 2015 which aims to accelerate clean energy innovation. Finland participated in seven of the eight innovation challenges of the first phase of Mission Innovation, which ended in 2020 (smart grids, off-grid access/energy storage, CCUS, sustainable biofuels, converting sunlight, clean energy materials, and affordable heating and cooling). Mission Innovation 2.0 was launched in 2021. Finland is participating in the areas of clean hydrogen, net zero industries and the innovation platform (Mission Innovation, 2020).

Finland is part of the Clean Energy Ministerial, a high-level global forum that promotes policies and programmes to advance the deployment of clean energy technologies. Finland participates in numerous Clean Energy Ministerial initiatives (EVs, biofuture platform, long-term scenarios for the energy transition, international smart grid action network, regional and global energy interconnection, equality in energy transitions, 21st century power partnership, and hydrogen) and campaigns (global commercial vehicle drive to zero, EV30@30, power system flexibility and biofuture) (Clean Energy Ministerial, 2021).

Finland supports international co-operation on energy R&D through the European Strategic Energy Technology (SET) Plan, which aims to accelerate the transition to a climate-neutral energy system through fast and competitive development of low-carbon technologies. The plan aims to better align EU and national R&D programmes and boost co-operation between programmes to avoid duplication and increase the impact of public spending. Finland chairs or co-chairs the SET Plan implementation working groups on industry, bioenergy and renewable fuels for sustainable transport, and nuclear energy. Finland also chairs the SET Plan bureau, which helps the European Commission co-ordinate SET Plan activities (EC, 2018).

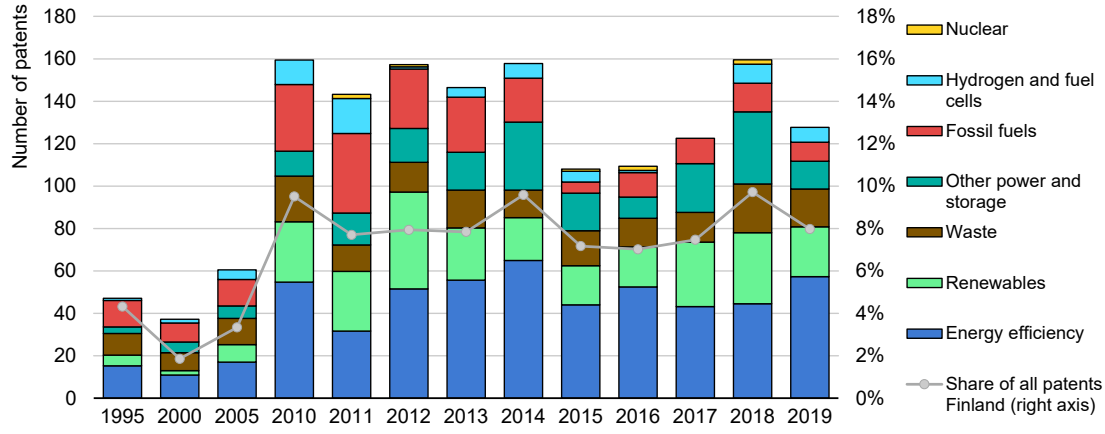
Finland supports international co-operation on energy technology innovation through the Clean Energy Transition Partnership (CETPartnership), a multilateral partnership that aims to accelerate the energy transition by pooling funding from national and regional R&D programmes, including Horizon Europe. The CETPartnership encourages international

co-operation beyond the European Union, including through international initiatives such as Mission Innovation. It brings together more than 50 national and regional R&D programme managers from over 30 countries to align priorities and pool budgets to support joint calls for proposals that are open to R&D entities from across the world. It aims to provide EUR 790 million in funding from 2022 to 2027. A first call offering EUR 210 million was launched on 12 September 2022, with Finland contributing EUR 5 million (CETP, 2018).

Intellectual property

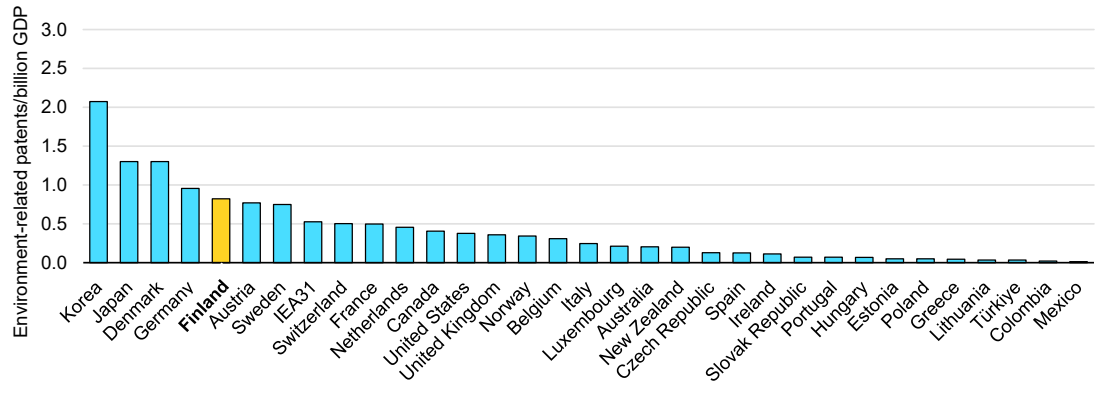
From 2010 to 2019, the number of new patents in energy-related technologies in Finland varied from a maximum of 159 in 2018 to a minimum of 37 in 2000 (Figure 5.3). In 2019, most patents were issued for energy efficiency (45%) followed by renewables (18%), waste (14%), other power and storage (10%), fossil fuels (7%), and hydrogen and fuel cells (5%). In 2019, 8% of patents in Finland were dedicated to energy-related technologies, compared to 10% in the European Union. In 2019, the number of patents for environment-related technologies per EUR billion GDP in Finland was 0.82, ranking fifth among IEA countries and notably higher than the IEA average of 0.53 (Figure 5.4).

Figure 5.3 New patents in energy-related technologies in Finland, 1995-2019



Source: IEA based on data from OECD (2022).

Figure 5.4 New patents in environment-related technologies by GDP in IEA countries, 2019



Source: IIEA based on data from OECD (2022).

Monitoring, evaluation and tracking of results

The measures in the National Roadmap for Research, Development and Innovation are monitored regularly and the results of the implementation of the road map are reported to the Ministerial Working Group on Competence, Education, Culture and Innovation, which includes the Ministers of Education, Economic Affairs and Employment, European Affairs and Ownership Steering, Economic Affairs, Science and Culture, Justice, and the Interior. The working group uses the monitoring report to determine if any changes are needed for the road map to achieve its goals.

The road map monitoring process primarily relies on data collected by Statistics Finland, which reports on the following metrics: government and private sector R&D expenditures as a share of GDP, private R&D expenditures by company size, foreign direct investment per GDP, private sector funding supporting co-operation between companies and research organisations, and the number of international students and researchers. The monitoring process is also supported by the Statistical Service of the Education Administration, which co-operates with Statistics Finland to report on the share of R&D employees with a doctoral degree. The Finnish Immigration Service reports on the internationalisation of activities (residence permits issued for experts and researchers). Business Finland supports the road map by reporting on the amount of EU funding delivered to Finland through Horizon Europe (Finland, Ministry of Transport and Communications, 2021b).

Business Finland has a separate process to monitor and evaluate its activities (including promoting technology innovation). The results of this process are included in a publicly available annual report and are used to adjust and update activities and programmes. The Ministry of Economic Affairs and Employment published an external evaluation of Business Finland in June 2021. The evaluation noted that the agency, established in 2018, is still working to complete its internal organisation and shift its full focus to delivering services. Business Finland also has annually updated performance agreements with the Ministry of Economic Affairs and Employment on operational goals for the year (Business Finland, 2022a).

In January 2022, Business Finland issued a report evaluating its international innovation collaboration advice and funding (Business Finland, 2022a).

The study's main finding was that the platforms facilitating international innovation collaboration and funding are impactful but currently underused. Three of the report’s recommendations (raising awareness, using the platforms more efficiently to leverage Finnish innovation objectives and tailoring specific support for first-time applicants) have been considered by Business Finland and first actions have already been implemented, among which are training of Business Finland’s customer interface, more active communication with potential participants and a renewed funding instrument for companies to support proposal preparation of EU applications.

The Strategic Research Council of the Academy of Finland is responsible for assessing the impact of its funds. The evaluation is implemented at programme level, aims to assess the current or prospective scientific and societal impact, and supports the development of new strategic research programmes. The evaluation focuses on the activities’ targeting, processes, outputs and outcomes. In assessing the scientific impact, particular attention is paid to the effectiveness of multidisciplinary work and the ability to reinvigorate research to address the challenges identified in the programme description (Strategic Research, 2021).

Programmes receiving funding from the Academy of Finland are required to provide reporting that includes a situational picture at the start of the project, annual reporting on progress, an interim report for follow-on funding (applies to long-term programmes) and a final report upon project completion. The final report includes information from the annual reports and more detailed information on the resources, outputs and results, effects and impacts. The final report is used for the programme evaluation conducted by the Strategic Research Council (Strategic Research, 2022).

Assessment

The Finnish government sees energy technology innovation as a key part of achieving the 2035 climate neutrality target and long-term emissions reduction targets. It supports cost reduction of new and emerging energy technologies for hard-to-abate sectors with the potential for global deployment to maximise climate benefits and promote Finland's economic competitiveness. Finland's high-quality education system supports the development of technology innovation skills and attracts foreign talent. More work is needed to ensure Finland has the highly skilled academic and labour force needed to support its ambitious R&D policy.

In 2021, Finland set a goal to increase total spending on R&D (public and private) to 4% of GDP by 2030 (versus 3% of GDP in 2021). The R&D Funding Act, which entered into force at the start of 2023, set increasing levels of annual government R&D funding to ensure that government R&D funding reaches 1.2% of GDP by 2030. This is intended to drive increased private sector R&D funding to reach the 4% goal. In addition, the government proposed developing a statutory plan for R&D funding. The plan would indicate policy guidelines for long-term R&D activities, along with principles for issuing R&D funding.

Finland should ensure increased public investment in energy technology innovation. While the legislation is not expected to set sectoral targets, annual budget allocations create an opportunity to inform spending. Further, if a statutory plan for innovation funding is developed, it should reflect the important role of energy innovation in achieving Finland's climate targets for 2035 and beyond. The potential role of energy innovation is clearly reflected in the NCES, which states the priorities to be bioenergy, hydrogen, smart energy systems and batteries. The statutory plan represents an opportunity to reiterate these priorities.

As public investment in R&D increases to achieve the 4% target, the allocation of funds should ensure that innovative technologies can move smoothly from low technology readiness levels to demonstration and commercialisation, recognising that later stages of R&D can have much higher costs. Currently, Finland's National Roadmap for Research, Development and Innovation indicates that an overwhelming majority of public sector funding is allocated towards basic and applied research at universities and technical institutions. Approximately 66% of public sector R&D funding is allocated to the higher education sector, 20% to public activities (including private non-profit activities) and just 12% to companies. The government should ensure that later-stage R&D, including demonstration projects, have adequate resources to help commercialise innovative technologies.

Industry has demonstrated strong demand for later-stage demonstration funding. For example, support for demonstration projects under the Resiliency and Recovery Facility

received 86 applications requesting EUR 1.65 billion in support for investments totalling over EUR 4 billion. This represents an unprecedented level of demand, indicating that Finland's industry is well-positioned to deliver major industrial projects to advance the green energy transformation and that funding from existing national programmes is likely insufficient. Finland should carefully monitor and evaluate the delivery of the Recovery and Resiliency Facility funding with a view to informing the design of future programming to ensure sustained support for demonstration projects and to increasing the chances of these projects reaching commercialisation. The prevalence of the Veturi or locomotive model for innovation, under which a major anchor firm leads large-scale industrial innovation projects, also supports the rationale for investment in large-scale demonstrations.

Early-stage funding plays an important role in the Finnish innovation system, and stakeholders have voiced support for this. Despite the need for additional funding for demonstration projects, it is imperative that funding for higher education and basic R&D be maintained. Finland is experiencing a lack of skills and expertise, which creates a bottleneck for the energy sector. This is particularly acute, given that emerging industries require new combinations of specialised expertise and skills, which may be extremely scarce. The education system is critical to ensure a pipeline of expertise.

Furthermore, exploring possible partnerships between industry and academia could provide pathways for developing specialised skills and expertise, as per the partnership between the nuclear industry and Lappeenranta-Lahti University of Technology. Additional measures to attract international students and support their continued residence in Finland following their education could help grow R&D expertise. For these reasons, policy makers should consider allocating new funding towards demonstration projects rather than taking funding from higher education and basic R&D.

Business Finland is the primary innovation agent for the government and has a core focus on developing technologies with global market potential (from R&D all the way to demonstration projects). This approach is sensible for a small country such as Finland, where limited domestic adoption cannot sustain the high level of investment required to advance technologies through the innovation cycle. Business Finland's approach also seeks to attract foreign partners to invest in Finland. Again, this is sensible given the limited capital available for investment in a small domestic market.

Finland's strategic priorities for innovation enable Finnish innovation funders to identify high potential opportunities for impact and focus scarce resources. For example, Business Finland is an active participant in the policy dialogue on the transition to a low-carbon future through international fora such as Mission Innovation. Business Finland has also conducted strategic foresight exercises to identify emerging trends and opportunities. This has allowed it to proactively develop targeted support programmes in areas such as smart energy systems, sustainable cities and the bioeconomy.

Through these targeted programmes, Business Finland has successfully created ecosystems of smaller firms complementary to the Veturi model, which focus on projects led by a larger company. For example, the Smart Energy Finland Programme allocated EUR 142 million to approximately 300 projects to support test platforms and ecosystems formed of companies, research institutes, customers and municipalities. The "Smart Otaniemi" ecosystem included 5 000 researchers, 25 R&D teams, 3 accelerators and over 200 SMEs.

The Ministry of Economic Affairs and Employment has also taken a similar strategic approach to identify priorities within a market-driven framework. This is most apparent in the 14 "climate road maps" for carbon neutrality by 2035, which were co-developed with industry and other stakeholders. These road maps allowed stakeholders to self-organise around a common set of shared priorities. They provide a robust follow up to the 2018 IEA in-depth review recommendation to develop a road map to prioritise clean energy R&D activities.

Public policy objectives could be at risk if they face technological challenges unique to Finland and therefore do not come forward in the export-oriented approach. It is unclear whether sufficient resources or analysis have been devoted to Finland's unique needs that may not be addressed by the global market. Circumstances unique to Finland (e.g. northern climate, dependence on bioenergy) may create challenges not addressed by the global innovation community but do provide opportunities for co-operation with countries with similar circumstances.

R&D stakeholders indicate that there are greater opportunities to align public funding authorities. There may be opportunities to better co-ordinate across innovation funders such as Business Finland and the Academy of Finland. This was highlighted in a recent evaluation of Business Finland, which found that programmes and national strategies should be better aligned. Internal co-ordination is particularly important given the "bottom-up" nature with which the government has developed its priorities.

In particular, the government should explore opportunities to improve collaboration between the Ministry of Economic Affairs and Employment, responsible for Business Finland, and the Ministry of Education, responsible for the Academy of Finland. This would better align priorities to ensure that the government is sending clear and consistent signals to industry and other external stakeholders. This could be achieved through the use of existing mechanisms, such as the Research and Innovation Council, chaired by the Prime Minister and co-chaired by the Minister of Science and Culture and the Minister of Economic Affairs and Employment. The council also includes the Minister of Education, making it an ideal vehicle to foster greater alignment.

Recommendations

The government of Finland should:

- Ensure that rising public investment in R&D supports greater investment in energy-related R&D, given the prominent role of innovation in the National Climate and Energy Strategy.
- Ensure sufficient funding for industrial-scale energy demonstration projects once funding from the Recovery and Resilience Fund ends.
- Ensure domestic innovation is not at risk under an export-oriented innovation system.
- Improve co-ordination between public R&D funding authorities on their respective priorities.

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6. Electricity

Key data

(2021)

Electricity generation: 71.7 TWh, -2% since 2011

Electricity generation mix: nuclear 33%, hydro 22%, bioenergy and waste 20%, wind 12%, natural gas 5.3%, coal 4.9%, peat 2.6%, solar 0.4%, heat 0.3%, oil 0.2%

Electricity consumption: 83.3 TWh (industry 49%, residential buildings 29%, service sector buildings 21%, transport 1%), +2% since 2010

Peak load: 14.3 GW (February 2021)

Installed capacity: 18.7 GW (19% variable renewables, 50% renewables)

Overview

Finland has one of lowest carbon intensities of electricity generation among IEA member countries and the government aims for the electricity sector to play a major role in achieving the 2035 carbon neutrality target and long-term emissions reductions. The government has introduced numerous measures to further reduce the carbon intensity of electricity generation and increase electrification of energy demand, especially in transport, heating and industry. Key policy goals for the electricity sector include maintaining the growth of onshore wind generation, introducing the first large-scale offshore wind generation projects before 2030, boosting the deployment of solar PV, maintaining strong generation from nuclear, ensuring the sustainability of biomass generation, phasing out coal-fired generation by 2029, and reducing generation from natural gas and peat.

The government aims for market forces to drive investment decisions in the electricity sector. However, energy taxation has been adjusted in recent years to make investments in low-carbon generation more attractive and investment subsidies are available for innovative and small-scale projects that provide low-carbon generation. The TSO's and DSOs' development plans reflect Finland's carbon neutrality goals, with investments that will increase grid capacity and flexibility to support higher shares of low-carbon generation and increased electrification of energy demand. The government is providing financial support for grid development with EU funding. There are also subsidies for electrification of demand from national and EU funding.

Finland is a net electricity importer. With the full operation of the 1.6 GW Olkiluoto 3 reactor (on 16 April 2023) and plans for greatly expanded renewable generation, Finland is aiming to become a net electricity exporter. Following the Russian invasion of Ukraine, Russia

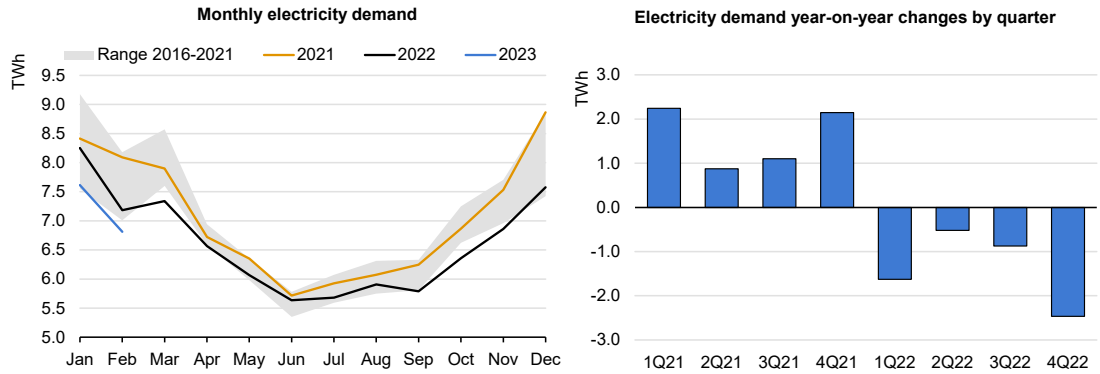
unilaterally decided to stop supplying electricity to Finland. Finland has been able to compensate for the loss of Russian electricity imports mainly through demand reduction (Figure 6.1).

Finland has a fully liberalised electricity market. However, a large share of electricity is supplied outside the market under the Mankala Model, in which several companies jointly set up a non-profit limited liability company. In addition, DSOs are still the main retail electricity suppliers.

Electricity demand, generation and trade

From 2010 to 2019, Finland's electricity demand was relatively stable, ranging between a minimum of 79.7 TWh in 2015 and a maximum of 84.8 TWh in 2010. Electricity demand dropped notably to 78 TWh in 2020 as a result of the Covid-19 pandemic and a historically warm winter that reduced heating demand. Demand rebounded to 83 TWh in 2021. Finland launched a consumer awareness campaign (Down a Degree, 2023) in August 2022 that aims to progressively increase public understanding of how to reduce energy demand to reduce the impacts of the energy crisis driven by the Russian invasion of Ukraine. The campaign led to significant electricity savings from August to December 2022 (Figure 6.1).

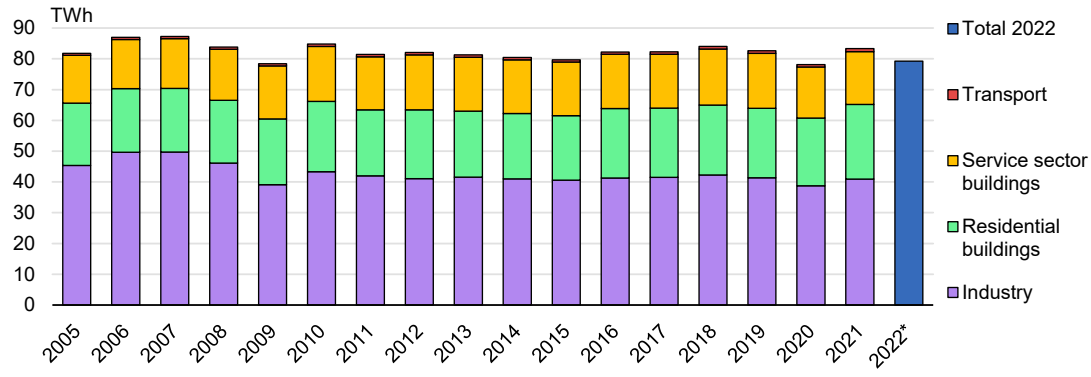
Figure 6.1 Monthly electricity demand in Finland, 2021-2023 and range in 2016-2021



Source: IEA (2023a).

Overall, demand decreased by 6.5% from 2021 to 2022. The industry sector accounts for the largest share of electricity demand (49% in 2021), followed by residential buildings (29%), service sector buildings (21%) and a small share from transport (1%), mostly rail (Figure 6.2). Changes in annual electricity demand are mainly linked to seasonal variations in temperature, as a large share of building heating is covered by electricity, and to the level of economic and industrial activity. A relatively large share of Finland's energy demand is covered by electricity, but there has been almost no increase in electrification in the last decade. From 2010 to 2020, the share of TFC covered by electricity barely increased, by only 0.1%, from 27.2% to 27.3%, but remained above the IEA average in 2020 of 23%. In line with energy and climate goals, the NCES estimates that electricity demand will increase in all sectors and total at least 92 TWh by 2030 and 96 TWh by 2040 (compared to 83 TWh in 2021).

Figure 6.2 Electricity demand by sector in Finland, 2005-2022



Sources: IEA (2023a; 2023b).

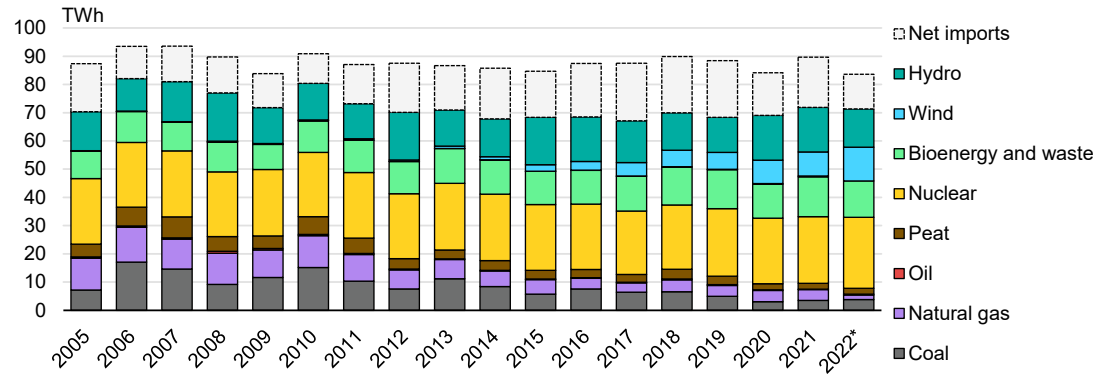
Thanks to its nuclear reactors and a high share of generation from renewable energy, Finland has one of the lowest carbon intensities of electricity and heat generation among IEA member countries (72.4 g CO_2/kWh in 2021, compared to the IEA average of 329 g CO_2/kWh). The carbon intensity of Finland's generation is expected to continue to decline thanks to increasing generation from nuclear and renewables, and a continuing transition away from generation based on fossil fuels and peat. From 2010 to 2021, there was declining generation from coal (15.1 TWh to 3.4 TWh), natural gas (11.3 TWh to 3.9 TWh) and peat (6.3 TWh to 1.9 TWh), and increasing generation from wind (0.3 TWh to 8.1 TWh) and bioenergy and waste (11.2 TWh to 14.2 TWh) (Figure 6.3). Finland has a high share of generation from bioenergy and waste (20% in 2021, compared to the IEA average of 4%). From 2010 to 2021, nuclear generation was relatively stable, between 22.5 TWh and 23.9 TWh, but is expected to increase up to an estimated 36 TWh in 2023 with the full operation of the new Olkiluoto 3 reactor, which entered into service 16 April 2023. Generation from hydro varies notably based on water availability and ranged from a minimum of 12.4 TWh to a maximum of 16.9 TWh between 2010 to 2021. There is very little generation from solar PV (0.3 TWh) and oil (0.2 TWh). Early data for 2022 show a marked 40% increase in electricity generation from wind, while gas-fired power plants produced 57% less electricity.

