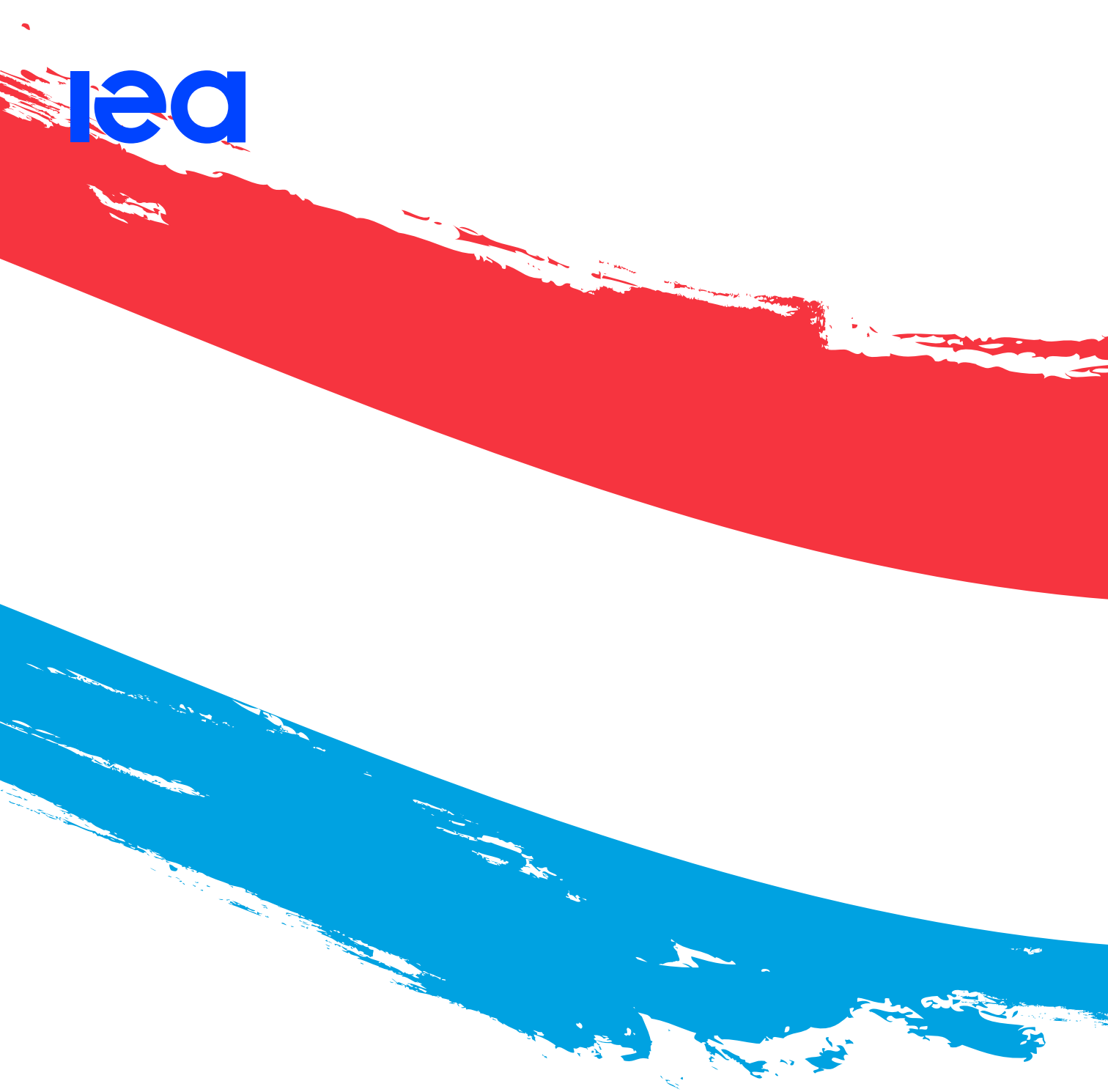

Luxembourg 2020

Energy Policy Review

International Energy Agency

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INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

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Foreword

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

As one of the founding members of the IEA, Luxembourg has a long and deep history with the Agency. I greatly appreciate its support for our work in various areas, including the Clean Energy Transitions Programme and our efforts to boost global progress on energy efficiency. I particularly value the engagement of Minister for Energy Claude Turmes, who is a member of the Global Commission for Urgent Action on Energy Efficiency, which was announced in July 2019 with the aim of developing key policy recommendations.

Luxembourg's energy demand and greenhouse gas emissions have shown signs of decoupling from its robust economic and population growth. The country has doubled the share of renewables in its energy supply over the past decade. The government is committed to the goals of the Paris Agreement and has adopted ambitious energy sector targets, including a 50-55% reduction of greenhouse gas emissions by 2030, compared with 2005 levels.

Luxembourg faces notable challenges in achieving those targets. The country's energy supply is dominated by fossil fuels. Energy demand and carbon dioxide emissions fell significantly between 2008 and 2015, but they started to increase again in 2016. This was driven by higher fuel consumption in the transport sector, mostly from fuel sales to freight trucks and commuters. It is encouraging that the government has recognised the need to reduce fuel demand in line with its energy sector targets. In a notable first step, it modestly increased the excise duties on diesel and gasoline in May 2019. Another increase, to be implemented by April 2020, is under consideration.

Luxembourg has generous support schemes for energy efficiency and renewable energy, two of the key pillars of clean energy transitions. However, the country's low taxes on energy represent a barrier to the additional investments needed in energy efficiency and renewables to meet the government's targets. The government's plan to gradually introduce carbon pricing, if done wisely, could stimulate the behavioural changes and investments required for the transition to a low-carbon energy system.

I strongly believe that both policy and regulatory reforms can help Luxembourg achieve a cost-efficient, equitable and sustainable pathway to meeting its ambitious energy transition goals. It is my hope that this report will help Luxembourg as it undertakes this endeavour.

Dr. Fatih Birol

Executive Director

International Energy Agency

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1. Executive summary

Overview

Since the 2014 IEA review of Luxembourg's energy policies, the country has made progress on its energy sector priorities of ensuring security of supply, promoting energy efficiency, increasing the use of renewable energy and reducing greenhouse gas (GHG) emissions. From 2007 to 2017, Luxembourg's gross domestic product (GDP) grew by 18% and its population increased by 24%, the fastest population growth among IEA member countries. Over the same period, total final consumption declined by 7%, indicating a decoupling of energy demand from GDP and population growth. The country also achieved notable reductions in GHG emissions. In 2017, total GHG emissions were down 20% from 1990 and 21% from 2005. From 2008 to 2018, Luxembourg's share of renewables in total primary energy supply (TPES) more than doubled, from 3.3% to 7.5%.

The government has adopted ambitious energy sector targets for 2020 and 2030. However, it is unclear if existing policies and support schemes adequately address the challenges presented by rapid population growth, an expanding economy and the current dependence on fossil fuels. This is especially true for the transport sector, which in 2017 accounted for 54% of energy demand and 65% of non-ETS GHG emissions.[1] Luxembourg's low cost of energy and the high purchasing power of its consumers are also a barrier, as they limit interest to invest in renewables and energy efficiency. Current policies and support schemes should be analysed, monitored and adjusted as needed to ensure a cost-effective achievement of Luxembourg's energy sector targets. Luxembourg's plan to gradually introduce carbon pricing that takes into account socio-economic impacts could provide a simple and more direct method to drive the transition to a clean, flexible and sustainable energy system.

Energy supply and demand

Luxembourg's energy system is characterised by high import dependence and reliance on fossil fuels. In 2018, 95% of its energy supply (100% of oil, natural gas and biofuels and 86% of electricity) were imported. It had the fourth-highest share of fossils fuels in TPES (78%) and the highest share of oil in TPES (60%) among IEA member countries. Oil is by far the dominant energy source, covering most transportation demand, but also notable shares of heating demand in the residential and commercial sectors. Natural gas is the second-largest energy source, covering large shares of industrial, residential and commercial demand.

[1] Under the European Union Emissions Trading System (ETS), non-ETS sectors include agriculture, residential, commercial, waste, non-energy intensive industry and transport excluding aviation within the European Economic Area.

In 2018, renewable energy covered 7.5% of TPES and came primarily from imported biofuels used in transport and biomass used in combined heat and power plants, along with small but growing contributions from electricity generated by wind and solar photovoltaics (PV). Hydropower contributes to the renewable energy share, but is not expected to grow. District heating is mainly limited to the commercial sector, but could play a more important role in meeting heating demand in the growing residential sector. Coal use has been almost eliminated with just a small share of non-energy use in industry.

Energy sector targets and policy

European Union (EU) directives are a key driver of Luxembourg's energy sector targets and policy. The government is also committed to international climate targets of the Kyoto Protocol and the Paris Climate Agreement. Luxembourg is pushing for a more aggressive approach on energy transition at the EU level and in some cases has adopted national targets that exceed the requirements of EU directives.

Luxembourg's renewable energy share is growing; it reached 6.4% of gross final energy consumption in 2017. Renewable energy statistical transfers from Estonia and Lithuania will be used to cover any gap to reach the 2020 target of 11% renewable energy in gross final energy consumption. Without a significant effort to reduce diesel sales in 2020, Luxembourg is running a high risk to miss its 2020 target of reducing non-ETS CO_2 emissions by 20% compared to 2005 levels. In 2017, Luxembourg's energy consumption was 48.4 terawatt hours (TWh), in line with the 2020 energy efficiency target of not surpassing 49.3 TWh in final energy consumption. However, energy consumption has been increasing since 2016, especially in the transport sector. This continued growth will challenge the country's ability to meet the 2020 energy efficiency target.

Luxembourg's draft National Energy and Climate Plan (NECP) defines its 2030 energy sector targets. The government has adopted a 2030 target to reduce non-ETS emissions by 50-55% versus 2005 levels, which exceeds the 40% reduction required by the EU and is in line with a below 2°/1.5° global temperature target. The draft NECP contains a 2030 renewable energy target of 23-25% of gross final consumption and a 2030 energy efficiency target of not surpassing 35.6 TWh of final energy consumption. Luxembourg must submit a finalised NECP to the European Commission by the end of 2019. Luxembourg is pushing for net-zero GHG emissions and 100% renewable electricity by 2050. Its ambitious energy sector targets (especially the 50-55% GHG reduction by 2030) will require a significant shift in its carbon-intensive energy mix, particularly in relation to the heavy reliance on oil in the transport sector.

Support schemes

Luxembourg has numerous support schemes to achieve its energy sector targets and long-term energy sector goals. The government currently provides support for renewables through a feed-in tariff and premium tariff for electricity generated from renewables, as well as investment subsidies supporting deployment of renewable energy projects. In 2018, Luxembourg introduced a tender system for PV projects and prepared legislation to support self-consumption of renewable electricity and encourage consumers to be active market participants (prosumers). Under the new law, which is

supposed to enter into force in early 2020, electricity from renewable energy directly consumed at the generation site will be exempt from grid fees.

Prime House is Luxembourg's main scheme to support energy efficiency renovations and building integrated renewable energy. In January 2017, the government reformed the scheme to provide more generous investment subsidies and also established the Climate Bank programme, which provides low-rate climate loans to encourage residents and companies to undertake energy efficiency renovations.

In 2015, Luxembourg introduced an energy efficiency obligation scheme, which requires electricity and gas suppliers to realise cumulative annual energy savings of 1.5% for end users through 2020. To encourage energy efficiency in the transport sector, annual vehicle registration fees are higher for less efficient vehicles. The Climate Pact programme, created in 2012, provides technical advice and funding to help municipalities implement measures on climate, renewables and energy efficiency. Municipalities receive certifications based on the number of measures they implement. The pact has been signed by all 102 municipalities and as of 2018, 88 had received certifications.

E-mobility

Luxembourg has embraced an e-mobility initiative aimed at electrification of the transport sector to reduce GHG emissions and fuel imports. The draft NECP contains a goal for 49% of all vehicles registered in Luxembourg to be electric vehicles (EVs) by 2030. Luxembourg is supporting e-mobility with subsidies for purchasing EVs, investment in a national EV charging network and by encouraging a shift from private vehicles to electrified public transportation. The Modu 2.0 Sustainable Mobility Strategy includes a goal to increase the use of public transportation by 50% from 2017 to 2025 and defines measures to improve the quality of electrified public transportation, including investment in park and ride centres linked to a major reworking of bus and train infrastructure.

Electricity infrastructure

Luxembourg expects sustained growth in electricity demand driven by increasing population and economic activity and by demand from e-mobility, heat pumps and large data centres. Luxembourg aims to cover over a third of 2030 electricity demand with renewables, mostly through variable renewable energy (VRE) from PV and wind generation. The share of VRE generation in imported electricity is also expected to increase significantly. Taken together, these factors will require substantial investment in electricity infrastructure. As approval processes for new transmission lines can take several years and grid projects could lag behind demand increases, the expansion of VRE generation could potentially result in network congestion and curtailment of VRE generation. There are, however, no rules for VRE curtailment or its compensation.

The government should examine relevant planning processes and regulations to synchronise grid infrastructure construction with renewables deployment and electricity demand growth. Building early-stage consensus between the different ministries, involved parties, local authorities and the public would enable fast and co-ordinated deployment of renewables and supporting infrastructure. Infrastructure plans and

processes should also facilitate the deployment of smart grid technologies such as demand-side response, batteries and other energy storage options.

Smart meters

Luxembourg has targets for at least 95% of all electricity meters to be smart meters by the end of 2019 and at least 90% of all gas meters to be smart meters by the end of 2020. One key objective of the smart meter deployment is to allow consumers to become active market participants (prosumers) through self-generation and self-consumption of electricity. A draft law presented in 2019 aims to establish a national energy data platform with the objective to simplify, standardise and manage market processes, including market communication, and to improve the management of electricity generation from renewable energy sources.

Luxembourg's smart meter deployment and the development of a national database for smart meter data lays the groundwork for time-of-use pricing, a wide range of demand-side response measures and energy services that could support VRE integration, smart EV charging and system flexibility. Luxembourg is planning to investigate options for time-of-use pricing once the smart meter deployment is completed. The regulations for smart meter data collection and management should establish a clear legal framework ensuring fair and transparent data access that supports innovation and creation of new energy sector services while ensuring data privacy.

Energy prices and taxation

Luxembourg has low electricity, natural gas and oil fuel prices, primarily due to low energy taxes. Low fuel prices encourage transiting freight trucks and the 200 000 daily foreign commuters to fuel their vehicles in Luxembourg. These non-resident drivers are responsible for around two-thirds of Luxembourg's transportation fuel consumption. The government has a policy priority to reduce this fuel consumption in line with GHG emissions reduction targets, and in May 2019 it modestly increased excise duties on diesel by EUR 0.02 per litre and on gasoline by EUR 0.01 per litre. The government is considering another increase in excise duties between February and April 2020 of up to EUR 0.05 per litre for diesel and up to EUR 0.03 per litre for gasoline. Total fuel tax revenues, including sales to residents and non-residents, amounted to about EUR 1 billion in 2017, roughly 5% of government revenues.

The low costs of energy in Luxembourg and the high purchasing power of its residents represent a significant barrier to achieving the energy sector targets. Low taxes result in low electricity, natural gas and heating oil prices providing little incentive to invest in renewables and energy efficiency. Low fuel prices decrease the advantage of EVs and higher efficiency vehicles and encourage non-residents to fuel in Luxembourg. Carbon pricing could offer a simple mechanism to drive behaviour that supports the government's policy goals and allow a recalibration of the various energy sector subsidy schemes to target areas where subsidies are most effective. In December 2019, the government announced that it will introduce a carbon tax of EUR 20 per tonne starting in 2021. The tax would increase to EUR 25 per tonne in 2022 and EUR 30 per tonne in 2023.

Key recommendations

The government of Luxembourg should:

- Consider gradual introduction of carbon pricing instruments, as energy is considered too cheap to drive behaviour towards more energy efficiency, e-mobility and fuel switching, taking into account the social dimension.
- Develop scenarios on how to achieve the ambitious renewable energy targets for 2030, including expectations for regional renewable energy deployment, for the different end-use sectors, and for centralised and decentralised options.
- Reconsider the adequacy of approval procedures for electricity infrastructure, establish rules to evaluate alternatives to grid extension, and consider whether it would be necessary to establish rules for congestion management and curtailment compensation in relation to VRE.
- Finalise a legal framework allowing smart meters and their energy data to support the active participation of consumers in the electricity and natural gas markets, facilitate new service providers, and enhance security of supply.
- Examine the effects of the recent fuel tax increases and consider further incremental increases that support the achievement of GHG emission reduction targets.
- Evaluate how much existing transport policies contribute to the 2030 energy efficiency target. Formulate a set of coherent measures to achieve a sustained reduction in fuel demand.

2. General energy policy

Key data (2018 provisional)

TPES: 3.9 Mtoe (oil 59.5%, natural gas 17.5%, coal 1.1%, bioenergy and waste 7.4%, hydro 0.2%, wind 0.5%, solar 0.3%, electricity exports 13.6%), -7.3% since 2008

TPES/capita (2017): 6.3 toe/capita (IEA average: 4.1 toe/capita)

TPES/GDP (2017): 73 toe/USD million PPP (IEA average: 105 toe/USD million PPP)

Domestic TPES: 0.21 Mtoe (biofuels and waste 80.1%, wind 10.2%, solar 5.8%, hydro 3.9%), +58.5% since 2008

TFC (2017): 3.7 Mtoe (oil 60.0%, natural gas 17.1%, electricity 15.0%, biofuels and waste 4.9%, district heat 1.6%, coal 1.2%, solar heat 0.1%), -7.4% since 2007

Country overview

The Grand Duchy of Luxembourg is located in Western Europe, bordering Belgium, France and Germany (Figure 2.1). With a territory of 2 586 square kilometres, it is the smallest International Energy Agency (IEA) member country and the second-smallest European Union (EU) member state after Malta. Luxembourg's geographic location makes it a hub for rail, road and air transportation, notably for freight. The country is divided into 102 communes. The capital, Luxembourg City, is the largest and most populous city and the political, economic and cultural centre of the country. Luxembourg has three official languages: French, German and Luxembourgish.

Luxembourg is a parliamentary constitutional monarchy. The prime minister is the head of government, and the grand duke is the head of state with primarily representative and ceremonial responsibilities. The reigning Grand Duke is Henri Albert Gabriel Félix Marie Guillaume de Luxembourg. The grand duke appoints the prime minister on the basis of election results. The current Prime Minister is Xavier Bettel (since 2013), succeeding Jean-Claude Juncker (President of the European Commission since 2014).

Luxembourg is a founding member of the IEA, the Organisation for Economic Co-operation and Development (OECD), and the European Union. It is part of the Schengen Area and adopted the euro as its currency in 1999. Luxembourg closely co-operates with neighbouring countries on energy policy, notably through the Benelux Union, the Pentalateral Energy Forum and the North Sea Region. Luxembourg City is one of the three official capitals of the European Union (together with Brussels and Strasbourg), and is the seat of several European institutions and agencies, including the European Investment Bank, the European Court of Justice, the European Court of Auditors, the Statistical Office of the European Union (Eurostat), the Secretariat of the European Parliament and others.

Figure 2.1 Map of Luxembourg

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

With a population of 613 900 in 2019, Luxembourg is one Europe's least-populous countries. From 2007 to 2018, its population grew by 24%, the fastest growth rate among IEA member countries (IEA, 2019a). By 2030, the population is forecast to increase by 34% (EC, 2019a). This trend is expected to drive increased energy demand, emissions and urbanisation.

In 2017, Luxembourg had the highest income per capita in the OECD (USD 76 220 in purchasing power parity per capita). Thanks to high incomes and favourable tax regimes, the country has stable investment conditions and attracts workers from other European countries, notably Belgium, France and Germany. In 2018, gross domestic product (GDP) was USD 67.5 billion (OECD, 2019a). At 5.3% of the labour force, the unemployment rate in 2018 was almost equal to the OECD average of 5.2% (OECD, 2019b). In 2018, Luxembourg ranked 19th in the World Competitiveness Index, an improvement from the year before when it was 22nd (WEF, 2018).

Luxembourg has a well-developed market economy that is closely tied to other EU countries. Intra-EU trade accounts for 83% of its exports, which go mainly to Germany, Belgium and France, with smaller shares to Switzerland and the United States. Roughly three-quarters (77%) of its imports come from EU countries, mostly Belgium, Germany and France. The most important sector of Luxembourg's economy is the financial and insurance sector, which contributes 27% to GDP. The service sector (wholesale and retail trade, transport, accommodation and food services) plays an important role, contributing 17% to GDP (EU, 2019). Steel production plays a key role in the industrial sector. ArcelorMittal, the world's largest steel manufacturer by volume, has its global headquarters in Luxembourg and operates the country's largest steel production facility (WSA, 2019). The industrial sector also includes chemicals, rubber and other products. Industry was historically the main driver of economic activity, but it has been overtaken by the financial sector. The government aims to diversify the economy, particularly through attracting digital technology companies. Luxembourg is home to regional headquarters or major offices of numerous global media, information and communications companies, including Amazon, AOL, Apple, eBay, PayPal and Skype (ME, 2019a).

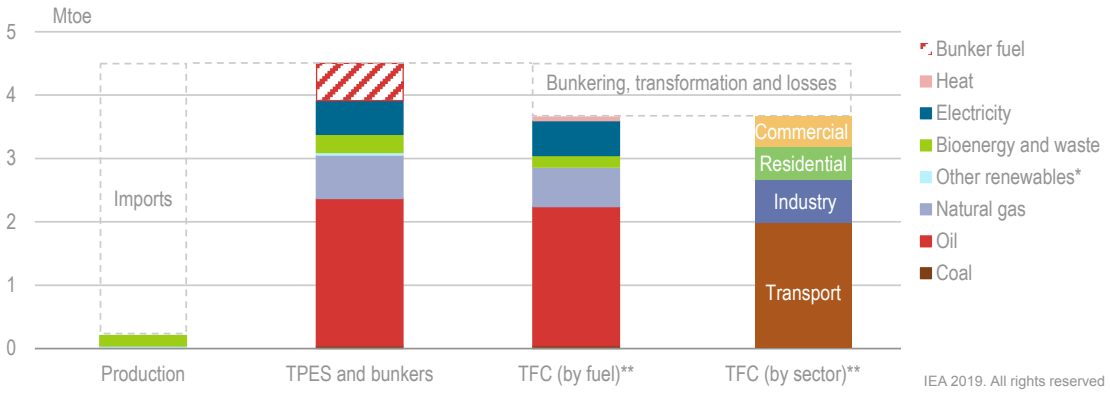
Luxembourg's is well positioned to continue its economic growth and the high quality of life enjoyed by its residents. However, the government needs to address notable challenges presented by rapid population growth and the current dependence of the energy system on fossil fuels. Luxembourg can support a swift energy transition by leveraging the expertise it has acquired in the service industry to sustainable development, especially the creation of innovative energy sector services for renewables, energy efficiency and mobility. This would support development of the smart flexible energy system needed to maintain the country's competitiveness and secure sustainable growth. Luxembourg has adopted ambitious energy sector targets and developed a wide range of policy measures aiming for a sustainable energy transition. Looking forward, the government will need to closely monitor the impacts of its energy policy and be ready to make adjustments as needed to ensure a rapid transition to a clean, flexible and sustainable energy system that supports economic growth for all residents.