A large share of Finland's electricity generation comes from co-generation plants (27% of total generation in 2021). This is higher than the averages for the European Union (22%) and IEA member countries (10%). Finland's co-generation plants are mainly powered by fossil fuels. In 2021, electricity generation from Finland's co-generation plants came from natural gas (31%) solid biomass (29%), coal (18%), peat (15%), waste (5%) and oil (2%).

Finland is a net importer of electricity (Figure 6.4). The level of net imports varies annually, depending mainly on the availability of domestic hydro generation and electricity prices in the Nordic electricity market. From 2010 to 2021, net electricity imports ranged from 11 TWh to 20 TWh and from 14% to 31% of Finland's electricity supply. Electricity imports once came mainly from Russia, which accounted for an average of 88% of net imports from 2005 to 2011. Since 2012 they have come mainly from Sweden, which accounted for 87% of net imports from 2012 to 2021 (in 2012, a new interconnection with Sweden, which also provides access to hydro generation in Norway, became operational, boosting import capacity by 40%). There are very limited electricity imports from Norway (just 0.26 TWh in 2021). Electricity is exported mainly to Estonia.

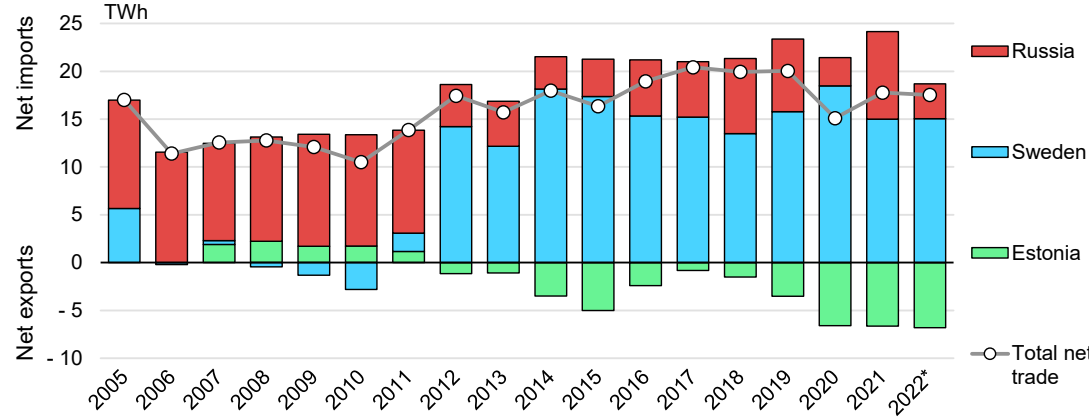
Russia stopped supplying electricity to Finland in May 2022, shortly after Finland announced plans to join NATO in response to Russia's invasion of Ukraine. A practical reason was also that Rao Nordic (the company which imported electricity from Russia) was not able to transfer money to Russia. Finland's electricity imports are expected to decrease notably in 2023 now that the Olkiluoto 3 reactor is fully commercially operational. Finland aims to be a net exporter of electricity by 2030, thanks to expanding generation from nuclear and renewable energy.

Figure 6.3 Electricity generation by source and net imports in Finland, 2005-2022



Sources: IEA (2023a; 2023b)

Figure 6.4 Finland's electricity imports and exports, 2005-2022

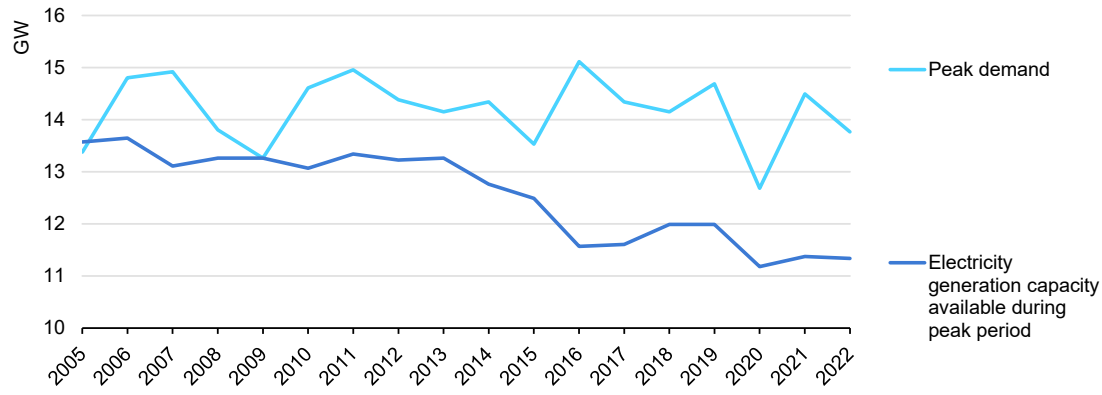


* Imports from Russia stopped in May 2022.

Sources: IEA (2023a; 2023b).

From 2010, to 2021, Finland's peak electricity demand fluctuated from a minimum of 13 GW in 2020 to a maximum of 15.1 GW in 2016 (Figure 6.5). Peak demand typically occurs during the winter heating season. From 2010 to 2022, generation capacity available during the peak demand periods experienced an overall decline, from 13.1 GW to 11.3 GW, with the gap to meet peak demand covered by electricity imports. Peak generation capacity is expected to increase notably now that the Olkiluoto 3 reactor is fully operational and as domestic renewable generation capacity increases. Electricity import capacity had been steady at around 5.4 GW through May 2022, when it dropped to around 4 GW because of Russia's unilateral decision to stop electricity supply to Finland.

Figure 6.5 Finland's peak demand and electricity generation capacity during peak, 2005-2022



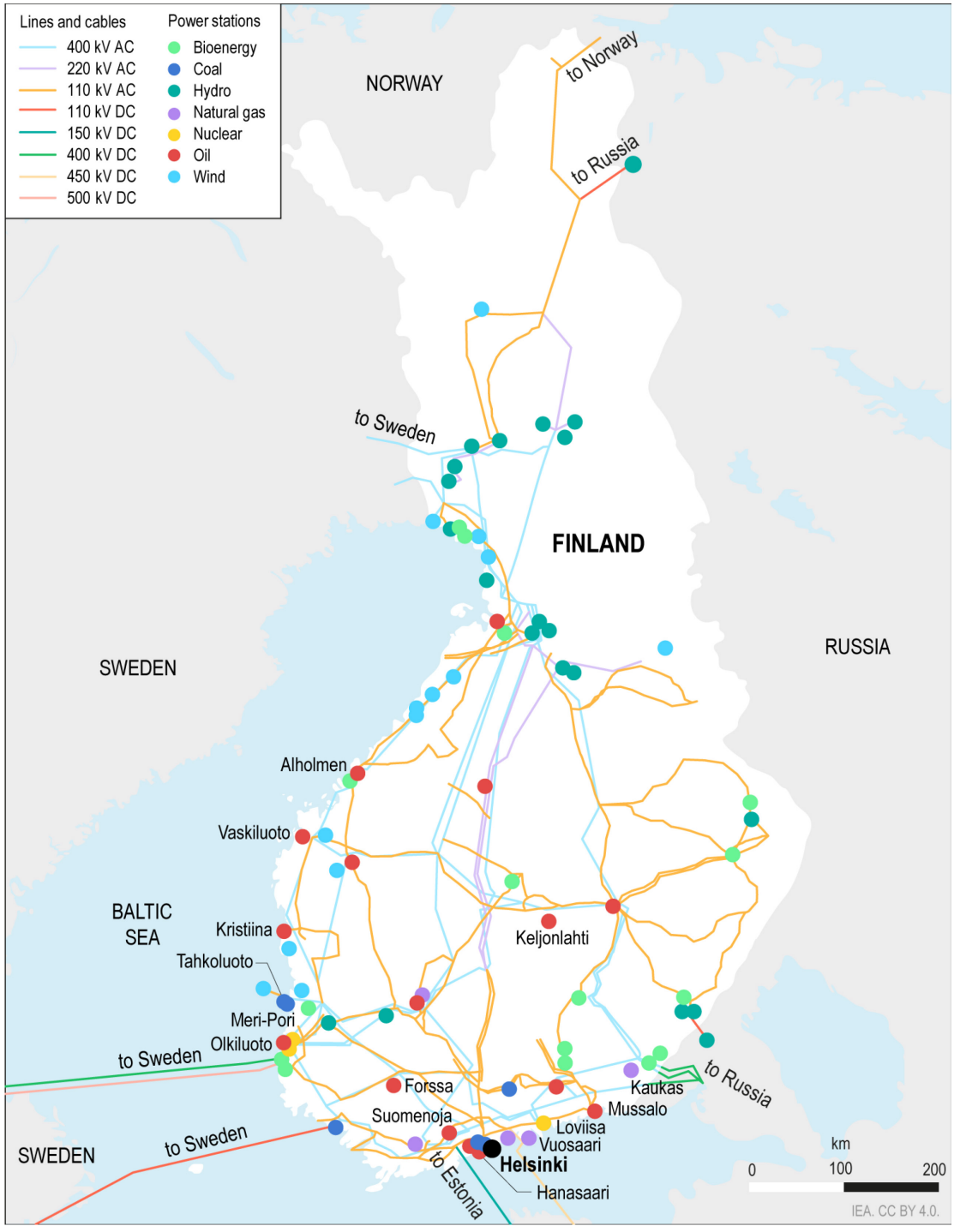
Source: IEA (2022).

Electricity infrastructure

Finland's electricity infrastructure consists of a generation fleet with around 18.7 GW of installed capacity in 2021 (mainly nuclear, wind, hydro and bioenergy, with smaller capacities for natural gas, coal and peat);, cross-border interconnections with Estonia, Norway, Sweden and Russia (interconnections with Russia have not been in operation since May 2022); and a well-developed transmission and distribution grid (Figure 6.6). Finland's electricity grid is part of the synchronous inter-Nordic system, which also includes eastern Denmark, Norway and Sweden. The Nordic System Operation Agreement includes common operating principles used by the Nordic TSOs (ENTSO-E, 2021). In addition to Finland's electricity interconnections with Estonia and Russia, the inter-Nordic grid has interconnections with western Denmark (Jutland), Germany, Lithuania, the Netherlands and Poland.

The TSO's and DSOs' development plans reflect Finland's carbon neutrality goals, with investments that will increase grid capacity and flexibility to support higher shares of low-carbon generation and increased electrification of energy demand. Finland's recovery and resilience plan dedicate EUR 151 million for new energy transmission and distribution infrastructure to support the carbon neutrality target. This funding will be awarded through a competitive tender process (see Chapter 1). The TSO (Fingrid) is a state-controlled company, with the largest share held directly by the Finnish state (38%) and the state-owned National Emergency Supply Agency (33%); the rest is owned by Finnish financing and insurance institutions. Under Finnish law, the TSO is ownership unbundled.

Figure 6.6 Electricity infrastructure in Finland



Installed generation capacity

From 2018 to 2021, Finland's installed generation capacity increased from 17.6 GW to 18.7 GW (Table 6.1). Most of this growth came from onshore wind (+1.2 GW), projects less than 1 MW (+0.3 GW, mainly solar PV), bioenergy (+0.3 GW) and utility-scale solar PV (+0.3 GW). Over the same period, there was a small decline in capacity for coal-fired

generation (-0.5 GW) and peat-fired generation (-0.5 GW); gas and oil-fired capacity both remained stable. In line with goals to reduce emissions and increase electrification, Finland aims to expand generation capacity to at least 27.8 GW by 2030, most of which will come from wind (onshore and offshore) and solar PV (see Chapter 4). The capacity of coal, peat and gas-fired generation will decline. Installed capacity is expected to increase significantly in 2023 with the full operation of the Olkiluoto 3 nuclear reactor (1.6 GW), making nuclear the largest single source of capacity in Finland (4.4 GW in total).

Table 6.1 Installed generation capacity in Finland, 2018-2021

Installed capacity (GW)	2018	2019	2020	2021	Change 2018-21
Hydro	3.2	3.2	3.2	3.2	0.0
Wind	2.0	2.2	2.4	3.2	+1.2
Nuclear	2.8	2.8	2.8	2.8	0.0
Bioenergy	2.3	2.6	2.7	2.6	+0.3
Natural gas	1.8	1.8	1.8	1.8	0.0
Coal	1.9	1.6	1.4	1.4	-0.5
Peat	1.8	1.8	1.5	1.3	-0.5
Oil	1.3	1.3	1.3	1.3	0.0
Projects less than 1 MW	0.18	0.20	0.36	0.49	+0.3
Solar PV above 1 MW	0.1	0.2	0.3	0.4	+0.3
Waste	0.2	0.2	0.2	0.2	0.0
Total	**17.6**	**17.9**	**18.0**	**18.7**	**+1.1**

Interconnections

Finland has cross-border electricity interconnections with Estonia, Norway, Russia and Sweden (Table 6.2). In 2022, these interconnections had a total import capacity of 5.38 GW and a total export capacity of 3.98 GW. It is expected that now that Olkiluoto 3 reactor is fully operational, import capacity on the section of the Aurora interconnection with Sweden will be reduced from 1.5 GW to 1.2 GW (Fingrid, 2022a). Since May 2022, the interconnections with Russia (total import capacity of 1.5 GW) have not been in operation. Finland plans to end its reliance on Russian energy, so it is likely that these lines will not be used again.

Finland's TSO (Fingrid) is responsible for the operation and development of cross-border interconnections in co-operation with neighbouring TSOs. Fingrid plans to expand cross-border interconnection capacity with Estonia and Sweden to strengthen regional electricity security and support Finland's goals to become a net electricity exporter. Fingrid and the Swedish TSO (Svenska kraftnät) plan to add another 400 kilovolt (kV) line to the existing Aurora interconnection by 2025, which should increase import capacity by 0.8 GW and export capacity by 0.9 GW (Fingrid 2022b). In June 2022, Fingrid and the Estonian TSO (Elering) announced plans to commission a third interconnection (Estlink 3) by 2035. This project is planned as a subsea DC cable with a capacity of 0.7 GW to 1.0 GW. There is also a proposed project to increase the capacity of the existing Fenno-Skan 1 DC cable to Sweden from 0.5 GW to 0.8 GW before 2030 (ENTSOE-E, 2015). The currently planned interconnection projects would more than compensate for the loss of import

interconnection capacity from Russia. By 2035, Finland's electricity import and export capacity (excluding Russia) could both reach around 5.7 GW.

Table 6.2 Finland's interconnection capacity, 2022 and 2035

Country	Interconnection	Type	Capacity, 2022 (MW)		Capacity, 2035 (MW)	
			Export	Import	Export	Import
Norway	Aurora	220 kV AC line	100	120	100	120
Sweden	Aurora	Two 400 kV AC lines	1 100	1 500	1 100	1 200
		400 kV AC line (2025)	-	-	900	800
	Fenno-Skan 1	400 kV DC subsea cable	500	500	800	800
	Fenno-Skan 2	500 kV DC subsea cable	800	800	800	800
Estonia	Estlink 1	150 kV DC subsea cable	350	350	350	350
	Estlink 2	450 kV DC subsea cable	650	650	650	650
	Estlink 3	DC subsea cable (2035)	-	-	1 000	1 000
Russia	Vyborg	Three 400 kV DC lines	320	1300	0	0
	Ivalo	110 kV DC line	160	160	0	0
	Imatra	110 kV DC line	160	160	0	0
Total			**3 980**	**5 380**	**5 700**	**5 720**

Transmission

From 2018 to 2021, the total length of AC lines in the transmission grid decreased slightly, from 16 300 km to 16 100 km (Table 6.3). In 2022, the transmission system also included 269 km of high-voltage DC cables (500 kV to 150 kV) and around 120 substations. Finland's autonomous island region of Åland is connected to the transmission grid via a 100 MW DC subsea cable (Fingrid, 2021b).

Table 6.3 Finnish electricity transmission system AC lines, 2018-2021

Lines (km)	2018	2019	2020	2021
400 kV	5 500	5 500	5 500	5 500
220 kV	1 600	1 300	1 300	1 400
110 kV	9 200	9 200	9 100	9 200
Total	**16 300**	**16 000**	**15 900**	**16 100**

Fingrid is responsible for planning, operating, maintaining and developing the electricity transmission grid. In 2021, it invested EUR 166 million in supporting grid infrastructure (an increase of EUR 29 million compared to 2020). Fingrid plans to increase annual grid investments to EUR 300 million by 2023. Fingrid's Development Plan 2022-2031 includes

EUR 2.1 billion of investments aligned with Finland's energy and climate goals. The plan indicates that the main upcoming challenges are decreasing generation from co-generation plants in southern Finland; integrating higher shares of generation from nuclear, wind and solar PV; and meeting increased electricity demand resulting from electrification (Fingrid, 2022c). The plan notes that this will require additional transmission lines between the south of Finland (demand centres) and the north and west (the main sites for wind generation and interconnections with Sweden). The Development Plan 2021-2030 includes investments for 3 700 km of new transmission lines (2 300 km of 400 kV and 1 400 km of 110 kV), 41 new substations and the modernisation of 21 existing substations.

Distribution

From 2016 to 2021, the total length of lines in the distribution grid increased from 396 000 km to 418 400 km, mainly due to growth in low-voltage lines (Table 6.4). Over the same period, there was an increase in the number (138 000 to 140 000) and capacity (48 100 MVA to 51 100 MVA) of distribution system substations (Table 6.5). From 2016 to 2021, DSOs invested EUR 4.8 billion in the distribution system, mainly for maintenance (EUR 4.0 billion) and also for new infrastructure (EUR 0.8 billion) (Table 6.6).

Table 6.4 Finnish electricity distribution system lines, 2016-2021

	Lines (km)			
	Low voltage (under 1 kV)	Medium voltage (1-70 kV)	High voltage (110 kV)	Total
2016	243 000	146 000	7 000	396 000
2021	256 000	155 000	7 400	418 400
Change	+13 000	+9 000	+400	+22 400

Table 6.5 Finnish electricity distribution system substations, 2016-2021

[Number of sbustations]	Medium/low voltage	Medium/medium voltage	High/medium voltage
2016	138 000	120	1 100
2021	140 000	90	1 100
Change	+2 000	-30	0

Table 6.6 Finnish electricity distribution system investments, 2016-2021

	Investments (EUR billion)		
	Maintenance	New infrastructure	Total
2016	0.65	0.1	0.75
2017	0.71	0.12	0.83
2018	0.71	0.13	0.85
2019	0.63	0.16	0.78
2020	0.7	0.11	0.8
2021	0.64	0.14	0.78
Total	4.04	0.75	4.79

In 2021, Finland had 77 electricity DSOs operating grids with a voltage below 110 kV and 9 DSOs operating grids with a voltage of 110 kV or above. In 2020, the five largest DSOs supplied around 50% of the electricity delivered at the distribution level. In 2021, only 20

DSOs had more than 50 000 consumers. The largest DSOs are Caruna Oy (private ownership), Elenia Verkko Oyj (private ownership) and Helen Sähköverkko Oy (owned by the city of Helsinki). Most DSOs are owned directly by municipalities or by municipally owned limited companies. Many DSOs serve only a few thousand consumers.

The Electricity Market Act requires electricity DSOs to be legally unbundled from electricity generation and trade activities if their annual electricity deliveries through 0.4 kV networks were 200 GWh or more during three consecutive years. In 2021, 54 DSOs were legally unbundled (37 that exceeded the 200 GWh threshold value and 17 that voluntarily unbundled). DSOs with 50 000 or more consumers must have legal and ownership unbundling of network and generation activities (this applied to 20 DSOs in 2021).

DSOs must submit a grid development plan to the Energy Authority every two years that details the measures to maintain or improve quality of supply in line with the requirements of the Electricity Market Act. The Energy Authority can require DSOs to amend their plans if deemed necessary. In 2021, the Electricity Market Act was amended to require DSOs to invest in cost-effective measures that consider flexibility services as an alternative to grid investments. The first grid development plans reflecting these requirements were delivered to the Energy Authority in June 2022. According to the submitted plans, DSOs plan to invest around EUR 9.7 billion from 2014 to 2036, with around one-third earmarked to increase quality of supply. Investments to expand and increase the flexibility of the distribution grids are also necessary to support increased deployment of small-scale renewable generation like solar PV, and electrification of energy demand, especially EVs and heat pumps.

Electricity market and prices

Finland has a fully liberalised electricity wholesale and retail market. Wholesale trading takes place through an open trading platform open to all market actors. Retail suppliers offer a variety of supply contracts, with prices based on competition. Consumers are free to choose and change their supplier. Electricity prices are not regulated and there are no social tariffs. The Energy Authority has regulatory responsibility over Finland's electricity market, including overseeing the development and operation of generation, energy storage, demand side response, and the transmission and distribution systems. The Energy Authority's most recent market report shows a relatively competitive electricity market. However, some key metrics indicate declining competition. In addition, a relatively limited number of companies own the majority of generation capacity.

Unbundling of commercial activities and network operations is required for most electricity companies. However, most legally unbundled electricity retailers still belong to the same group of companies as the DSOs, or are owned by one or several DSOs. The number of new entrants and the market share of new entrants has been low.

The Mankala Model plays a major role in Finland's electricity market and the development of generation capacity. The Mankala Model aims to combine resources and share risks to carry out large-scale power plant projects with competitive production costs. Under the Mankala Model, a group of companies become shareholders in a joint venture power company that funds the construction or purchase of generation assets. The shareholders commit to paying the power company's costs in proportion to their holdings. The power company sells all the electricity and heat it generates to shareholders in proportion to their holdings. It does not produce profits or pay dividends. The shareholders may use the

electricity and heat themselves or sell it to other consumers through Finland's wholesale or retail markets (EPV Energio, 2022). In 2021, companies operating under the Mankala Model were responsible for around 40% of total electricity generation, 66% of nuclear electricity generation, and large shares of hydro and wind generation and co-generation (Pellervo, 2023).

Wholesale market

Finland is part of a wholesale electricity market that links over 20 European countries. This market has been consistently expanded and more tightly integrated as part of the ongoing project to create a single European internal electricity market. The wholesale market manages day-ahead and intraday electricity trading between interconnected European bidding zones. Most bidding zones are correlated with national borders and Finland is a single bidding zone. Within the European market, Finland is part of the Nordic wholesale electricity market, which covers the Nordic countries and the Baltic states. In 2022, around 70% of trade in the Nordic wholesale electricity market took place at the power exchange located in Oslo, Norway.

Finland is taking part in a joint European bidding zone review that will examine an alternative bidding zones configuration to identify potential new configurations to improve European wholesale market operations. The review is ongoing, but so far Finland has indicated it wants to retain its current single bidding zone. Possible changes in the bidding zone structures will be implemented at the beginning of 2025 at the earliest (Fingrid, 2021a).

The Energy Authority publishes an annual report on the status of Finland's energy markets. The most recent report, covering 2018-21, was published in July 2022 (Energiavirasto, 2021). The report provides key metrics on Finland's wholesale electricity market (Table 6.7) and described recent changes to market operations and competition. Day-ahead wholesale prices have experienced notable volatility in recent years, dropping to a historic low in 2020 as pandemic restrictions reduced demand, and surging to all-time highs in 2021 and again in 2022 (154.04 EUR/MWh) as a result of the energy crisis (Nord Pool Group, 2022).