Supply and demand

Luxembourg's energy system is characterised by high import dependence and a reliance on fossils fuels (Figure 2.2). In 2018, 95% of total primary energy supply (TPES) was imported and came primarily from oil (60%) followed by natural gas (18%) and electricity

(14%). All oil and natural gas and 86% of electricity were imported in 2018. Luxembourg's domestic energy supply covers only 5% of TPES, the lowest share among IEA member countries. In 2018, the domestic share of TPES came primarily from bioenergy used in combined heat and power plants, with small but growing contributions from electricity generated by wind, hydropower and solar photovoltaics (PV). Renewable energy (biomass and imported biofuels as well as growing wind and solar contributions) covered 7.5% of TPES.

Figure 2.2 Overview of the Luxembourg's energy system by fuel and sector, 2018



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

** TFC data are from 2017.

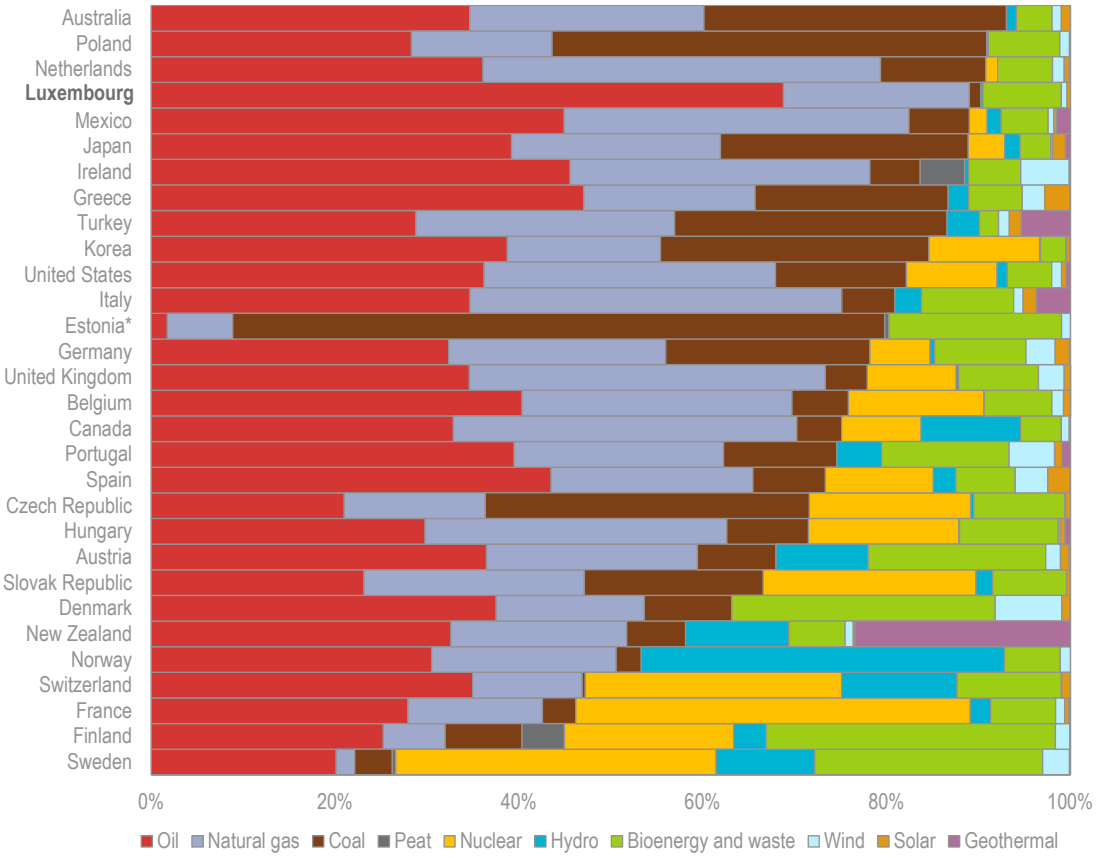
Notes: Data are provisional. Mtoe: million tonnes of oil equivalent; TPES: total primary energy supply; TFC: total final consumption.

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

Among IEA member countries, in 2018 Luxembourg had the fourth-highest share of fossil fuels in TPES (78%) and the highest share of oil in TPES (60%) (Figure 2.3). The high share of oil in TPES is linked to the dominant role of transportation in Luxembourg's energy system. In 2017, transportation accounted for 54% of total final consumption (TFC), by far the largest share among IEA member countries. Transport emissions represented two-thirds of energy-related CO_2 emissions. Several factors drive transport consumption: Luxembourg has low fuel taxation in comparison to neighbouring countries and is a hub for European transport. As a result, a lot of freight trucks refuel as they pass through Luxembourg. In addition, a large percentage of the workforce commutes from neighbouring countries and refuels in Luxembourg to take advantage of the lower fuel costs.

Luxembourg's TPES gradually decreased from a peak of 4.4 million tonnes of oil equivalent (Mtoe) in 2005 to 3.7 Mtoe in 2016 (Figure 2.4). This decline came mostly from falling natural gas consumption (-0.41 Mtoe) linked to the reduced use and decommissioning of the only large thermal generation plant in Luxembourg, a 375 MW combined cycle gas turbine. TPES has been rising since 2016, driven mostly by higher oil consumption in the transport sector (+0.19 Mtoe) and increased use of bioenergy (+0.06 Mtoe). In 2018, TPES was 3.9 Mtoe, an 11% drop from the 2005 peak, but a 6% increase from 2016. Coal plays a minor role in Luxembourg's energy supply (Box 2.1).

Figure 2.3 TPES in IEA member countries by source, 2018

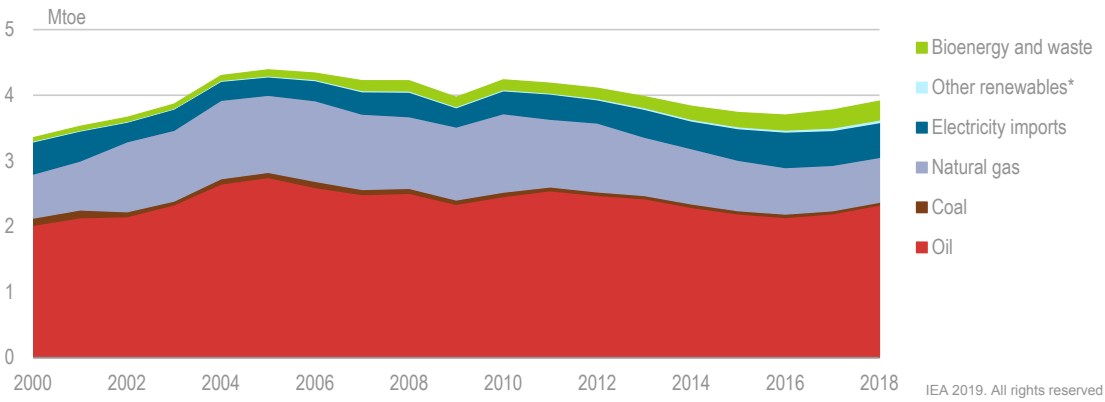


* Estonia's oil shale TPES is shown as coal.

Notes: Countries are ranked by share of fossil fuels in TPES. Excludes electricity imports and exports. Data are provisional.

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

Figure 2.4 TPES by source, Luxembourg, 2000-18



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

Notes: TPES does not include bunker fuels. Mtoe: million tonnes of oil equivalent.

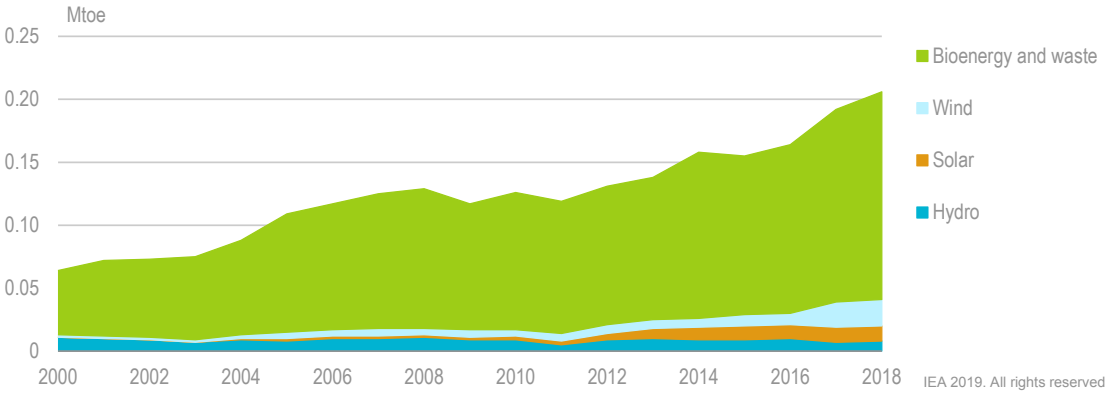
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Box 2.1 Coal in Luxembourg

Coal was a major source of energy in Luxembourg from the 1970s to the 1980s, but has nearly been phased out of Luxembourg's energy supply. Luxembourg ceased coal-fired electricity generation in 1998 and the industrial sector is the only area where coal is still used. In 2017, total supply of coal was only 0.05 million tonnes of oil equivalent, representing 1% of total primary energy supply, 1% of total final consumption and 2% of total energy-related CO_2 emissions. Currently, coal is used in the non-metallic minerals industry (92%) and the steel industry (8%). Luxembourg is part of the Powering Past Coal Alliance, which advocates that EU and OECD countries phase out unabated coal-fired electricity generation no later than 2030, with the rest of the world no later than 2050, to limit the impacts of climate change (PPAC, 2019).

Domestic energy production increased by 58% from 2008 to reach 0.21 Mtoe in 2018, but still covers only 5% of TPES (Figure 2.5). In 2018, bioenergy and waste accounted for 80% of domestic production primarily from solid biofuels, municipal and industrial waste, and biogas. The remaining domestic production comes from electricity generated by wind, PV and hydropower.

Figure 2.5 Domestic contribution to TPES by source, Luxembourg, 2000-18



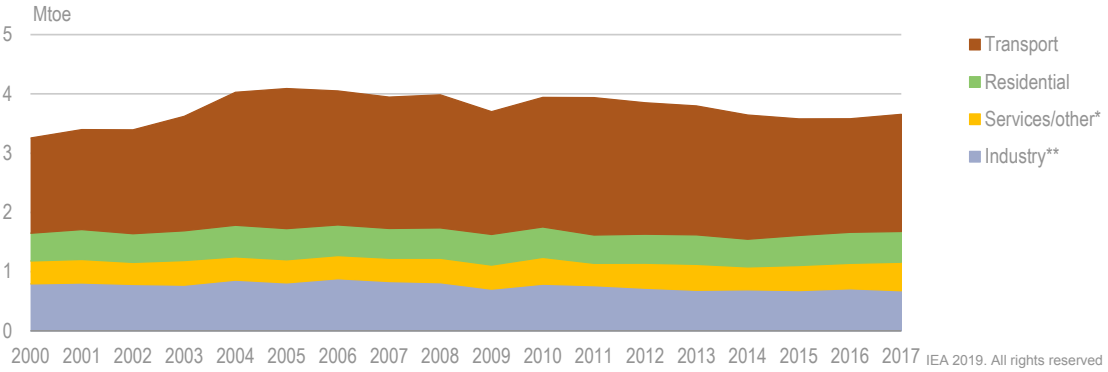
Note: Mtoe: million tonnes of oil equivalent.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

The transport sector dominates energy demand in Luxembourg. In 2017, transport accounted for 54% of TFC (Figure 2.6). Transport energy demand peaked at 2.3 Mtoe in 2011 and steadily decreased through 2016, but started to increase again in 2017 to reach 2.0 Mtoe. Industry demand declined by nearly 20% from 2007 to 2017, but is still the second-largest demand sector at 0.68 Mtoe. Despite a growing population, residential sector demand has been stable at around 0.5 Mtoe for several decades. In line with the growing GDP and the increased role of the service sector, energy demand from the sector has seen the largest increase, growing 23% from 2007 to 2017 to reach 0.48 Mtoe.

For the energy sector as a whole, oil is the dominant fuel, covering 60% of TFC in 2017; transportation fuels accounted for most oil consumption (Figure 2.7). Natural gas (17%) and electricity (15%) covered most of the remaining share of TFC. Bioenergy accounts for

just 5% of TFC, mainly for heating in industry and residential buildings, and biofuels in transport. The energy mix in TFC varies notably across Luxembourg's energy sectors. Refined oil fuels covered 94% of transport energy demand in 2017, with 78% coming from diesel and 16% from gasoline. Biofuels blended into diesel and gasoline covered just 6% of transport energy demand. Industry TFC comes mostly from electricity (40%) and gas (40%) and is the only sector with coal consumption. Gas is the largest energy source for the residential sector (46%), but there is still a notable reliance on oil heating fuel (33%). The commercial sector has the most diversified energy mix and is the only sector were district heating is used; however, 25% of commercial energy consumption comes from heating oil and there is very little direct use of renewable energy.

Figure 2.6 TFC by sector, Luxembourg, 2000-17



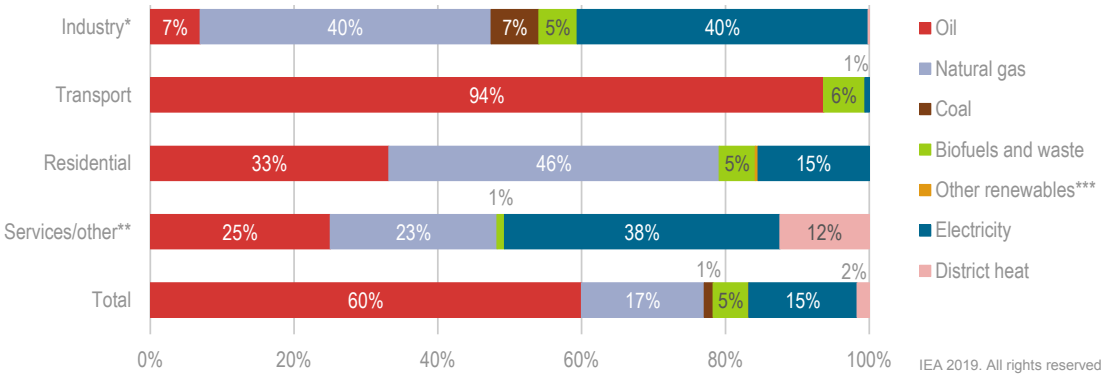
* *Services/other* includes commercial and public services, agriculture and forestry.

** *Industry* includes non-energy consumption.

Note: Mtoe: million tonnes of oil equivalent.

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

Figure 2.7 TFC by source and sector, Luxembourg, 2017



* *Industry* includes non-energy consumption.

** *Services/other* includes commercial and public services, agriculture and forestry.

*** *Other renewables* includes wind, photovoltaics and hydropower.

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

Energy sector institutions

The Ministry of Energy and Spatial Planning and the Ministry of the Environment, Climate and Sustainable Development are the key institutions that formulate and implement Luxembourg's energy policy. The Ministry of Mobility and Public Works is responsible for transportation policy, which plays an important role in Luxembourg's energy system. Taxation of energy products falls within the competence of the Ministry of Finance.

The Ministry of Energy and Spatial Planning has the main responsibility over energy policy. Within the ministry, the Department of Energy, with a staff of 15 in 2018, has an overall co-ordination and planning role for energy policy and is in charge of formulating policies covering electricity, oil and gas markets, energy efficiency, and renewable energy. Some responsibilities for energy efficiency and renewable energy support policies are shared with the Ministry of the Environment, Climate and Sustainable Development.

The Ministry of the Environment, Climate and Sustainable Development is responsible for co-ordinating sustainable development, taking all appropriate measures to protect the natural and human environment against climate change and managing the investment system that supports private and municipal energy investments. Three administrations operate under its legal authority: the Environment Agency, the Nature Conservation Agency and the Water Management Agency.

MyEnergy is a public organisation under the authority of the Ministry of Energy and Spatial Planning; the Ministry of the Environment, Climate and Sustainable Development; and the Ministry of Housing. MyEnergy promotes awareness of government energy policy priorities and provides information on energy-related subsidies to facilitate investments in energy efficiency and renewable energy by all market participants.

The Institut Luxembourgeois de Régulation (ILR) is Luxembourg's regulatory authority. It establishes market rules and conditions to ensure fair competition across Luxembourg's economy. The ILR regulates the electricity and natural gas sectors, including all activities of transmission and distribution system operators and electricity and natural gas suppliers. It also collects and publishes a wide variety of energy sector data.

STATEC is the government's statistical office and co-operates with the Ministry of Energy and Spatial Planning and the Ministry of the Environment, Climate and Sustainable Development to collect and publish energy statistics and data, and to develop energy scenarios.

Energy sector targets and policy

Luxembourg's energy policy priorities are ensuring security of supply (through diversification and reduction of import dependence), promoting energy efficiency, increasing the use of renewable energy and reducing greenhouse gas (GHG) emissions. EU directives are a key driver of its energy sector targets. However, the government is committed to international climate targets of the Kyoto Protocol and Paris Agreement, has pushed for a more aggressive approach on energy transition at the EU level, and in many cases has adopted national targets that exceed the requirements of EU directives. Table 2.1 gives Luxembourg's 2020 and 2030 energy sector targets.

Luxembourg's 2020 CO_2 reduction, energy efficiency and renewable energy targets were set in EU directives that established mandatory targets for each EU member state. Luxembourg's plans to achieve its 2020 targets are detailed in its National Energy Efficiency Action Plan (ME, 2017), National Renewable Energy Action Plan (MEFT, 2010) and National Communication of Luxembourg under the United Nations Framework Convention on Climate Change (MSDI, 2018). These documents or associate reports to the European Commission (EC) track progress towards the 2020 targets.

Table 2.1 Luxembourg's energy sector targets for 2020 and 2030

	2020	2030
Non-ETS CO_2 reduction*	20% vs. 2005	50-55% vs. 2005
Renewable energy**	11%	23-25%
Energy efficiency***	Not surpassing 49.3 TWh of final energy consumption	Not surpassing 35.6 TWh of final energy consumption

* Emissions from agriculture, transport, residential, commercial, waste and non-energy intensive industry.

** Share of renewable energy in gross final energy consumption.

*** Luxembourg's final energy consumption was 52.1 TWh in 2005, 47 TWh in 2016 and 48.4 TWh in 2017.

Note: TWh: terawatt hour.

Sources: MEFT (2010), *National Renewable Energy Action Plan*, https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020; ME (2017), *Fourth National Energy Efficiency Action Plan*, https://ec.europa.eu/energy/sites/ener/files/documents/lu_neeap_2017_en.pdf; MSDI (2018), *Seventh National Communication of Luxembourg under the United Nations Framework Convention on Climate Change*, https://unfccc.int/sites/default/files/resource/39752148_Luxembourg-NC7-1-LU_NC7_180212.pdf; MESP and MECSD (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

Luxembourg is on track to meet its 2020 target for renewable energy. In 2017, renewable energy covered 6.4% of gross final energy consumption. The remaining gap to reach the 2020 target of 11% will be covered through statistical transfers with Estonia and Lithuania under the EU co-operation mechanisms. Luxembourg's CO_2 emissions peaked in 2005 at 11.4 Mt, and by 2015 had fallen 25% to 8.7 Mt. Without a significant effort to reduce diesel sales in 2020, Luxembourg is running a high risk to miss its 2020 target of reducing non-ETS (Emissions Trading System) CO_2 emissions by 20% versus 2005 levels. In 2016, Luxembourg reduced its energy consumption to 47.0 TWh in line with the 2020 target of less than 49.3 TWh. However, since 2016, consumption has been steadily increasing, especially in the transport sector, reaching 48.4 TWh in 2017. The continued growth in population and GDP and increasing diesel sales to transiting freight trucks will challenge the country's ability to meet the 2020 energy efficiency target.

Luxembourg's 2030 targets are derived from the EU Clean Energy Package (CEP), adopted on 26 March 2019, which set the following EU-wide targets for 2030:

- cut CO_2 emissions by at least 40% from 1990 levels
- achieve a 32% share of renewable energy in gross final consumption
- increase energy efficiency by at least 32.5% compared to the EU business-as-usual projection.

Under the CEP, the EU Effort Sharing Regulation sets country-specific CO_2 reduction targets for 2030 versus 2005. Luxembourg has the highest target among EU member states: a 40% reduction of non-ETS emissions (EC, 2019b). Luxembourg has adopted an

even higher 2030 target of a 50-55% reduction in non-ETS emissions. These ambitious targets will require a significant shift in its carbon-intensive energy mix, especially in relation to the country's heavy reliance on oil in the transport sector.

The CEP does not define country-specific renewable energy or energy efficiency targets. Instead, each EU member state is required to submit a National Energy and Climate Plan (NECP) proposing contributions to the EU-wide 2030 targets. In February 2019, Luxembourg delivered its draft NECP to the EC for review, proposing a 2030 renewable energy target of 23-25% of gross final consumption and a 2030 energy efficiency target of not surpassing 35.6 TWh of final energy consumption (MESP and MECSD, 2019).

On 18 June 2019, the EC published its assessment of the renewable energy and energy efficiency contributions proposed by Luxembourg and all other EU member states in their draft NECPs (EC, 2019c). The EC recommended that all member states improve their draft plans in order to meet the EU targets. According to the EC's assessment, the proposed member state contributions and supporting policies set in the NECPs do not support the achievement of the 2030 EU-wide targets.

The EC's comments on Luxembourg's draft NECP welcomed the country's targets on CO_2 emissions, energy efficiency and renewable energy. The EC requested that the final NECP significantly increase the level of detail on policy measures to support achievement of these targets, especially in relation to the ambitious 50-55% reduction of non-ETS emissions. For renewables, the EC requested that Luxembourg clearly indicate how the 2020 target of 11% renewables in gross final consumption will be maintained as a baseline for achievement of the 23-25% target for 2030. The EC also noted the need for an indicative trajectory of renewables deployment that meets EC reporting requirements and detailed measures to meet the targets for e-mobility and renewables in transportation. Clarification on the frameworks for renewable self-consumption and energy communities was also requested. For energy efficiency, the EC noted a need for Luxembourg to define its 2030 target as a specific value for both primary and final energy consumption and increase the level of detail on supporting policies (EC, 2019c).

The EC also requested a comprehensive assessment of the investment needed to achieve Luxembourg's energy sector targets, as well as information on the financial sources to be mobilised for implementation of the existing and planned policies and measures. The EC also noted the need for the NECP to further develop the approach to addressing energy poverty by integrating just and fair transition aspects, notably by providing more details on social, employment and skills impacts of planned objectives, and policies and measures. Luxembourg and all other EU member states must submit their final NECPs addressing all the EC's comments by the end of 2019 (EC, 2019c). Looking to the future, Luxembourg is pushing for net-zero GHG emissions and 100% renewable electricity at the EU level by 2050.

Support schemes

Luxembourg has numerous support schemes for achieving its 2030 targets and long-term energy sector goals. The government currently provides support for renewables through a feed-in tariff and premium tariff for electricity generated from renewables and investment subsidies supporting deployment of renewable energy projects. In February 2018, Luxembourg introduced a tender system for PV projects (RES Legal, 2019). It has legislation to support self-consumption of renewable electricity and encourage consumers to be active market participants (prosumers). Under the new law, which is supposed to

enter into force in early 2020, electricity from renewable energy directly consumed at the generation site will be exempt from grid fees.

In 2015, Luxembourg introduced an energy efficiency obligation scheme as part of its implementation of the EU Energy Efficiency Directive. The scheme requires electricity and gas suppliers to realise cumulative annual energy savings of 1.5% for end users through 2020 (ME, 2017). To encourage energy efficiency in the transport sector, annual vehicle registration fees are higher for less efficient vehicles. There is also a broad e-mobility effort being undertaken to support electrification of transport and a modal shift from private vehicles to the use of more efficient public transportation (MSDI, 2017).

In January 2017, Luxembourg passed the Climate Bank and Sustainable Housing Package to support energy efficiency and renewable energy in buildings. The package established the Climate Bank programme, which provides low-rate climate loans to encourage residents and companies to undertake energy efficiency renovations. The package also reforms the existing Prime House financial aid scheme to provide increased investment subsidies for both energy efficiency renovations and building integrated renewable energy systems. The package created a certification system for new housing construction (LENOZ) that covers energy efficiency and broader sustainability categories and also established an online one-stop shop for all housing-related aid provided by the government (Government of Luxembourg, 2017).

In 2012, Luxembourg created the Climate Pact programme with municipalities to collaborate on climate, renewable energy and energy efficiency. Under the pact, MyEnergy provides technical advice and funding to support a broad range of climate actions. The pact defines 79 specific measures that can be undertaken by municipalities and includes a process that awards certifications to municipalities based on the number of measures implemented (PacteClimat, 2019). The pact has been signed by all 102 municipalities and as of 2018, 88 had received certification (Government of Luxembourg, 2018). The pact was updated in 2018 to include measures related to air pollution and the circular economy. The government is working to improve the design of the pact to reward more quantitative results and extend it past 2020 (PacteClimat, 2019).

Third Industrial Revolution Strategy

In November 2016, Luxembourg launched the Third Industrial Revolution Strategy, which provides a comprehensive set of measures to transition Luxembourg to a smart, circular economy (TIR, 2016). The strategy includes focus areas on energy, mobility, buildings, food, industry and finance. In relation to energy, the strategy provides a wide range of potential policy, market and regulator measures focusing on the transformation of the energy system by 2050. The government is using the strategy as a guiding document for its overall economic development plans and has implemented, or is the process of implementing, numerous policy proposals from the strategy. In the energy sector, this includes deployment of gas and electricity smart meters (see Chapters 7 and 9), policy changes supporting prosumers and a strong push for e-mobility (see Chapter 7 for a more detailed discussion on e-mobility).

E-mobility

Luxembourg has embraced a broad e-mobility initiative aiming to reduce GHG emissions and fuel imports through electrification of transport. The draft NECP aims for 49% of vehicles registered in Luxembourg to be electric vehicles (EVs) by 2030. Luxembourg is

supporting this e-mobility goal with EV subsidies and investment in a national EV charging network. It is also supporting e-mobility by encouraging a shift from private vehicles to electrified public transportation. Luxembourg's Strategy for Sustainable Mobility (Modu 2.0) includes a goal to increase the number of public transport users by 50% between 2017 and 2025, and defines measures to increase the level and quality of electrified public transportation, e.g. investment in park and ride centres linked to a major reworking of bus and train infrastructure (MSDI, 2017). E-mobility, along with a biofuels blending mandate, are important policy measures to support Luxembourg's target of 10% renewables in its transport sector's gross final consumption by 2020 and 21.9% by 2030.

Energy poverty

Addressing energy poverty is a policy priority set in the draft NECP. The government currently has a variety of measures to support low-income households in overcoming energy poverty. The Climate Bank includes zero interest rate loans for energy efficiency projects undertaken by low-income households (Government of Luxembourg, 2017).

MyEnergy collaborates with the Ministry of the Environment, Climate and Sustainable Development and the Ministry of Family, Integration and the Greater Region to identify and support low-income households with energy-related issues. This includes providing information and advice on energy savings as well as direct support to reduce energy consumption by replacing energy-intensive appliances. Qualifying households can apply for a public grant covering 75% of the cost of the appliance, including value-added tax, with a limit of EUR 750 per appliance. The social welfare offices can draw up a financing plan with the household for the portion of the cost that is not subsidised (ME, 2017).

The Law of 1 August 2007 on organisation of the electricity and gas markets stipulates that a household which cannot pay electricity or gas bills can receive social assistance (Government of Luxembourg, 2007). In this case, the network operator is obliged to set up a prepayment meter at the request of the energy supplier(s). The Law of 18 December 2009 on the organisation of social assistance stipulates that the responsible social welfare office must examine whether a household is able to pay energy bills and to determine if they are entitled to social assistance (Government of Luxembourg, 2009).

Energy sector labour

The availability of skilled workers could be a barrier to achieving the government's energy transition goals. Energy efficiency renovation projects compete in the construction sector with new buildings, which are in high demand due to increasing population and a growing economy. The government's goals for renewable energy, notably building mounted PV, will also require a large labour force with specific skills. The government and the private sector have developed some programmes to help address this issue.

LuxBuild2020 is an EC-funded programme supporting the development of Luxembourg's energy sector labour force. It aims to improve the skills of building professionals in the fields of energy efficiency renovations and installation of renewable energy systems in buildings. Since 2014, the four partners of the LuxBuild2020 consortium have carried out multiple projects to improve the accessibility and supply of training for craftsmen and construction workers. MyEnergy manages and promotes awareness of the programme. The Building Sector Training Institute (IFSB), the Federations of Artisans and the Chamber of Trades develop and execute continuing education of energy sector workers (MyEnergy, 2019). The IFSB and the Building Technical Engineering Skills Centre (CdC-

GTB) have also independently created competence centres for craftsmen of all sectors and promoted increased productivity though new concepts of pre-designed and pre-fabricated renovation of buildings.

The government should closely monitor the labour force size and skill set in areas relevant to its energy transition goals and be ready implement/support additional training programmes. A review of the education system could also be warranted to see if the key subjects and skills relevant to the energy transition are being taught at the needed level.

Regional co-operation

Luxembourg's draft NECP has 2030 policy objectives to further regional co-operation on energy security and support the completion of the internal electricity market with intensified cross-border competition between suppliers. In line with these objectives, Luxembourg maintains strong regional co-operation through the Pentalateral Energy Forum (PLEF) with Austria, Belgium, France, Germany, the Netherlands and Switzerland. The PLEF has launched initiatives to strengthen European energy markets, for example the introduction of regional energy security analysis in 2013. PLEF countries are co-ordinating on finalising their NECPs and developing a joint energy vision for 2030 (MESP and MECSD, 2019). This co-operation focuses on the following key areas:

- medium to long-term infrastructure development and increased market coupling
- exchange of analysis and assumptions on the use of various energy sources
- integration of renewable energy into the electricity and gas networks and understanding the impact of renewables on markets and energy security
- possible impact of national energy efficiency measures on markets
- impact and regulatory incentives of sector coupling
- flexibility options, including energy storage and hydrogen
- incentives for reducing CO_2 emissions.

Luxembourg also co-operates on energy market and security issues through the Benelux Union with Belgium and the Netherlands (Benelux, 2018) and on offshore wind through the North Sea Region with Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway and Sweden (EC, 2016).

Energy prices and taxation

In 2018, Luxembourg had the lowest electricity prices among its neighbouring countries (Table 2.2). The lower prices in Luxembourg result primarily from significantly lower taxes on electricity, especially in comparison to Germany, Luxembourg's main source of electricity imports.

Table 2.2 Electricity prices in Luxembourg and neighbouring countries, 2018

USD/MWh

	Industry				Households			
	Price	Pre-tax	Tax	Tax (%)	Price	Pre-tax	Tax	Tax (%)
Belgium	136.52	101.95	34.57	25%	328.66	225.56	103.11	31%
Germany	145.40	75.00	70.40	48%	353.29	162.69	190.60	54%
France	116.35	90.74	25.62	22%	202.37	129.78	72.59	36%
Luxembourg	83.49	72.40	11.09	13%	191.37	146.05	45.33	24%

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

In 2018, industry natural gas retail prices in Luxembourg were close to the median value among IEA member countries, but had one of the lowest tax rates. Luxembourg's 2018 household natural gas price was the sixth-lowest among IEA member countries and was significantly lower than in the neighbouring countries (Table 2.3).

Table 2.3 Natural gas prices in Luxembourg and neighbouring countries, 2018

USD/MWh

	Industry				Households			
	Price	Pre-tax	Tax	Tax (%)	Price	Pre-tax	Tax	Tax (%)
Belgium	31.64	30.10	1.54	5%	69.23	55.02	14.20	21%
Germany	30.81	26.06	4.76	15%	77.08	58.28	18.80	24%
France	43.58	36.57	7.01	16%	89.69	64.58	25.11	28%
Luxembourg	33.05	32.42	0.64	2%	50.73	45.70	5.03	10%

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Luxembourg has the lowest automotive fuel prices and taxes among neighbouring countries (Table 2.4). The low fuel prices are a key driver for the high share of oil in Luxembourg's energy system as they encourage freight trucks and the 200 000 daily foreign commuters to fuel their vehicles in Luxembourg. The government has a policy priority to reduce this fuel consumption in line with its GHG emissions reduction targets. To that end, the government increased the excise duties on diesel by EUR 0.02 per litre and on gasoline by EUR 0.01 per litre on 1 May 2019. Total fuel tax revenues, including sales to residents and non-residents, amounted to about EUR 1 billion in 2017, roughly 5% of state revenues. On 9 December 2019, the government announced that it is considering increasing the excise duties for diesel by EUR 0.03 to EUR 0.05 per litre and for gasoline by EUR 0.01 to EUR 0.03 per litre between February and April 2020. (Government of Luxembourg, 2019).

An inter-ministerial committee of the Ministries of Finance; the Economy; the Environment, Climate and Sustainable Development; and Energy and Spatial Planning is charged with monitoring the development of fuel sales, analysing the factors underlying the observed evolution and monitoring the impact of new government measures, including the recent tax increase. The committee should examine how policy measures related to fuel and electricity prices are contributing to the achievement of energy sector targets.

The low cost of energy in Luxembourg and the high purchasing power of its residents represent a significant barrier to achieving the government's energy sector targets. Low

electricity, natural gas and heating oil prices decrease the economic incentives to invest in energy efficiency measures and renewable energy projects. Low fuel prices lessen the advantage of higher efficiency vehicles and encourage freight trucks and commuters to fuel in Luxembourg. Carbon pricing could be used to better align fossil fuel costs with environmental impacts. Carbon pricing could offer a simple mechanism to drive behaviour that supports the government's policy goals and allow a recalibration of the various energy sector subsidy schemes to target areas where subsidies are the most effective.

On 16 December 2019, the government announced that it will introduce a carbon tax of EUR 20 per tonne starting in 2021. The tax would increase to EUR 25 per tonne in 2022 and to EUR 30 per tonne in 2023. The government estimates that the carbon tax could generate as much as an additional EUR 150 million of revenue. Half of this sum will be used to support households in need, while the other half will be invested in national measures aimed at advancing Luxembourg's clean energy transition (Delano, 2019).

Table 2.4 Fuel prices in Luxembourg and neighbouring countries, Q2 2019

USD per litre

Fuel type		Belgium*	Germany	France*	Luxembourg
Automotive diesel	Total price	1.72	1.47	1.64	1.25
	Tax component	0.97 (56%)	0.76 (52%)	0.96 (58%)	0.57 (46%)
Unleaded gasoline	Total price	1.71	1.65	1.75	1.47
	Tax component	0.97 (57%)	1.0 (61%)	1.1 (61%)	0.74 (50%)

* Belgium and France provide partial refunds of diesel excise duties for fuel purchased by international transportation companies and bus line operators that are registered in the European Union. In 2018 and 2019, the refund was EUR 0.18-0.22 per litre in France and EUR 0.25 per litre in Belgium. There are restrictions on the types of vehicles that qualify and it can take over a year to receive the refund (Eurovat, 2019).

Notes: Quarterly price data are based on national average weekly prices as reported to the IEA by member countries. Luxembourg and Belgium maintain maximum price-setting mechanisms for oil products (including diesel and gasoline). France and Germany do not set fuel prices. In Belgium, France and Germany, the actual price paid can vary from the average value.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Assessment

Luxembourg intends to speed up its ongoing energy transition. Improving energy efficiency, supporting renewable energy, and promoting more sustainable public and individual mobility are key elements of its energy and climate policy. Luxembourg wants to be proactive in the European energy transition, with a view to achieving a sustainable, secure and competitive energy supply. The government sees the energy transition also as part of the Third Industrial Revolution process launched in 2015, to which it can contribute with decentralised energy production and storage, the digitalisation of energy networks, the use of more sustainable means of transport, and the energy efficiency of the building stock. With a structural approach, the government could turn Luxembourg into a test bed for an integrated implementation of these new technologies.

Luxembourg is a small country with a unique energy situation defined by import dependence and the dominance of the transport sector in energy consumption and emissions. Luxembourg is also unique with its strong population growth; in the last

10 years, it welcomed 120 000 more inhabitants, a growth of 24%. This comes with challenges for transport, housing and energy supply, notably as the country has adopted stringent targets for energy efficiency and reducing GHG emissions.

Luxembourg is committed to international climate targets and has pushed for net-zero GHG at the European Union level by 2050. Luxembourg's NECP is the key document setting targets for GHG reduction, energy efficiency and renewable energy by 2030. The final NECP will be submitted to the European Commission before the end of 2019.

The draft NECP proposes a GHG emission reduction target of 50-55% compared to 2005 levels, well above the 40% target allocated to Luxembourg under the EU Effort Sharing Regulation. Luxembourg's CO_2 emissions peaked in 2005 at 11.5 Mt, and fell by 25% to 8.6 Mt in 2015. From 2015 to 2017, emissions were flat; they increased slightly in 2017 due to raising diesel consumption. Without a significant effort to reduce diesel sales in 2020, Luxembourg is running a high risk to miss its 2020 CO_2 reduction goal of 20% versus 2005 levels, while the 2030 target continues to represent a significant challenge.

Luxembourg has adopted energy efficiency targets in line with the EU Energy Efficiency Directive. By 2020, final energy consumption should not exceed 49.3 TWh, compared to 52.1 TWh in 2005. In 2016, the target was fulfilled with a consumption of 47.0 TWh, but increased consumption in 2017 and 2018, especially in the transport sector, and continued growth in population and GDP will challenge the country's ability to meet the 2020 target. For 2030, Luxembourg has a target of not surpassing 35.6 TWh of final energy consumption, which will require significant improvements to energy efficiency policies.

In 2017, renewable energy accounted for 6.4% of gross final consumption, mostly from biodiesel used in the transport sector, biomass for heat and electricity generation, and small but growing contributions from wind and PV generation. Luxembourg's 2020 renewable energy target is 11% of gross final consumption. The gap between domestic renewable production and the 2020 target will be covered through agreements with Estonia and Lithuania under the EU statistical transfer mechanism. In its draft NECP, Luxembourg proposed a 2030 renewable energy target of 23-25% in gross final consumption and indicated that around 19% could be produced domestically, while the remainder will be achieved thanks to EU co-operation mechanisms.

National renewable electricity production currently meets 8.5% of electricity gross final consumption. The draft NECP contains an ambitious 2030 target for 30.3% of electricity gross final consumption from renewables. Luxembourg has numerous support schemes for renewable electricity generation, but it is not clear if these are sufficient to support the ambitious 2030 targets. In addition, policy documents emphasise energy security, including expansion of domestic electricity generation from renewables.

The government has many support schemes for renewables (both for investments and operation) and for energy efficiency. However, it will be faced with difficulties in achieving its targets, given the low cost of energy and the high purchasing power of consumers, which limits interest to invest in renewables and energy efficiency. High subsidies will be needed to change behaviour and it is unclear whether the various subsidy schemes are aligned to achieve the goals. Carbon pricing could be used to make fossil fuels more expensive. This would better align fossil fuel costs with their environmental impacts and offer a simpler mechanism to drive behaviour that supports the government's policy goals and could allow a recalibration of subsidy schemes to target areas where they will be most

effective. Luxembourg should enact the proposed carbon tax and monitor its impact to see if the level of the tax needs to be adjusted to drive the desired energy transition goals.

As in most IEA countries, oil is the dominant fuel in the transport sector, covering 94% of transport demand. Luxembourg aims to increase the share of renewables in transport through a biofuels blending mandate (that includes requirements for second-generation biofuels) and an e-mobility initiative that includes subsidies for electric vehicles, investing in a public EV charging network with 800 public charging stations to be installed by 2020 and supporting a shift from private vehicles to electrified public transportation. Additional measures seem to be necessary to support Luxembourg's targets for renewables in its transport sector consumption, of 10% by 2020 and 21.9% by 2030.

Luxembourg's central location in Europe makes it a transportation hub; its labour force has a large share of cross-border commuters, and the country has lower fuel taxes than its neighbouring countries. As a result, a significant portion of oil demand results from transiting drivers, especially for road freight, who choose to refuel in Luxembourg. In addition, some 200 000 commuters enter Luxembourg daily, refuelling in the country. These factors contribute to Luxembourg's extremely high share of oil in TFC (60%) compared to other countries.

In 2017, 44.5% of the country's non-ETS GHG emissions came from fuel sales to non-residents. On the other hand, some 5% of the government revenues stem from fuel taxes, including revenues from fuel sales to transiting drivers. The government recognises the fuel exports issue and has indicated that fuel sales must be reduced to align with the GHG emissions reduction targets. As a first step, on 1 May 2019, the government increased the excise duties on diesel by EUR 0.02 per litre and gasoline by EUR 0.01 per litre. Between February and April 2020, the government is considering another increase in excise duties of up to EUR 0.05 per litre for diesel and up to EUR 0.03 per litre for gasoline.

Addressing energy poverty is an expressed goal in the draft NECP and the government has established investment subsidies to assist low-income households to purchase high-efficiency appliances. In January 2017, a reform of the Prime House subsidy programme and the Climate Bank came into force. The Climate Bank aims to facilitate investment in energy efficiency and renewable energy by private and legal persons. Supported measures include renovation projects, replacement of technical installations and, in the case of interest-free loans, energy advice on residential buildings. It is also possible to have energy consultancy services paid directly by Climate Bank for low-income families. The government should conduct a study of the socio-economic impacts of the NECP to determine if they are in line with its energy poverty goals.

Recommendations

The government of Luxembourg should:

- Consider gradual introduction of carbon pricing instruments, as energy is considered too cheap to drive behaviour towards more energy efficiency, e-mobility and fuel switching, taking into account the social dimension.
- Design robust policy packages to achieve the ambitious targets in the draft NECP in a cost-effective manner.

- Develop long-term energy scenarios in line with the government objective of a climate-neutral economy by 2050.
- Ensure Luxemburg has the skilled workforce required to meet its ambitious mid- to long-term energy and climate targets.

References

Benelux (2018), *Pentalateral Energy Forum PENTEX2018 – First Pentalateral Electricity Crisis Exercise*, Benelux, Brussels, www.benelux.int/nl/kernthemas/holder/energie/pentalateral-energy-forum.

Delano (2019), *Carbon Tax at Heart of Climate Plan, Delano, Luxembourg City,* https://delano.lu/d/detail/news/carbon-tax-heart-climate-plan/208777.

EC (European Commission) (2019a), *Population Projections,* EC, Brussels, https://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-/main-tables.

EC (2019b), *Clean Energy for all Europeans Package Completed: Good for Consumers, Good for Growth and Jobs, and Good for the Planet,* EC, Brussels, https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en.

EC (2019c), *United in Delivering the Energy Union and Climate Action: Setting the Foundations for a Successful Clean Energy Transition,* EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285.

EC (2016), *North Seas Countries Agree on Closer Energy Cooperation,* EC, Brussels, https://europa.eu/rapid/press-release_IP-16-2029_en.htm.

EU (European Union) (2019), *EU Member Countries in Brief: Luxembourg,* EU, Brussels, https://europa.eu/european-union/about-eu/countries/member-countries/luxembourg_en#overview.

Eurovat (2019), *Excise Duty Belgium*, Eurovat, Brussels, www.eurovat.eu/en/diesel-tax-reclaim#slideshow-1.

Government of Luxembourg (2019), Increase in excise duties on fuels at the start of 2020, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/fr/actualites/toutes_actualites/communiques/2019/12-decembre/16-augmentation-accises.html/.