Table 6.7 Key indicators of Finland's wholesale electricity market, 2018-2022

Wholesale electricity market indicators	2018	2019	2020	2021
Electricity production (TWh)	67.5	66.1	66.1	69.0
Total annual electricity demand (TWh)	87.4	86.1	81.1	86.8
Imports volume (TWh)	22.5	23.9	21.6	24.5
Exports volume (TWh)	2.6	3.9	6.7	6.7
Traded volume in the spot market (TWh)				
• Day-ahead buy volume	61.6	63.2	59.0	62.8
• Day-ahead sell volume	48.6	50.1	45.2	52.3
• Intraday buy volume	1.1	1.0	1.0	1.1
• Intraday sell volume	1.0	1.0	1.0	1.1
Average day ahead price in the Finnish bidding zone (EUR/MWh)	46.80	44.04	28.02	72.34

In 2021, there were more than 100 companies generating electricity in Finland. However, only 32 of these companies owned assets with a total capacity over 100 MW and only 4

owned assets with a total capacity over 1 GW (Table 6.8). Fortum (a state-owned company) has historically been the largest owner of generation capacity (2.8 GW in 2021). However, it is expected that in 2023, TVO (a private company that owns the Olkiluoto nuclear plant) will become the largest owner of generation capacity (3.4 GW) with the completion of the Olkiluoto 3 reactor. Helen Oy (owned by the city of Helsinki) owns the third-largest share of generation capacity (1.1 GW in 2021). Many of the largest electricity generation companies operate under the Mankala Model. Most electricity generation companies are owned by municipalities and operate smaller scale co-generation plants for district heating. The TSO owns around 1 GW of generation assets, which are used as reserves (Fingrid, 2022c).

Table 6.8 Finnish electricity generation companies with more than 100 MW, 2021

Company name	Capacity (MW)	Plant types
Fortum	2 764	Nuclear, fossil, renewables
TVO	1 780	Olkiluoto nuclear plant
Helen Oy	1 147	Multiple energy sources
Kemijoki Oy	1 122	Hydro
Fingrid Oyj (TSO)	968	Reserve power plants
Stora Enso Oyj	636	Forest industry
Metsä Fibre Oy	550	Forest industry
UPM-Kymmene Oyj	485	Forest industry
Tuuliwatti Oy	437	Wind
PVO Vesivoima Oy	413	Hydro
Tampereen Sähkölaitos	349	Multiple energy sources
Vantaan Energia Oy	304	Multiple energy sources
Oy Alholmens Kraft Ab	270	Mainly biomass
Turun Seudun Energiantuotanto Oy	253	Multiple energy sources
EPV Tuulivoima Oy	233	Wind
Vaskiluodon Voima Oy	230	Multiple energy sources
Oulun Energia Oy	207	Multiple energy sources
Jyväskylän Voima Oy	190	Multiple energy sources
Kilpilahden Voimalaitos Oy	152	Oil refining by-products
Suomen Hyötytuuli Oy	150	Wind
Tuulipuisto Oy	138	Wind
Haapajärven Savinevan Tuulivoima Oy	133	Wind
Sappi Finland Oy	128	Forest industry
wpd Oy	128	Multiple energy sources
Seinäjoen Voima Oy	120	Multiple energy sources
Kaukaan Voima Oy	119	Multiple energy sources
Kuopion Energia Oy	118	Multiple energy sources
Lahti Energia Oy	109	Multiple energy sources
Kainuun Voima Oy	108	Multiple energy sources
Länsi-Suomen Voima Oy	105	Multiple energy sources
Lappeenrannan Lämpövoima Oy	102	Multiple energy sources
Savon Voima Oyj	101	Multiple energy sources
Total	14 049	

In Finland's wholesale electricity market, trading takes the form of bilateral direct trading among market actors via a power exchange run by a nominated electricity market operator (NEMO). In 2017, the Energy Authority, in co-operation with other Nordic regulatory

authorities, approved a multi-NEMO arrangement, which enables multiple NEMOs to offer day-ahead and intraday trading services in Finland. In 2019, the Energy Authority designated the European market coupling operator (EPEX SPOT SE) as Finland's NEMO for an indefinite period, with an obligation to inform the Energy Authority of relevant changes to market operations. Since 2019, the Swedish NEMO Nasdaq Oslo ASA has had the right to offer day-ahead trading services in Finland. Since May 2022, the Swedish NEMO Nasdaq Spot AB has the right to offer day-ahead trading services in Finland. EPEX SPOT SE launched intraday continuous trading and clearing services on 25 May 2020 and started offering day-ahead trading services on 3 June 2020. Nasdaq Oslo ASA and Nasdaq Spot AB have not yet started offering day-ahead trading services in Finland.

Finland has been part of the European Cross-Border Intraday (XBID) solution since the first wave of XBID go-live in June 2018. XBID allows for orders entered by market participants for continuous matching in one bidding zone to be matched by orders similarly submitted by market participants in any other bidding zone within the XBID solution's reach, as long as transmission capacity is available. Finland also has markets for frequency containment reserves (FCR products), fast frequency reserve, automatic frequency restoration reserve, and balancing energy and balancing capacity markets (Fingrid, 2022e).

In September 2022, following Russia's unliteral decision to stop supplying natural gas via Nord Stream 1, the government offered EUR 10 billion in liquidity guarantees to Finnish electricity companies. This is intended as a last-resort financing option for companies that would otherwise be threatened with insolvency because of ballooning collateral requirements for operation on key energy-trading platforms (Mukherjee and Lehto, 2022).

Retail market

The Energy Authority regularly publishes an electricity market monitoring report that provides numerous details on the status of the market (Table 6.9). The 2021 report indicates that there are 58 retail suppliers selling electricity to households and other small-scale consumers. This was a slight reduction from recent years because of mergers and a few suppliers exiting the market. The report notes that there is a small number of retail suppliers selling electricity to large consumers (but most of this demand is met outside the retail market through the Mankala Model).

The report notes that only a few electricity retailers are ownership unbundled from electricity network activities. Most legally unbundled electricity retailers still belong to the same group of companies as the DSOs or are owned by one or several DSOs. Electricity retail supply does not require any licence or registration from the Energy Authority. The report notes that the exact market shares of individual retailers are not available. However, it provides estimates indicating that the three largest retail suppliers of small and medium-sized consumers have a 41% market share (by delivered kWh) and that this share has increased slightly in recent years. It also notes that of the 58 active retailers, only 7 have a market share of over 5% (by delivered kWh) and only 6 have a market share over 5% (by number of consumers). The number of these larger retailers has increased since 2018 due to mergers.

In 2021, the Herfindahl-Hirschman Index (HHI) was over 800 for all segments of the retail market, indicating a rather competitive marketplace. However, this is a notable increase from 2018, when the HHI was 450 for some market segments. This indicates decreasing

competition. In addition, the Energy Authority indicates that over this time, there was only a limited number of new entrants into the market and that the market share of new entrants remained low.

The Energy Authority maintains a website (https://sahkonhinta.fi) giving retail price comparisons intended to help consumers make informed choices. Electricity consumers are protected by the obligation imposed on suppliers that limits cutting off electricity because of unpaid bills, especially in the winter. Electricity supply can usually be cut off five weeks after the customer has been reminded of outstanding payments. During the winter months (October to April), the electricity supply will not be cut off in a home with electric heating until four months have elapsed since the due date of missed payments.

Table 6.9 Key retail market indicators in Finland, 2018-2021

Electricity retail market indicators	2018	2019	2020	2021
Number of electricity customers (million)	**3.58**	**3.61**	**3.56**	**3.60**
• Household customers	3.12	3.15	3.09	32
• Other customers	0.46	0.47	0.50	0.40
Number of electricity suppliers	72	71	63	58
Market share of the three largest suppliers by metering point	35-40%	40-45%	45%	41%
Number of retailers with market shares >5%	4	7	6	6
Number of retailers with customer shares >5%	3	5	6	6
External switching rate	**10.9%**	**13.9%**	**15.5%**	**16.2%**
• Households	11.1%	14.3%	15.6%	16.2%
• Other customers	10.2%	12.3%	14.7%	17.1%
Share of consumers by contract type				
• Fixed-term contract	42%	49%	52%	54%
• Open-ended contract	49%	40%	40%	37%
• Dynamic price contract	9%	11%	8%	9%
Herfindahl-Hirschman Index (energy sold)	450-475	725-750	875-900	825-850
• Households	575-600	800-825	875-900	725-750
• Other customers	450-475	750-775	975-1 000	800-825
Herfindahl-Hirschman Index (metering points)	625-650	850-875	925-950	800-825
• Households	650-675	875-900	950-975	875-900
• Other customers	450-475	800-825	825-850	775-800
Households with a contract for partial self-generation	13 200	21 400	29 900	37 100

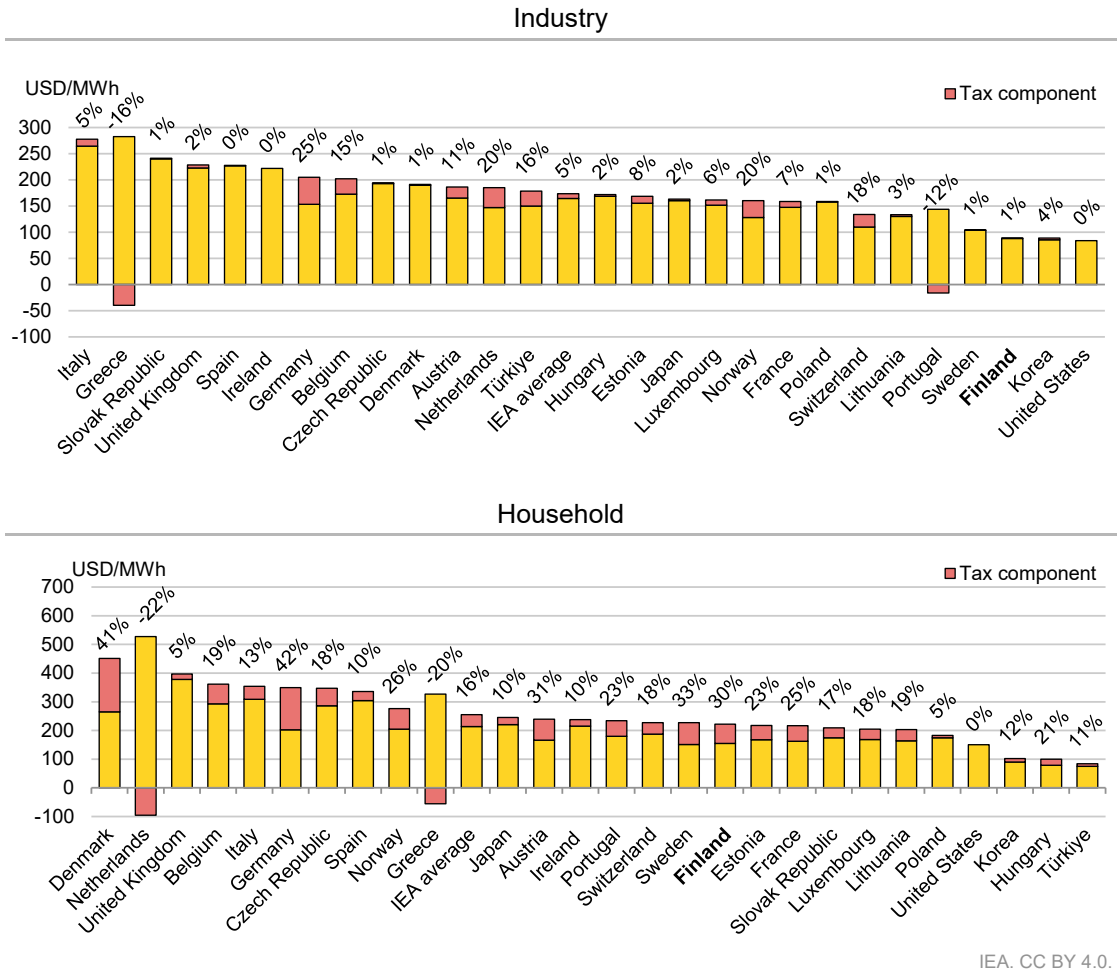
Retail prices, tariffs and taxes

In the second quarter of 2022, Finland's industry electricity price was the third-lowest among IEA countries at 88.8 USD/MWh, with a tax rate of 1%, compared to an IEA average price of 173.7 USD/MWh and an average tax rate of 5% (Figure 6.7) Finland's household prices were 17th highest at 222.3 USD/MWh, with a tax rate of 30%, compared to an IEA average price of 255 USD/MWh and an average tax rate of 16%.

From 2018 to 2021, the retail electricity price for a typical household consumer increased by around 2 EUR/MWh (Table 6.10). Over this period, the share of taxes in the energy price declined slightly from 31.9% to 30.6%. At the start of 2022, the share of taxes continued to decline and was 29% for a typical household consumer with annual

consumption of 5 MWh (Figure 6.7). As a result of the energy crisis, electricity price offers for households increased by four to five times from early 2021 to early 2023.

Figure 6.7 Industry and household electricity prices in Finland, 2Q 2022



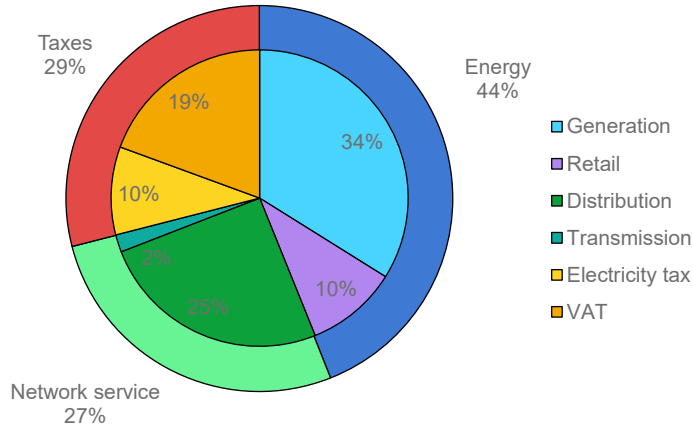
Note: Industry prices are unavailable for Australia, Italy, Mexico and New Zealand; household prices are unavailable for Italy, Mexico and New Zealand. Tax information is unavailable for the United States.

Source: IEA (2022).

Table 6.10 Electricity price breakdown for a typical household consumer in Finland, 2018-2021

	2018	2019	2020	2021
Total (EUR/MWh)	**17.96**	**18.62**	**18.64**	**19.97**
• Network tariffs (excluding taxes)	5.93	6.18	6.38	3.2
• Energy costs and supply margin (excluding taxes)	6.30	6.58	6.40	7.65
• Taxes	5.73	5.86	5.86	6.11

Figure 6.8 Electricity price breakdown for a typical household consumer in Finland, 2022



In late 2021, the global energy crisis resulted in a sharp increase in Finland's electricity prices. In early 2022, the Electricity Market Act was amended to reduce retail electricity prices by reducing the allowed profits for DSOs and the allowed increase in distribution network tariffs. The rate of return for DSOs was reduced from 5.73% to 4%, the lowest level ever. The upper limit for annual tariff increases was reduced from 15% to 8%. These changes are expected to reduce DSO charges to consumers by EUR 350 million (Finland, Ministry of Economic Affairs and Employment, 2021).

Electricity policy

The government aims for the electricity sector to play a major role in achieving the 2035 carbon neutrality target and long-term emissions reductions. The government expects most investment in the electricity sector to be driven by market forces, but it has introduced support measures to encourage investments to further reduce the carbon intensity of electricity generation and increase electrification of energy demand (see Chapters 3 and 4). Energy taxation has also been adjusted to make investments in low-carbon generation and electrification more attractive (see Chapter 1). The government is also encouraging the TSO and DSOs to make significant investments that support increased low-carbon generation and electrification.

Renewable generation

Renewables are the largest source of electricity generation in Finland, providing 38 TWh or 53% of total generation in 2021 (mainly from hydro, forestry biomass and onshore wind). Finland is pushing for much higher generation from renewables, mainly from wind and solar PV. The NCES estimates that wind generation will increase to at least 23 TWh by 2030 and 30 TWh by 2035 (compared to 8.1 TWh in 2021) and that solar PV generation will increase to at least 2.4 TWh by 2030 and 3.4 TWh by 2035 (compared to 0.3 TWh in 2021). Industry estimates indicate that growth in wind and solar PV generation could be even higher. The government also aims to maintain high shares of generation from hydro and sustainable use of forestry biomass.

The government expects most of the renewable generation capacity to be deployed on a market basis. However, the Energy Aid programme and an *ad hoc* support scheme to award funds from the EU Recovery and Resilience Facility can provide investment subsidies to renewable projects that demonstrate new technologies or deploy small-scale distributed renewables (see Chapter 1). Finland is providing operational subsidies (FIT and FIP) to existing renewable electricity projects that met certain requirements, but these subsidies are no longer available for new projects.

With the removal of operational subsidies, long-term PPAs are becoming a driver for new renewable energy projects in Finland. The first announcement of a merchant project without any subsidy support was made in May 2018. This project used a PPA to support a 21 MW wind project. Since then, the use of PPAs to support renewable projects has accelerated and they are being used by private companies and municipal energy utilities. The signing of PPAs reached a record level in 2022 and is expected to expand. However, larger wind farm project developers have stated that investment decisions are no longer fully dependent on a long-term PPA, and that many projects can be profitable by selling on the open market (Chambers and Partners, 2022).

The government is promoting the deployment of wind generation by allocating additional funding for national wind power surveys for studies to speed up planning and permitting by municipalities and regional councils. In 2022, an additional EUR 1.5 million in funding was provided to support these efforts. Wind generation projects deployed in Finland require approval from Finland's Defence Forces to ensure that they do not interfere with military radar systems. This requirement has led to a concentration of wind projects in western Finland, creating some concerns about grid constraints. Historically, the Defences Forces rejected around 20% of submitted projects. Since Russia's invasion of Ukraine, the Defence Forces have been rejecting a higher share (around 33%) of submitted wind projects (YLE News, 2022).

Finland aims for offshore wind to play a major role in achieving its climate goals; however, it thus far has only one small (44 MW) offshore wind farm (Tahkoluoto), which started operations in 2017. In December 2021, Finland started developing a competitive tender process to lease areas for offshore wind projects in public waters. The winner of an auction is given exclusive rights to develop a specific area and must pay the agreed lease price, the cost of subsea cables and other offshore infrastructure to connect to the onshore grid, and a grid connection fee. The electricity TSO is responsible for any costs to upgrade the onshore grid to receive offshore wind generation. The auction will not offer any financial support. However, investment aid for offshore wind projects can be granted through an *ad hoc* support scheme to award funds from the EU Recovery and Resilience Facility. In addition, the government has reduced the property tax for offshore wind turbines compared to onshore turbines.

Prior to the decision to use an auction system for offshore wind leases, the government had already agreed to lease two areas for offshore wind development. One lease is for additional sea area to expand the existing Tahkoluoto wind farm from 500 MW to 900 MW. The second is for the new Korsnäs offshore wind farm, with a total capacity of at least 1 400 MW, expected to be fully operational by 2028 (Wind Europe, 2022). Going forward, all new leases will be allocated through the auction system.

The government also wants offshore wind generation deployed in the Finnish exclusive economic zone located outside Finland's public waters. Developing wind generation in the

exclusive economic zone would require legislative amendments. However, the government is already taking steps to promote offshore wind projects in the exclusive economic zone. In January 2022, the private company OX2 received exploration permits for two offshore wind farms that could fit 310 turbines in the Gulf of Bothnia exclusive economic zone. The permits enable more extensive seabed exploration (Baltic Wind, 2022).

The government is providing financial support to increase solar PV deployment, which has been relatively limited in Finland. Solar PV received one of the highest levels of funding from the Energy Aid programme (a total of EUR 37.5 million from 2018 to 2021). Small-scale solar PV is exempt from energy taxation and eligible for a tax deduction for expenses incurred when installing renewable generation in a private home. Support for energy communities will also likely boost solar PV deployment. In 2020, the government adopted a decree enabling electricity generation sharing in energy communities and the introduction of hourly net metering. An amendment to the Electricity Market Act adopted in August 2021 allows for energy communities that cross property boundaries. The government also aims to support distributed generation by making it easier for SMEs to sign PPAs, with solar PV being one of the attractive options for such PPAs.

Nuclear generation

Nuclear energy plays a key role in Finland's energy sector and is a central part of the government's plans to achieve carbon neutrality and reduce energy import dependence (see Chapter 7). Finland's two nuclear power plants (Olkiluoto with three reactors and Loviisa with two reactors) have a total generation capacity of 4.39 GW and typically account for around one-third of Finland's electricity generation. The share of generation from nuclear is expected to substantially increase now that the Olkiluoto 3 reactor is fully operational. After facing significant delays, Olkiluoto 3 is the first nuclear reactor deployed in Europe in over 15 years and one of the largest reactors in the world (1.6 GW). The plant operator estimates that Olkiluoto 3 will generate 12 TWh per year, enough to cover around 14% of annual electricity demand, reduce electricity imports by 60% and increase the share of carbon-free electricity generation to over 90% (TVO Nuclear, 2022).

Finland's energy policy focuses on maintaining a high share of nuclear generation and ensuring the safe, secure and efficient operation of nuclear power plants. The Finnish state is not involved in investment decisions on nuclear power plants and does not provide subsidies for nuclear energy. The NCES states that applications for new nuclear power plants are considered under the processes established in the Nuclear Energy Act and that extending operating licences for existing nuclear power plants is welcomed, provided that all licence conditions are met. The government granted several reactor lifetime extensions, most recently in 2018 and 2023.

The Loviisa nuclear plant is based on Russian technology and has been reliant on nuclear fuel imports from Russia. Since Russia's invasion of Ukraine, Russia has indicated that it is considering banning the export of nuclear fuel to Finland, and Finland has placed a strong focus on reducing reliance on Russian energy imports (Normanton, 2022). So far, neither country has taken actions that would stop deliveries of nuclear fuel from Russia to Finland. In May 2022, the Loviisa plant operator stated that it had fuel in storage to support two years of operations (Fortum, 2022). The Russian invasion of Ukraine did result in the cancellation of a planned third nuclear plant in May 2022. The Hanhikivi 1 project aimed to deploy a 1.2

GW reactor in northern Finland. It was based on Russian technology and led by a consortium that included the Russian state-owned nuclear company Rosatom (Fennovoima, 2022).

Electrification

A relatively large share of Finland's energy demand is covered by electricity, but there has been almost no increase in electrification in the last decade. From 2010 to 2020, the share of TFC covered by electricity barely increased, by just 0.1%, from 27.2% to 27.3%, but remains above the IEA average of 23% in 2020. Rapidly accelerating electrification of energy demand across all sectors is a key policy goal and a central part of Finland's plan to achieve carbon neutrality and long-term emissions reductions. The NCES estimates that electricity demand will increase in all sectors and total at least 92 TWh by 2030 and 96 TWh by 2040 (compared to 83 TWh in 2021). The largest increases in electricity demand are expected to come from transport and industry (a notable share of heating is already electrified).

The government has introduced a variety of measures to support the electrification of energy demand (see Chapter 3). There is a subsidy to convert oil heating to other heating systems, with a focus on heat pumps. Several energy efficiency programmes for buildings include grants or financing for electrification. The government is also supporting the use of large-scale heat pumps for district heating networks. In the transport sector, there are subsidies and tax reductions for EVs, financial support for deploying EV charging and a goal for complete electrification of rail demand. For industry, a subsidy is available to support projects that reduce GHG emissions, including through electrification. Finland's hydrogen strategy also includes goals to greatly expand the production of low-carbon hydrogen (including through electrolysis) and electro-fuels to support emissions reductions in hard-to-abate sectors like heavy road transport, marine shipping, aviation and industrial processes (see Chapter 1).

Several changes were made to energy taxation to encourage electrification. The energy tax rate for electricity used by industry and other energy-intensive activities was reduced to the lowest rate allowed under EU tax rules (0.5 EUR/MWh)[4], while taxation of fossil fuels was increased. The energy tax rate of electricity used by heat pumps and electric boilers supporting district heating networks or meeting certain efficiency standards and electricity used by pumps in geothermal heating plants was also reduced to 0.5 EUR/MWh. In addition, an energy tax refund for energy-intensive industry will be phased out by 2025.