Government of Luxembourg (2018), *Climate Bank and Sustainable Housing Package*, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/lu_neeap_2017_en.pdf.

Government of Luxembourg (2017), *Climate Pact Under the Sign of the Circular Economy*, Government of Luxembourg, Luxembourg City, http://luxembourg.public.lu/en/actualites/2018/05/30-pacteClimat/index.html.

Government of Luxembourg (2009), *Law of 18 December 2009 on the Organization of Social Assistance*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/loi/2009/12/18/n14/jo.

Government of Luxembourg (2007), *Law of 1 August 2007 on the Organization of the Electricity Market*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/loi/2007/08/01/n13/jo.

IEA (International Energy Agency) (2019a), *IEA Country Data: Luxembourg*, IEA, Paris, https://www.iea.org/countries/Luxembourg.

IEA (2019b), *World Energy Balances 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.ME (Ministry of the Economy) (2019a), *Conquer the World from Your Luxembourg Headquarter*, ME, Luxembourg City, https://photos.state.gov/libraries/luxembourg/210349/pdf/Broch_Headquarters_BD.pdf.

ME (2019b), *Financial Aid for Research and Development Projects*, ME, Luxembourg City, https://guichet.public.lu/en/entreprises/financement-aides/aides-recherche-developpement/rdi/aides-rdi.html.

ME (2017), *Fourth National Energy Efficiency Action Plan*, ME, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/lu_neeap_2017_en.pdf.

MEFT (Ministry of the Economy and Foreign Trade) (2010), *National Renewable Energy Action Plan*, MEFT, Luxembourg City, https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

MSDI (Ministry of Sustainable Development and Infrastructures) (2018), *Seventh National Communication of Luxembourg under the United Nations Framework Convention on Climate Change,* Government of Luxembourg, Luxembourg City, https://unfccc.int/sites/default/files/resource/39752148_Luxembourg-NC7-1-LU_NC7_180212.pdf.

MSDI (2017), *Modu 2.0 Strategy for Sustainable Mobility,* Government of Luxembourg, Luxembourg City, https://environnement.public.lu/dam-assets/actualites/2019/04/modu2-fr-brochure.pdf.

MyEnergy (2019), *LuxBuild2020*, MyEnergy, Luxembourg City, www.myenergy.lu/fr/experts/luxbuild2020.

OECD (Organisation for Economic Co-operation and Development) (2019a), *Gross Domestic Product,* OECD, Paris, https://data.oecd.org/gdp/gross-domestic-product-gdp.htm#indicator-chart.

OECD (2019b), *Unemployment Rate,* OECD, Paris, https://data.oecd.org/unemp/unemployment-rate.htm.

PactClimate (2019), *Climate Pact* (*PacteClimat*)*,* Government of Luxembourg, Luxembourg City, www.pacteclimat.lu/fr.

PPAC (Power Past Coal Alliance) (2019), *Declaration,* PPAC, London, https://poweringpastcoal.org/about/Powering_Past_Coal_Alliance_Declaration.

RES Legal (2019), *Renewable Electricity Promotion in Luxembourg*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/tools-list/c/luxembourg/s/res-e/t/promotion/sum/164/lpid/163.

TIR (Third Industrial Revolution Consulting Group) (2016), *The 3rd Industrial Revolution Strategy Study*, TIR, Bethesda, www.troisiemerevolutionindustrielle.lu//wp-content/uploads/2016/11/TIR-CG_Luxembourg-Final-Report_Long-Version.pdf.

WEF (World Economic Forum) (2018), *The Global Competitiveness Report 2018*, WEF, Geneva, www3.weforum.org/docs/GCR2018/05FullReport/TheGlobalCompetitivenessReport2018.pdf.

WSA (World Steel Association) (2019), *Top Steel-producing Companies 2018,* WSA, Brussels, www.worldsteel.org/steel-by-topic/statistics/top-producers.html.

3. Climate

Key data (2017)

GHG emissions without LULUCF*: 10.2 $MtCO_2$-eq, -21% since 2005, -20% since 1990

GHG emissions with LULUCF*: 9.9 $MtCO_2$-eq, -20% since 2005, -23% since 1990

Energy related CO_2 emissions:**

CO_2 emissions from fuel combustion: 8.6 $MtCO_2$, -25% since 2005

CO_2 emissions by fuel: oil 77%, natural gas 19%, coal 2%, non-renewable waste 2%

CO_2 emissions by sector: transport 66%, residential 13%, industry 11%, commercial 7%, heat and electricity generation 3%

CO_2 intensity per GDP*** (2016): 0.16 $kgCO_2$/USD (IEA average 0.24 $kgCO_2$/USD)

* Source: UNFCCC (2019), *Luxembourg 2019 National Inventory Report*, https://unfccc.int/documents/194915. LULUCF stands for land-use, land-use change and forestry.

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

*** Gross domestic product in 2010 numbers and PPP (power purchase parity).

Overview

In 2017, Luxembourg's total greenhouse gas (GHG) emissions were 10.2 $MtCO_2$-eq (million tonnes CO_2 equivalent) of which 86% came from energy-related combustion processes, primarily oil consumption in the transport sector. 2017 emissions were down 20% from 1990 and 21% from 2005, but increased slightly versus the level in 2016 (Figure 3.1).

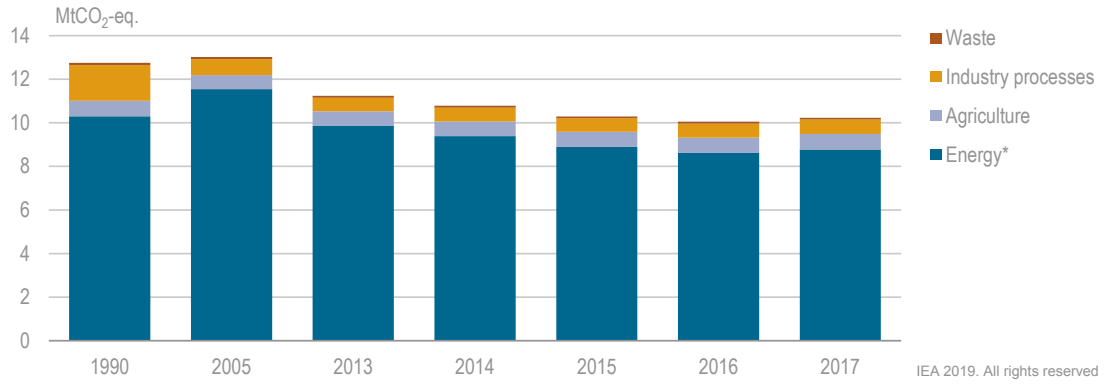
In 2017, the transport sector was responsible for 66% of energy-related CO_2 emissions followed by residential (13%), industry (11%), commercial (7%), and heat and electricity generation (3%). Reflecting the high share of transport emissions, oil was the dominant source of energy-related GHG emissions (77%), followed by natural gas (19%), coal (2%) and non-renewable waste (2%). In 2017, 44.3% of Luxembourg's non-ETS emissions[1] came from non-resident commuters and transiting freight trucks and cars fuelling in the country (see Chapter 2). Diesel fuel sales to transiting freight trucks alone accounted for 32.5% of non-ETS (Emissions Trading System) emissions.

Luxembourg's non-ETS emissions are subject to a 2020 target under the European Union (EU) Effort Sharing Decision (ESD) and a 2030 target under the EU Effort Sharing

[1] Non-ETS sectors include agriculture, residential, commercial, waste, non-energy intensive industry and transport excluding aviation within the European Economic Area.

Regulation (ESR). The government has set a 2030 target in line with the Paris Climate Agreement that exceeds the ESR target (Table 3.1).

Figure 3.1 Luxembourg's greenhouse gas emissions



As of 2017, Luxembourg had reduced GHG emissions by 20% from 1990 levels, but reductions have stalled in recent years.

* Energy includes heat and electricity generation, commercial, residential, industrial energy consumption and transport.

Note: $MtCO_2$-eq: million tonnes CO_2 equivalent.

Source: UNFCCC (2019), *Luxembourg 2019 National Inventory Report*, https://unfccc.int/documents/194915.

Table 3.1 Luxembourg's non-ETS emission reduction status, 2017 and 2020 and 2030 targets

	2017 status	2020 target	2030 target
Non-ETS GHG reduction vs. 2005	**16.1%**	**20%**	**50-55%***

* The 2030 Effort Sharing Regulation target for Luxembourg is a 40% reduction versus 2005.

Sources: MSDI (2018), *Seventh National Communication of Luxembourg under the United Nations Framework Convention on Climate Change*, https://unfccc.int/sites/default/files/resource/39752148_Luxembourg-NC7-1-LU_NC7_180212.pdf; MESP and MECSD (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

The main measures supporting GHG emission reductions in Luxembourg are tied to increasing the use of renewable energy sources in heat production, electricity generation and transportation, and to increasing energy efficiency across all sectors. These include a range of subsidies for investment in renewable energy and energy efficiency, tariffs supporting generation from renewables, and various mandates and targets.

Luxembourg has embraced a broad e-mobility initiative aiming to reduce transport sector emissions through electrification of transport (see Chapter 7). Through the draft National Energy and Climate Plan (NECP), Luxembourg aims for 49% of registered vehicles to be electric vehicles (EVs) by 2030. This goal is supported with EV subsidies and investment in a national EV charging network. Luxembourg's updated Strategy for Sustainable Mobility (Modu 2.0) includes a goal to increase the number of public transport users by 50% from 2017 to 2025, and defines measures to increase the level and quality of electrified public transport. In 2019, the fuel tax was modestly increased with the aim to reduce emissions from non-resident and transiting drivers fuelling in Luxembourg.

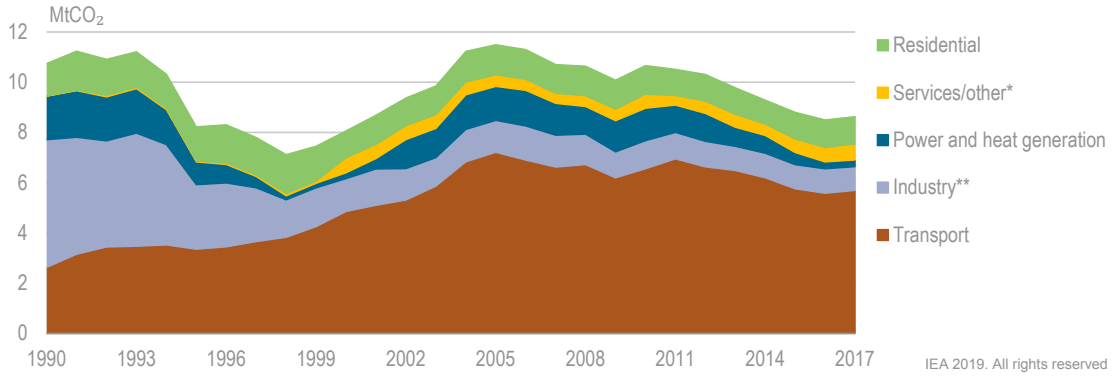
The government has noted that without a significant effort to reduce diesel sales in 2020, Luxembourg is running a high risk to miss its 2020 target of reducing non-ETS CO_2. The European Environment Agency (EEA) indicated in 2018 that Luxembourg's existing measures will not be enough to meet the 2020 emission reduction target. Luxembourg is, as a last resort, entitled to close the projected gap between the 2020 target and actual emissions by transferring surplus annual emission allocations from earlier years when emission reductions exceeded the indicative trajectory required under the ESD (EEA, 2018).

Stalling GHG emission reductions in recent years and increased emissions in 2017 show that Luxembourg needs to adjust policy to support sustained emission reductions. The ambitious 50-55% reduction target will require significant changes across the entire energy sector, especially in the transport sector, and may require more aggressive fuel taxes and increased incentives for electric and fuel-efficient vehicles.

Energy-related CO_2 emissions

In 2017, Luxembourg's energy-related CO_2 emissions (emissions from vehicles, industry, buildings, and heat and electricity plants) were 8.6 $MtCO_2$, or 86% of total GHG emissions. 2017 energy-related CO_2 emissions were down 20% versus 1990 and 25% versus 2005 levels (Figure 3.2). However, emission reductions have stalled in recent years and increased slightly in 2017.

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



Transport is the largest source of energy-related emissions, accounting for 66% of in 2017.

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

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

Note: $MtCO_2$-eq: million tonnes CO_2 equivalent.

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

Transport has been the largest source of energy-related CO_2 emissions since 1995. In 2017, the sector accounted for 66% of total CO_2 emissions, the highest share among IEA member countries. As noted in Chapter 2, several factors drive the high transport emissions. Luxembourg's central location in Europe makes it a transportation hub and its labour force has 200 000 daily cross-border commuters. It also has lower fuel taxes than neighbouring countries, encouraging non-residents and transiting drivers to fuel in Luxembourg. In 2017, 44.3% of Luxembourg's non-ETS emissions came from

non-resident commuters and transiting freight trucks fuelling in the country. Diesel fuel sales to transiting freight trucks alone accounted for 32.5% of non-ETS emissions.

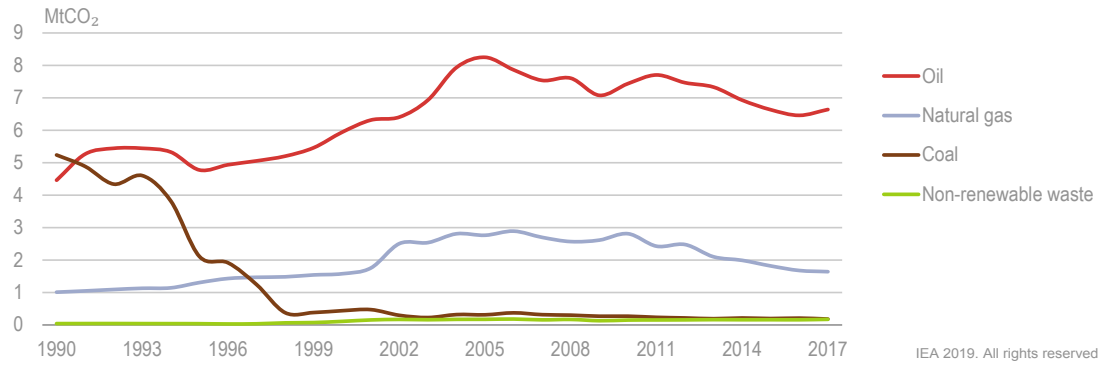
Outside of transport, 2017 energy-related CO_2 emissions came from residential (13%), industry (11%), commercial (7%), and from heat and electricity generation (3%). The low emissions from heat and electricity generation reflects Luxembourg's reliance on electricity imports (see Chapter 7) and the high share of renewables in domestic heat and electricity generation (see Chapter 6).

Energy-related CO_2 emissions peaked in 2005 at 11.5 million tonnes (Mt), and fell by 25% to reach 8.6 Mt in 2017. The main drivers for emission reductions since 2005 are falling emissions from transport (down by 1.52 Mt, but with a slight increase in 2017) and electricity generation (down by 1.09 Mt). The drop in emissions from electricity generation resulted almost entirely from the decommissioning of Luxembourg's only large thermal power plant in 2016, the Twinerg combined cycle gas turbine (see Chapter 7). From 2005 to 2017, industry sector emissions dropped by 0.32 Mt and residential sector emissions fell by 0.11 Mt, while commercial sector emissions increased by 0.17 Mt.

In 2017, oil accounted for 77% of total energy-related CO_2 emissions, reflecting the central role of the transport sector in Luxembourg's energy system (Figure 3.3). Natural gas was the second-largest emission source (19%), followed by coal and non-renewable waste (both 2%). Emissions from oil peaked in 2005 at 8.2 Mt, dropped to 6.5 Mt in 2016 but increased to 6.6 Mt in 2017. Oil emissions are driven primarily by changing levels of transport fuel consumption, but consumption of heating oil in buildings also contributes.

Natural gas emissions peaked at 2.9 Mt in 2006 and have fallen almost every year since then to reach 1.6 Mt in 2017. The drop in natural gas emissions was driven almost exclusively by the reduced use and decommissioning of the Twinerg combined cycle gas turbine plant. Following the plant's closure, natural gas continues to be used for heating in buildings and in small combined heat and power plants. Coal emissions were 0.2 Mt in 2017 and came from the non-metallic minerals industry (92%) and the steel industry (8%). Non-renewable waste emissions (0.2 Mt in 2017) came from Luxembourg's only combined heat and power waste incineration facility.

Figure 3.3 Energy-related CO_2 emissions by fuel, Luxembourg, 1990-2017



Oil is the largest source of energy-related emissions, mainly from the transport sector.

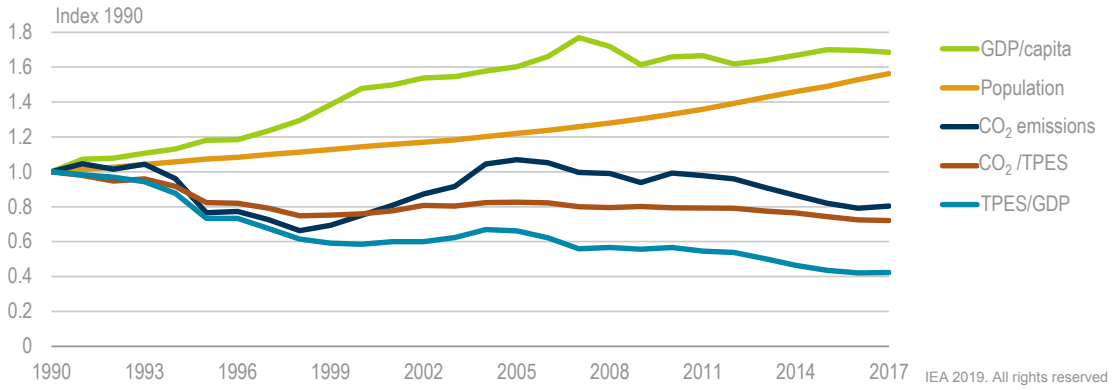
Note: $MtCO_2$-eq: million tonnes CO_2 equivalent.

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

CO_2 emission drivers and carbon intensity

Luxembourg's CO_2 emissions are driven by population growth and economic development, along with changes in the energy intensity of the economy (TPES/GDP), the carbon intensity of the energy supply (CO_2/TPES) and by fuels sales. From 1990 to 2017, Luxembourg's gross domestic product (GDP) per capita grew by 69% and the population increased by 56%, while CO_2 emissions declined by 20% (Figure 3.4). Emission reductions were mainly achieved through a 58% drop in energy intensity, linked to the switch from energy and emission-intensive iron-ore based steelmaking to the lower intensity steelmaking using electric arc furnaces and the transition to a service-based economy. A 28% decline in the carbon intensity of the energy supply due to the closure of the Twinerg gas power plant and increasing use of bioenergy also contributed to emission reductions.

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

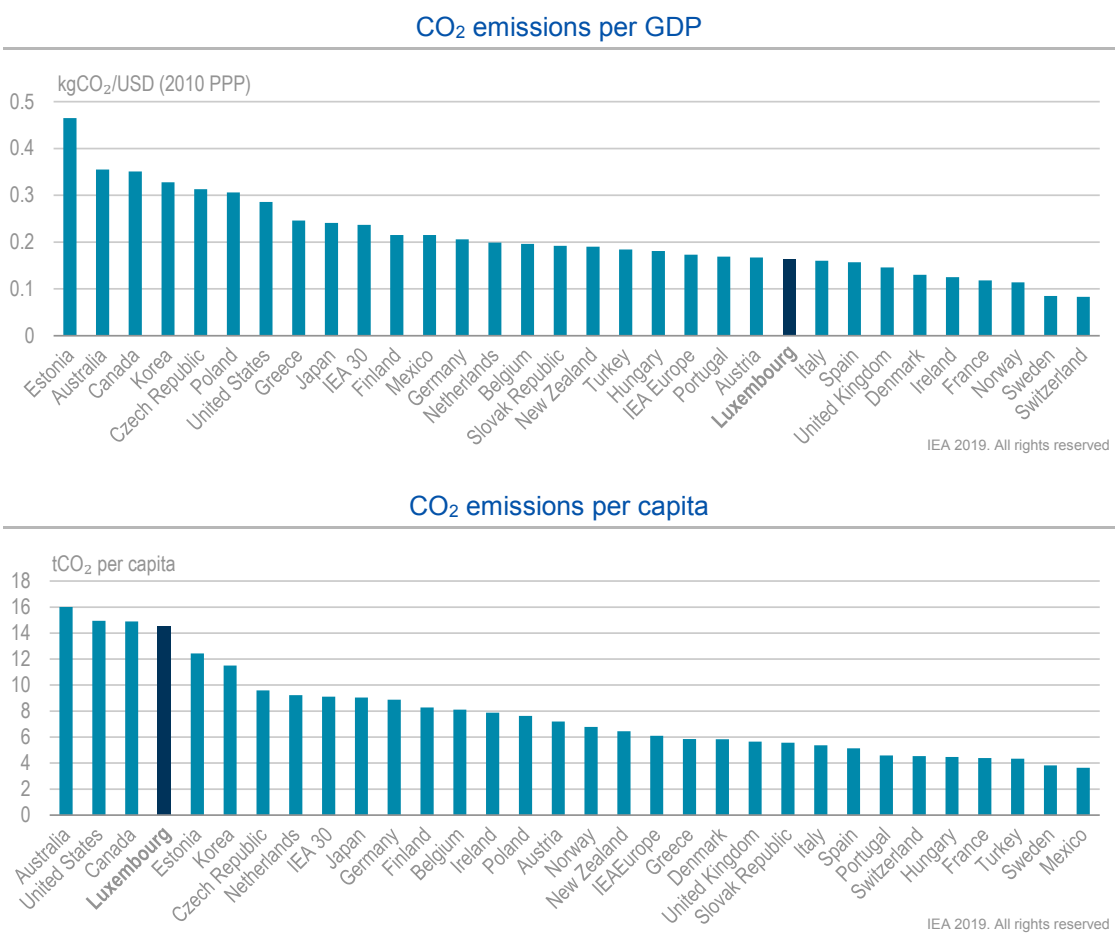


Despite large economic growth per capita, energy-related CO_2 emissions have declined, mostly thanks to reduced energy intensity of the economy.

Notes: Real GDP in USD 2010 prices and PPP. TPES: total primary energy supply.
Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics.