Fossil and peat generation

A relatively small share of Finland's electricity generation comes from fossil fuels, mainly natural gas (5.5% of generation in 2021), followed by coal (4.8%), peat (2.6%) and oil (0.3%). However, around two-thirds of electricity from co-generation plants is generated from fossil fuels, mainly natural gas (31%), coal (18%) and peat (15%). In line with its climate targets, Finland is taking numerous steps to reduce the use of fossil fuels and peat for electricity and heat generation.

In May 2019, the Finnish parliament approved a ban on coal-fired generation after 1 May 2029 (Finland, Ministry of Economic Affairs and Employment, 2019). To encourage the

[4] A separate strategic stockpile fee of 0.13 EUR/MWh was left unchanged for a total tax rate 0.63 EUR/MWh.

rapid retirement of coal-fired plants, there is a subsidy for companies that phase out coal-fired generation by 2025. The subsidy has a budget of EUR 90 million, with half available to companies that replace coal plants with co-generation plants using wood-based fuels. The other half of the budget supports companies that replace coal plants using new technologies based on heat storage, waste heat and geothermal heat (Borenius, 2018).

Finland has set a non-binding goal to reduce the use of peat for energy by at least 50% by 2030. In line with this goal, a peat floor price mechanism was introduced to ensure a reduced use of peat even if the ETS prices significantly decline. Because of high ETS prices and other factors reducing the competitiveness of peat, the use of peat for energy may end before 2030. Three private companies that are the largest users of peat for energy in Finland have announced plans to stop using peat by 2022-24 and have already moved significant heat and electricity generation to plants powered with forestry biomass and/or waste (Pledge Times, 2022).

The government indicates that the reduction in peat energy use should take place in a fair manner, both regionally and socially, and should not jeopardise the security of electricity and heat supply. Support measures have been introduced to limit the economic impact of reduced peat. Following the Russian invasion of Ukraine, the National Emergency Supply Agency decided to establish an emergency reserve of peat that can cover six months of Finland's peat demand (see Chapter 1).

The government expects electricity generation for gas and oil to continue to fall based on market forces. There are no goals for phasing out gas- or oil-fired generation by a specific year and no support measures to encourage early retirement of gas- or oil-fired plants.

System flexibility

Smart meters

Nearly 100% of electricity consumers in Finland have had a smart meter with hourly measurement resolution since 2013. Most of the current smart meters will come to the end of their lifetime in 2025-30. Finland is transitioning the retail market to 15 minutes balance settlement by the summer of 2023. By this time, all large consumers (over 3*200A fuse) will have a second-generation smart meter with a 15-minute resolution and all consumers whose smart meter can be remotely updated will have it adjusted to the 15-minute resolution. All other customers will receive smart meters with a 15-minute resolution by 2028.

All customers have the possibility to choose an electricity contract with dynamic pricing based on the day-ahead market prices. Almost all retail suppliers provide the option of dynamic contracts to their customers. At the end of 2021, approximately 9% of retail consumers had a dynamic electricity price contract. There are many service providers, including aggregators, who give small consumers the possibility to participate in balancing markets.

Datahub, the centralised information exchange system for the retail electricity market, went live in February 2022. In accordance with the Electricity Market Act, information related to electricity accounting points, such as customer and consumption data, will be stored in

Datahub. The system is intended to speed up information exchange between parties, with the data being available to everyone entitled to it at the same time in an impartial and up-to-date manner (Fingrid, 2023).

In addition to electricity companies' customer service portals, the information stored in Datahub will be available for viewing through Datahub's own customer service portal after the system's introduction in 2023. The service will display the user's personal data and customer information for their accounting point. Logging into the service uses the Suomi.fi strong authentication. Through the service, electricity consumers can also authorise a third party to act on their behalf in Datahub. The launch of the customer service portal will be announced separately.

Demand side response

DSR is well developed in Finland. The government estimates that there was around 1 000 MW of DSR participating in the day-ahead market in September 2022. The government expects the amount of DSR participating in the day-ahead market to increase going into the winter of 2022/23. Based on Fingrid's estimations, there is up to 200 MW of DSR in intraday markets, up to 530 MW DSR up-regulation and 100 MW DSR downregulation in balancing markets, 410 MW DSR up-regulation in FCR-D, 10 MW DSR in FCR-N, and 80 MW DSR in fast frequency reserve markets (Fingrid, 2022e).

In 2018, the Smart Grid Working Group proposed a programme to increase DSR capacity and the opportunities for consumers to provide DSR to participate. The working group's key proposals were: 1) clarifying the roles of actors in the market-based implementation of DSR (e.g. principles for the storage of electricity, discontinuation of the load control implemented by distribution networks); 2) improving the operating prerequisites for different energy communities and aggregation models; 3) defining the functionalities of next-generation smart meters; 4) enabling flexibility in the operation of grid companies; and 5) enabling joint invoicing for all suppliers.

Energy storage

Finland has limited deployment of energy storage. In 2022, the largest energy storage projects were all battery projects and included 30 MW/30 MWh in Lappeenranta, 6 MW/6.6 MWh in Li, 4 MW/1.5 MWh in Lempäälä, 2 MW/2.1 MWh in Espoo, 2 MW/1 MWh in Järvenpää and 1.2 MW/0. 6 MWh in Helsinki. There are also several battery-storage projects and a pumped hydroelectric energy storage under development in Pyhäsalmi, with up to 150 MW of capacity, depending on the final concept. The Energy Authority has taken the approach that DSOs should not own or operate storage facilities. The Electricity Market Act requires DSOs to consider demand response, electricity storage and other alternatives to grid expansion in their development plans. Some DSOs have procured services from electricity storage facilities.

There are no specific targets for energy storage capacity, but the government aims to increase the deployment of energy storage. Some partial investment subsidies can be granted, but generally new projects are based on market revenues. It is supported through the Energy Aid programme. The taxation of electricity storage was reformed at the beginning of 2019 to eliminate double taxation (for storing and discharge) and regulation concerning the definition of equipment used in independent electricity generation was specified on 14 September 2020. Strategy 2025, published in June 2021, presents a road map for Finland to become a major player in the international battery industry.

Electricity emergency response

Electricity emergency response and organisation

Finland's electricity emergency preparedness planning and emergency response procedures are governed by EU Regulation (2019/941) on risk-preparedness in the electricity sector, the Finnish Electricity Market Act (2013/588) and the Finnish Emergency Powers Act (1991/1080).

The Energy Authority (Energiavirasto) has responsibility for risk preparedness and emergency response in the electricity sector. Its responsibilities include updating electricity emergency scenarios every four years and organising electricity emergency exercises in co-operation with the TSO and other relevant stakeholders.

In an emergency situation, the Energy Authority would act as the crisis co-ordinator. The TSO, Fingrid Oyj, would be responsible for working to restore electricity supply and instructing DSOs and power suppliers. The Ministry of Economic Affairs and Employment (MEAE) would be responsible for communication with the general public and negotiating assistance from neighbouring countries.

Electricity emergency preparedness

Reserve capacity

In addition to the peak load reserve capacity (see above), the TSO maintains around 1.2 GW of "frequency restoration reserves" for use in emergency situations.

Emergency fuel reserves

All power plant operators are required to hold emergency fuel reserves. The quantity of backup fuel supply must equal the equivalent of three months of the previous year's consumption. The National Emergency Supply Agency holds additional emergency reserves of fuel oil, diesel and coal.

Risk preparedness plans

The Energy Authority updates its risk preparedness plans every four years in co-operation with the TSO, DSOs and the MEAE. The latest risk preparedness plan was released in 2021 and covered ten "crisis scenarios", including extreme weather situations, a cyberattack and a physical attack on a control centre.

The Electricity Market Act requires that the TSO and DSOs also develop individual risk preparedness plans to be submitted to Energy Authority every three years.

Security of distribution networks

The Electricity Market Act requires DSOs to continuously work towards improving the security of their distribution networks. DSOs are required to submit reports every two years to the Energy Authority outlining work that has been done to improve the security of overhead lines in high-risk environments (e.g. forests) as well as to increase the share of ground cables in their networks. For most network operators, the target for ground wiring is around 50%.

The share of ground wiring in the medium voltage network in Finland almost doubled between 2016 and 2020, while the share of the overhead lines in forests, roadsides and other open areas decreased.

Electricity emergency response measures

If there is a credible threat of a significant disruption to electricity supply, the Energy Authority would initially consult with the TSO and the MEAE to decide whether to declare a state of "alarm". If a state of "alarm" is declared, the MEAE would begin consultations with neighbouring countries to ascertain whether imports can be increased through interconnections while the TSO would consult with generators and consider calling on any available reserve capacity. If the Energy Authority declares a state of "emergency", the National Emergency Supply Agency can give an order permitting generators to utilise backup fuel reserves and potentially release its own fuel reserves.

Through the so-called "Haga declarations" on Nordic Co-operation on Civil Security and Emergency Management (signed between Finland, Denmark, Iceland, Norway and Sweden, in 2009 and 2013), Nordic countries are obliged to assist each other in the event of an electricity supply emergency if they have available spare generation and transmission capacity that can be used to send electricity imports to a neighbouring country.

If an emergency situation cannot be resolved by increasing imports, calling on reserve capacity and using backup fuel reserves, the government can, if necessary, use the powers within the Emergency Powers Act to restrict the use of electricity. A plan for restricting the use of electricity is outlined in the Plan for Restrictions of Electricity Use.

Assessment

The government aims for the electricity sector to play a major role in achieving the 2035 carbon neutrality target and long-term emissions reductions. The government expects most investment in the electricity sector to be driven by market forces, but it has introduced support measures to encourage investments to further reduce the carbon intensity of electricity generation and increase electrification of end use sectors. Energy taxation has also been adjusted to make investments in low-carbon generation and electrification more attractive. The government is also encouraging the TSO and DSOs to make significant investments to support increased low-carbon generation and electrification.

Finland has fully liberalised electricity wholesale and retail markets. Electricity prices are not regulated and there are no social tariffs. The Energy Authority's most recent market report shows a relatively competitive electricity market. However, some key metrics indicate declining competition. In addition, a relatively limited number of companies own the majority of generation capacity, most electricity retailers are still affiliated with DSOs, and the number of new entrants and their market shares are low. The state-owned company Fortum plays a major role in electricity generation and in the wholesale and retail electricity markets.

Finland has taken numerous steps to address high electricity prices resulting from the global energy crisis. This includes reducing the allowed profits for DSOs and creating a variety of programmes to provide tax breaks or funding to consumers to offset high electricity costs. These measures focus on direct payment to offset costs in the short term

and should be complemented by actions such as building insulation and renovation and distributed energy resources (renewable generation, energy storage and DSR) to improve long-term resilience to price shocks, especially for vulnerable consumers, while driving electrification and reducing emissions. Targeting and measuring the impacts of this work would be assisted by a clear national definition of energy poverty.

In May 2019, the Finnish parliament approved a ban on coal-fired generation after 1 May 2029. To encourage the rapid retirement of coal-fired plants, there is a subsidy for companies that phase out coal-fired generation by 2025. Finland has set a non-binding goal to reduce the use of peat for energy by 50% by 2030 (it is mainly used in co-generation plants) but it is expected that market forces will end the use of peat well before 2030. The government expects that generation from gas and oil will continue to fall based on market forces.

DSR is well developed in Finland. The government estimates that there was around 1 000 MW of DSR participating in the day-ahead market in September 2022. DSR also has notable participation in other markets (balancing, frequency, etc.). Finland is working on policy changes to increase DSR market participation. The government should aim to bring more companies and household consumers to remunerated DSR programmes, a resource easy and important to tap, thanks to Finland's lead in the roll-out of smart metering and dynamic pricing. Aggregators will play a key role in boosting the role of distributed DSR and the government should ensure the market and regulations are supportive for aggregators.

DSR from industry in the electricity market is attractive in the short run due to the energy crisis and in the longer run due to the increased need for flexibility in the electricity sector. The government should work with industry to remove any barriers to industrial DSR and ensure that industrial DSR provides wider benefits to the electricity system.

Finland has limited deployment of battery storage (less than 50 MW in 2022). However, there are battery storage projects under development and numerous large-scale thermal energy storage facilities are in operation. The government is supporting energy storage through investment subsidies and changes to taxation and regulation.

As the share of generation from variable renewable energy increases, the need for investments in both short-, medium- and long-term storage will grow. Battery storage can play a key role in increasing system flexibility. Thermal storage can play a critical role in reducing peak heating demand and supporting more flexible and cost-effective operation of both district heating networks and the electricity system.

A portfolio of variable renewable energy sources, DSR and storage geographically spread around the country can facilitate the integration of the electricity, industry and transport sectors through energy system integration. Finland can build on its experience with system integration to support more efficient use of variable renewable generation and smart flexibility solutions. Aggregators will play a critical role in delivering the benefits of distributed energy resources.

The Finnish transmission and distribution networks are well-developed and maintained and provide a good basis for additional distributed generation and smart grid functionalities. Their extension and maintenance should go hand-in-hand with the national energy and climate strategies, including facilitating investments in flexibility services as an alternative to classical grid expansion. The TSO's and DSOs' most recent development

plans indicate notable increases in funding needs. However, it is possible that the number of renewable energy projects coming on line will grow at a rate not seen before in Finland, and more ambitious investments in grid expansion and flexibility may be necessary.

Fingrid has deployed dynamic line rating systems on several high-voltage power lines, boosting capacity by an estimated 10%. Fingrid has indicated an interest in expanding the use of dynamic line rating to other parts of the transmission system and would like to use it on the interconnection with Sweden. This is an excellent low-cost option to boost transmission capacity and support the integration of renewable generation.

The strong increase in variable renewable energy projects and the relative isolation of Finland's grid could lead to the need to curtail some variable generation in the near future. Thanks to Finland's robust grid and strong interconnection capacity, curtailment has been very rare and there are no regulations on how it is handled or compensated for. Low curtailment levels can be a cost-effective alternative to grid expansion and can help with system balancing. Before curtailment becomes a major issue, Finland needs to establish clear rules for curtailment so that wind farm project developers are not discouraged from investments.

Adequate interconnections to Norway, Sweden and the Baltics are increasingly important to reap the full benefits of Nordic and Baltic market integration and supply security. The planned upgrades with the reliable neighbours are, therefore, highly relevant. The government should ensure that its permitting responsibilities for these lines are completed in a timely manner and co-operate closely with neighbouring governments to ensure these projects are completed as soon as possible.

The Energy Authority estimates that the HHI in terms of energy volumes in the retail market is about 850, showing a rather competitive marketplace. However, the HHI has been increasing, indicating reduced competition. In addition, the number of new entrants and the market share of new entrants has been low. The current period of high prices and market volatility could lead to further mergers or market exit of suppliers and decreased competition. More effort is needed to ensure that Finland's electricity market is attractive to new entrants and innovative products.

Finland is a global leader in smart meters, which have been in place for almost all consumers since 2013. Finland is now rolling out second-generation smart meters with a 15-minute resolution to support transitioning the retail market to a 15-minute balance settlement by mid-2023. Despite the widespread and long-standing availability of smart meters, there has been relatively limited use, with just 9% of consumers on a spot price contract in 2021 and relatively limited development of new retail products. However, with the very high prices at the moment, most retail suppliers are now only offering spot price contracts and the share of consumers on spot contracts is set to greatly increase.

It seems that the benefits of contracts with spot prices are not fully understood, and fixed contracts or dynamic contracts (which allow suppliers to change prices on a monthly or seasonal basis) are the norm for households. This represents an information task for the government, as spot prices will often be an economically attractive choice as the fixed price has a high mark up. Spot prices will also incentivise behavioural reactions to prices and open up for potential demand response.

Datahub, the centralised information exchange system for the retail electricity market, went live in February 2022. Datahub provides a single interface for suppliers to get information

on consumers to support product development, automates some of the supplier switching processes and gives consumers detailed real-time access to their electricity consumption data.

The current high-price environment creates notable risks for consumers and suppliers. However, the wide coverage of smart meters, introduction of the Datahub and increasing share of consumers with spot price contracts create an excellent opportunity to create new retail products that could help shield consumers from high prices and reduce the electricity supply risks by driving consumption to off-peak periods. However, this requires consumers to be informed about the benefits and make behavioural changes. The government can help support this through information campaigns and encouraging retailers to develop more attractive products.

Recommendations

The government of Finland should:

- Raise consumer awareness for the active role it can play in the electricity market and fully implement regulations supporting aggregation.
- Prioritise support for demonstration projects for electrification and the uptake of smart flexibility solutions to accelerate the integration of variable renewable generation.
- Ensure that support to consumers to deal with high electricity prices delivers sustained reductions in electricity demand through improved building energy efficiency, with a focus on the most vulnerable consumers and the worst performing buildings.

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7. Nuclear

Key data

(2022)

Number of reactors: Five at two sites

Installed capacity: 4.39 GW

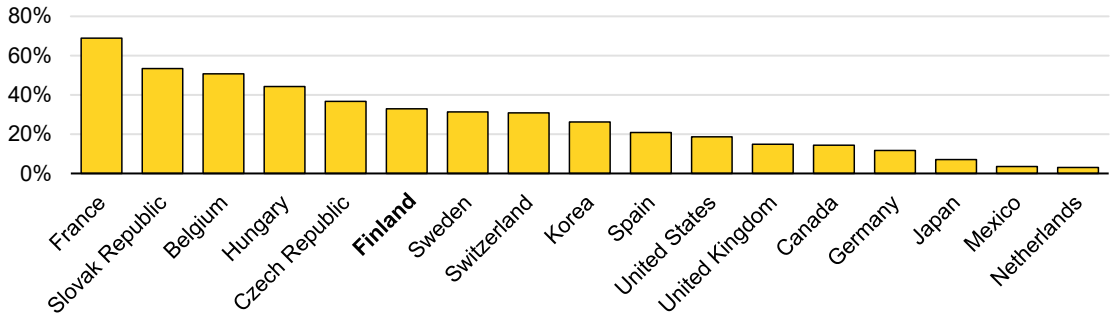
Electricity generation (2021): 23.9 TWh

Share of nuclear (2021): 33% of total electricity generation

Overview

Nuclear energy plays a key role in Finland's energy sector and is a central part of the government's plans to achieve carbon neutrality by 2035 and reduce energy import dependence. Nuclear is the largest source of electricity generation in Finland, amounting to 33% of total electricity generation in 2021, and this figure is expected to increase to more than 40% now that the Olkiluoto 3 European pressurised reactor (EPR) reactor is fully operational. As of 2021, Finland had the sixth-highest share of nuclear generation among IEA member countries (Figure 7.1). Finland's two nuclear power plants (Olkiluoto with three reactors and Loviisa with two reactors) have a total installed generation capacity of 4.39 GW.

Figure 7.1 Share of nuclear in electricity generation in IEA member countries, 2021



Source: IEA (2022).

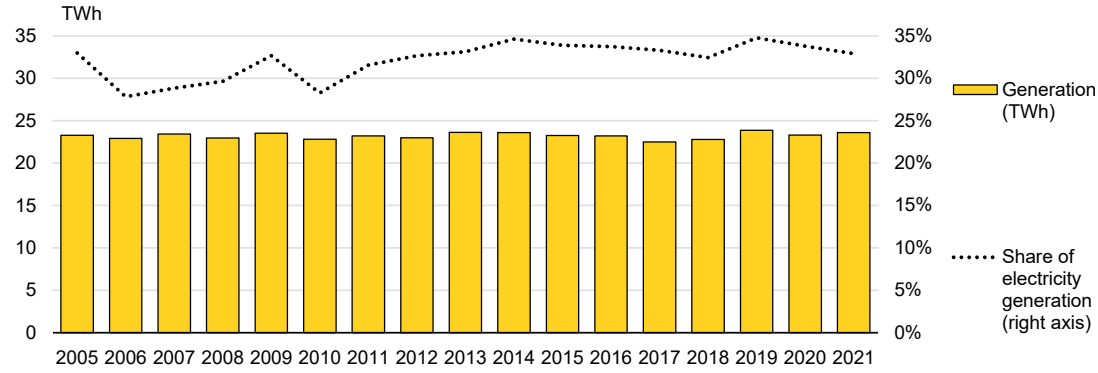
Thanks to its two nuclear power plants and a high share of generation from renewable energy, Finland has one of the lowest carbon intensities of electricity generation among IEA member countries (72.4 g CO_2/kWh in 2021, compared to the IEA average of 329 g CO_2/kWh). Electricity generation from nuclear energy has been steady, ranging from

a minimum of 22.3 TWh to a maximum of 23.9 TWh between 2005 to 2021 (Figure 7.2), and is expected to increase notably (up to an estimated 36 TWh in 2023) now that the Olkiluoto 3 reactor is fully operational.

The Olkiluoto 3 reactor is one of the largest reactors in the world in terms of nominal electrical power output, with an electric capacity of 1.6 GW. After significant delays, Olkiluoto 3 started commercial operations 16 April 2023. TVO (the operator of the Olkiluoto plant) estimates that Olkiluoto 3 will generate 12 TWh per year, enough to cover around 14% of annual electricity demand, reduce electricity imports by 60% and increase the share of carbon-free electricity generation to over 90% (TVO Nuclear, 2022).

Finland is also a global leader in nuclear waste management and disposal. The Onkalo nuclear waste disposal facility, under construction near the Olkiluoto nuclear power plant, is expected to start operating in 2025 and will be the world's first permanent geological disposal facility for spent nuclear fuel and high-level radioactive waste.

Figure 7.2 Nuclear electricity generation in Finland, 2005-2021



Note: TWh = terawatt hour.
Source: IEA (2022).

Nuclear energy policy and regulation

Nuclear energy plays a key role in the government's plans to achieve carbon neutrality and reduce energy import dependence. There is a strong focus on ensuring the safe, secure and efficient operation of nuclear power plants and on finalising the deployment of a long-term storage facility for spent nuclear fuel and radioactive waste. The Finnish state is not involved in investment decisions on nuclear power plants and does not provide subsidies for nuclear energy. Finland's NCES states that applications for new nuclear power plants are considered under the processes established in the Nuclear Energy Act and that extending operating licences for existing nuclear power plants is welcomed, provided that all licence conditions are met.

The Nuclear Energy Act establishes the general principles governing the regulation of nuclear energy, including plant licensing and nuclear waste management. The government intends to reform the act during the next parliamentary term (which should start in 2023) to account for new technology developments, especially developments that concern small modular reactors (SMRs). Nuclear energy is also regulated under the Radiation Protection Act, which aims to protect human health from the adverse effects of radiation. The Act was

adopted in 2018 (replacing a previous act from 1991) and is based on the Basic Safety Standards Directive of the European Atomic Energy Community (Euratom).

The Ministry of Economic Affairs and Employment has overall responsibility for nuclear energy, including issuing final decisions on licences for the construction and operation of nuclear power plants, overseeing the planning and implementation of nuclear waste management, supervising nuclear R&D, and proposing legislation related to nuclear energy. The ministry manages the Nuclear Waste Management Fund, which is separate from the state budget and is funded by companies operating nuclear power plants in Finland. It consists of three separate funds: the Financial Provision Fund, which covers costs related to the decommissioning of nuclear power plants and the disposal of nuclear waste, and two funds that support public nuclear energy research and innovation (R&I) – the Nuclear Safety Research Fund and the Nuclear Waste Research Fund.

The Radiation and Nuclear Safety Authority (STUK) is an independent governmental organisation responsible for processing nuclear energy and waste management licence applications and supervising compliance with licence requirements, issuing regulations on nuclear safety and supervising compliance with these regulations. STUK carries out nuclear plant inspections and defines the required competencies for people responsible for nuclear safety. The Ministry of the Environment, the Ministry for Foreign Affairs, regional government authorities and municipalities where nuclear facilities are located also participate in the supervision of nuclear power plants.

Nuclear power plants

Finland has two operational nuclear power plants (Olkiluoto with three reactors and Loviisa with two reactors) with a total installed generation capacity of 4.39 GW in 2022 (Table 7.1). A new reactor (Olkiluoto 3) was connected to the Finnish grid in March 2022 and became fully operational on 16 April 2023 (Finland, Ministry of Economic Affairs and Employment, 2022a).

Table 7.1 Nuclear energy plants in Finland, 2022

Reactor	Capacity (MW)	Technology type	Started commercial operations	Operating licences expire	Operator
Loviisa 1	507	pressurised water (VVER)	1977	2050	Fortum
Loviisa 2	507		1981	2050	
Olkiluoto 1	890	boiling water (BWR)	1979	2038	TVO
Olkiluoto 2	890		1982		
Olkiluoto 3	1 600	pressurised water (EPR)	December 2022		
Total	**4 394**				

Note: VVER = water-water energetic reactor; BWR = boiling water reactor; EPR = European pressurised reactor.

Olkiluoto 3 is the first nuclear reactor deployed in Europe in over 15 years. A consortium led by Areva and Siemens started construction on Olkiluoto 3 in 2005. It was planned to be the first example of a new pressurised water design, the EPR, developed by Areva subsidiary Framatome, and to begin commercial operations in 2009. The project was delayed by over a decade because of numerous problems, including inadequate

completion of design and engineering work prior to starting construction. The cost of the project is estimated to have tripled to almost EUR 9 billion.

The operating licence for Olkiluoto 3, issued in March 2019, is valid through 2038. It is anticipated that this licence will be extended. The government indicates that the expected service life of Olkiluoto 3 is at least 60 years and it has granted lifetime extensions for other reactors in the past (Heinrich Böll Stiftung, 2021). In September 2018, the government granted TVO a licence to extend the operation of the Olkiluoto 1 and Olkiluoto 2 reactors until the end of 2038. This means an operational life of 59 years for Olkiluoto 1 and 56 years for Olkiluoto 2.

In March 2022, Fortum applied for a licence to extend the operation of Loviisa 1 and Loviisa 2 until the end of 2050. The government granted the licence in February 2023 and the extension to 2050 means an operational life of 73 years for Loviisa 1 and 69 years for Loviisa 2 (Fortum, 2022a). There currently are no plans to build new nuclear power plants or to upgrade the capacity of existing ones in Finland.

All the uranium fuel used in Finland's reactors is imported as fuel assemblies ready to load into reactors. TVO mainly procures fuel for the Olkiluoto plant using long-term procurement contracts with several suppliers at each stage of the fuel production chain. The uranium purchased by TVO comes mainly from Kazakhstan, Canada and Australia, with the fuel assemblies manufactured in Germany, Spain or Sweden (TVO Nuclear, 2021). Fortum purchases fuel for the Loviisa plant through a long-term contract with the Russian nuclear fuel company TVEL. The current contract with TVEL is valid through 2027 for Loviisa 1 and 2030 for Loviisa 2. In 2021, Finland spent EUR 121 million on nuclear fuel imports, with EUR 32 million (21%) spent on imports from Russia (Finland, Ministry of Economic Affairs and Employment, 2022b).

Since Russia's invasion of Ukraine, Finland has placed a strong focus on reducing reliance on Russian energy imports (Normanton, 2022). So far, neither country has taken actions that would stop deliveries of nuclear fuel from Russia to Finland. Fortum has nevertheless placed a strong priority on enhancing the diversity and security of the fuel supply to its Loviisa plant. In November 2022, Fortum announced the signature of an agreement with Westinghouse electric company (Westinghouse, 2022) for the design, licensing and supply of a new fuel type for the Loviisa nuclear power plant.

A planned third nuclear plant was under development in Northern Finland at the Hanhikivi site but was cancelled in 2022. The project was led by Fennovoima, a company jointly owned by a consortium of Finnish state-owned energy companies (66%) and the Russian state-owned nuclear company Rosatom (34%). Fennovoima had contracted with Rosatom to build a 1.2 GW Russian VVER reactor design at the plant. Fennovoima invested around EUR 600 million to prepare the site and planned to start plant construction in mid-2023. In May 2022, however, Fennovoima rescinded its construction licence application and cancelled its contract with Rosatom (Fennovoima, 2022).

Uranium mining and enrichment

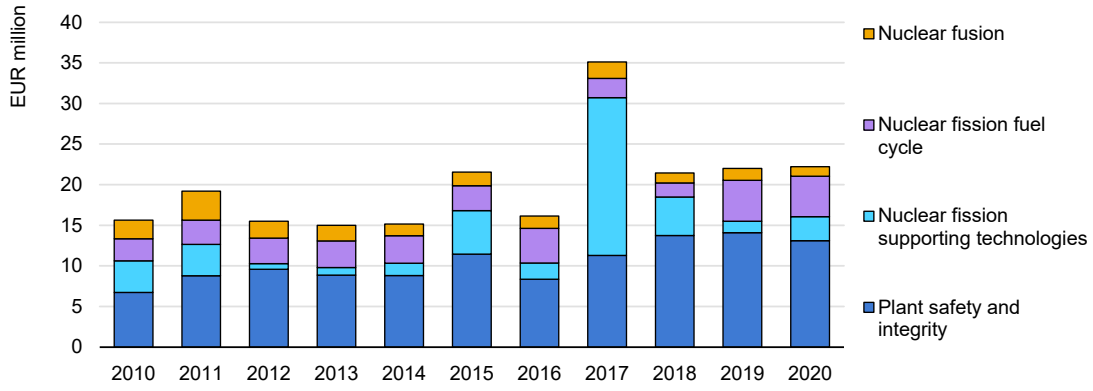
Finland does not currently have any uranium mining or nuclear fuel enrichment facilities. However, Terrafame, a 70% state-owned mining company, has been working to establish a facility to produce yellow cake uranium at a mine in the Kainuu region that produces nickel and other metals for batteries. In February 2022, the government granted a uranium

recovery and refining permit that allows Terrafame to produce up to 250 tonnes of uranium each year. Only minor investments and final approvals are needed before uranium production can start. Once operational, it would be the only site in the European Union mining and processing uranium. The project is not directly associated with either of Finland's nuclear power plants (Vanttinen, 2020).

Nuclear research and innovation

From 2010 to 2020, Finland's total public budget for energy R&I declined significantly, from USD 383 million to USD 176.6 million; however, over the same period, the public budget for nuclear energy R&I experienced an overall increase, from EUR 15.6 million to EUR 19.4 million, with a notably higher budget in several years (Figure 7.3). Nuclear energy R&I in Finland focuses on the safety and operational performance of nuclear power plants and the management and disposal of waste. From 2010 to 2020, Finland dedicated EUR 218 million to nuclear energy R&I, with the majority (EUR 114 million) going to plant safety and integrity, followed by nuclear fission supporting technologies (EUR 46 million), nuclear fission fuel cycle (EUR 37 million), and nuclear fusion (EUR 20 million). In 2020, Finland ranked sixth among IEA member countries for public budget dedicated to nuclear energy R&I by GDP.

Figure 7.3 Nuclear energy research and innovation budget in Finland, 2010-2020



Source: IEA (2022).

Finland does not have any institutes dedicated solely to nuclear energy R&I. Most nuclear R&I research takes place at VTT, especially the VTT Centre for Nuclear Safety, which provides experimental and computational research, development and technical support for services focused on safety and efficiency in nuclear power generation and radioactive waste management. It works in Finland and internationally with both industry and regulators (VTT Technical Research Centre, 2021a). Other major research institutes active in nuclear energy R&I include the Universities of Aalto, Lappeenranta Technical, Helsinki, Jyväskylä and Tampere; the Geological Survey of Finland; and the Finnish Meteorological Institute. In addition, STUK, Fortum, TVO and Posiva carry out internal nuclear energy R&I, or finance nuclear energy R&I research at research institutes and universities.

Finland is highly active in international collaboration on nuclear energy R&I, including through the following multilateral initiatives: the Generation IV International Forum, the

International Project on Innovative Nuclear Reactors and Fuel Cycles, the International Framework for Nuclear Energy Cooperation, the Multinational Design Evaluation Programme, the Multinational Fuel Assurance Concept and the EU Sustainable Nuclear Energy Technology Platform. Finnish organisations participate in other efforts aimed at the international harmonisation of nuclear safety standards (IAEA, 2022).

Finland's main publicly funded programme for nuclear R&I is the National Nuclear Safety and Waste Management Research Programme (SAFER2028), currently valid for the period 2023-28. It is a six-year technical and scientific research programme that supports R&I on nuclear safety and nuclear waste management, relevant to use for nuclear energy in Finland. The results of the programme are public. It is a continuation of the government's nuclear safety (SAFIR) and nuclear waste management safety (KYT) programmes. As with SAFIR and KYT, SAFER2028 is funded by the national Nuclear Waste Management Fund. SAFER2028 has an annual budget of around EUR 10 million. The first call for proposals was opened in August 2022 for funding in 2023 (SAFER2028, 2022).

Concerning innovation and the potential future use SMRs in Finland, in October 2022, Fortum announced it was starting a two-year feasibility study to explore the potential of new nuclear in Finland, both for SMRs and large conventional reactors (Fortum, 2022b). This study will assess the enabling factors and requirements that would make a case for, in particular, novel SMR application in Finland and aims to explore novel partnerships, new business models and technologies under a broader lens which would include not only technological and regulatory, but wider legal, political and societal considerations.

Research reactor decommissioning

Finland has one nuclear research reactor, the FiR 1, a 250 kW water-cooled, pool-type TRIGA reactor that was operated by VTT. The reactor was specifically designed for university research and also served in isotope production and radiation therapy. It was shut down permanently in 2015 and the government issued a decommissioning licence in June 2021. It will be the first reactor to be decommissioned in Finland. The main activities of the decommissioning project include radiological characterisation; spent nuclear fuel management; dismantling and management of reactor systems, structures and components; and final clearance of the site. Fortum is the main contractor for decommissioning the research reactor and the storage and final disposal of the decommissioning waste. The spent fuel from the reactor was sent to the United States in January 2021 for further use and final disposal. Dismantling of the reactor is expected to start at the end of 2022 and the decommissioning should be completed by the end of 2023 (VTT Technical Research Centre, 2021b).

Nuclear waste management

The Nuclear Energy Act requires that the nuclear waste generated in Finland must be stored and permanently disposed of in Finland. Under the Act, producers of nuclear waste are responsible for all nuclear waste management activities and associated costs. Companies operating nuclear power plants in Finland (currently only TVO and Fortum) must pay annual contributions to the Nuclear Waste Management Fund, which is managed by the Ministry of Economic Affairs and Employment, to cover all costs resulting from nuclear power plant decommissioning and the management of spent fuel and radioactive

waste, including treatment, storage and final disposal. Companies that are obliged to contribute to the fund are entitled to borrow back 75% of the contributions against securities.

The most recent government report on the Nuclear Waste Management Fund (published in September 2019) indicated that the fund held around EUR 2.6 billion and that this amount was expected to increase following the commissioning of Olkiluoto 3. The report noted that the government aims for the fund to operate well into the 2100s, until all obligations have been met, and recommended changes to improve the long-term fund performance while ensuring that there are enough assets available to cover the costs of nuclear waste management (Finland, Ministry of Economic Affairs and Employment, 2019).

Low and intermediate level waste resulting from nuclear power plant operations are treated and stored onsite. The Olkiluoto plant and the Loviisa plant each have their own repository in bedrock at a depth of 60-110 metres. These repositories have been sized to store all low- and intermediate-level waste produced during the operating life of the plants. Once all this waste has been placed in the repositories, the repositories will be filled in and sealed. Spent nuclear fuel from nuclear power plant operations is temporarily stored at onsite storage pools. Interim storage capacity at the Olkiluoto plant was expanded in 2013 to account for the additional spent fuel from the Olkiluoto 3 reactor.

Posiva, a company jointly owned by TVO (60%) and Fortum (40%), was created to design, construct and manage a permanent geological disposal facility for spent nuclear fuel and high-level radioactive waste from the Olkiluoto and Loviisa plants. Legal and financial responsibility for the spent fuel remains with the company that generated it. In 2015, the government granted Posiva a construction licence for the Onkalo nuclear waste disposal facility, which started construction near the Olkiluoto nuclear power plant in 2016. In December 2021, Posiva applied for an operating licence valid from March 2024 to 2070. STUK is reviewing the licence and the facility is expected to start operating in 2025. It will be the world's first permanent geological disposal facility for spent nuclear fuel and high-level radioactive waste (World Nuclear News, 2022).

The Onkalo project includes an encapsulation area where spent fuel rod assemblies will be packed into water and airtight double-layered metal canisters. The canisters will be positioned vertically in the repository at a depth of around 400 metres. The canisters are placed in holes drilled at the bottom of the repository tunnels, spaced a few metres from each other and surrounded with bentonite clay. Once the canister has been deposited, the tunnels will be filled and the shafts leading to the repository closed. The facility will include around 10 km of tunnels with a total volume of around 365 000 cubic metres. It has been designed to store the full volume of waste from the Olkiluoto and Loviisa reactors, estimated at around 6 500 tonnes of spent fuel (NEA, 2021).

Assessment

Nuclear energy plays a key role in Finland's energy sector and is a central part of the government's plans to achieve carbon neutrality by 2035 and reduce energy import dependence. The role of nuclear in Finland is expected to increase notably following the start of operations of the Olkiluoto 3 reactor on 16 April 2023.

Finland is a global leader in nuclear waste management and will become the first country in the world to start operating a permanent solution for final disposal of spent nuclear fuel. The Onkalo nuclear waste disposal facility, under construction near the Olkiluoto nuclear power plant, is expected to start operations in 2025 and will be the world's first permanent geological disposal facility for spent nuclear fuel and high-level radioactive waste.

The Nuclear Energy Act, the key law regulating nuclear power in Finland, is undergoing a major revision that requires discussions in parliament, with a current plan for an updated Act to come into effect in 2027 or later. This revision aims to clarify and set the responsibilities of all actors and stakeholders in new nuclear developments and to streamline the permitting process to better take into account novel applications of nuclear power such as SMRs. Revision of the Nuclear Energy Act should be completed in an expeditious manner. The current plan to complete the legislation in 2027 or later creates uncertainty, which could discourage investments in new energy projects.

Finland's Nuclear Waste Management Fund (in place since 1988) is funded by annual payments made by operators under the waste management obligation set in the Nuclear Energy Act, together with the investment returns of the fund. The fund is not included in the state budget and operates under the Ministry of Economic Affairs and Employment. It consists of three separate funds: the Financial Provision Fund, the Nuclear Safety Research Fund and the Nuclear Waste Research Fund. The government aims for the fund to continue operating well into the 2100s, until all obligations have been met, and has recommended changes to improve its long-term performance and ensure it covers the cost of all future nuclear waste management.

Finnish nuclear power plant operators are considering the long-term operation of all of Finland's five existing power reactors. In 2018, the government granted TVO a licence to extend the operation of the Olkiluoto 1 and Olkiluoto 2 reactors until the end of 2038, representing an operational lifetime for these two BWR reactors of 59 and 56 years, respectively. In 2022, Fortum applied for a licence to extend the operation of Loviisa 1 and Loviisa 2 until the end of 2050, which was granted in February 2023, supporting the operational lifetimes of these two VVER reactors of 73 and 69 years, respectively. The government indicates that the service life of Olkiluoto 3 is anticipated to be at least 60 years, with its current licence issued in 2019 and valid through 2038.

In May 2022, the power company Fennovoima terminated the contract it had with Rosatom to build the Hanhikivi 1 nuclear power plant. Significant investments and infrastructure development have already been made in the Hanhikivi site and the future of this site and its potential use for future energy development projects is uncertain. Once litigation over the site has been resolved, the government should support the deployment of energy infrastructure at the site in line with its energy transition and security goals.

Since Russia's invasion of Ukraine, Finland has placed a strong focus on reducing reliance on Russian energy imports. While Fortum's fuel agreement with Russia's TVEL is valid until the end of the current operating licences for the two VVER Loviisa reactors (in 2027 and 2030, respectively), Fortum has placed a strong priority on enhancing the diversity and security of nuclear fuel supply. In November 2022, Fortum announced the signature of an agreement with Westinghouse electric company for the design, licensing and supply of a new fuel type for the Loviisa nuclear power plant.

In 2022, public support for nuclear in Finland was the highest ever recorded in the country, with over 60% of respondents declaring having a positive attitude towards nuclear power while only 11% took a negative stance, according to an April 2022 survey published by Finnish Energy.

While the Finnish government adopts a technology-neutral position and relies on the market to support new energy developments, there is clear political support for nuclear energy. A unique investment framework is in place (the Mankala Model) in Finland, 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. New risk-sharing mechanisms to incentivise investment in new nuclear energy project developments (such as SMRs) could be considered.

A licence was granted in June 2021 to VTT to decommission the FiR-1 research reactor in Otaniemi, which has functioned as a key research and training facility for over 50 years. No nuclear reactors have been decommissioned in Finland before, and experience from decommissioning the Otaniemi reactor will be important when planning the decommissioning of Finnish nuclear power plants or future SMRs. As such, this first decommissioning experience could result in valuable recommendations to consider for the Nuclear Energy Act amendment currently in the making.

Finland is fit to become a leader in new nuclear innovation for deep decarbonisation. Its electricity generation is already more than 90% decarbonised. Finland has sparsely populated areas, small and remote communities, harsh winters and heavy reliance on heating, a long-standing and robust technical culture of safety, societal acceptance of nuclear technology, and regulatory excellence. These aspects make Finland a robust case for considering SMR demonstration projects, including for heat applications. It is to be noted that Fortum is currently leading a two-year feasibility study that will look at novel SMR applications in Finland and the necessary prerequisites or enabling factors that would make a case for innovative nuclear in Finland.

The government of Finland should seize this opportunity to further consolidate Finland's position as a global leader in nuclear technology innovation development, first by ensuring that the Olkiluoto 3 and Onkalo deep geological repository start operations as scheduled and communicating publicly on these successes.

The government of Finland should work in concert with the nuclear industry to ensure that the emerging new nuclear ecosystem of innovation is attractive to investors and accepted by society. Setting up the proper enabling framework could be achieved by encouraging partnerships (industries, TSO, DSOs, nuclear energy companies, nuclear reactor developers and R&D institutions, SMR vendors, local communities, and universities) to ensure that new nuclear initiatives in Finland, such as SMR applications, find their fit in the local communities, answer the regional needs and meet economic feasibility targets.

For this, the government should provide adequate resources and manpower to the regulator to prevent bottlenecks in licensing and permitting the delivery of new nuclear SMR projects. This is in line with the ambition to transition Finland to net zero by 2035.

Recommendations

The government of Finland should:

- ☐ Further strengthen public confidence in the excellence of the Finnish nuclear industry by communicating broadly on the deployment of Europe's most modern and powerful reactor and the world's first nuclear waste final disposal solution.
- ☐ Complete the update of nuclear legislation in a timely and transparent manner.
- ☐ Actively create the conditions for a Finnish ecosystem of excellence in nuclear innovation. Clearly define roles and responsibilities and innovative risk-sharing mechanisms to foster multilateral partnerships that can undertake new nuclear project initiatives around SMR applications.
- ☐ Create conditions to ensure Western fuel supply security for the two reactors in Loviisa nuclear power plant in the 2023 to 2024 time frame.

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8. Natural gas

Key data

(2021)

Natural gas production: no domestic production

Net imports: 2.6 billion cubic metres (bcm), -38% since 2011

Share of natural gas: 0% of energy production, 6% of total energy supply, 5% of electricity generation, 11% of heat generation, 3% of total final consumption, 1% of transport, 6% of industry and 1% of buildings

Overview

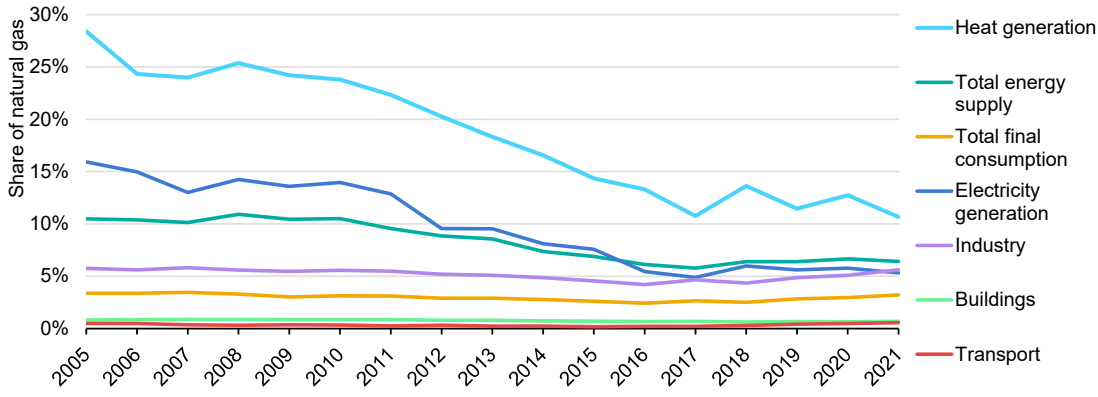
Natural gas plays a relatively small role in Finland's energy mix, accounting for around 3% of TFC (Figure 8.1). However, natural gas is a key fuel for some parts of heavy industry.

Until 2022, Finland sourced the vast majority of its natural gas from Russia by pipeline. However, following Russia's invasion of Ukraine, Russia terminated pipeline gas deliveries to Finland in May 2022. The loss of Russian gas prompted major gas consumers to use alternative fuels (primarily coal, biomass and propane) and implement efficiency measures. As a result, natural gas consumption declined by over 50% in Finland in 2022.

The Finnish government succeeded in securing a long-term gas supply to substitute Russian gas with increased LNG imports through a floating storage regasification unit (FSRU). The FSRU was installed at the Port of Inkoo in December 2022 and began commercial operations in January 2023.

In the short term, with the FSRU now in operation, natural gas consumption may rise. However, demand is likely to decline in the longer term as the Finnish government pursues policies that promote the uptake of alternatives to natural gas, including renewable gases and low-carbon hydrogen.

Figure 8.1 Share of natural gas in Finland's energy system, 2005-2021



Source: IEA (2022).

Gas demand and supply

Demand

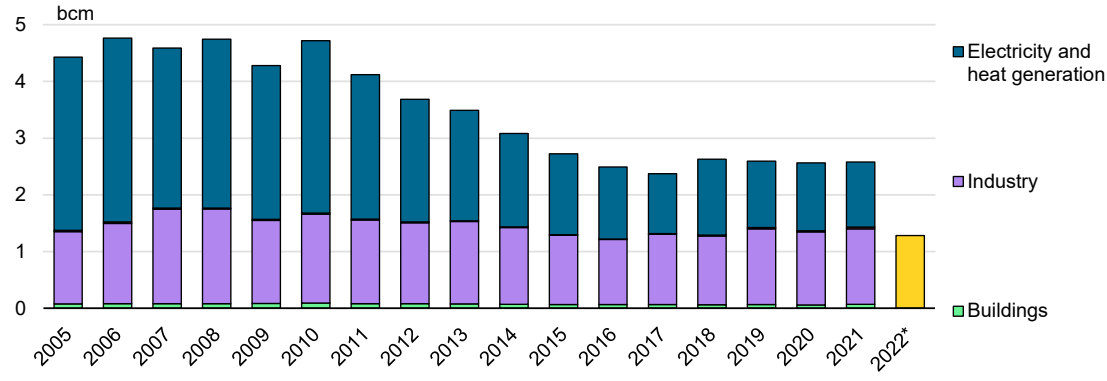
Natural gas demand is relatively small in Finland, at 2.6 bcm in 2021 (Figure 8.2). Demand for natural gas fell significantly in the early 2010s, partly due to changes in the tax model in 2011 which impacted gas use in co-generation production. From 2018 to 2021, gas demand was stable.

Gas demand fell by over 50% in 2022 following the loss of Russian supply and related price increases. Many major gas consumers reduced consumption or switched to alternative fuels. A significant amount of gas has been replaced with coal and biomass in the power and heat sector, while Finland's only oil refiner, Neste, which accounted for a substantial proportion of Finland's gas consumption in 2021, replaced almost all of its natural gas consumption with hydrogen production with propane.

While demand may rise in the short term as Finland has secured alternative sources to replace Russian gas supply, natural gas consumption is likely to fall further in the medium to long term as the Finnish government pursues policies to reduce consumption in industry and power generation and promote the uptake of renewable gases and low-carbon hydrogen.

Industry (52% of total demand in 2021) and electricity and heat generation (45%) account for the vast majority of gas demand. The share of total demand from industry progressively increased from 2011 to 2017 as industry demand remained stable and demand from electricity and heat generation declined. Consumption in residential and commercial buildings is negligible; in 2021, fewer than 700 residential buildings and only 1 100 commercial buildings used natural gas for heating.

Figure 8.2 Natural gas demand by sector in Finland, 2005-2022



* Breakdown by sector not available for 2022.

Source: IEA (2022).