In 2017, the carbon intensity of Luxembourg's economy was 0.16 kilograms of CO_2 per USD ($kgCO_2$/USD), the tenth-lowest among IEA member countries. The same year, Luxembourg had the fourth-highest CO_2 emissions per capita among IEA member countries (Figure 3.5). The low carbon intensity reflects the fact that most electricity is imported: the emissions related to Luxembourg's electricity imports are assigned to the exporting country where the generation takes place. Another factor explaining the low carbon intensity is the service sector orientation of Luxembourg's economy. In 2017, 59% of Luxembourg's gross value added came from the service sector (53% excluding public administration). The high emissions per capita reflect the significant impact of non-resident commuters and transiting freight trucks fuelling in Luxembourg (see Chapter 2).

Figure 3.5 Carbon intensity in IEA member countries, 2017



Luxembourg has the tenth-lowest CO_2 emissions per GDP among IEA countries, but the fourth-highest CO_2 emissions per capita.

Note: tCO_2: tonne of carbon dioxide.

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

Institutions

Overall responsibility for Luxembourg's climate policy lies with the Ministry of the Environment, Climate and Sustainable Development, which co-ordinates sustainable development and takes all appropriate measures to protect the natural and human environment against the impacts of climate change. Three administrations operate under its legal authority: the Nature Conservation Agency, the Water Management Agency and the Environment Agency, which through its technical expertise helps the ministry elaborate plans, strategies, support schemes and regulatory instruments related to air emissions and pollutants, use of resources, and the circular economy. The Environment Agency and the ministry monitor the use of energy efficiency state-aid programmes and manage Luxembourg's GHG inventory and reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and the European Commission.

The Ministry of Energy and Spatial Planning has the main responsibility for energy policy, which strongly affects Luxembourg's GHG emissions. Policy authority over the transport

sector, Luxembourg's largest source of GHG emissions, is shared between the Ministry of Mobility and Public Works (responsible for policy in relation to transportation infrastructure) and the Ministry of Finance (authority over taxation of fuels and cars). In addition, together with the Ministry of the Environment, Climate and Sustainable Development, the Ministry of Finance is responsible for developing concrete measures in the area of sustainable finance following the publication of the Luxembourg Sustainable Finance Roadmap (UNEP FI, 2018). Two administrations under the legal authority of the Ministry of Agriculture, Viticulture and Rural Development work on policies and measures to adapt agricultural practices to the impacts of climate change as well as to mitigate emissions.

Climate targets and policy

As a European Union (EU) member state, Luxembourg's climate policies are subject to targets and policies set in EU directives. Emissions from large power plants and energy-intensive industries in Luxembourg are regulated under the EU-wide ETS, which uses tradable emission credits to encourage emission reductions. For non-ETS sectors,[2] emissions are subject to national targets for 2020 under the EU ESD and for 2030 under the EU ESR. The government adopted a 2030 target in line with the Paris Agreement that exceeds ESR requirements (Table 3.2).

Table 3.2 Luxembourg's emission reduction status, 2017 and 2020 and 2030 targets

	2017 status	2020 target	2030 target
Non-ETS greenhouse gas reduction vs. 2005	**16.1%**	**20%**	**50-55%***

* The Effort Sharing Regulation 2030 target for Luxembourg is a 40% reduction versus 2005.

Sources: MSDI (2018), *Seventh National Communication of Luxembourg under the United Nations Framework Convention on Climate Change,* https://unfccc.int/sites/default/files/resource/39752148_Luxembourg-NC7-1-LU_NC7_180212.pdf; MESP and MECSD (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

Luxembourg's plans to achieve the 2020 target are detailed in the National Communication of Luxembourg under the UNFCCC (MSDI, 2018). The government has noted that without a significant effort to reduce diesel sales in 2020, Luxembourg is running a high risk to miss its 2020 target of reducing non-ETS GHG emissions. The EEA indicated in 2018 that Luxembourg's existing measures will not be enough to meet the 2020 target. To date, the reported additional measures do not change this prospect. Luxembourg is, as a last resort, entitled to close the projected gap between the 2020 target and actual emissions by transferring surplus annual emission allocations from earlier years when emission reductions exceeded the indicative trajectory required under the ESD (EEA, 2018).

Under the EU Clean Energy Package (CEP), the ESR sets country-specific emission reduction targets for 2030. Luxembourg has the highest ESR target among EU member states – a 40% reduction in 2030 of non-ETS emissions versus 2005 levels (EC, 2019a). The CEP requires each EU member to submit an NECP detailing plans to achieve 2030 targets for emission reductions, energy efficiency and renewable energy (see Chapters 4

[2] Non-ETS sectors include agriculture, residential, commercial, waste, non-energy intensive industry and transport excluding aviation within the European Economic Area.

and 6). In February 2019, Luxembourg delivered its draft NECP to the European Commission (EC) for review (MESP and MECSD, 2019).

On 18 June 2019, the EC published its assessment of Luxembourg's draft NECP. It welcomed Luxembourg's 2030 targets, but requested significantly more detail on policies and measures to support the achievement of the 50-55% reduction in non-ETS emissions. The EC also requested a comprehensive assessment of the investments needed to achieve Luxembourg's energy sector targets (including those for emission reductions), as well as information on the financial sources to be mobilised for implementing the existing and planned policies and measures. Luxembourg and all other EU member states must submit their final NECPs addressing all the EC's comments by the end of 2019 (EC, 2019b).

In 2018, the EEA indicated that Luxembourg's existing and planned GHG reduction measures will not support achievement of the 2030 emission reduction target[3] (EEA, 2018). Looking to the future, Luxembourg is aiming for net-zero GHG emissions and 100% renewable electricity by 2050. Its ambitious 2030 targets and long-term carbon neutrality goals will require a significant shift in the country's carbon-intensive energy mix, especially for the heavy reliance on oil in the transport sector (see Chapter 2).

The main measures supporting GHG emission reductions in Luxembourg are tied to increasing renewable energy in heat production, electricity generation and transportation, and to increasing energy efficiency across all sectors. These include a wide variety of subsidies for investment in renewable energy and energy efficiency, tariffs supporting generation from renewables and various mandates and targets. Emission reductions in the transport sector are also supported through the e-mobility initiative, the Modu 2.0 sustainable mobility strategy and a recent modest increase of the fuel tax aiming to reduce the level of non-resident and transiting drivers fuelling in Luxembourg (see Chapters 4 and 6 for a detailed description of the above policies, measures and programmes).

Energy prices

In 2018, Luxembourg had the lowest electricity prices among its neighbouring countries. The lower prices in Luxembourg result primarily from significantly lower taxes on electricity, especially in comparison to Germany, Luxembourg's main source of electricity imports. In 2018, natural gas prices for industry in Luxembourg were close to the median value for IEA member countries, but with one of the lowest tax rates. Luxembourg's 2018 household natural gas price was the sixth lowest among IEA member countries and was significantly lower than in its neighbouring countries. The low natural gas price for households results partly from a low tax rate of 10%. Heating oil prices are low and drive a high share of oil heating in the residential (33% of energy demand) and commercial sectors (25% of energy demand).

The government modestly increased excise duties on diesel by EUR 0.02 per litre and gasoline by EUR 0.01 per litre on 1 May 2019. However, for the second quarter of 2019, Luxembourg had the seventh-lowest diesel price and the ninth-lowest gasoline price among IEA member countries. During the same quarter, Luxembourg had the lowest diesel and gasoline prices and taxes among neighbouring countries. The low fuel prices

[3] The EEA noted that Luxembourg will have a gap of 25.3% in 2030 non-ETS emissions in comparison to the ESR target of a 40% reduction versus 2005. This translates into a gap of 35.3% to 40.3% compared to Luxembourg's more ambitious target of a 50-55% reduction target.

are mainly due to lower value-added tax and excise duties on oil products than in neighbouring countries. On 9 December 2019, the government announced that it is considering increasing the excise duties for diesel by EUR 0.03 to EUR 0.05 per litre and for gasoline by EUR 0.01 to EUR 0.03 per litre between February and April 2020. (Government of Luxembourg, 2019).

On 16 December 2019, the government announced that it will introduce a carbon tax of EUR 20 per tonne starting in 2021. The tax would increase to EUR 25 per tonne in 2022 and EUR 30 per tonne in 2023. The government estimates that the carbon tax could generate as much as an additional EUR 150 million of revenue. Half of this sum will be used to support households in need, while the other half will be invested in national measures aimed at advancing Luxembourg's clean energy transition (Delano, 2019).

E-mobility and sustainable transport

Luxembourg has embraced a broad e-mobility initiative aiming to reduce transport sector emissions through electrification of transport. The draft NECP's goal for 49% of vehicles registered in Luxembourg to be electric vehicles (EVs) by 2030 is supported by EV subsidies and investment in a national EV charging network. The e-mobility initiative also supports a shift from private vehicles to electrified public transportation (see Chapters 4 and 7 for details on e-mobility and other transport measures).

As noted above, Luxembourg's Strategy for Sustainable Mobility aims to increase the number of public transport users by 50% from 2017 to 2025, and defines measures to increase the level and quality of electrified public transport, e.g. investment in park and ride centres linked to a major reworking of bus and train infrastructure and making all modes of public transport (except first-class rail) free for all users after March 2020 (MSDI, 2017).

Luxembourg's annual vehicle registration fees are higher for vehicles with higher emissions. The government has also adjusted the charge paid when leasing a vehicle, decreasing the charge for plug-in hybrid electric vehicles (PHEVs) and other highly efficient vehicles and increasing the charge for less efficient vehicles. In 2018, about 40% of new car registrations were company cars leased by corporations for their employees. Initial results show that the increased company car charge has encouraged the purchase of PHEVs and reduced the purchase of inefficient vehicles.

The e-mobility and sustainable transport policies will likely result in a more efficient transport sector, but their contribution to meeting the GHG emission reduction targets remains to be determined. The government should also consider the creation of a bonus-malus system that coherently combines the subsidies for EVs and the various fees and taxes for less efficient vehicles.

Climate and energy fund

Luxembourg's Climate and Energy Fund was established in 2004 to support national and international climate action. Currently the fund is well endowed, with around EUR 600 million of unused budgetary appropriations. It finances energy efficiency and renewable energy projects and is funded with 40% of the CO_2-based vehicle tax and a share of the excise duties on diesel and gasoline, known as the "Kyoto-cent". The "Kyoto-cent" is an additional tax on gasoline and diesel sold in Luxembourg (EUR 0.02 and EUR 0.025 per litre respectively). In May 2019, the "Kyoto-cent" was increased by

EUR 0.01 per litre for gasoline and EUR 0.02 per litre for diesel. However, only half of the May 2019 tax increase is allocated to the fund; the other half is earmarked for social measures, notably linked to the energy transition. In 2018, the CO_2-based vehicle tax contributed EUR 26.78 million to the Climate and Energy Fund, whereas the "Kyoto-cent" contributed EUR 62.41 million.

Stakeholder consultations

In 2018, a series of workshops were organised to ensure early and effective participation of relevant stakeholders and the general public in the preparation of the NECP and to reflect upon a low-carbon mid-century strategy for the country: two climate-related workshops based on a co-creation process – the Climate Innovation Lab focusing on mitigation policies in different sectors and the Climate Policy Lab reflecting upon the governance of the climate policy in Luxembourg; on the energy side, an afternoon of reflection and exchanges on the energy transition.

In 2018, Luxembourg's Ministry of Finance and Ministry of the Environment, Climate and Sustainable Development announced the establishment of the "Luxembourg Sustainable Finance Initiative", which aims to bring together relevant actors in the sustainable finance field and shall serve as a forum for developing the National Strategy for Sustainable Finance for Luxembourg based on the 2018 Luxembourg Sustainable Finance Roadmap.

Through the "Generatioun Klima" processes the government consults with the public and energy sector stakeholders on the development of the NECP. The first consultation was held in May 2019 as a co-creation process focusing on housing and sustainable construction, mobility, industries and businesses, agriculture, energy, changing lifestyle, governance, and finance. The same month, the government organised a series of discussions called "climateXchange", giving secondary school students the opportunity to provide inputs that will feed into the NECP. These climateXchange discussions were organised in response to student demonstrations on climate change that took place across Europe in spring 2019. Additional consultations are planned in preparation for the finalisation of the NECP before 31 December 2019 (Government of Luxembourg, 2019b), notably an Internet-based public consultation and a dialogue with the key sectoral stakeholders.

Regional co-operation

Luxembourg co-operates on regional efforts to reduce GHG emissions, including the Benelux Union Talanoa Dialogue 3, a process organised under the UNFCCC to support co-operation towards the achievement of the Paris Agreement targets (UNFCCC, 2018). As part of this inclusive and participatory process, which took place 24 September 2018 in Brussels, regional project proposals were developed with stakeholders from the Benelux member states in the areas of sustainable mobility, energy and resource efficiency, green finance, and a just energy transition. Luxembourg, Belgium and the Netherlands signed a joint declaration to strengthen regional co-operation on achieving the Paris Climate Agreement targets. One of the declaration's main focus areas is the implementation of the Regional Energy and Climate Dialogue 2030, which promotes co-operation on the NECPs and on implementing co-ordinated long-term national strategies for reducing GHG emissions (MESP and MECSD, 2019).

Climate finance

Luxembourg is a global leader in climate finance. Both the government and the financial sector have a strong commitment to supporting climate-related bonds, funds and other financial instruments (Government of Luxembourg, 2018). Some of the government's key initiatives to support climate finance include:

- The 2018 Luxembourg Sustainable Finance Roadmap was drafted in partnership with the United Nations Environment Programme. It serves as a basis to develop a national sustainable finance strategy that leverages Luxembourg's role as an international financial centre to support the objectives of the Paris Agreement.
- The European Investment Bank's Climate Finance Platform is a joint initiative between Luxembourg and the European Investment Bank that combines financial guarantees and technical assistance to mobilise investments in climate-related projects.
- The International Climate Finance Accelerator is public-private partnership giving financial and operational backing to fund managers launching innovative climate action funds.
- The Amundi Planet Emerging Green One Fund is a joint venture between the government and the International Finance Corporation that invests in green bonds issued by banks in developing countries.

Luxembourg is a global centre for the issuing and trading of financial instruments that promote action on climate change, UN Sustainable Development Goals, and broader social and environmental goals. In 2016, the Luxembourg Stock Exchange launched the Luxembourg Green Exchange (LGX), the largest platform exclusively dedicated to sustainable finance. The LGX is the first exchange to use industry best practices for sustainable financial instruments as mandatory requirements for instruments to be listed and traded. In 2019, the LGX was the world's leading exchange for sustainable securities and home to almost half of the world's listed green bonds (LuxSE, 2019).

Financial instruments can be listed on the LGX as green, social, sustainable or ESG (environment, social and governance). Green bonds and funds are the most relevant instruments in relation to supporting climate action and emission reductions. For bonds or funds to qualify as green instruments on the LGX, any proceedings earned must be used exclusively to finance or refinance green projects (LGX, 2019). The LGX recognises several broad categories of green projects, including:

- renewable energy
- energy efficiency
- pollution prevention and control
- environmentally sustainable management of living natural resources and land use
- terrestrial and aquatic biodiversity conservation
- clean transportation
- sustainable water and wastewater management
- climate change adaptation
- eco-efficient and/or circular economy adapted products, production technologies and processes
- green buildings which meet regional, national or internationally recognised standards or certifications.

Assessment

In 2017, Luxembourg's total GHG emissions were 10.2 $MtCO_2$-eq, 86% of which came from energy-related combustion processes, primarily consumption of oil in the transport sector. Luxembourg's total GHG emissions have decreased 20% from 1990 levels and 21% from 2005 levels. However, reductions have stalled in recent years and GHG emissions increased slightly in 2017.

Luxembourg has committed to reducing non-ETS emissions by 50-55% by 2030, compared to 2005. This target goes beyond Luxembourg's 40% reduction obligation under the EU's ESR, and is driven by the government's commitment to the Paris Agreement. The 2030 target will be set between 50% and 55% in the finalised NECP, which must be submitted before 31 December 2019.

The main measures supporting GHG emission reductions in Luxembourg are tied to increasing renewable energy in heat production, electricity generation and transportation, and to increasing energy efficiency across all sectors. The specific contributions of these various measures to achieving the 2030 GHG emission reduction targets should be identified to prioritise support to the most effective measures. However, the EEA has indicated that Luxembourg's existing and planned policies and measures are not sufficient to achieve the 2030 emission reduction target. As such, Luxembourg will need to strengthen and expand existing measures and look into the creation of new, more effective emission reduction measures.

Stalling GHG emission reductions in recent years and increased emissions in 2017 show that Luxembourg needs to adjust policy to support sustained emission reductions. The ambitious 50-55% reduction target will require significant changes across the entire energy sector, especially in the transport sector, and may require more aggressive fuel taxes and increased incentives for electric and fuel-efficient vehicles. Increased EV uptake could be encouraged through public procurement, increased investment in charging infrastructure and discriminatory road use pricing for vehicles (e.g. road toll that discriminates by level of emissions).

The transport sector is the main source of Luxembourg's GHG emissions. Transport emissions peaked in 2005 and have fallen since, but started to increase again in 2017 to reach 66% of non-ETS emissions. Several factors drive the high transport sector emissions. Luxembourg's central location in Europe makes it a transportation hub and its labour force has 200 000 daily cross-border commuters. It also has lower fuel taxes than neighbouring countries, encouraging non-residents and transiting drivers to fuel in Luxembourg. In 2017, non-residents refuelling in Luxembourg accounted for 44.5% of non-ETS emissions with 32.5% coming from diesel sales to freight trucks.

Luxembourg has prioritised emission reductions in the transport sector through the e-mobility initiative, Modu 2.0 Sustainable Mobility Strategy, lower fees for more efficient vehicles and increased transportation fuel taxes. In May 2019, fuel excise duties were modestly increased on diesel by EUR 0.02 per litre and on gasoline by EUR 0.01 per litre. But despite these tax increases, Luxembourg still has lower fuel prices than neighbouring countries. The government is considering another round of increases on transport excise duties between February and April 2020. It is recommended that the government monitor the impact of tax increases and consider further incremental fuel tax increases to support achievement of the 2030 GHG reduction target.

E-mobility is a cornerstone of the government's plan to reduce transportation emissions. E-mobility is being supported through subsidies on EV purchases and investments in a national EV charging network. In addition, vehicle taxes and fees have been adjusted to favour the use of EVs and discourage purchasing inefficient combustion engine vehicles. To further incentivise the transition to e-mobility and more fuel-efficient vehicles, stronger incentives should be considered; the subsidies for electric vehicles and the various fees for less efficient vehicles could be merged into a bonus-malus system.

Increasing the use of public transport is also key to reducing transport sector GHG emissions. The government intends to boost the use of public transport by making all modes (except first-class rail) free for all users after March 2020. It has also recognised that the frequency and quality of service need to be improved and is making multi-billion euro investments in new tram lines, upgraded rail and bus services, and construction of park and ride centres located in transit hubs.

The low cost of energy and high purchasing power of consumers in Luxembourg creates a notable barrier to achieving the ambitious 2030 GHG reduction target. Low energy prices reduce the financial savings that can be achieved through investment in energy efficiency and renewable energy, reducing interest in these GHG reducing measures. High subsidies and/or strong regulatory measures will be needed to make investments in energy efficiency and renewables more attractive and it is unclear whether the various subsidy schemes currently in place are sufficient to support the achievement of Luxembourg's GHG reduction target.

While implementing the planned carbon tax, Luxembourg should consider carbon pricing based on the carbon content in fuels. Such a price could be introduced at a low level and adjusted to meet long-term targets. Such a system has low transaction costs and can work in conjunction with the EU's ETS, as in many EU member states. The carbon price can be paid by importing companies and costs passed on to consumers. Revenues could support the Climate and Energy Fund and compensate low-income households for higher energy costs. The government should also examine how to more effectively leverage the Climate and Energy Fund, which has EUR 600 million in unused budgetary appropriations, to support achievement of the GHG targets.

To ensure the sustainability and credibility of the transition to a low-carbon economy in Luxembourg, a broad stakeholder process should be considered for the development of the 2050 low-carbon strategy, with a clear link to existing 2030 targets. Strong stakeholder engagement and clear agreement with broad parliamentary support on the long-term strategy can create a credible signal to the market and society.

At an international level, Luxembourg is a leader in sustainable climate finance, hosting the world's largest exchange for green and sustainable financial instruments. The government should continue its robust support for climate finance as the mobilisation of private capital will be essential in meeting the goals of the Paris Agreement.

Recommendations

The government of Luxembourg should:

- Introduce a carbon pricing system with revenues channelled to effective GHG emission reduction measures and compensation for low-income households.
- Strengthen the incentives for electric vehicles and more fuel-efficient vehicles by establishing a bonus-malus system.
- Examine the effects of the recent fuel tax increases and consider further incremental increases that support the achievement of GHG emission reduction targets.
- Ensure a broad and robust stakeholder consultation process when developing a long-term energy and climate strategy that is compatible with the Paris Agreement.

References

Delano (2019), *Carbon Tax at Heart of Climate Plan*, Delano, Luxembourg City, https://delano.lu/d/detail/news/carbon-tax-heart-climate-plan/208777.

EC (European Commission) (2019a), *Clean Energy for All Europeans Package Completed: Good for Consumers, Good for Growth and Jobs, and Good for the Planet*, EC, Brussels, https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en.

EC (2019b), *United in Delivering the Energy Union and Climate Action: Setting the Foundations for a Successful Clean Energy Transition*, EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285.

EEA (European Environment Agency) (2018), *Trends and Projections in Europe 2018*, EEA, Luxembourg City, www.eea.europa.eu/publications/trends-and-projections-in-europe-2018-climate-and-energy.

Government of Luxembourg (2019a), Increase in excise duties on fuels at the start of 2020, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/fr/actualites/toutes_actualites/communiques/2019/12-decembre/16-augmentation-accises.html/.

Government of Luxembourg (2019b), *Generation Klima*, Government of Luxembourg, Luxembourg City, https://environnement.public.lu/fr/actualites/2019/04-2019/Generatioun_Klima_Planeit.html.

Government of Luxembourg (2018), *Luxembourg Sustainable Finance Roadmap*, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/dam-assets/documents/actualites/2018/10-octobre/04-sustainable-finance/Luxembourg-Sustainable-Finance-Roadmap-WEB.pdf.