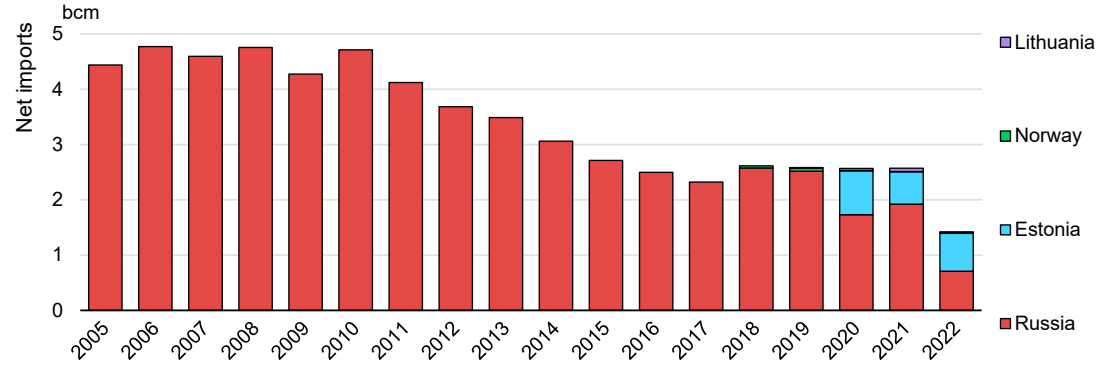
Supply

Finland has no domestic natural gas production and is, therefore, completely dependent on imported gas. Until 2017, all of Finland's natural gas imports came from Russia by pipeline. However, the construction of small-scale LNG import capacity and the commissioning of the Balticconnector pipeline in 2020 allowed Finland to somewhat reduce its dependence on Russian gas.

Nevertheless, until 2022, Russia remained the most significant supplier of gas to Finland, accounting for 75% of its total imports in 2021 (Figure 8.3). However, Gazprom cut off gas supply to Finland in May 2022 after the Finnish state-owned gas supplier, Gasum, refused its request for payment in Russian roubles.

In 2021, around 23% of Finland's gas imports were delivered from Estonia through the Balticconnector pipeline. Since May 2022, Finland has been importing increasing volumes through the Balticconnector, but the available capacity is insufficient to meet typical winter demand.

Figure 8.3 Finland's natural gas imports by country, 2005-2022



Source: IEA (2022).

Gas infrastructure

Finland has limited natural gas infrastructure, encompassing two cross-border interconnections, three small-scale LNG terminals, and a small gas network that mainly supplies industrial users and natural gas co-generation plants (Figure 8.4). In January 2023, commercial operations began at a new FSRU in the southern port of Inkoo.

Figure 8.4 Finland's natural gas infrastructure

Interconnections

Until Russia suspended gas imports to Finland in May 2022, a large majority of Finland's natural gas supply was imported through a 1 310 km pipeline that enters eastern Finland from Russia at the Imatra interconnection point. The Imatra interconnection has a total capacity of 22 mcm/d, far in excess of Finland's average daily gas consumption of 7.1 mcm in 2021, and also comfortably above the 2021 daily peak consumption of 18 mcm.

The bidirectional Balticconnector pipeline was commissioned in early 2020. The 77 km offshore pipeline runs between Inkoo in southern Finland and Paldiski in northwest Estonia; it is jointly owned by the Finnish TSO, Gasgrid Finland, and the Estonian TSO, Elering. The nominal transmission capacity between Estonia and Finland is around 8 mcm/d. However, the available capacity from south to north is currently 5.5 mcm/d due to constraints in the Baltic states' gas systems.

By connecting the Finnish gas grid to the Estonian gas grid, the Balticconnector pipeline has allowed Finland to import gas from the Klaipeda LNG terminal in Lithuania and make use of the Inčukalns gas storage facility in Latvia. Following the commissioning of the Gas Interconnection Poland-Lithuania (GIPL) pipeline in May 2022, Finland also gained access to the EU gas market.

LNG terminals

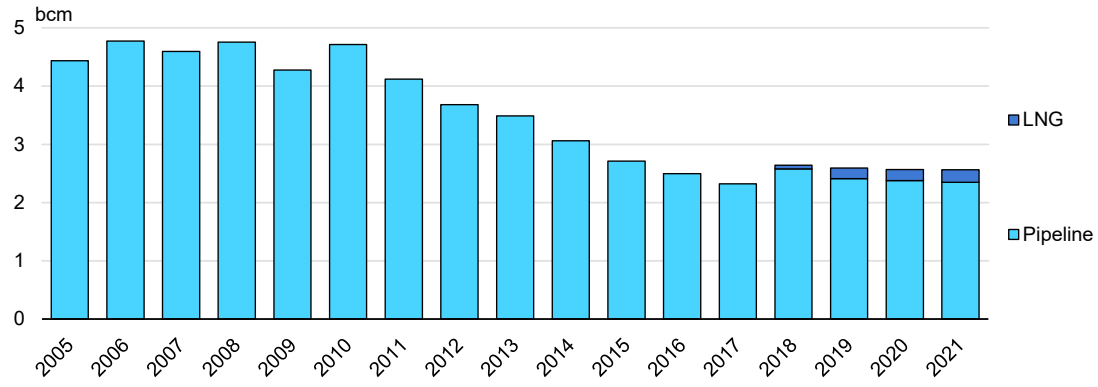
Finland has three small-scale LNG terminals which serve industrial consumers and, to a lesser extent, supply LNG bunkers. Two of the three LNG terminals are disconnected from the main gas grid. In 2021, 8% of Finland's gas supply was imported as LNG (Figure 9.5).

Finland's first LNG import terminal, the Pori LNG terminal on the western coast, was commissioned in September 2016. LNG deliveries from Pori to industrial customers can be made through a local connecting pipeline, sea tanker or road tanker. The Pori terminal has a storage capacity of 30 000 bcm.

As the second LNG import terminal, the Manga terminal in Tornio, in the far north of Finland, commenced commercial operations in 2019. The terminal also supplies industrial consumers via a local distribution pipeline, as well as by road tanker. The Manga terminal has a storage capacity of 50 000 bcm.

A third small-scale LNG terminal in Hamina, 145 km east of Helsinki, began commercial operations in October 2022. The Hamina terminal is the first on-grid LNG terminal in Finland and is expected to provide up to 1.7 TWh (170 mcm) of natural gas to the grid annually. It has a storage capacity of 30 000 bcm.

Figure 8.5 Finland's natural gas imports by source, 2005-2021



Note: bcm = billion cubic metres; LNG = liquefied natural gas.
Source: IEA (2022).

Floating storage regasification unit

The combined available import capacity through the Balticconnector pipeline and Finland's LNG terminals (two of which are also not connected to the main gas grid) does not compensate for the loss of Russian gas supply.

Therefore, in May 2022, the TSO, Gasgrid Finland, signed a ten-year agreement with US-based Excelerate Energy for the delivery of an FSRU. The FSRU, Exemplar, has a regasification capacity of 5 bcm/y. In January 2023, commercial operations began at the deep-water port of Inkoo in southern Finland. The FSRU is connected to the Finnish gas transmission network. According to Gasgrid Finland, the Exemplar may also be used to supply Estonia and Latvia through the Balticconnector pipeline.

Transmission and distribution

Gasgrid Finland is Finland's only natural gas TSO. The TSO operates a 1 150 km high-pressure transmission pipeline network, confined to the south of the country. Compressor stations are located in Imatra, Kouvola and Mäntsälä. In addition to natural gas, small quantities of biogas are injected into the gas transmission network from four biogas plants (Espoo, Kouvola, Lahti and Riihimäki). Around 75% of gas consumers receive gas directly from the transmission network.

There are 16 registered DSOs in Finland. Gas distribution networks, which have a combined length of 1 805 km, are connected to the transmission network and concentrated in the south of the country. Many DSOs are owned by municipalities; others are owned by industrial gas consumers.

Storage

Finland has no large-scale natural gas storage facilities. Within Finland, gas can be stored as line-pack in pipelines, and as LNG at the LNG terminals in Hamina, Pori and Tornio and at the FSRU in Inkoo. Gas can also be stored at the Inčukalns gas storage facility in Latvia and delivered to Finland via the Balticconnector pipeline.

Gas market and prices

The Finnish gas market is overseen by the regulator, the Energy Authority (Energiavirasto). The Energy Authority is an independent public institution. The government appoints its director.

Gas market liberalisation

Until 2020, Finland was exempt from EU rules on unbundling and third-party access in the gas sector (EU Gas Directive 2009/73/EC) due to the isolated nature of the Finnish gas market. As a result, the gas market was essentially free from competition and fully controlled by the state-owned company, Gasum, which acted as the TSO and was the only importer and wholesale supplier.

However, upon the commissioning of the Balticconnector pipeline in January 2020, the Finnish gas sector became subject to EU legislation on gas market competition, and the government implemented the Natural Gas Market Act.

In line with the EU directive on unbundling, the Natural Gas Market Act legislated the separation of gas transmission and sales activities, resulting in the creation of the new TSO, Gasgrid Finland, which was unbundled from Gasum. Gasgrid Finland remains fully state-owned. The Natural Gas Market Act also legislated open access to the natural gas transmission and distribution networks, as well as to Finland's LNG terminals.

DSOs in Finland are currently not subject to EU unbundling rules specifying the separation of distribution and supply activities, as the directive does not apply to DSOs with less than 100 000 customers, a threshold which all Finnish DSOs fall below. As a result, many DSOs in Finland are also involved in retail supply.

Baltic gas market – FinEstLat

Since opening its gas market, Finland has been actively involved in creating a regional gas market with other Baltic countries. The common Baltic natural gas market, known as the FinEstLat market, came into operation in 2020, becoming Europe's first multi-country gas market.

Wholesale market and trading

In 2021, there were 39 registered wholesale gas suppliers in Finland. However, the Finnish wholesale market remains concentrated, with the state-owned Gasum holding a market share of around 60%.

Since the beginning of 2020, gas- trading services have been provided by Get Baltic exchange. Get Baltic administers the electronic trading system for spot and forward natural gas products with physical delivery across Finland, Estonia, Latvia and Lithuania.

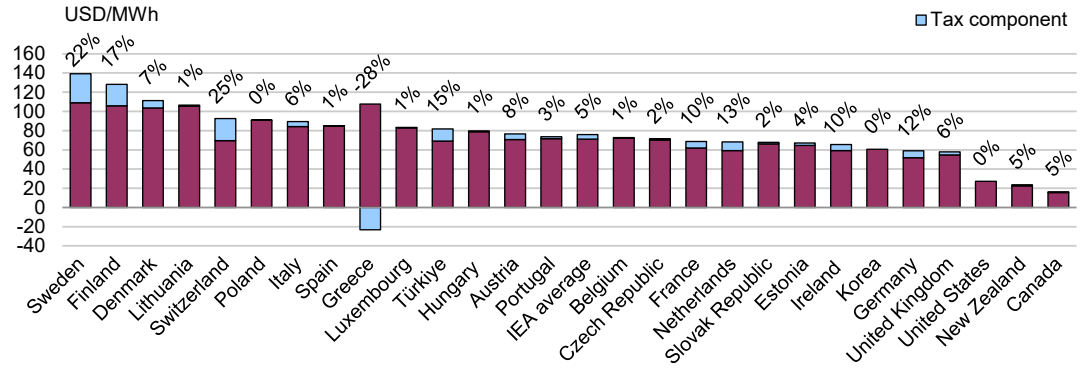
Retail market

The Finnish retail gas market is very small, with around 25 000 retail consumers in total. Retail consumers mainly consist of households which use gas for cooking purposes only. In 2021, there were 15 registered gas retailers in Finland.

Prices and taxation

In the second quarter of 2022, industry natural gas prices in Finland were the second-highest among IEA countries at 128.27 USD/MWh, with a substantial tax rate of 17% (Figure 8.6). In comparison, the IEA average price was 75.88 USD/MWh, with an average tax rate of 5%. Prices rose considerably higher in 2022; in September 2022, the spot price on the Get Baltic exchange exceeded 200 USD/MWh.

Figure 8.6 Natural gas prices for industry in Finland, 2Q 2022



Note: Tax information is not available for the United States and 2Q 2022 prices are unavailable for Australia, Japan, Mexico and Norway.
Source: IEA (2022).

Gas policy

As outlined in the NCES and Roadmap to Fossil-Free Transport, the Finnish government is pursuing policies aimed at reducing gas consumption in industry, decarbonising gas supply, enhancing regional gas market co-operation, supporting increased gas consumption in transportation, and diversifying gas supply sources.

Phasing out Russian gas imports

The government has sought to increase the gas supply from alternative sources and intends to maintain a more diversified range of supply sources in the future. These efforts were assisted by the commencement of LNG imports through the new FSRU in January 2023.

In May 2022, the European Commission introduced the REPowerEU plan, which proposes numerous measures intended to end the European Union's reliance on Russian energy imports while supporting the energy transition. Under the REPowerEU plan, the European Union adopted a natural gas storage obligation requiring that, in total, EU gas storage facilities be at least 80% full by 5 November 2022 and 90% full by 1 November in subsequent years. Finland does not have natural gas storage but is contributing to this gas storage obligation requirement by storing gas in Latvia's underground gas storage facility, which is connected to Finland via the Balticconnector pipeline that links Finland to the gas network of the Baltic states via Estonia. On 5 November 2022, the European Union's total gas storage was 95% full and Latvia's was 58% full. The high level of storage filling

contributed, along with mild weather, to lower pressure on gas prices during the winter of 2022/23 (Reuters, 2023). On 1 January 2023, the EU storage was 84% full and Latvia's 47%. On 1 March, the European Union's storage was 61% full and Latvia's 37%.

Regional gas market integration

Since 2017, Finland and the Baltic states (Estonia, Latvia and Lithuania) have been working towards gas market integration. Their governments, national regulatory authorities and TSOs participate in the Regional Gas Market Coordination Group to promote closer co-operation within the FINESTLAT market area.

Renewable gases

Finland's NCES places a strong emphasis on scaling up the production of renewable gases. Finland currently has five biogas plants connected to the gas network, but biogas consumption in the gas network has not increased significantly in recent years. In 2020, the government developed a national biogas programme aimed at strengthening the role of biogas.

Hydrogen

The NCES includes a national hydrogen strategy that aims to promote green hydrogen production and the use of hydrogen in industry, which will serve to limit future gas consumption. The strategy sets a target of achieving an electrolysis capacity of at least 0.2 GW by 2025 and at least 1.0 GW in 2030 (compared to just 9 MW in 2021).

The gas TSO, Gasgrid Finland, is also working to accelerate the development of hydrogen infrastructure in Finland. Gasgrid is working alongside Sweden's Nordion Energi to develop the Nordic Hydrogen Route, a cross-border project aimed at building a network of pipelines in the Bothnia Bay region. It has also begun a hydrogen transmission demonstration project to supply the Ovako steel mill in Imatra with by-product hydrogen produced by the chemicals company, Kemira.

In February 2023, the government adopted a resolution on hydrogen. The objective is to make Finland the leader in the European hydrogen value chain by 2030, building on the secure supply of abundant, inexpensive clean electricity and other competitive advantages. The resolution sets out 20 measures to build a vibrant hydrogen sector in the country.

Gas in transportation

The government is aiming to expand the role of renewable gases, CNG and LNG in the transport sector. The Roadmap to Fossil-Free Transport includes goals for 2.5 TWh of biogas consumption in transport by 2030, translating into approximately 100 000-130 000 passenger vehicles and approximately 6 000 heavy-duty vehicles powered with 100% biogas.

The government also provides subsidies for CNG and LNG vehicles and refuelling stations. For the period 2022-25, the government is planning to spend EUR 9.2 million (EUR 2.3 million/year) to support the development of CNG refuelling station projects and EUR 10.8 million (EUR 2.7 million/year) for LNG refuelling station projects. It is envisaged that this support will enable doubling the number of CNG refuelling stations (from 25 to 50)

and an increase in the number of LNG refuelling stations from 7 to 40. The government anticipates that this infrastructure would be sufficient for a fleet of approximately 65 000 CNG-powered vehicles and 1 500 LNG vehicles by 2025.

Gas emergency response

Emergency response organisation

The MEAE is responsible for gas emergency response policy and preparedness in Finland. The Gas Division of the National Emergency Supply Agency (NESA), a government agency operating within the MEAE, would take the lead in co-ordinating the response to a major gas supply disruption.

The gas market regulator, the Energy Authority, has responsibility for monitoring the security of gas supply in conjunction with NESA, as stipulated in the Natural Gas Market Act (587/2017).

NESA is responsible for preparing demand estimates, while the Energy Authority is obligated to maintain information on transmission network capacity and availability, as well as to monitor the balance between supply and demand. The Energy Authority publishes an annual report on the security of gas supply in Finland.

Emergency response measures

Major gas consumers in Finland are legally required to hold backup reserves of alternative fuel equivalent to three months' consumption.

In addition to the volumes held by large-scale consumers, NESA holds state-owned emergency fuel stocks, mostly in the form of coal and fuel oil. NESA's stocks cover five months' gas consumption, not including industry consumption.

There are three natural gas crisis levels in Finland: "early warning", "alert" and "emergency", corresponding to the levels outlined in EU Regulation (994/10). In the event of an "emergency" level crisis, the emergency response would primarily involve fuel switching. NESA can permit industry users to use their emergency fuel reserves while it can also release state-owned reserves for the use of protected customers and power generators.

In May 2022, NESA declared an "early warning" in the Finnish gas market as a result of the loss of Russian gas pipeline supply. However, due to the significant reduction in demand as a result of industry-led efforts, the government did not raise the gas crisis state to a level above "early warning", and therefore did not resort to the implementation of emergency measures.

Assessment

Since Russia ceased pipeline flows in May 2022, Finland has been highly successful in significantly reducing natural gas demand. This significant demand reduction was a result of the efforts of industrial gas consumers to make efficiency improvements and switch to alternative fuel sources (largely coal, biomass and propane).

The ability of many large gas consumers in Finland to use alternative fuels is undoubtedly highly beneficial to energy security and negated the need for the government to implement measures to restrict gas supply. However, it is nonetheless undesirable that the use of comparably higher carbon-intensity fuels persists for any longer than absolutely necessary. Efforts should continue for procuring alternative sources of natural gas supply to replace Russian gas in the short term and to curtail natural gas consumption in the longer term.

The commencement of operations at the Hamina LNG terminal in October 2022 will facilitate the sourcing of alternative gas supplies, and with the entry into operation of the Exemplar FSRU in January 2023, Finland theoretically has enough entry capacity to cover peak demand and still send surplus volumes to neighbouring markets.

In the longer term, the Finnish government's strong climate ambitions and policies will incentivise a shift away from natural gas to alternative energy sources. However, successfully navigating a shift away from natural gas towards hydrogen and low-carbon gases will necessitate careful co-ordination to mitigate undesirable transitional impacts.

While there are a number of examples of innovative hydrogen and other renewable gas projects across the economy, and a clear desire on the part of industry to progress quickly towards a renewable gas or low-carbon hydrogen-centric future, the government needs to integrate and co-ordinate activities and better signal and support coherent pathways for investment.

The government should engage with all relevant stakeholders to gain a better understanding of industrial low-emission gas needs, both now and over the coming decades. Co-ordinating the collective views of industry, gas and electricity TSOs, and municipality representatives will be critical in assessing infrastructure requirements and opportunities and ensuring local community support.

To further facilitate investment certainty, it is important that the regulatory requirements are clear and transparent at the earliest stage. While EU regulatory mandates are already under development in relation to the operation of, for example, future hydrogen markets and infrastructure access, the government could also begin to consider options to review or streamline permitting requirements for projects that will, over time, form the basis of core infrastructure.

Social licence is important for all new infrastructure developments; therefore, the gas TSO should undertake further analysis of options to utilise existing gas network corridors to minimise the possibility of unnecessary community disruption.

The government should also undertake an analysis to ascertain the need for funding support, potentially around specific industrial zones or clusters identified by industry and the TSOs. This could assist in ensuring more efficient use of new infrastructure in the early stages of the development of the industry.

While the development of low-emission gas transmission infrastructure presents significant opportunities, the trajectory of the existing natural gas network must also be carefully considered, as it is not simple to rapidly displace all natural gas in the network with low-emission alternatives. For example, while Gasgrid is currently assessing the

potential for blending limited amounts of hydrogen into the gas network, issues of embrittlement and the practical capacity of end use processes to accommodate hydrogen blends could remain a significant challenge.

Similarly, while it may be possible to replace a share of the existing supply with biomethane or synthetic methane, it is unclear whether production could be scaled up sufficiently to support all existing and expected gas demand over the coming years. This suggests a strong risk that the gas network could become a stranded asset. To address this risk, the government should assess whether the operation of the existing gas network is viable, and if it is not, assess whether support should be given to consumers that cannot easily switch to an alternative energy source.

Recommendations

The government of Finland should:

- ☐ Co-ordinate with key stakeholders to develop realistic scenarios for displacing natural gas with clean or renewable alternatives that are consistent with its climate goals, and determine the required policies, regulation, infrastructure and funding.
- ☐ Assess whether the operation of the existing gas network is viable. If not, evaluate whether support should be given to consumers that cannot easily switch to an alternative energy source.

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9. Oil

Key data

(2021)

Net imports of crude oil:* 174.4 kb/d, -2% since 2011

Domestic oil products production: 210 kb/d, -33% since 2011

Net exports of oil products: 22.8 kb/d (total imports 50.0 kb/d, total exports 72.8 kb/d), -34% since 2011

Share of oil: 0% of energy production, 21% of total energy supply,** 0.2% of electricity generation, 4% of heat generation, 26% of total final consumption, 81% of transports, 22% of industry and 6% of buildings

Oil consumption by sector: 179 kb/d (domestic transport 47%, industry including non-energy consumption 31%, buildings 13%, international bunkers 6%, electricity and heat generation 3%)

* "imports/exports of crude oil" includes crude oil, natural gas liquids and feedstock.

** Total energy supply does not include oil used for international bunkering.

Overview

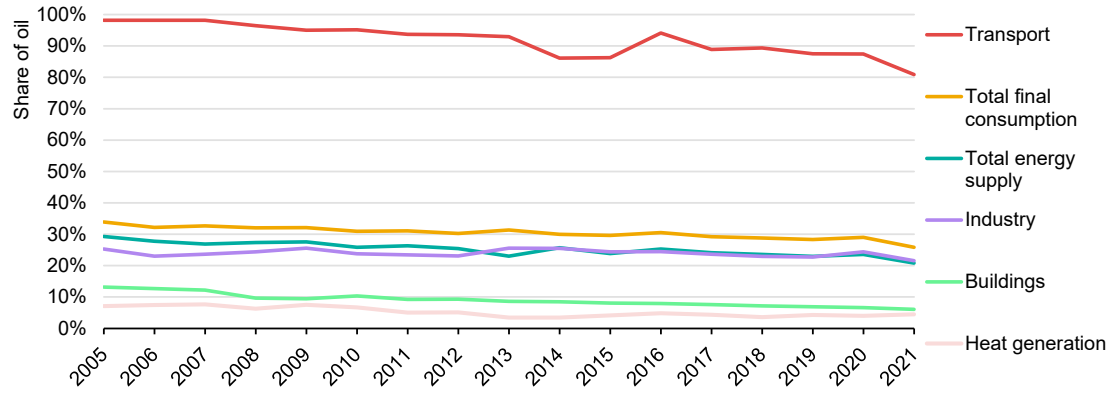
The share of oil in Finland's energy supply mix remains substantial but is considerably lower than the average for IEA countries; oil accounted for 21% of TES in 2021, compared to the IEA average of 35% (Figure 9.1). The share of oil in TFC fell from 34% to 26% from 2005 to 2021.

Following the closure of the 58 kb/d Naantali refinery in 2021, Finland only has one remaining crude oil refinery, the 206 kb/d Porvoo refinery. The country is entirely dependent on crude oil imports but remains a marginal net exporter of oil products.

Finland has historically imported a substantial majority of its oil from Russia, but in July 2022, the only refiner and main oil importer in the country, Neste, announced that it would no longer import Russian oil because of Russia's invasion of Ukraine.

Demand for oil products has trended slowly downwards for well over a decade. Oil product demand is likely to reduce significantly in the coming decade as a result of a range of policy measures promoting the use of alternative fuels in transportation, industry, heating and buildings.

Figure 9.1 Shares of oil in Finland's energy sector, 2005-2021



Source: IEA (2022).

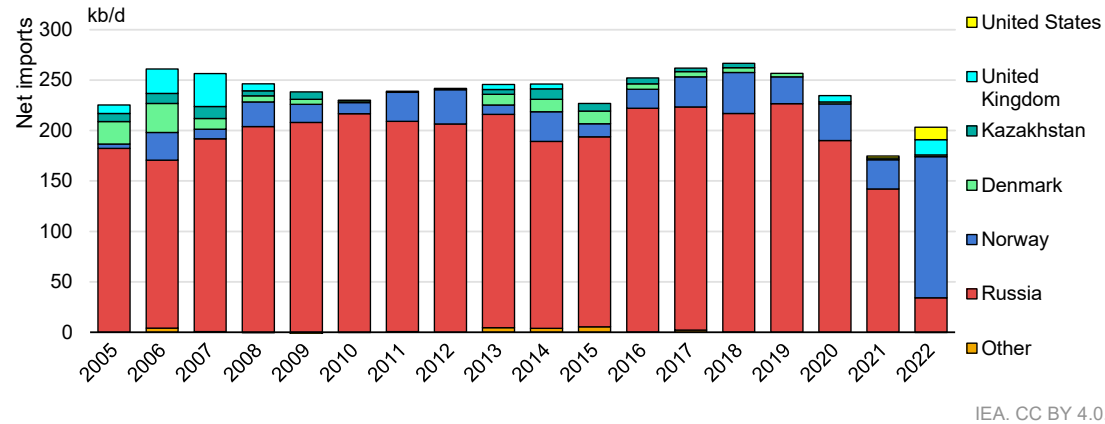
Oil supply and demand

Crude oil trade

With no domestic production, Finland is entirely reliant on imported crude oil. In 2021, Finland imported 174 kb/d of crude oil (Figure 9.2), 26% lower than in 2020, largely due to the closure of the Naantali refinery in March 2021, as well as reduced crude processing at the Porvoo refinery.

Finland has historically imported a substantial majority of its crude oil from Russia; Russian crude oil accounted for 81% of its total crude oil imports in 2021. However, Neste, Finland's only refiner, announced that it would no longer import Russian crude in July 2022 as a result of Russia's invasion of Ukraine. Russian crude oil has been replaced largely by Norwegian North Sea crudes. Prior to 2022, Norway was already a significant supplier of crude oil to Finland, accounting for the vast majority of non-Russian crude imports.

Figure 9.2 Finland's crude oil, natural gas liquids and refinery feedstock net imports by country, 2005-2022



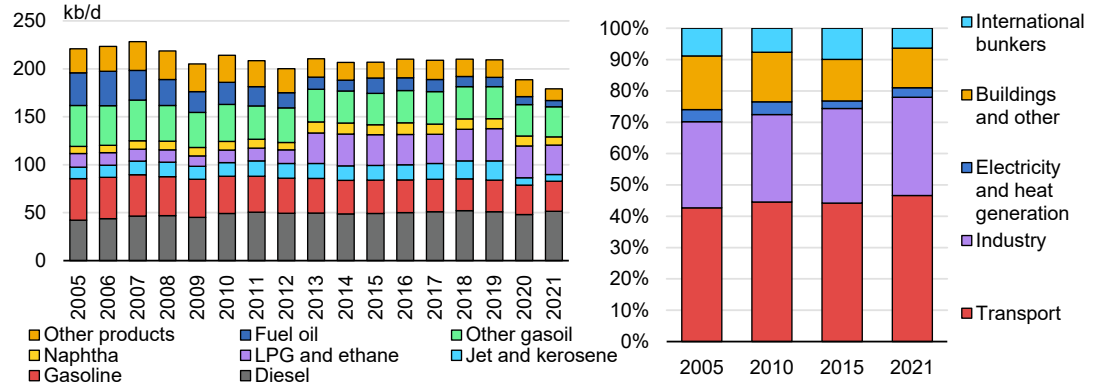
Source: IEA (2022).

Oil product demand

Total demand for oil products was 179 kb/d in 2021 (Figure 9.3). Oil product demand fell by 10% in 2020 as a result of the impact of Covid-19 on mobility and economic activity. Prior to 2020, total oil product demand had trended mildly downwards since the mid-2000s, largely as a result of reduced gasoline and fuel oil consumption. The decline in fuel oil consumption has been particularly notable; fuel oil demand fell from 34 kb/d in 2005 to just 6.4 kb/d in 2021 due to tightened environmental regulations. Oil product demand is now concentrated in the transport and industry sectors, which respectively accounted for 47% and 31% of demand in 2021.

Going forward, oil product demand is expected to decline substantially in Finland in both the transportation and industry sectors as a result of government policies to promote the uptake of alternative fuels (see the section on “Oil policy”).

Figure 9.3 Oil products demand by sector in Finland, 2005-2021

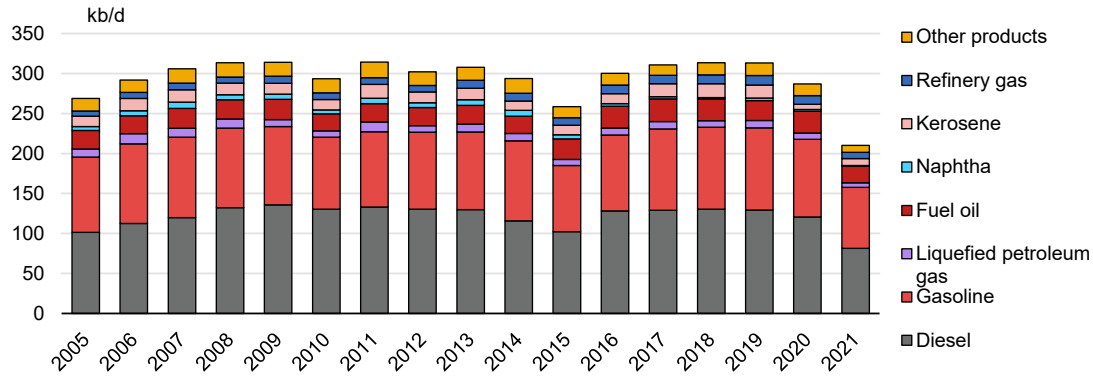


Source: IEA (2022).

Oil product production and trade

Total oil product production in Finland amounted to 210 kb/d in 2021 (Figure 9.4), 27% lower than 2020, largely as a result of the closure of the Naantali refinery. Since 2021, all of Finland’s refining production has come from Neste’s Porvoo refinery. Refinery output is dominated by motor fuels, with gasoline and diesel, respectively, accounting for 36% and 39% of total oil products production in 2021.

Figure 9.4 Oil products production in Finland, 2005-2021

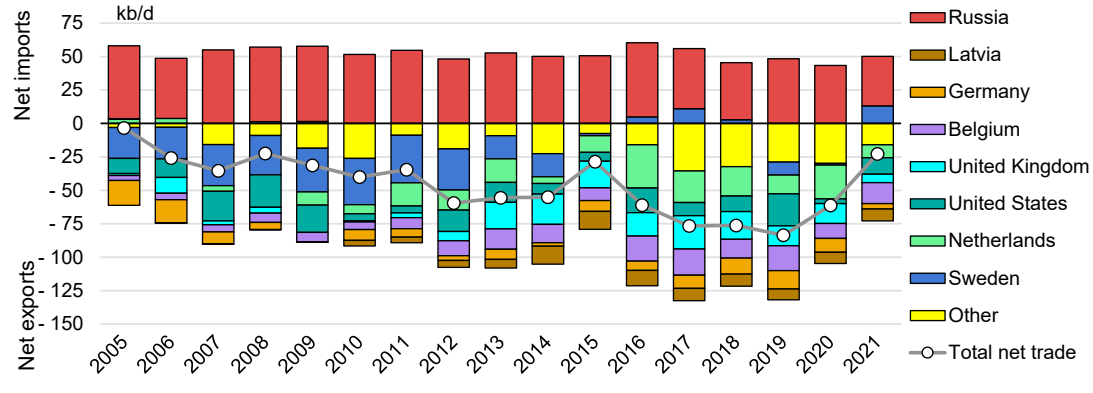


Source: IEA (2022).

Finland is a small net exporter of oil products, with net exports of 23 kb/d in 2021 (Figure 9.5). However, net exports in 2021 were substantially lower than in 2020 after production fell when the Naantali refinery closed and production from the Porvoo refinery was lower. In 2021, Finland was a net exporter of gasoline, jet fuel and fuel oil, while it was a net importer of diesel/gasoil and naphtha.

Finnish oil products are sent to a range of countries, with the most significant net export with Belgium (16 kb/d), the United States (12 kb/d), the Netherlands (10 kb/d), Latvia (9 kb/d), the United Kingdom (6 kb/d), Estonia (6 kb/d) and Germany (4 kb/d) in 2021. The vast majority of oil product imports came from Russia in 2021, with 37 kb/d. Imports of Russian oil products declined substantially in 2022, and ceased completely in February 2023 as a result of the EU's sixth package of sanctions against Russia.

Figure 9.5 Finland's net exports of oil products by country, 2005-2021



Source: IEA (2022).

Oil policy

The Finnish government has a range of policy measures aimed at significantly reducing oil consumption in transportation, industry, heating and buildings, principally through promoting the uptake of renewables (see Chapters 3 and 4).

The NCES outlines a variety of measures to further reduce oil consumption in transport by improving efficiency and encouraging the uptake of alternative fuels. A list of measures that will serve to limit oil consumption in transportation was also outlined in the Roadmap to Fossil-Free Transport, adopted by the government in June 2021. The measures detailed in the road map are designed to support the government's objective to reduce GHG emissions from transport by at least 50% by 2030 (versus 2005) and end fossil fuel consumption in transport entirely by 2045.

In line with EU policy objectives, the government also supports the complete phase-out of seaborne Russian oil imports.

Biofuels

The government views the use of liquid biofuels as a key interim strategy to limit oil consumption in transportation. Finland's biofuels blending mandates were among the highest in the worldmr at 19.5% in early 2022. The government has plans to significantly increase them to 34% by 2030, including a sub-target of 10% for advanced biofuels.

However, in April 2022, the government unexpectedly reduced the biofuels blending mandate to 12% in an effort to contain rising fuel prices. In September 2022, the reduction of the blending mandate was extended until the end of 2023. This has created doubt around Finland's ability to meet its EU emissions reduction target for road transport (of -29% by 2025 compared to 2005). The reduction of the blending mandate has also cast doubt on the government's commitment to supporting increased biofuels penetration, despite its ambitious longer term objectives, and has been viewed as a negative investment signal by domestic biofuels producers.

Electric vehicles

In the longer term, the government views the uptake of EVs as the principal means of limiting oil consumption and achieving its goal of ending fossil fuel consumption in transportation. Finland is a leader in the promotion and uptake of EVs, with ambitious targets for EV penetration, supported by relatively strong incentives. However, subsidies for EVs will end in 2023.

CNG, LNG and biogas

The Finnish government is also targeting the displacement of oil in transport to some extent with CNG, LNG and biogas. The government provides subsidies for CNG and LNG vehicles that could be powered with biogas, as well as subsidies for gas refuelling stations.

Reducing oil consumption in heating and buildings

The government is pursuing to end the use of heating oil by 2030. It aims to achieve this target by providing grants for low-emission heating solutions. In 2021, Finland introduced a biofuels blending obligation for light fuel oil used in heating. This obligation applies to retail suppliers selling over 1 million litres of light fuel oil per year, with the obligated share set at 3% for 2021, and progressively increasing to 30% by 2030.

Oil market and prices

Wholesale and retail

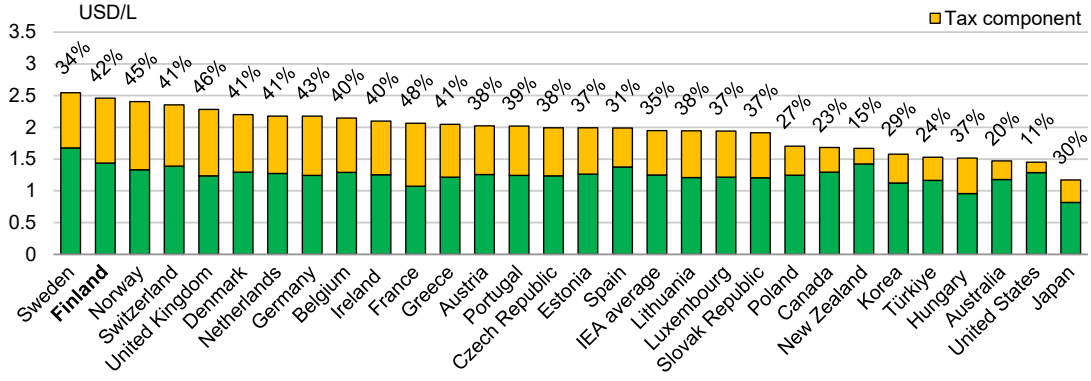
Neste, a majority state-owned oil company, is the dominant player in the Finnish oil market. Neste is the only refiner and is by far the largest player in the wholesale market. North European Oil Trade, part-owned by retailer St1, is also a major wholesaler.

Neste is also the most significant player in the retail market, while ABC, St1 and Teboil have large networks. There are around 2 000 retail stations in Finland.

Prices and taxation

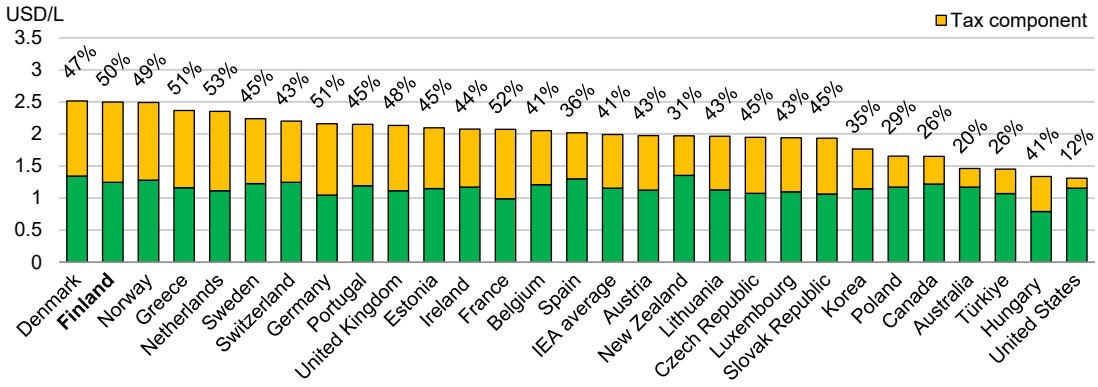
Oil product prices are unregulated in Finland. Finnish motor fuel prices are among the highest in the IEA, largely due to a high tax component. In the second quarter of 2022, the price of automotive diesel in Finland ranked the second highest among IEA countries, at USD 2.54 per litre (USD/L) with a 42% tax rate (including excise duties and VAT), compared to an IEA average price of 1.95 USD/L and 35% average tax rate (Figure 9.6). Over the same period, the price of premium unleaded gasoline (95 RON) also ranked second among IEA member countries, at 2.50 USD/L, including a 50% tax rate, while the IEA average price and tax rate for RON 95 stood at 1.99 USD/L and 40%, respectively (Figure 9.7).

Figure 9.6 Price comparison for automotive diesel in the IEA, 2Q 2022



Source: IEA (2022).

Figure 9.7 Price comparison for unleaded gasoline (95 RON) in the IEA, 2Q 2022



Note: Q2 2022 automotive diesel prices are unavailable for Italy and Mexico; Q2 2022 unleaded gasoline prices are unavailable for Italy, Japan and Mexico.
Source: IEA (2022).

Oil infrastructure

Finland has limited oil infrastructure composed of 1 refinery, 6 oil ports, 6 larger coastal storage facilities and 19 smaller inland storage facilities. There are no crude oil or oil product pipelines in Finland (Figure 9.8).

Refineries

There is one operational crude oil refinery in Finland, the Porvoo refinery, with a crude distillation capacity of 206 kb/d. The 58 kb/d Naantali refinery was permanently closed in 2021.

Neste is pursuing a plan to achieve carbon-neutral production at Porvoo by eliminating its consumption of fossil fuels by 2030. In September 2022, Neste also announced that it was undertaking a study into the future viability of the Porvoo refinery as a crude processing facility. The study will consider the possibility of significantly increasing the production of biofuels and potentially starting renewable-based hydrogen production at the refinery site. The timing of the completion of the study has not yet been determined, leaving significant doubt about the future of oil products production in Finland.

Transportation

Finland has six main oil import terminals. A crude oil import terminal is located at the Porvoo refinery, while a new product import, storage and distribution terminal will be constructed at the now-closed Naantali refinery site. Oil product transportation is undertaken largely by cabotage and road tanker.

Storage

Finland's total oil storage capacity is around 63 million barrels (mb), located in 25 coastal and major inland storage facilities. Major coastal terminals are at Porvoo (44 mb) and Naantali (6 mb), as well as Inkoo (3.1 mb), Kokkola (2.5 mb), Kemi (1.6 mb) and Hamina (0.6 mb). While the major storage facilities are mostly owned by industry, NESA also owns storage terminals in Finland.

Figure 9.8 Finland's oil infrastructure, 2022

Oil emergency policy and stockholding

Oil emergency policy

The MEAE has overall responsibility for the security of the oil supply and emergency oil policy. NESA, a government agency operating within the MEAE, is in charge of emergency preparedness and response.The use of emergency stocks is the core element of Finland's oil emergency response strategy. In addition to the release of public stocks, the MEAE

also has the authority under the Compulsory Stockholding of Fuels Act to make stocks available by lowering the stockholding obligation on industry. The Emergency Powers Act (1552/2011) stipulates that the government can also implement a variety of demand restraint measures.

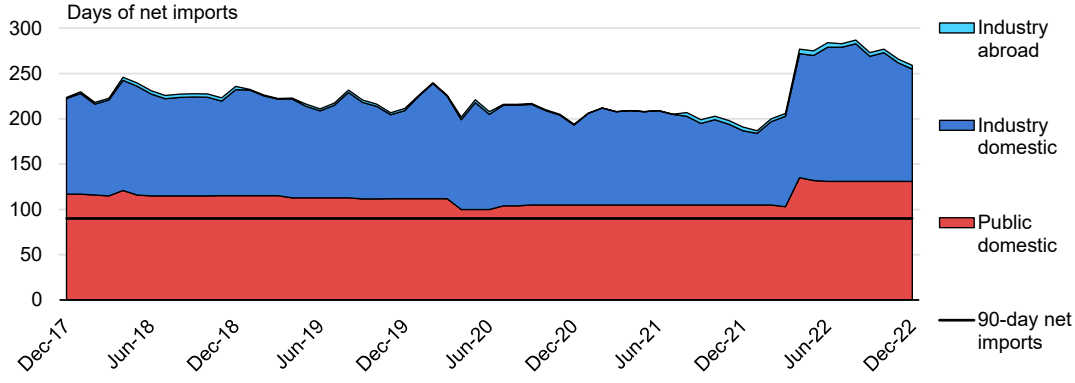
Oil stockholding

Finland meets its stockholding obligation to the IEA and supports the domestic security of the oil supply through a combination of holding public stocks and a compulsory stockholding obligation imposed on importers of crude oil and oil products. The government's target is to hold emergency stocks at a level equivalent to five months of oil consumption through the combination of public and obligated industry stocks.

NESA is responsible for managing public stocks under the Security of Supply Act. A compulsory industry obligation is imposed on entities which annually import more than 39.5 kb (5 000 tonnes) of kerosene/jet fuel, 84.5 kb (10 000 tonnes) of motor gasoline and diesel, or 147.5 kb (20 000 tonnes) of crude oil. The obligation is set at two months of net imports in the previous calendar year. Finland has consistently maintained oil stocks at a level significantly above the IEA's 90-day net imports requirement. As of December 2022, Finland held stocks at a total level of 259 days of net imports (Figure 9.9).

Finland participated in the IEA collective actions of March and April 2022 by releasing 746 kb of public oil stocks, in line with its suggested level of contributions based on consumption.

Figure 9.9 Emergency oil stocks by type in Finland, December 2017-December 2022



Source: IEA (2022).

Assessment

Demand for oil products in Finland will inevitably decline further in the coming decade and beyond as a result of government policies to promote the uptake of alternative fuels. The government is particularly focused on reducing oil demand in the transportation sector to achieve its objectives to reduce greenhouse gas emissions in transport by 50% versus 2005 levels by 2030 and to phase out fossil fuel consumption in transport entirely by 2045. These ambitious objectives are laudable, but if they are to be achieved, the government will need to closely monitor the evolution in oil demand and regularly assess whether

additional measures are required to accelerate the displacement of oil. Finland has historically paid strong attention to the security of the oil supply, exemplified by an oil stockholding regime encompassing public stocks and a compulsory stockholding obligation on industry. The government should continue to maintain a strong focus on the security of the oil supply, even as demand declines, given that oil will remain a substantial part of Finland's energy mix for some time.

With the future of Finland's only remaining oil refinery uncertain, particular attention should be given to the adequacy of oil import infrastructure. Attention should also be paid to the future composition of Finland's emergency oil stocks as demand trends evolve, and strong consideration should be given to holding low-carbon liquid fuels in their unblended form as part of Finland's emergency reserves.

Following Russia's invasion of Ukraine, the Finnish government committed to a complete phase-out of Russian oil imports. Previously heavily reliant on Russian oil, Finland has made commendable efforts to significantly reduce imports from Russia by sourcing alternative supplies.

The government has taken some measures to shield consumers from increased oil prices following Russia's invasion of Ukraine, including by significantly reducing its biofuels blending mandate. While the desire to protect vulnerable consumers from higher oil prices is understandable, the effectiveness of this measure is questionable, and it has been viewed as a negative investment signal by biofuels producers, despite Finland's ambitious long-term targets for biofuels penetration. The lowering of the biofuels blending mandate has also cast some doubt on Finland's ability to meet its EU emissions reduction target for road transport (of -29% by 2025 compared to 2005). The government should, therefore, carefully consider whether this measure should be continued and seek to avoid the implementation of untargeted measures to shield consumers from higher oil prices in the future.

Recommendations

The government of Finland should:

- ☐ Maintain a strong focus on the security of oil supply as demand declines, ensuring that adequate infrastructure is in place for product storage and imports, particularly if crude processing ends at the Porvoo refinery.
- ☐ Assess whether additional measures are needed to further reduce oil consumption to achieve the 2030 target to reduce transport emissions by 50% versus 2005.

Reference

IEA (International Energy Agency) (2022), World Energy Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-balances (accessed on 19 September 2022)

ANNEX A: Review team and supporting stakeholders

Review criteria

The Shared Goals, adopted by the IEA Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews. The IEA Shared Goals are available on line.

Review team and preparation of the report

The IEA's in-depth review visit of Finland took place online from 16 to 24 October 2022. The review team met with government officials, energy suppliers, market participants, interest groups, consumer associations, research institutions and other stakeholders. The report was drafted based on information obtained in these meetings, the review team's assessment of Finland's energy policy, the government's response to the IEA energy policy questionnaire, and subsequent research by the IEA. The members of the team were:

IEA member countries

Robert McGuinness, Ireland (team leader)

Suzan van Kruchten, Netherlands

Nethe Veje Laursen, Denmark

Evren Görün, Türkiye

Peter Massie, Canada

Eero Ailio, European Commission

Michael Nelson, Australia

Gea Tiits, Estonia

Nuclear Energy Agency

Franco Michel-Sendis

International Energy Agency

Aad van Bohemen

Ronan Graham

Peter Journeay-Kaler

The team is grateful for the co-operation and assistance of the many Finnish colleagues who supported the review. Thanks to their hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable. The team expresses its gratitude to Mika Lintilä, Minister of Economic Affairs and Employment, and Riku Huttunen, Director General for Energy, whose overview comments helped frame all the discussions during the review. The team extends a special thanks to

Juho Korteniemi, Salla Palander and Elina Johansson for their tireless efforts in co-ordinating the review visit, prompt responses to the team's many requests and patience throughout the weeks leading up to, during and after the review.