IEA (International Energy Agency) (2019), *CO_2 Emissions from Fuel Combustion 2019* (database), www.iea.org/statistics.

LGX (Luxembourg Green Exchange) (2019), *Luxembourg Green Exchange*, LGX, Luxembourg City, www.bourse.lu/documents/brochure-LGX-EN.pdf.

LuxSE (Luxembourg Stock Exchange) (2019), *Sustainability Standards and Labels*, LuxSE, Luxembourg City, www.bourse.lu/sustainability_standards_and_labels.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, Government of Luxembourg, Luxembourg City,

https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

MSDI (Ministry of Sustainable Development and Infrastructures) (2018), *Seventh National Communication of Luxembourg under the United Nations Framework Convention on Climate Change*, Government of Luxembourg, Luxembourg City, https://unfccc.int/sites/default/files/resource/39752148_Luxembourg-NC7-1-LU_NC7_180212.pdf.

MSDI (2017), *Modu 2.0 Strategy for Sustainable Mobility*, Government of Luxembourg, Luxembourg City, https://environnement.public.lu/dam-assets/actualites/2019/04/modu2-fr-brochure.pdf.

UNEP FI (United Nations Environment Programme – Finance Initiative) (2018), *Luxembourg Sustainable Finance Roadmap*, Luxembourg City, https://gouvernement.lu/dam-assets/documents/actualites/2018/10-octobre/04-sustainable-finance/Luxembourg-Sustainable-Finance-Roadmap-WEB.pdf.

UNFCCC (United Nations Framework Convention on Climate Change) (2019), *2019 National Inventory Submissions*, UNFCCC, Bonn, https://unfccc.int/documents/194915.

UNFCCC (2018), *2018 Talanoa Dialogue Platform,* UNFCCC, Bonn, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/2018-talanoa-dialogue-platform.

4. Energy efficiency (focus area)

Key data (2017)

Total final consumption (TFC): 3.7 Mtoe (oil 60.0%, natural gas 17.1%, electricity 15.0%, bioenergy and waste 4.9%, district heat 1.6%, coal 1.2%, solar 0.1%) -7.4% since 2007

Consumption by sector: transport 54.1%, industry 18.5%, residential 14.2%, commercial 13.2%

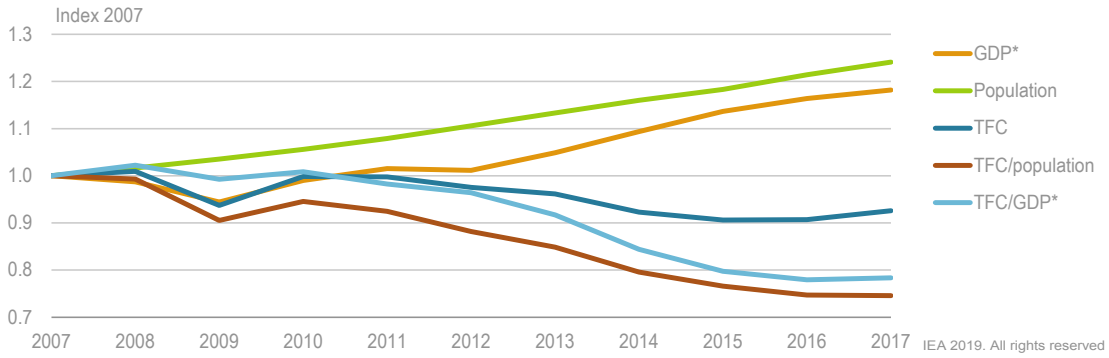
Energy consumption (TFC) per capita: 6.1 toe (IEA average 2.9 toe)

Energy intensity (TFC/GDP): 71.0 toe/USD million PPP (IEA average: 73.9 toe/USD million PPP), -21% since 2007

Overview

From 2007 to 2017, Luxembourg's gross domestic product (GDP) grew by 18% and its population by 24% (Figure 4.1), the fastest population growth among IEA member countries. During the same period, total final consumption (TFC) declined by 7%, indicating a decoupling of energy demand from GDP and population. However, TFC increased 2% from 2015 to 2017. The government expects continued economic growth, and population is forecast to increase 34% by 2030 (EC, 2019a). Without significant energy efficiency measures, increasing GDP and population will lead to higher energy demand in Luxembourg.

Figure 4.1 Luxembourg's energy consumption, intensity and drivers, 2007-17



Luxembourg has seen a decoupling between TFC and both population and GDP in the last decade. However, TFC has increased slightly since 2015.

* GDP data are in billion USD 2010 prices and PPPs (purchase power parity).

Note: GDP: gross domestic product; TFC: total final consumption.

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

In 2017, transport accounted for 54% of TFC and fossil fuels covered 94% of transport demand. Several factors drive the high share of transport in TFC. Luxembourg's central location in Europe makes it a transportation hub, its labour force has 200 000 daily cross-border commuters and the country has lower fuel taxes than neighbouring countries. As a result, almost 50% of transport demand results from commuters and transiting drivers, especially freight trucks, fuelling in Luxembourg.

Industry was the second-largest source of energy demand in 2017 (19% of TFC). Industry demand has declined significantly since 2007, but has been stable in recent years. Residential demand was 14% of TFC in 2017. While residential demand has not grown significantly since 2007, it is expected to increase in line with Luxembourg's growing population. The commercial sector had the smallest share of demand (13% of TFC in 2017), but the fastest demand growth driven by increasing GDP and Luxembourg's transition to a service-oriented economy.

Luxembourg has 2020 and 2030 energy efficiency targets in accordance with its obligations under European Union (EU) directives. The 2020 target requires that Luxembourg not surpass 49.3 terawatt hours (TWh) of final energy consumption (EC, 2012). Luxembourg's final energy consumption increased in 2016 and 2017 to reach 48.4 TWh.[1] The expected growth in GDP and population and increasing diesel sales to transiting freight trucks present notable challenges to achieving the 2020 target.

Luxembourg's draft National Energy and Climate Plan (NECP) contains an ambitious 2030 energy efficiency target requiring that Luxembourg not surpass 35.6 TWh of final energy consumption (MESP and MECSD, 2019). Achieving this target will require sustained implementation of strong energy efficiency measures across all energy sectors.

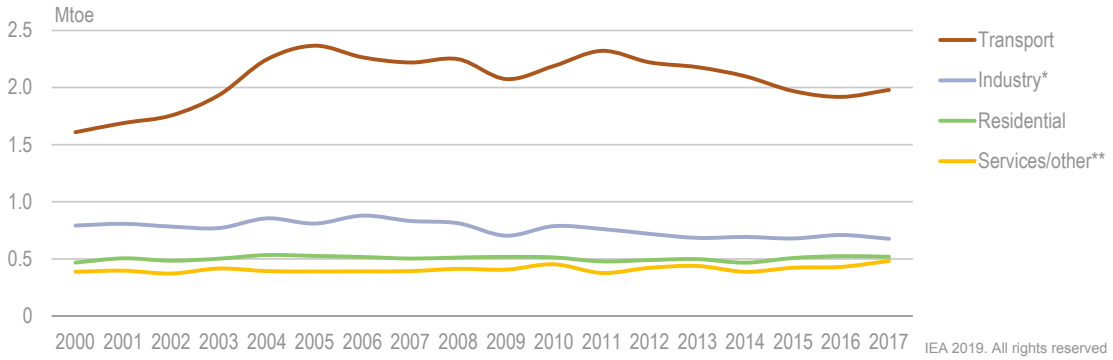
Energy consumption by sector

The transport sector dominates energy demand in Luxembourg. In 2017, transport accounted for 54% of TFC (Figure 4.2). Transport demand peaked at 2.3 million tonnes oil equivalent (Mtoe) in 2011, steadily declined until 2016 and started to increase again in 2017 to reach 2.0 Mtoe. Industry demand declined 19% from 2007 to 2017, but has been flat in recent years and accounted for the second-largest share of TFC in 2017 (0.68 Mtoe). Despite a growing population, residential sector demand has been stable at around 0.5 Mtoe for several decades. In line with the growing GDP and the increased role of the service sector, commercial sector demand had the largest increase, growing 23% from 2007 to 2017 to reach 0.48 Mtoe.

Luxembourg has the highest energy consumption per capita among IEA member countries (Figure 4.3). The high per capita consumption results partly from high consumption of transport fuels, with a large share of transport consumption coming from non-residents fuelling in Luxembourg. In comparison, Luxembourg's energy intensity (in TFC/GDP) is around the median for IEA member countries.

[1] 48.4 TWh of final energy consumption comes from STATEC (Luxembourg's statistics and data service) and includes aviation fuel consumption that is not included in the IEA energy consumption data presented in this chapter.

Figure 4.2 TFC by sector, Luxembourg, 2000-17



Transport accounted for over half of TFC in 2017, driven partly by fuel consumption from transiting freight trucks and cross-border commuters.

* *Industry* includes non-energy use.

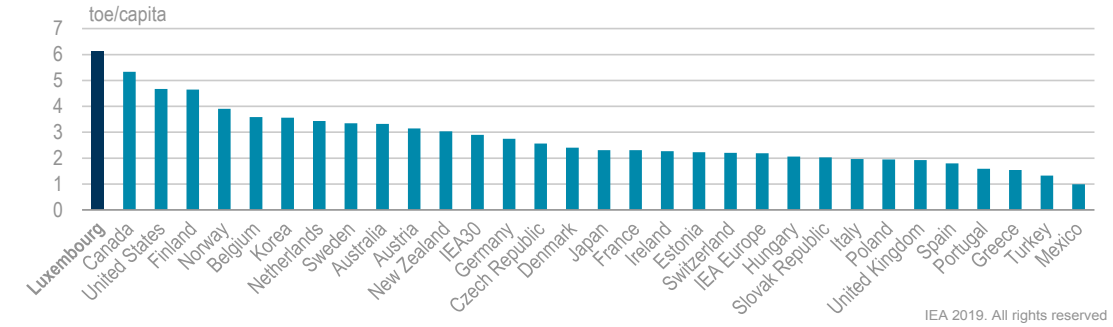
** *Services/other* includes commercial and public services, agriculture, forestry and fishing.

Note: Mtoe: million tonne oil equivalent.

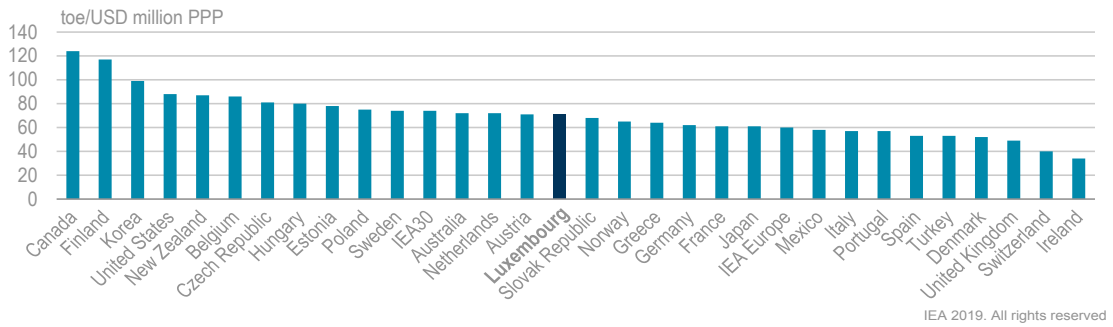
Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics.

Figure 4.3 Energy intensity in IEA member countries, 2017

Energy consumption per capita



Energy consumption per GDP (TFC/GDP PPP)



The large transport energy demand, driven by non-residents fuelling in Luxembourg, gives Luxembourg the highest TFC per capita in the IEA.

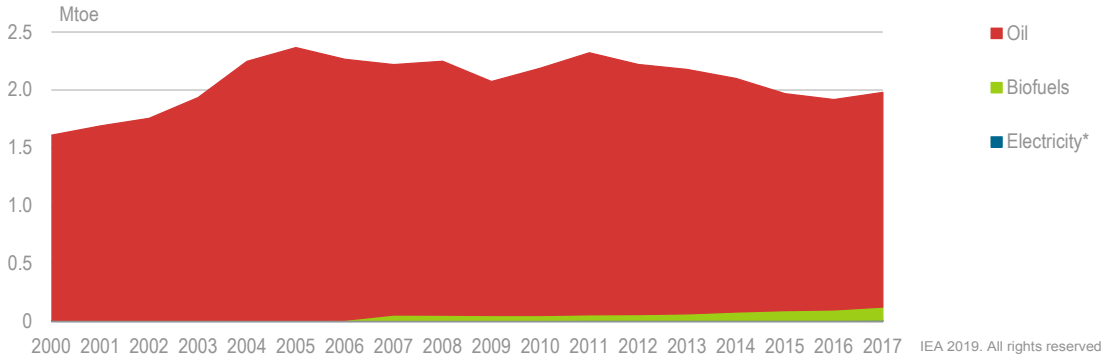
Notes: toe: tonnes of oil equivalent. Energy intensity in total final energy consumption, not including the energy transformation sector. GDP data are in billion USD 2010 prices and PPPs (purchase power parity).

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

Transport

Luxembourg's transport sector has accounted for more than 50% of TFC since 2002 (Figure 4.4). From 2007 to 2017, transport consumption averaged 2.1 Mtoe, but with notable fluctuations. After peaking in 2005 at 2.4 Mtoe, transport energy demand decreased to 2.0 Mtoe in 2017. In 2017, road transportation accounted for 98.6% of transport demand with small shares from rail (1.3%) and domestic aviation (0.1%). Oil dominates transport sector consumption, accounting for 94% in 2017 (with 78% coming from diesel). Biofuels (mostly biodiesel) accounted for 6% of total transport demand in 2017. Electricity accounted for only 1%, mainly used by rail transport.

Figure 4.4 Transport TFC by source, Luxembourg, 2000-17



Oil covered 94% of transport demand in 2017. Diesel fuel accounted for 78%, reflecting the impact of transiting freight trucks.

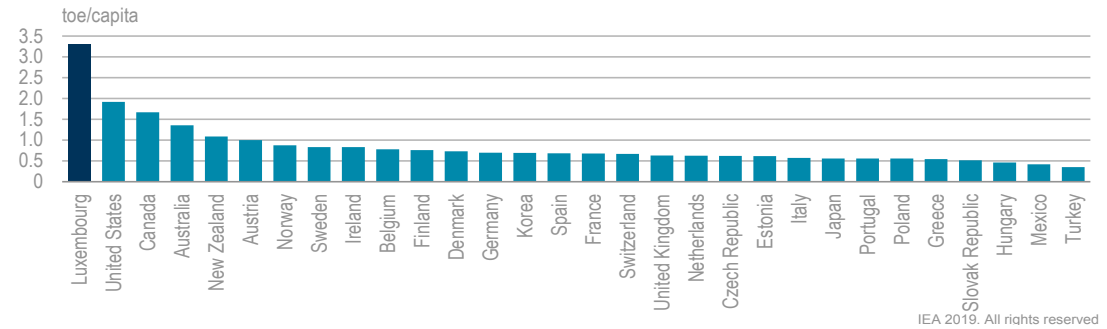
* Not visible on this scale.

Notes: Mtoe: million tonnes oil equivalent. The transport sector demand excludes international aviation and navigation.

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

Compared to other IEA member countries, Luxembourg had by far the highest per capita transport energy demand in 2017 (Figure 4.5), explained by 200 000 daily cross-border commuters and transiting drivers fuelling in Luxembourg.

Figure 4.5 Transport energy demand per capita in IEA member countries, 2017



Luxembourg has by far the highest transport energy demand per capita in the IEA, nearly five times that of Germany, indicating the impact of non-residents fuelling in Luxembourg.

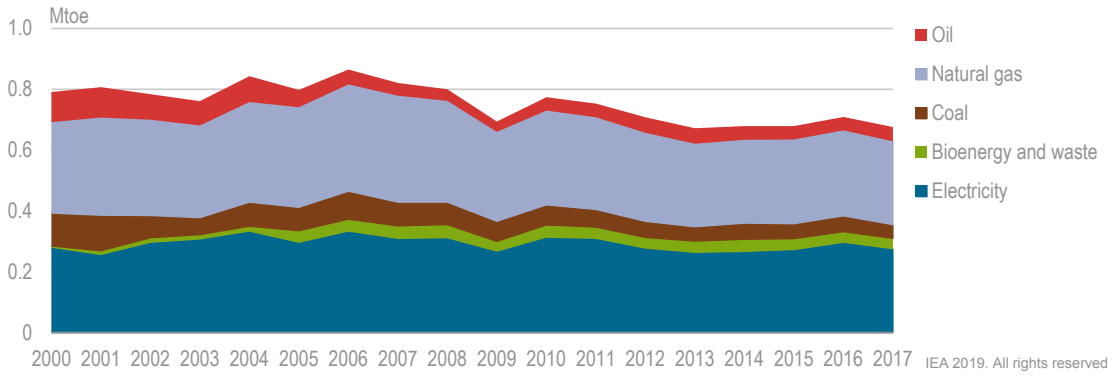
Note: toe: tonnes of oil equivalent.

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

Industry

Industry demand declined by 19% between 2007 and 2017, but has been relatively stable since 2013 (Figure 4.6). Industry is still the second-largest demand sector with 0.68 Mtoe and 19% of TFC in 2017. In that year, industry sector consumption had the following breakdown: natural gas (41%), electricity (41%), coal (7%), oil (7%) and bioenergy (5%). From 2007 to 2017, industry sector consumption of coal dropped 42%, natural gas fell 22%, bioenergy dropped 16%, and electricity consumption decreased 11% while oil consumption grew 12%.

Figure 4.6 TFC in industry by source, Luxembourg, 2000-17



Industrial TFC decreased 19% from 2007 to 2017, but has remained relatively stable since 2013.

Notes: Mtoe: million tonnes oil equivalent. Includes non-energy consumption.

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

The iron and steel industry accounted for the largest share of industrial energy consumption, at 46% in 2017 (Figure 4.7). Non-metallic minerals was the second-largest industry sector consumer (21%). All other industry sectors had shares of 9% or less.

Figure 4.7 Energy consumption in industry sectors, Luxembourg, 2017

Iron and steel manufacturing accounts for nearly half of total industrial energy consumption, using mainly electricity and natural gas.

* *Other* includes machinery, paper, mining and quarrying, transport equipment, non-ferrous metals and non-specified industry consumption.

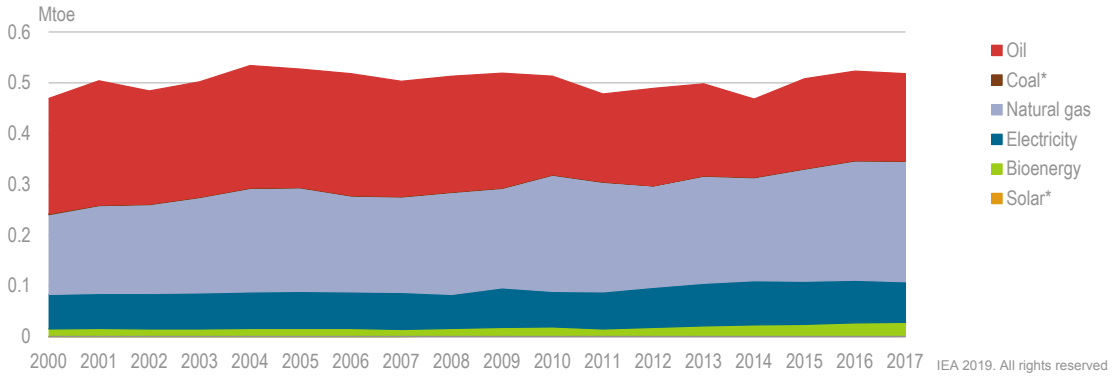
Note: Includes fuel consumption for non-energy use.

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

Residential

Despite a growing population, residential sector demand was stable at around 0.5 Mtoe since 2000, but has increased slightly in recent years, reaching 0.52 Mtoe and 14% of TFC in 2017 (Figure 4.8). In 2017, residential sector consumption had the following breakdown: natural gas (46%), oil (33%), electricity (15%), bioenergy (5%) and solar thermal (0.4%). From 2007 to 2017, residential sector consumption of bioenergy grew 86%, natural gas consumption increased 27% and electricity consumption increased 10%. While oil consumption fell 24%, heating oil still accounts for a significant share of heating demand in residential buildings.

Figure 4.8 Residential sector TFC by source, Luxembourg, 2000-17



Residential demand has been stable at around 0.5 Mtoe since 2000 and natural gas covers almost half. Although the share of heating oil is falling, it still covers a third of demand.

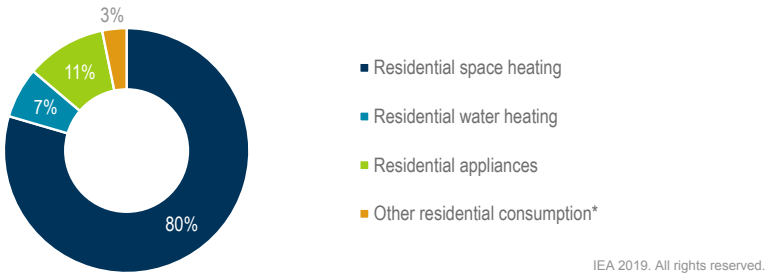
* Not visible on this scale.

Notes: Mtoe: million tonnes of oil equivalent. The commercial sector includes commercial and public services, agriculture, forestry and fishing.

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

Heating is the main source of residential energy demand (Figure 4.9). In 2016, residential sector demand had the following breakdown: space heating (80%); electric appliances (11%); water heating (7%); and space cooling, lighting and cooking (3%).

Figure 4.9 Residential TFC sector by end use, Luxembourg, 2016



Space and water heating accounted for 87% of residential energy consumption in 2016. Energy demand for heating has decreased slightly despite the population growth.