The review was prepared under the guidance of Aad van Bohemen, Head of the Energy Policy and Security Division, IEA. Peter Journeay-Kaler managed the review and is the author of the report. Ronan Graham co-ordinated the emergency response component of the review, wrote the chapters on oil and natural gas, and contributed to the chapter on electricity. Alessio Scanziani wrote the chapter on energy efficiency. Alessio Scanziani, Anders Caratozzolo, Clémence Lizé, Eléonore Carré and Su Min Park prepared and drafted the sections relating to energy data contained in each chapter. The following IEA staff provided helpful comments, chapter reviews and updates: Fabian Voswinkel, Brendan Reidenbach, Britta Labuhn, Ilkka Hannula, Simon Bennett, Isaac Portugal, Gergely Molnar and Toril Bosoni.

Special thanks to the IEA secretariat with regard to the data, publication and editing. Astrid Dumond and Isabelle Nonain-Semelin managed the editing, layout and publication. Ismail Aykin and Han Young Chang worked on formatting and references. Eléonore Carré and Charner Ramsey prepared the maps. Roberta Quadrelli, Steve Gervais and Dionysia Lyngopoulou provided support on statistics. Jad Mouawad, Jethro Mullen and Gregory Viscusi supported the press launch. Jennifer Allain was the editor.

Meetings held with the following organisations

Aalto University
Association of Energy Users in Finland (ELFi)
Association of Finnish Municipalities
Bioenergy Association
Business Finland
Chemical Industry Federation of Finland
Climate Leadership Coalition
Confederations of Finnish Industries
Consumers Union of Finland
Energy Authority
Energy Vaasa Cluster
Fingrid (TSO)
Finnish Association for Nature Conservation
Finnish Biocycle and Biogas Association
Finnish Clean Energy Association
Finnish Climate Change Panel
Finnish Competition and Consumer Authority (FCCA)
Finnish Energy
Finnish Forest Industries
Finnish Heat Pump Association (SULPU)
Finnish Home Owners Association

Finnish Innovation Fund (SITRA – Suomen Itsenäisyyden Juhlarahasto)

Finnish Nature Panel (Suomen Luontopaneeli)

Finnish Real Estate Federation

Finnish Safety and Chemicals Agency (Tukes)

Finnish Wind Power Association (Suomen Tuulivoimayhdistys)

Fortum

Gasgrid

Gasum

Greenpeace

Haminan Energia

Housing Finance and Development Centre of Finland (ARA)

Hydrogen Cluster

Kemijoki Oy

Lappeenranta-Lahti University of Technology (LUT)

Manga LNG

Ministry of Agriculture and Forestry

Ministry of Economic Affairs and Employment (MEAE)

Ministry of Environment

Ministry of Finance

Ministry of Transport and Communications

Motiva

National Emergency Supply Agency (NESA)

National Emergency Supply Organization (NESO)

Neste

North European Oil Trade Oy (ST1/ABC)

Radiation and Nuclear Safety Authority (STUK)

Savon Voima

Steel and Metal Producers

Technical Research Centre of Finland (VTT)

Technology Industries of Finland

Teollisuuden Voima Oyj (TVO)

World Energy Council Finland (WEC)

World Wildlife Fund Finland (WWF)

ANNEX B: Key statistical data and notes

Unit: PJ

SUPPLY		1973	1990	2000	2010	2019	2020	2021
TOTAL PRODUCTION		**204.5**	**505.8**	**625.3**	**729.9**	**792.1**	**755.1**	**810.3**
Coal		-	-	-	-	-	-	-
Peat		2.4	75.8	45.6	75.7	43.9	24.2	10.2
Oil		-	-	4.2	2.8	-	-	-
Natural gas		-	-	-	-	-	-	-
Biofuels and waste[1]		164.3	181.2	274.2	350.9	413.3	382.0	446.1
Nuclear		-	209.6	245.2	248.7	260.4	254.1	257.4
Hydro		37.9	39.1	52.8	46.5	44.7	57.2	56.9
Wind		-	-	0.3	1.1	21.7	29.7	30.6
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	0.0	0.0	0.1	0.6	0.9	1.2
TOTAL NET IMPORTS[3]		**677.8**	**633.3**	**687.4**	**651.7**	**509.2**	**514.0**	**483.5**
Coal	Exports	0.7	0.0	1.1	1.4	6.2	4.2	4.9
	Imports	102.5	183.6	149.1	167.1	94.3	75.2	68.0
	Net imports	101.8	183.6	148.0	165.7	88.1	71.0	63.1
Oil	Exports	7.5	71.1	213.6	287.6	405.3	372.2	276.0
	Imports	577.6	504.2	654.4	681.9	756.8	720.5	576.7
	Int'l marine and aviation bunkers	-7.2	-37.2	-42.2	-31.2	-48.8	-24.5	-23.1
	Net imports	562.8	395.9	398.6	363.1	302.7	323.8	277.6
Natural gas	Exports	-	-	-	-	-	-	-
	Imports	-	91.4	143.6	160.7	89.6	88.7	88.8
	Net imports	-	91.4	143.6	160.7	89.6	88.7	88.8
Electricity	Exports	0.9	1.3	1.2	18.8	14.0	24.0	24.2
	Imports	16.4	39.6	43.9	56.6	86.2	78.4	88.2
	Net imports	15.5	38.3	42.8	37.8	72.2	54.4	64.0
TOTAL STOCK CHANGES		**-4.0**	**-26.7**	**-1.6**	**76.4**	**29.3**	**13.8**	**65.0**
TOTAL SUPPLY (TES)[4]		**880.6**	**1188.3**	**1356.0**	**1529.8**	**1392.8**	**1328.7**	**1390.9**
Coal		105.4	171.7	151.6	192.0	89.2	77.2	87.9
Peat		1.6	51.0	62.1	95.9	56.7	43.1	38.2
Oil		555.2	396.1	380.5	395.7	319.2	313.0	289.8
Natural gas		-	91.4	143.6	160.7	89.1	88.4	89.1
Biofuels and waste[1]		165.1	191.1	274.2	347.2	431.6	403.6	467.9
Nuclear		-	209.6	245.2	248.7	260.4	254.1	257.4
Hydro		37.9	39.1	52.8	46.5	44.7	57.2	56.9
Wind		-	-	0.3	1.1	21.7	29.7	30.6
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	0.0	0.0	0.1	0.6	0.9	1.2
Electricity trade[5]		15.5	38.3	42.8	37.8	72.2	54.4	64.0
Shares in TES (%)								
Coal		*12.0*	*14.4*	*11.2*	*12.6*	*6.4*	*5.8*	*6.3*
Peat		*0.2*	*4.3*	*4.6*	*6.3*	*4.1*	*3.2*	*2.7*
Oil		*63.0*	*33.3*	*28.1*	*25.9*	*22.9*	*23.6*	*20.8*
Natural gas		-	*7.7*	*10.6*	*10.5*	*6.4*	*6.7*	*6.4*
Biofuels and waste[1]		*18.7*	*16.1*	*20.2*	*22.7*	*31.0*	*30.4*	*33.6*
Nuclear		-	*17.6*	*18.1*	*16.3*	*18.7*	*19.1*	*18.5*
Hydro		*4.3*	*3.3*	*3.9*	*3.0*	*3.2*	*4.3*	*4.1*
Wind		-	-	-	*0.1*	*1.6*	*2.2*	*2.2*
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*
Electricity trade[5]		*1.8*	*3.2*	*3.2*	*2.5*	*5.2*	*4.1*	*4.6*

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: PJ

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
TFC	**803.4**	**934.6**	**1023.2**	**1105.2**	**1075.7**	**1014.5**	**1067.1**
Coal	43.6	48.7	27.4	21.1	15.3	13.9	15.7
Peat	1.0	16.8	13.7	12.9	8.8	6.5	5.8
Oil	471.4	389.0	345.9	341.8	304.4	294.2	275.6
Natural gas	-	40.2	38.4	34.5	30.4	30.1	34.2
Biofuels and waste[1]	165.1	147.4	188.4	203.6	259.7	241.0	267.8
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	0.0	0.0	0.0	0.1	0.1	0.1
Electricity	97.0	212.2	272.5	300.6	292.7	276.8	295.5
Heat	25.3	80.2	136.8	190.7	164.3	151.9	172.4
Shares in TFC (%)							
Coal	*5.4*	*5.2*	*2.7*	*1.9*	*1.4*	*1.4*	*1.5*
Peat	*0.1*	*1.8*	*1.3*	*1.2*	*0.8*	*0.6*	*0.5*
Oil	*58.7*	*41.6*	*33.8*	*30.9*	*28.3*	*29.0*	*25.8*
Natural gas	-	*4.3*	*3.8*	*3.1*	*2.8*	*3.0*	*3.2*
Biofuels and waste[1]	*20.5*	*15.8*	*18.4*	*18.4*	*24.1*	*23.8*	*25.1*
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	-
Electricity	*12.1*	*22.7*	*26.6*	*27.2*	*27.2*	*27.3*	*27.7*
Heat	*3.1*	*8.6*	*13.4*	*17.3*	*15.3*	*15.0*	*16.2*
TOTAL INDUSTRY[6]	**317.1**	**442.0**	**529.8**	**504.9**	**521.5**	**495.0**	**510.4**
Coal	38.7	48.4	27.2	20.9	15.2	13.8	15.6
Peat	0.7	16.0	12.4	10.3	6.5	5.0	4.4
Oil	209.4	111.9	106.6	105.7	102.4	102.8	95.7
Natural gas	-	38.5	35.1	30.5	27.3	27.2	30.7
Biofuels and waste[1]	-	102.7	142.5	126.4	179.4	167.1	174.4
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	-	-	-	-	-	-
Electricity	65.0	117.1	154.4	145.3	138.8	129.9	137.2
Heat	3.3	7.3	51.6	65.8	51.9	49.2	52.4
Shares in total industry (%)							
Coal	*12.2*	*11.0*	*5.1*	*4.1*	*2.9*	*2.8*	*3.1*
Peat	*0.2*	*3.6*	*2.3*	*2.0*	*1.2*	*1.0*	*0.9*
Oil	*66.0*	*25.3*	*20.1*	*20.9*	*19.6*	*20.8*	*18.8*
Natural gas	-	*8.7*	*6.6*	*6.0*	*5.2*	*5.5*	*6.0*
Biofuels and waste[1]	-	*23.2*	*26.9*	*25.0*	*34.4*	*33.8*	*34.2*
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	-	-	-	-	-	-
Electricity	*20.5*	*26.5*	*29.1*	*28.8*	*26.6*	*26.2*	*26.9*
Heat	*1.0*	*1.7*	*9.7*	*13.0*	*9.9*	*9.9*	*10.3*
TRANSPORT[4]	**101.0**	**165.4**	**165.6**	**180.9**	**174.8**	**162.4**	**167.8**
OTHER[7]	**385.3**	**327.2**	**327.8**	**419.4**	**379.4**	**357.1**	**389.0**
Coal	4.4	0.3	0.2	0.2	0.1	0.1	0.1
Peat	0.3	0.7	1.3	2.6	2.3	1.5	1.4
Oil	161.7	113.3	76.4	64.0	49.1	49.5	44.1
Natural gas	-	1.7	2.7	3.5	2.3	2.1	2.5
Biofuels and waste[1]	165.1	44.7	45.9	71.6	62.3	57.2	65.7
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	0.0	0.0	0.0	0.1	0.1	0.1
Electricity	31.8	93.6	116.1	152.7	150.8	144.0	155.0
Heat	22.0	72.9	85.3	124.8	112.4	102.7	120.0
Shares in other (%)							
Coal	*1.1*	*0.1*	*0.1*	-	-	-	-
Peat	*0.1*	*0.2*	*0.4*	*0.6*	*0.6*	*0.4*	*0.4*
Oil	*42.0*	*34.6*	*23.3*	*15.3*	*12.9*	*13.9*	*11.3*
Natural gas	-	*0.5*	*0.8*	*0.8*	*0.6*	*0.6*	*0.6*
Biofuels and waste[1]	*42.8*	*13.7*	*14.0*	*17.1*	*16.4*	*16.0*	*16.9*
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Electricity	*8.2*	*28.6*	*35.4*	*36.4*	*39.7*	*40.3*	*39.9*
Heat	*5.7*	*22.3*	*26.0*	*29.8*	*29.6*	*28.8*	*30.9*

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: PJ

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
ELECTRICITY GENERATION[8]							
Input (PJ)	144.4	494.3	644.0	791.7	651.9	625.2	668.0
Output (PJ)	94.0	195.8	252.0	290.5	247.2	249.4	259.7
Output (TWh)	26.1	54.4	70.0	80.7	68.7	69.3	72.1
Output shares (%)							
Coal	*18.7*	*18.5*	*13.1*	*18.8*	*7.2*	*4.4*	*4.9*
Peat	*9.4*	*5.1*	*5.7*	*7.8*	*4.4*	*3.1*	*2.9*
Oil	*31.6*	*3.1*	*0.8*	*0.6*	*0.4*	*0.3*	*0.2*
Natural gas	*-*	*8.6*	*14.5*	*14.0*	*5.6*	*5.8*	*5.3*
Biofuels and waste[1]	*-*	*9.5*	*12.4*	*13.9*	*20.1*	*17.4*	*19.5*
Nuclear	*-*	*35.3*	*32.1*	*28.3*	*34.8*	*33.6*	*32.7*
Hydro	*40.3*	*20.0*	*21.0*	*16.0*	*18.1*	*22.9*	*21.9*
Wind	*-*	*-*	*0.1*	*0.4*	*8.8*	*11.9*	*11.8*
Geothermal	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Solar/other[2]	*-*	*-*	*-*	*0.1*	*0.2*	*0.3*	*0.4*
TOTAL LOSSES	**79.8**	**282.1**	**356.8**	**422.4**	**336.4**	**313.0**	**336.3**
of which:							
Electricity and heat generation[9]	23.9	211.7	246.1	296.9	230.2	214.8	226.3
Other transformation	19.0	11.7	36.9	32.1	19.0	16.2	30.7
Own use and transmission/distribution losses	36.9	58.7	73.8	93.4	87.3	82.1	79.3
Statistical differences	**-2.6**	**-28.4**	**-24.0**	**2.2**	**-19.3**	**1.1**	**-12.5**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
GDP (billion 2015 USD)	93.61	155.95	196.07	233.61	254.70	249.03	256.56
Population (millions)	4.67	4.99	5.18	5.36	5.52	5.53	5.54
TES/GDP (MJ per 2015 USD)[10]	9.41	7.62	6.92	6.55	5.47	5.33	5.42
Energy production/TES	0.23	0.43	0.46	0.48	0.57	0.57	0.58
Per capita TES (GJ per capita)	188.73	238.32	261.99	285.25	252.22	240.22	250.97
Oil supply/GDP (MJ per 2015 USD)[10]	5.93	2.54	1.94	1.70	1.25	1.26	1.13
TFC/GDP (MJ per 2015 USD)[10]	8.58	5.99	5.22	4.73	4.22	4.07	4.16
Per capita TFC (GJ per capita)	172.18	187.44	197.68	206.07	194.80	183.43	192.56
CO_2 emissions from fuel combustion ($MtCO_2$)[11]	47.9	53.8	54.6	62.0	40.7	36.0	35.9
CO_2 emissions from bunkers ($MtCO_2$)[11]	0.3	1.8	2.1	0.7	1.1	1.0	0.9
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-18**	**18-19**	**19-20**	**20-21**
TES	1.8	1.3	1.2	-0.9	-2.2	-4.6	4.7
Coal	2.9	-1.2	2.4	-6.2	-22.2	-13.4	13.8
Peat	22.7	2.0	4.4	-5.3	-8.4	-23.9	-11.4
Oil	-2.0	-0.4	0.4	-2.0	-4.8	-1.9	-7.4
Natural gas	-	4.6	1.1	-6.9	-2.0	-0.8	0.8
Biofuels and waste[1]	0.9	3.7	2.4	2.5	1.8	-6.5	15.9
Nuclear	-	1.6	0.1	-0.0	4.7	-2.4	1.3
Hydro	0.2	3.0	-1.3	0.4	-6.6	27.9	-0.6
Wind	-	-	14.2	45.3	3.2	37.0	3.0
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	3.8	9.4	27.9	52.2	42.8	33.2
TFC	0.9	0.9	0.8	-0.2	-0.9	-5.7	5.2
Electricity consumption	4.7	2.5	1.0	-0.1	-1.8	-5.4	6.8
Energy production	5.5	2.1	1.6	1.4	-2.8	-4.7	7.3
Net oil imports	-2.0	0.1	-0.9	-1.2	-8.4	7.0	-14.3
GDP	3.0	2.3	1.8	0.9	1.2	-2.2	3.0
TES/GDP	-1.2	-1.0	-0.5	-1.8	-3.3	-2.5	1.6
TFC/GDP	-2.1	-1.4	-1.0	-1.2	-2.0	-3.6	2.1

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.

Footnotes to key statistical data

[1] *Biofuels and waste* comprise 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 and biofuels.

[4] Excludes international marine bunkers and international aviation bunkers.

[5] Total supply of electricity represents net trade. A negative number in the share of TES indicates that exports are greater than imports.

[6] *Industry* includes non-energy use.

[7] *Other* includes residential, commercial and public services, agriculture/forestry, fishing, and other non-specified.

[8] *Inputs to electricity generation* include inputs to electricity, co-generation and heat plants. *Output* refers only to electricity generation.

[9] Losses 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] MJ per thousand USD dollars at 2015 prices and exchange rates.

[11] "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach methodology from the 2006 IPCC Guidelines. Emissions from international marine and aviation bunkers are not included in national totals.

Statistical notes for data used in the report

Unless otherwise noted, all GDP data are in USD 2015 prices and PPPs (purchasing power parities).

Total energy supply (TES) comprises 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. electricity generation and refining) or in final use.

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

Total final energy consumption (TFEC) excludes non-energy use, which is counted in total final consumption. TFEC provides a more accurate assessment of the share of energy demand covered by renewable energy and is better aligned with the European Union's gross final energy consumption metric, which is used to set EU member states' renewable energy targets.

The shares of renewables in total final energy consumption, electricity generation, heating and cooling, and transport differ if computed with the IEA or Eurostat methodology. Eurostat's methodology includes multiplying factors and normalisation procedures.

Bioenergy refers to solid and liquid biofuels, renewable waste and biogas and excludes non-renewable waste.

Buildings includes the energy use of the residential sector (residential buildings) and commercial and public service sectors (service sector buildings).

Transport excludes international aviation and navigation.

Industry includes both energy and non-energy use of the industry sector, agriculture, forestry and fishing.

Non-energy use refers to fuels used as raw materials and not used as fuel or transformed into another fuel. This typically comprises raw materials used in the chemical and petrochemical sector.

The "IEA average" is the equivalent of a weighted average of the IEA member countries, excluding Lithuania.

ANNEX C: Glossary and list of abbreviations

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

Acronyms and abbreviations

BEV	battery electric vehicle
BWR	boiling water reactor
CCS	carbon capture and storage
CCUS	carbon capture storage and utilisation
CNG	compressed natural gas
DH	district heat
DSO	distribution system operators
DSR	demand side response
EC	European Commission
EED	Energy Efficiency Directive
EPR	European pressurised reactor
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
EU	European Union
EUR	euro
EV	electric vehicle
FCCA	Finnish Competition and Consumer Authority
FCR	frequency containment reserve
FEC	final energy consumption
FIP	feed-in premium
FIT	feed-in tariff
FSRU	floating storage regasification unit
GDP	gross domestic product
GHG	greenhouse has
GIPL	Gas Interconnection Poland-Lithuania
HHI	Herfindahl-Hirschman Index
ICT	information and communications technology
IEA	International Energy Agency
IPCEI	Important Projects of Common European Interest
LNG	liquefied natural gas
LULUCF	land use, land-use change and forestry
MEAE	Ministry of Economic Affairs and Employment

NATO	North Atlantic Treaty Organization
NCES	National Climate and Energy Strategy
NEA	Nuclear Energy Agency
NECP	National Energy and Climate Plan
NEMO	nominated electricity market operator
NESA	National Emergency Supply Agency
OECD	Organisation for Economic Co-operation and Development
PEC	primary energy consumption
PPA	power purchase agreement
PPP	purchasing power parity
PV	photovoltaics
R&D	research and development
R&I	research and innovation
RED	Renewable Energy Directive
SET	Strategic Energy Technology Plan
SME	small and medium-sized enterprise
SMR	small modular reactor
STUK	Radiation and Nuclear Safety Authority
TCP	technology collaboration programme
TES	total energy supply
TFC	total final consumption
TFEC	total final energy consumption
TSO	transmission system operator
TVO	Teollisuuden Voima Oyj
USD	United States dollar
VAT	value-added tax
XBID	European Cross-Border Intraday

Units of measure

bcm	billion cubic metres
CO_2-eq	carbon dioxide equivalent
g CO_2/kWh	gramme of carbon dioxide per kilowatt hour
GJ	gigajoule
GW	gigawatt
GWh	gigawatt hour
kb/d	thousand barrels per day
km²	square kilometre
kt CO_2-eq	kilotonne of carbon dioxide equivalent
kV	kilovolt
kW	kilowatt

L	litre
mb	million barrels
mcm	million cubic metres
MJ	megajoule
Mt CO_2	million tonnes of carbon dioxide
Mt CO_2-eq	million tonnes of carbon dioxide equivalent
MW	megawatt
MWh	megawatt hour
PJ	petajoule
pkm	passenger-kilometre
t CO_2	tonne of carbon dioxide
TJ	terajoule
tkm	tonne-kilometre
TWh	terawatt hour

Annex D: Hydrogen projects in Finland, 2022

Project name	Date online	Status	Technology	Type of electricity	Type of renewable	Product	End use	Announced capacity	IEA zero carbon estimated capacity (nm3H2/hour)
Kokkola H_2 plant	2014	Operational	ALK	Other/unknown		H_2		9 MW	1 957
VTT Bio economy+	2019	DEMO	PEM	Other/unknown		Synfuels	Synfuels	0.025 MW	5
Balance project	2019	DEMO	SOEC	Other/unknown		Various	Power, heat, synfuels	0.006 MW	2
P2X Harjavalta project	2024	FID	ALK	Dedicated renewable	Unknown	H_2		20 MW	4 348
Power2AX	2024	Feasibility study	Other turkelectrolysis	Dedicated renewable	Onshore wind	H_2	Mobility, power, heat	225 t H_2/y	289
Vantaa-Wartsila methanation	2025	FID	Other electrolysis	Dedicated renewable	Onshore wind	CH4	CH4 grid injection	20 MW	4 444
SHARC – Sustainable Hydrogen and Recovery of Carbon (phase 1)	2025	Feasibility study	Other electrolysis	Other/unknown		H_2	Refining	50 MW	11 111
SHARC – Sustainable Hydrogen and Recovery of Carbon (phase 2)	2027	Feasibility study	Other electrolysis	Other/unknown		H_2	Refining	165 MW	36 667
SHARC – Sustainable Hydrogen and Recovery of Carbon (phase 3)	2029	Feasibility study	Other electrolysis	Other/unknown		H_2	Refining	270 MW	60 000
Wartsila – Vaasan		Feasibility study	Other electrolysis	Dedicated renewable	Unknown	H_2			0
Raahe hub		Concept	Other electrolysis	Other/unknown		H_2			0

We wish to acknowledge the traditional custodians of the land of the ACT Region where the in-depth review took place, the Ngunnawal people, and pay respect to their Elders, both past and present.

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Finland 2023

Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices and experiences to help drive secure and affordable clean energy transitions.

Finland has set one of the most ambitious climate targets in the world, a legal obligation to reach carbon neutrality by 2035. It has made notable progress towards this target, deploying the first new nuclear reactor in Europe in over 15 years and strongly expanding wind generation. Thanks to the progress Finland has made on its clean energy transition, the country has the second lowest share of fossil fuels in its energy supply among IEA members. It is also reducing its reliance on Russian energy imports and ensuring energy security by increasing imports from other countries, raising domestic renewable energy production and improving energy efficiency.

Despite these notable successes in clean energy and energy security, significant challenges remain. Imported fossil fuels still account for over a third of the energy supply while some areas of the Finnish economy, such as transport and key industrial activities, remain dependant on fossil fuels. Also, land use change and forestry in Finland, which have historically offset a significant amount of greenhouse gas emissions, became a net source of emissions for the first time in 2021.

In this report, the IEA provides a range of energy policy recommendations to help Finland smoothly manage the transition to a secure, efficient and flexible carbon neutral energy system.