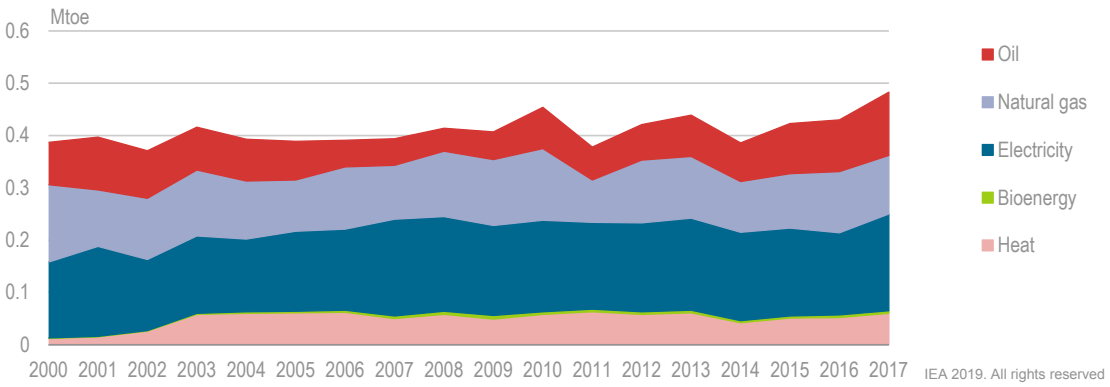
* *Other residential consumption* includes energy for cooking, lighting and space cooling.

Source: IEA (2018), *Energy Efficiency Indicators Highlights 2018*, www.iea.org/statistics.

Commercial

In line with Luxembourg's growing GDP and population and the increased role of the service sector in the economy, the commercial sector had the largest increase in energy demand, growing 23% from 2007 to 2017 to reach 0.48 Mtoe and 13% of TFC (Figure 4.10). In 2017, commercial sector consumption had the following breakdown: electricity (38%), oil (25%), natural gas (23%), district heating (DH) (15%) and bioenergy (1%). From 2007 to 2017, commercial sector consumption of oil grew 137%, DH consumption increased 20%, and natural gas consumption increased 9%, while electricity and bioenergy consumption were flat. The commercial sector is the main user of DH. Luxembourg is transitioning DH energy consumption from natural gas to biomass (see Chapter 6).

Figure 4.10 Commercial sector TFC by source, Luxembourg, 2000-17



The commercial sector had the largest increase in demand, growing 23% from 2007 to 2017. Demand for heating oil has grown in recent years.

Notes: Mtoe: million tonnes of oil equivalent. The commercial sector includes commercial and public services, agriculture, forestry and fishing.

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

Institutions

The Ministry of Energy and Spatial Planning has the main responsibility for energy efficiency policy. Within the ministry, the Department of Energy formulates policies on energy efficiency. Some responsibilities for energy efficiency policies are shared with the Ministry of the Environment, Climate and Sustainable Development, which manages the system supporting private and municipal energy efficiency investments. The Ministry of Mobility and Public Works is responsible for transport policy, which plays an important role in relation to Luxembourg's energy efficiency targets and policy.

MyEnergy is a public organisation under the Ministry of Energy and Spatial Planning; the Ministry of the Environment, Climate and Sustainable Development; and the Ministry of Housing. MyEnergy promotes awareness of energy efficiency policy and provides information on energy efficiency related subsidies to facilitate investments in energy efficiency measures by all market participants.

Policy

European Union (EU) directives are key drivers of Luxembourg's energy efficiency targets and policy. Table 6.2 gives Luxembourg's 2020 and 2030 energy efficiency targets.

Table 4.1 Luxembourg's energy efficiency targets, 2020 and 2030

Sector	2020	2030
Energy efficiency*	Not surpassing 49.3 TWh of final energy consumption	Not surpassing 35.6 TWh of final energy consumption

* Luxembourg's final energy consumption was 52.1 TWh in 2005, 47 TWh in 2016 and 48.4 TWh in 2017.

Sources: ME (2017), *Fourth National Energy Efficiency Action Plan*, https://ec.europa.eu/energy/sites/ener/files/documents/lu_neeap_2017_en.pdf; MESP and MECSD (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

The 2012 EU Energy Efficiency Directive (EED) (2012/27/EU) established a set of measures supporting achievement of the 2020 target of a 20% reduction in EU-wide energy consumption compared to the business-as-usual projection (EC, 2012). The EED requires EU member states to:

- set energy efficiency targets, based on primary or final energy consumption, primary or final energy savings, or energy intensity
- require energy suppliers to realise at least a 1.5% reduction of annual energy demand for final consumers through an energy efficiency obligation (EEO) scheme, or other measures that achieve the same savings
- require large companies to regularly audit energy consumption and identify energy efficiency measures
- provide incentives to support energy audits by small and medium-sized enterprises
- develop a national building renovation strategy and implement measures to improve energy efficiency in public buildings
- ensure that national governments purchase only products, services and buildings with a high energy efficiency performance.

Under the EED, EU member states set indicative national energy efficiency targets to contribute to the EU-wide target. These targets must be defined in a National Energy Efficiency Action Plan (NEEAP), which also details the specific measures to be taken to reach the target. The EED requires submission of an updated NEEAP every three years along with annual reports on progress towards energy efficiency target. Luxembourg submitted its fourth NEEAP to the EC in 2017, specifying a 2020 energy efficiency target of not surpassing 49.3 gigawatt hours (GWh) of final energy consumption and 52.1 GWh of primary energy consumption (ME, 2017). Although final energy consumption was 48 TWh in 2017, the government noted in its most recent annual report to the EC that growing GDP and population and increasing diesel sales to transiting freight trucks are challenging the country's ability to meet the 2020 energy efficiency target (ME, 2017).

Luxembourg's 2030 energy efficiency targets are derived from the EU Clean Energy Package (CEP), which set an EU-wide 2030 target to increase energy efficiency by at least 32.5% compared to the business-as-usual projection. Within the CEP, the energy efficiency target is set under the updated EED (2018/2002), which was published on

21 December 2018 (EC, 2019a). Under the CEP, each EU member state is required to submit a National Energy and Climate Plan (NECP) proposing contributions to the EU-wide 2030 targets for energy efficiency, GHG reductions (see Chapter 3) and renewable energy (see Chapter 6). In February 2019, Luxembourg delivered its draft NECP to the EC, proposing a 2030 target of not surpassing 35.6 TWh of final energy consumption (MESP and MECSD, 2019).

On 18 June 2019, the EC published its assessment of Luxembourg's draft NECP. The EC welcomed the 2030 energy efficiency target, but requested that Luxembourg define the target as a specific value for both primary and final energy consumption and give more details on policies supporting the achievement of the target. The EC also requested a comprehensive assessment of the investments needed to achieve Luxembourg's energy sector targets (including energy efficiency), as well as information on the financial resources to be mobilised for implementing existing and planned policies and measures. Luxembourg and all other EU member states must submit their final NECPs addressing all the EC's comments by the end of 2019 (EC, 2019b). Achieving the 2030 target will require Luxembourg to deliver a notable increase in energy efficiency across all sectors.

Energy efficiency obligation

In 2015, Luxembourg introduced an EEO scheme as part of its implementation of the EED. The scheme requires electricity and gas suppliers to realise cumulative annual energy savings of 1.5% for end users through 2020, equal to a total reduction of 6 TWh of energy demand. Suppliers can meet their obligations through a limited number of standardised energy efficiency measures or through any measures that meet well-defined criteria set in the EEO regulation. Suppliers can offer these measures to any end user. Suppliers pay a maximum fine of EUR 2.00 per MWh on unfulfilled obligations and are required to meet any unfulfilled obligations within the next four years.

To date the most successful measure implemented under the EEO has been the replacement of gas and oil heaters with condensing boilers. The EEO also supported switching to efficient lighting, especially in larger functional buildings. The EEO achieved a satisfactory level of switching to high-efficiency appliances. The government has simplified EEO requirements to report savings from appliances and expects the rate of appliance switching to increase.

The government anticipated the EEO scheme would deliver 50% of the energy efficiency savings needed to achieve the 2020 target, but the scheme has consistently underperformed. Most energy suppliers indicated that they are not able to meet to EEO requirements. Some energy suppliers have created incentive programmes that provide supplier-funded subsidies to end users who invest in energy efficiency measures. These programmes require the end user to have the measure installed by a contractor trained in an approved programme.

The EEO was updated in May 2019 to improve its performance. The requirement to document the condition of a building before renovation was eliminated and now a building's age serves as a baseline for measuring energy efficiency improvements. The EEO was also amended to allow energy suppliers to meet their obligation through efficiency measures implemented in the transportation logistics sector. Despite these and other changes, several suppliers indicate that they still cannot meet their obligations. Significant changes are needed for the EEO to deliver savings in line with the 2020 and 2030 targets.

The government is determined to continue and optimise the EEO for 2021-30 in compliance with the amended EED. Planned EEO improvements include standardisation of certain efficiency measures and simplification of the calculation methodology to keep the processing effort as low as possible, and simplification of the guidelines on accountability and the calculation method for more efficiency measures. Also, the creation of new energy efficiency instruments for small and medium-sized enterprises, and large office buildings (financial de-risking instruments, transparency platform for audits and the exemplary role of public buildings) will increase the obligated suppliers' opportunities for investment in energy efficiency. The EEO target for 2021-30 will be set at 1.2-1.5% of annual savings in final energy and will cover all sectors.

The government should ensure that the updated EEO is transparent and efficient, that qualifying efficiency measures are both sufficient to support energy efficiency targets and realistic for mass implementation by the obligated suppliers, and that other efficiency programmes do not undermine end user interest in participating in the EEO.

Industry voluntary agreement on energy efficiency

In compliance with EED requirements, Luxembourg has a voluntary agreement on energy efficiency between the government and the Business Federation of Luxembourg (FEDIL). In 2017, the agreement was extended with a target to improve industry energy efficiency by 7% by 2020, based on 2014-15 average consumption (ME, 2017).

Participating companies agree to set annual energy efficiency targets and conduct yearly consultations with an EEO supplier to identify energy efficiency measures; however, the companies are not obliged to implement the identified measures. The agreement obliges companies to have internal managers responsible for improving energy efficiency and to run annual energy efficiency trainings for their employees. Before 2020, participating companies must submit a report on the efficiency measures taken and participate in an exchange of energy-saving practices organised by MyEnergy and FEDIL. Companies that achieve the requirements of the agreement are eligible for reduced energy taxes and levies.

The agreement between the government and industry has supported significant energy savings. In 2017, the 50 companies from the industrial and tertiary sectors participating in the voluntary agreement realised a total energy savings of 47 549 MWh (MyEnergy, 2019a). An extension of the agreement beyond 2020 is currently under consideration. Industry stakeholders indicated that most of the lower cost efficiency measures have been implemented and that an extension of the agreement will need to provide clear incentives for industry to invest in higher cost energy efficiency measures.

Enhanced building renovation strategy

In 2017, Luxembourg's building renovation rate was less than 1%. In compliance with EED requirements, Luxembourg released the Enhanced Building Renovation (EBR) Strategy in 2017, which aims to increase the rate and quality of renovations. The EBR identifies key barriers to renovations. The government aims to implement the EBR with a focus on extensive renovations that implement as many efficiency measures as possible, and on efficiency measures that can be easily replicated in a large number of buildings. The government will submit a revised long-term renovation strategy in line with the obligations of the EU Buildings Directive. This plan will contain new measures and an increased level of financial support.

Energy Performance of Buildings Directive

The EU Energy Performance of Buildings Directive (EPBD) (2010/31/EU) requires all buildings built in the EU after 2020 and public buildings built after 2018 to meet a nearly zero-energy building (NZEB) standard. In accordance with the directive, EU countries must draw up national plans to increase the number of NZEBs. A new version of the 2010 EPBD came into force in 2018 (2018/844/EU) and aims to accelerate the cost-effective renovation of buildings and decarbonise the EU building stocks by 2050 (EC, 2018). In line with EPBD requirements, Luxembourg issued the Grand Ducal decree of 23 July 2016 stipulating the NZEB standard is applicable for residential buildings after 1 January 2017 and for non-residential buildings after 1 January 2019. The NZEB standard also includes requirements for building incorporated renewable energy (see Chapter 6). The government plans to regularly increase the energy efficiency standard for all buildings, aiming to substantially reduce building energy consumption and increase building incorporated renewable energy by 2030.

Energy efficiency support schemes

Luxembourg has numerous support schemes to encourage residents, companies and municipalities to invest in energy efficiency measures. MyEnergy is developing a smartphone application to be released at the end of 2019 which will allow contractors to show customers what subsidies they can receive from the government and their municipality. MyEnergy's website was updated in 2017 to provide a single portal for information on all energy sector subsidies, including those supporting energy efficiency (MyEnergy, 2019b).

Prime House

Luxembourg's Prime House programme is the main support scheme for energy efficiency measures. It is managed by the Ministry of the Environment, Climate and Sustainable Development and supports energy efficiency projects that improve the long-term sustainability of residential buildings.

In January 2017, Luxembourg passed the Climate Bank and Sustainable Housing Package to support energy efficiency and renewable energy in buildings. The package extended and reformed the Prime House scheme to provide increased investment subsidies for both energy efficiency renovations and building integrated renewable energy systems (ME, 2017). The updated Prime House scheme awards investment subsidies for renovation projects in residential buildings that are more than ten years old. Subsidies are awarded on the condition that invoices for the renovation are issued between 1 January 2017 and 31 December 2020. Awarding of subsidies also requires a review by an energy consultant, who must issue a report certifying that the renovation meets all Prime House requirements (MECSD, 2017).

Prime House subsidies cover insulation of the building and upgrading of centralised or decentralised heating/cooling systems. The measures undertaken in a renovation and the performance class of the materials used determine the amount of subsidy. Additional subsidies are granted for renovations that use qualifying sustainable materials. If the building attains a thermal insulation class of C, B or A after the renovation, the amount of subsidy granted for measures implemented on the thermal envelope can be increased, under the condition that the thermal insulation has improved by at least two classes. The total amount of financial aid from Prime House subsidies is subject to technology-specific

limits per project/building that may not exceed 25-50% of the cost of the energy efficiency measures with technology-specific caps on the amount covered (MECSD, 2017).

Climate Bank

The 2017 Climate Bank and Sustainable Housing Package established the Climate Bank programme with the objective of fostering sustainable renovation of housing more than ten years old. The Ministry of Housing launched a Climate Bank programme which provides zero interest and subsidised loans to fund energy efficiency renovations that meet certain performance requirements (MyEnergy, 2019a). Climate Bank loans can be combined with the subsidy support available through the Prime House programme discussed above.

Zero interest loans are reserved for low-income households that meet socio-economic requirements in accordance with the amended Law of 25 February 1979 concerning housing assistance. Qualifying households have to repay the capital of the loan, which may not exceed EUR 50 000, and must be repaid within 15 years. The programme covers 10% of the principal amount of the loan (up to EUR 5 000) to reduce the amount to be repaid. The programme also covers various fees required to process the loan. The government fully guarantees the loan to reduce the collateral required by the issuing bank. In 2019, the following banks supported Climate Bank zero interest loans: Banque BCP, Banque and Caisse d'Épargne de l'État, International Bank in Luxembourg, BGL BNP Paribas, Fortuna Bank, and ING Luxembourg.

The Climate Bank programme also subsidises interest-bearing loans for qualifying energy efficiency projects undertaken by any natural or legal person owning a residence more than ten years old in Luxembourg. There are no income restrictions for the loan, which is limited to a principal amount of EUR 100 000 per residence, and must be repaid within 15 years. The programme provides a reimbursement of 1.5% of the principal amount of the loan up to EUR 10 000. Qualifying residents are free to take the loan from any bank.

LENOZ certification

Under the Climate Bank and Sustainable Housing Package, Luxembourg introduced a voluntary national sustainability certification scheme for residential buildings called LENOZ (Luxembourg sustainability certification). LENOZ certification, launched in 2018, requires assessment of the sustainability of a residential building based on six categories: location, society, economy, ecology, building and technology, and function (MyEnergy, 2019a).

The goal of the certification is to promote sustainability of housing and transparency in the real estate market. LENOZ certification is awarded based on a review conducted by a qualified energy consultant. To encourage households to attain a LENOZ certification, the government provides financial assistance to pay the cost of the review (EUR 1 500 for single-family houses and EUR 750 per unit in multi-family residences).

Climate Pact

In 2012, Luxembourg created the Climate Pact programme with municipalities to collaborate on energy efficiency, climate and renewable energy. Under the pact, MyEnergy provides technical advice and funding to support a broad range of climate actions, including energy efficiency projects. The pact defines 79 measures that can be undertaken by municipalities and includes a process that awards certifications to municipalities based on the number of implemented measures (PacteClimat, 2019). The

pact has been signed by all 102 municipalities and as of 2018, 88 of them had received certification (Government of Luxembourg, 2017).

Environmental Protection Fund

The Environmental Protection Fund, in place since 1999, provides investment subsidies for energy efficiency renovations of public buildings owned by municipal administrations, confederations of municipalities and public institutions under the supervision of municipalities. The fund covers installation of heat pumps and other energy-saving technologies with subsidies that vary from 30% to 50% of investment costs depending on the technology. The fund also supports the construction of DH heating networks by covering 40% of equipment and installation costs (ME, 2017).

Energy efficiency support from renewable energy programmes

Energy efficiency measures are also indirectly supported through Luxembourg's numerous renewable energy investment subsidies (see Chapter 6). These subsidies cover a range of qualifying investment costs for projects deployed by residents, companies and municipalities. Subsidies support investment in heat pumps, solar thermal, district heating and other technologies that can reduce energy demand in buildings (RES Legal, 2019a).

Luxembourg's Chamber of Trades (Chambre des Metiers) provides training programmes to certify contractors in the installation of renewable energy projects (many of these projects also reduce energy demand). The trainings cost EUR 675 per technology certification and last three or four days depending on the technology. Since 2017, installers can be certified for the following technologies: solar thermal, heat pumps, PV, and wood-fuelled stoves and boilers (RES Legal, 2019b).

Energy prices

In 2018, Luxembourg had the lowest electricity prices among its neighbouring countries. The lower prices result primarily from significantly lower taxes on electricity, especially in comparison to Germany, Luxembourg's main source of electricity imports. In 2018, natural gas prices for industry in Luxembourg were close to the median value among IEA member countries, but with one of the lowest tax rates. Luxembourg's 2018 household natural gas price was the sixth lowest among IEA member countries and was significantly lower than in the neighbouring countries. The low natural gas price for households results partly from a low tax rate of 10%.

For the second quarter of 2019, Luxembourg had the lowest price for heating oil, the seventh-lowest price for diesel and the ninth-lowest price for gasoline among IEA member countries. During the same quarter, it had the lowest diesel and gasoline prices and taxes among its neighbouring countries. The low fuel prices are mainly due to lower value-added tax and excise duties on oil products.

The low cost of energy and high purchasing power of consumers in Luxembourg creates a notable barrier to achieving the energy efficiency targets. Low energy prices reduce the financial savings that can be achieved through energy efficiency measures, reducing the interest to invest in energy efficiency. High subsidies will be needed to make efficiency investments more attractive and it is unclear whether the various energy efficiency subsidy schemes currently in place are sufficient to drive the demand reductions needed to achieve Luxembourg's energy efficiency targets.

The planned carbon tax could be used to make fossil fuels more expensive and increase the financial attractiveness of energy efficiency measures. Carbon pricing is a simple mechanism to drive investment in energy efficiency across numerous sectors to support the achievement of the energy efficiency targets and allows for a recalibration of energy efficiency subsidies to target areas where subsidies are the most effective.

The low diesel and gasoline prices are also one of the key drivers for Luxembourg's high energy consumption and CO_2 emissions, as they encourage freight trucks and the 200 000 daily foreign commuters to fuel their vehicles in Luxembourg. The government has a policy priority to reduce this fuel consumption in line with its energy efficiency and GHG emissions reduction targets. To this end, it modestly increased the excise duties on diesel by EUR 0.02 per litre and gasoline by EUR 0.01 per litre on 1 May 2019. In addition, annual vehicle registration fees and the charge paid for leasing a company car are higher for less efficient vehicles. Between February and April 2020, the government is considering another increase in excise duties of up to EUR 0.05 per litre for diesel and up to EUR 0.03 per litre for gasoline.

An inter-ministerial committee of the Ministries of Finance; the Economy; the Environment, Climate and Sustainable Development; and Energy and Spatial Planning is charged with monitoring the development of transport fuel sales, analysing the factors underlying the observed evolution, and monitoring the impact of new government measures, including the recent tax increase.

E-mobility

Luxembourg has embraced a broad e-mobility initiative aiming to reduce fuel consumption and GHG emissions of the transport sector through electrification of transport. The draft NECP aims for 49% of vehicles registered in Luxembourg to be electric vehicles by 2030. This goal is supported with EV subsidies and investment in a national EV charging network. The e-mobility initiative also supports a shift from private vehicles to electrified public transportation. Luxembourg's Strategy for Sustainable Mobility (Modu 2.0) includes a goal to increase the number of public transport users by 50% from 2017 to 2025, and defines measures to increase the level and quality of electrified public transport, e.g. investment in park and ride centres linked to a major reworking of bus and train infrastructure (MSDI, 2017). The government has a 2030 goal for RGTR, the regional bus company, to have a 100% electric bus fleet. The Modu 2.0 Strategy also includes a goal to increase private vehicle occupancy rates at peak traffic hours. These policies will likely result in a more efficient transport sector, but their contribution to meeting the energy efficiency targets needs to be determined.

Assessment

From 1990 to 2017, Luxembourg's growth in population and GDP drove an increase in total final consumption, which peaked in 2005. Since 2005, energy demand has dropped and seems to be decoupling from population and economic growth. In 2017, TFC was 11% below the 2005 peak despite increases in both population and GDP. TFC did, however, increase in 2016 and 2017 (mainly due to higher fuel sales volumes to transiting freight trucks and non-resident commuters), indicating a need for additional energy efficiency measures.

Luxembourg's 2020 energy efficiency target is driven by obligations under the EU's EED. In compliance with the EED, Luxembourg submitted its Fourth National Energy Efficiency Action Plan in June 2017, which sets a 2020 target for final energy consumption. The seventh annual EED monitoring report noted that final energy consumption was in line with the 2020 target. The report also indicated, however, that increased consumption from 2016 to 2017, mainly from diesel sales to transiting freight trucks, and continued growth in population and GDP present challenges to achieving the 2020 energy efficiency target.

Luxembourg's draft NECP proposes an ambitious 2030 energy efficiency target for final energy consumption to remain below 35.6 TWh. This target will be fixed in the finalised NECP to be submitted to the EC before 31 December 2019. Achieving the 2030 target will require sustained implementation of energy efficiency measures across all energy sectors, especially in the transport and industry sectors.

The transport sector is the largest energy consumer in Luxembourg. Almost 50% of transport TFC comes from non-residents refuelling in Luxembourg. The government has a policy priority to reduce this fuel consumption in line with its energy efficiency targets. In support of this goal Luxembourg increased diesel and gasoline excise duties on 1 May 2019 and is considering another increase between February and April 2020.

To encourage a more efficient transport sector, annual vehicle registration fees are higher for less efficient vehicles. The government has also adjusted the charge paid when leasing a vehicle, decreasing the charge for plug-in hybrid electric vehicles and other highly efficient vehicles, and increasing the charge for less efficient vehicles. In 2018, about 40% of new car registrations were company cars leased by corporations for their employees. Initial results show that the increased company car charge has encouraged the purchase of PHEVs and reduced the purchase of inefficient vehicles.

Other transport policies focus on GHG emissions, e-mobility and public transport. These policies will likely result in a more efficient transport sector, but their contribution to meeting the energy efficiency targets has not been determined. The government should determine the impact of current transport policy to see if additional measures are needed to meet the energy efficiency targets. It should also examine the energy efficiency impacts of shared mobility (e.g. car and ride sharing services) and of intelligent transportation systems like autonomous vehicles.

The inter-ministerial committee charged with monitoring the development of transport fuel sales, analysing the factors underlying the observed evolution and monitoring the impact of new government measures should examine how policies and measures related to fuel prices are contributing to the achievement of energy efficiency and other energy sector targets. It should also examine the high level of heating oil sales and see what measures can be taken to improve building energy efficiency by reducing heating oil use. Any policy changes affecting energy prices need to consider the social dimension and be crafted to ensure public acceptance.

The EEO scheme introduced in 2015 requires electricity and gas suppliers to realise cumulative annual energy savings of 1.5% for end users through 2020, equal to 6 TWh of total demand reduction. Suppliers can meet their obligations through a limited number of energy efficiency measures and can offer these measures to any end user. The government anticipated that the scheme would deliver 50% of the energy efficiency savings needed to achieve the 2020 target, but the scheme has consistently underperformed, and most energy suppliers are unable to meet the EEO demand

reduction targets. The EEO was updated recently to reduce reporting requirements and allow suppliers to meet obligations through efficiency measures implemented in the transport sector.

Despite these and other changes, the EEO is still not delivering the desired level of savings and significant changes are needed for the scheme to support achievement of the 2020 target. The government should thoroughly evaluate the scheme to assess whether current EEO measures support achievement of the 1.5% savings target. This review should examine the overall evaluation, measurement and verification process, which should be streamlined if needed. It should also look at other elements of the EEO that can impact the performance of the obliged suppliers (e.g. incentives, penalties, and cost and lost revenue recovery regimes). Allowing the trading of certificates would improve the EEO's flexibility and make it easier for all suppliers to meet their obligations.

Energy efficiency in buildings

In line with EED requirements, Luxembourg has enacted regulations requiring all new buildings to meet the nearly zero-energy building standard. The energy efficiency calculation method for non-residential buildings will be revised in 2019 to further tighten energy efficiency requirements. In 2018, Luxembourg introduced a voluntary national certification scheme for sustainability in residential buildings. These measures should help to reduce energy demand from the expected growth of new housing, but the government should determine how much they will contribute towards meeting the 2030 energy efficiency targets.

The building renovation rate in Luxembourg is low, at less than 1% in 2017. The Enhanced Building Renovation (EBR) strategy aims to increase the quality and rate of renovations. The strategy does not estimate how much building renovations can contribute to the 2020 or 2030 energy efficiency targets, but it does identify key barriers to building renovations. As of September 2019, the government had not developed any plans or programmes dedicated to increasing the renovation rate. However, it aims to implement the EBR strategy with a focus on extensive renovations that implement as many efficiency measures as possible and efficiency measures that can be easily replicated in a large number of buildings.

Prime House is the main financing instrument to support energy efficiency in residential buildings. It provides investment subsidies for renovations that meet certain energy efficiency performance criteria. Public awareness of Prime House appears too low and the level of subsidies may not be sufficient given the high cost of renovations and low energy prices in the country. The government and multiple stakeholders indicated that the Prime House programme is not delivering the desired level energy savings. Key barriers are a lack of interest in renovations due to low energy prices, the complexity of the application process and the lack of labour, which seems to be absorbed by new construction projects.

To help address some of the barriers to increasing renovation rates, MyEnergy is developing a smartphone application, which will allow contractors to show customers what subsidies they can receive from the government and their municipality. MyEnergy plans to expand the app to provide detailed information based on feedback from users.

The Environmental Protection Fund, in place since 1999, provides investment subsidies for energy efficiency renovations of public buildings owned by municipal administrations, confederations of municipalities and public institutions under the supervision of

municipalities. Energy efficiency measures are indirectly supported through Luxembourg's renewable energy support schemes which provide financial incentives for technologies such as heat pumps, solar thermal and district heating that can also reduce energy demand.

In 2017, district heating was used only in the commercial sector. However, it could also support efficient heating in residential buildings. The government should examine current district heating support measures and determine what barriers may be limiting greater use of district heating, especially in new residential developments. The industrial sector, particularly steel production, could be an excellent source of waste heat to support district heating systems. The potential of district heating using industry waste heat should be examined.

From 2007 to 2017, the commercial sector had the highest increase in energy consumption, growing 23%. The government should examine increased support for energy efficiency in commercial sector buildings. This could include expanding or adjusting existing energy efficiency programmes targeting the residential sector to include commercial buildings and/or creating programmes tailored to the commercial sector.

In order to increase the rate and quality of renovations, existing support schemes must be more attractive and administrative and regulatory processes simplified. The government should also track how renovation is contributing to the achievement of energy efficiency targets and consider initiating pilot projects where renovations are undertaken in entire neighbourhoods at one time. This could be supported through a government call for tenders that would bundle energy efficiency measures and take advantage of economies of scale.

Energy efficiency in industry

In 2017, a voluntary agreement between the government and FEDIL was extended through 2020 with a target to improve industry energy efficiency by 7%, based on 2014-15 average consumption. Participating companies agree to annual energy reduction targets and to yearly consultations with an EEO supplier. The agreement obliges companies to have internal managers responsible for improving energy efficiency and to run annual energy efficiency trainings for their employees. Before 2020, participating companies must submit a report on the efficiency measures taken and take part in an exchange of energy-saving practices organised by MyEnergy and FEDIL. Companies that achieve the requirements of the agreement are eligible for reduced energy taxes and levies.

In line with EED requirements, the Rational Use of Energy Act was amended in 2016 to require that large companies prepare an energy audit every four years. Under the voluntary agreement, companies that obtain ISO 50001 certification are exempt from this energy audit obligation. There are no data on how many companies have ISO 50001 certification and there is no obligation to report this certification. The next voluntary agreement will likely include a reporting requirement.

The voluntary agreement between the government and industry has supported significant energy savings. A third extension of the agreement is currently under consideration, which would come into force after the current agreement expires in 2020. Industry stakeholders indicated that most of the lower cost-efficiency measures have already been implemented and the next agreement will need to support higher cost energy efficiency measures with longer payback periods.

Recommendations

The government of Luxembourg should:

- Evaluate how much existing transport policies contribute to the 2030 energy efficiency target. Formulate a set of coherent measures to achieve a sustained reduction in fuel demand.
- Improve the EEO scheme by simplifying the process for obligated suppliers to validate energy savings and by reviewing which efficiency measures qualify for the scheme.
- Enhance access to Prime House renovation grants by simplifying the application process. Prime House should also support aggregation of several projects with common renovation needs under a single application.
- Create effective price signals to increase interest in energy efficiency across all sectors and to reduce the time required to see a financial return on energy efficiency investments.

References

EC (European Commission) (2019a), *Clean Energy for all Europeans Package Completed: Good for Consumers, Good for Growth and Jobs, and Good for the Planet,* EC, Brussels, https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en.

EC (2019b), *United in Delivering the Energy Union and Climate Action: Setting the Foundations for a Successful Clean Energy Transition,* EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285.

EC (2018), *New Energy Performance in Buildings Directive Comes into Force on 9 July 2018*, EC, Brussels, https://ec.europa.eu/info/news/new-energy-performance-buildings-directive-comes-force-9-july-2018-2018-jun-19_en.

EC (2012), *Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency*, EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0027.

Government of Luxembourg (2017), *Climate Pact Under the Sign of the Circular Economy*, Government of Luxembourg, Luxembourg City, http://luxembourg.public.lu/en/actualites/2018/05/30-pacteClimat/index.html.

IEA (International Energy Agency) (2019), *World Energy Balances 2019* (database), www.iea.org/statistics.

IEA (2018), *Energy Efficiency Indicators Highlights 2018* (database), www.iea.org/statistics.

ME (Ministry of the Economy) (2017), *Fourth National Energy Efficiency Action Plan*, ME, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/lu_neeap_2017_en.pdf.

MECSD (2017), *Applying for Financial Aid for Energy Efficiency Enhancement of a Residential Building (PRIMe House 2017)*, Government of Luxembourg, Luxembourg City, https://guichet.public.lu/en/citoyens/logement/renovation-transformation/performances-energie/assainissement-energetique-regime-2017.html.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and*

Climate Plan for Luxembourg, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

MSDI (Ministry of Sustainable Development and Infrastructures) (2017), *Modu 2.0 Strategy for Sustainable Mobility,* Government of Luxembourg, Luxembourg City, https://environnement.public.lu/dam-assets/actualites/2019/04/modu2-fr-brochure.pdf.

MyEnergy (2019a), *Quelles aides pour votre projet* [Available project support], MyEnergy, Luxembourg City, www.myenergy.lu/fr/particuliers/lois-et-reglements/soutien-financier#prets-climatiques.

MyEnergy (2019b), *Annual Report for the Year 2017 as Part of the FEDIL 2017-2020 Voluntary Agreement*, MyEnergy, Luxembourg City, www.myenergy.lu/uploads/editor/files/Entreprises/AV_Fedil_20172020/Bilan_FEDIL_Accord_volontaire_2017_20190325_V_Publiee.pdf.

PacteClimat (2019), *Climate Pact* (*PacteClimat*), MyEnergy, Luxembourg City, www.pacteclimat.lu/fr.

RES Legal (2019a), *Legal Sources on Renewable Energy*, EC, Brussels, www.res-legal.eu/en/search-by-country/luxembourg.

RES Legal (2019b), *Training Programmes for Installers*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/policy/aid/training-programmes-for-installers-16/lastp/163.

5. Energy research, development and demonstration

Overview

Luxembourg has a 2020 target to increase total research, development and demonstration (RD&D) spending to 2.3-2.6% of gross domestic product (GDP) in support of the EU target of dedicating 3% of EU GDP to RD&D by 2020 (EC, 2018). There is no specific target or policy for the share of funding dedicated to energy RD&D. In line with the national target, the government increased its RD&D funding from USD 114 million in 2007 to USD 311 million in 2016. However, over the same period, private sector spending on all RD&D dropped from USD 584 million to USD 330 million. The large drop in private sector spending caused total RD&D funding in Luxembourg to decline from 1.6% to 1.26% of GDP (OECD, 2019a), far short of the 2020 target.

Luxembourg does not track the share of public or private RD&D funding dedicated to energy and no government institution has responsibility or oversight of energy RD&D funding or policy. 2012 was the last year that Luxembourg reported energy RD&D funding to the IEA. In that year Luxembourg spent EUR 75 million on energy RD&D, with EUR 60 million dedicated to energy efficiency. This equalled 0.21% GDP, the highest share of spending on energy RD&D as a share of GDP among IEA member countries in 2012 (IEA, 2014). Luxembourg's energy RD&D spending in 2012 was approximately 18% of the total government and private sector RD&D spending of EUR 428 million (OECD, 2019b).

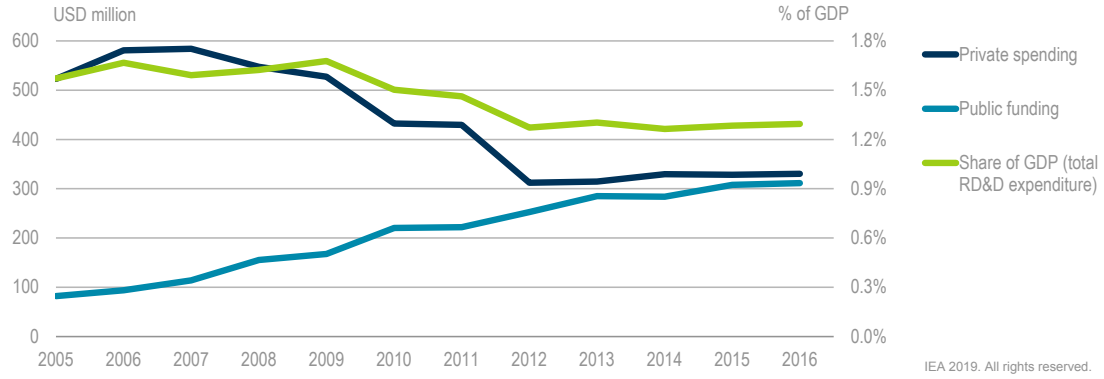
In 2018, Luxembourg ranked as an innovation leader, the top category in the European Commission (EC) European Innovation Scoreboard (FNR, 2019a). However, given its small size, Luxembourg does not possess the critical mass of researchers to engage in all areas of energy research. Luxembourg should prioritise energy RD&D areas that could be impactful in transforming Luxembourg's energy system and supporting government goals like e-mobility, variable renewable energy (VRE) integration, prosumer market participation and smart cities.

RD&D funding, policy and institutions

Luxembourg has a 2020 target to increase total RD&D spending to 2.3-2.6% of GDP (1.5-1.9% of GDP from private spending and 0.7-0.8% of GDP from public funding). This target was set to support the EU target of dedicating 3% of EU GDP to RD&D by 2020, as defined in the Europe 2020 strategy. This ten-year strategy, adopted by the EC in June 2013, includes a wide range of targets and measures supporting smart, sustainable and inclusive growth of the EU economy (EC, 2018). The government has significantly increased RD&D

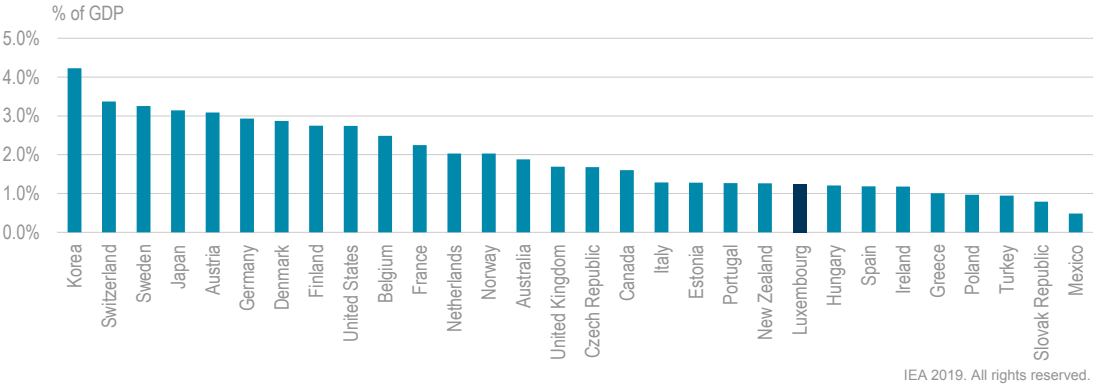
funding every year since 2005, to reach USD 311 million (0.63% of GDP) in 2016, and is close to achieving the public funding component of the 2020 target (Figure 5.1). Starting in 2007, private RD&D spending fell significantly and was flat from 2012 to 2016, when it amounted to USD 330 million (0.67 % of GDP), well short of the private RD&D component of the 2020 target. OECD data show that in 2017, total RD&D funding fell slightly to USD 651 million (1.26% of GDP), giving Luxembourg very little time to achieve the increased funding level needed to achieve the 2020 RD&D target of 2.3-2.6% of GDP. The breakdown between public and private funding is not available for 2017 (OECD, 2019a). In 2016, Luxembourg ranked 22nd among IEA member countries in the share of GDP dedicated to RD&D (Figure 5.2).

Figure 5.1 Luxembourg's RD&D expenditures, 2005-16



Source: OECD (2019b), *OECD Economic Surveys: Luxembourg 2019*, https://doi.org/10.1787/424839c1-en.

Figure 5.2 Share of GDP for RD&D in IEA member countries, 2016



Source: OECD (2019b), *OECD Economic Surveys: Luxembourg 2019*, https://doi.org/10.1787/424839c1-en.

Luxembourg does not have an explicit policy on energy RD&D. However, the Ministry of the Economy and the Ministry of Energy and Spatial Planning work closely together to align their decisions on energy-related RD&D projects. The Ministries of the Economy and of Higher Education and Research are evaluating RD&D policy in 2019 and considering adding sector-specific and mission-oriented calls for proposals to the current bottom-up approach where researchers are free to propose any topic in their funding requests. In December 2017, the Ministry of the Economy published the Research and Innovation Smart Specialisation Strategy (RIS3), which added eco-technology as one of the national economic priorities for

innovation and research. RIS3 defines eco-technology to include smart mobility solutions, intelligent energy grids, energy efficiency and renewable energy (ME, 2017).

Two main implementing bodies support RD&D in Luxembourg: the National Research Fund (Fonds National de la Recherche, FNR) and Luxinnovation. The FNR is the main source of RD&D funding in Luxembourg and supports public sector research at the University of Luxembourg and public research institutes, including the Luxembourg Institute of Science and Technology (LIST) (FRN, 2019b). Researchers can propose any research topic; the FNR's funding selection process does not consider government energy policy or goals. From 2007 to 2017, FNR annual RD&D funding increased from EUR 7.8 million to EUR 59 million per year. FNR total RD&D funding from 2014 to 2018 equalled EUR 315 million, but only 1.5% of it was dedicated to energy-related projects. The FNR indicated that this low funding rate resulted from the limited number and low quality of applications related to energy RD&D (FNR, 2019a).

Luxinnovation, the national agency for innovation and research, works closely with the Ministry of the Economy to promote RD&D by supporting start-ups, private companies and public research organisations by formulating RD&D project proposals, pre-screening project applications and providing guidance during project execution. Luxinnovation assists researchers to draft funding applications to meet the selection criteria of the Ministry of the Economy and Horizon 2020, the main EU RD&D funding programme (Luxinnovation, 2019a). Luxembourg recently expanded the list of available grant schemes and broadened Luxinnovation's role in supporting grant applications. In 2019, a third of government-funded private RD&D expenditures resulted from grants supported by Luxinnovation, considerably more than its European equivalents (OECD, 2019b). As of August 2019, Luxinnovation had supported 384 Luxembourg research organisations in retaining EUR 123 million in funding from the Horizon 2020 programme (EC, 2019).

Until October 2018, the Department of Research and Innovation in the Ministry of the Economy had the sole responsibility for co-ordinating government funding of private sector RD&D. Following the 2018 election, Luxembourg established a separate Ministry of Energy and Spatial Planning and enabled it to promote energy RD&D in the field of renewable energy and energy efficiency. Companies are free to define their RD&D objectives and submit proposals for financial support. The Ministry of the Economy assesses whether submitted projects contribute to wider goals of economic development, as formulated in Luxembourg's Third Industrial Revolution economic strategy, and comply with the EU General Block Exemption Regulation on State Aid and the promotion of RD&D (ME, 2019). The Ministry of the Economy does not explicitly record how much of its annual budget for RD&D is spent on energy projects. Nevertheless, each RD&D project related to renewable energy and energy efficiency measures is evaluated by the Ministry of Energy and Spatial Planning before a formal decision is taken to fund the project by the State Aid Commission and the Ministers of the Economy and Finance.

Government funding of private RD&D is allocated based the Law of 17 May 2017 on the promotion of research, development and innovation and the Law of 15 December 2017 on environmental protection (Luxinnovation, 2019b). The Law of 15 December 2017 on environmental protection is geared towards investment projects including demonstration projects, for example small-scale biomass gasification. These laws call for private RD&D funding to be allocated as cash grants (non-refundable capital aid), corresponding to a percentage of eligible costs based on the size of the company applying for aid. RD&D costs can be co-financed 15-80% by the government, with the higher levels of funding

prioritised for smaller companies. The laws define the following funding regimes: 1) the FIT4 programme to improve small and medium-sized enterprise (SME) performance and competitiveness through innovation projects; 2) innovation aid covering up to 50% of external services/consulting linked to SME innovation activities; 3) research, development and innovation projects aiming to develop new products/services; and 4) environmental protection projects. The selection criteria established in the laws allow for examination of various impacts/benefits, such as economic, innovation, environmental, energy efficiency and sustainability potential. Every project is evaluated on its own merits (Government of Luxembourg, 2019).

In 2008, Luxembourg introduced a tax-related RD&D incentive that provides an 80% tax exemption on qualifying income associated with RD&D, e.g. patent or other forms of knowledge capital. This incentive did not lead to increased private RD&D spending. While the exemption was restricted to companies operating in Luxembourg, it was not required for RD&D spending to take place in Luxembourg to qualify for the tax exemption. In April 2018, the incentive was amended to provide tax relief only in relation to RD&D spending in Luxembourg (Draft Law No. 7163) (OECD, 2019b).

Without increased private sector spending on RD&D, Luxembourg will likely not achieve its 2020 RD&D funding target of 2.3-2.6% of GDP. To boost private RD&D spending, Luxembourg could consider introducing expenditure-based RD&D tax incentives. This would encourage increased RD&D spending by a wider range of companies, especially SMEs that are not well positioned to benefit from income-based RD&D tax incentives. Expenditure-based tax incentives can account for the increased risks associated with RD&D undertaken by SMEs, and support SMEs and start-ups that may lack the financial resources to sustain RD&D projects to completion (OECD, 2019b). The current RD&D tax relief system should be examined to determine how it could support RD&D funding targeted at Luxembourg's energy policy goals.

International collaboration

Through Luxinnovation, Luxembourg participates in projects funded by European networks dedicated to RD&D, such as the European Space Agency and the intergovernmental initiative EUREKA. Luxembourg also has strong bilateral RD&D co-operation with Austria, Belgium, France, Germany, Switzerland and other countries and participates in three EU-funded transnational Interreg programmes, namely Interreg NorthWestEurope, Interreg Europe and Interreg Grande Région. The main goal of this transnational collaboration is to foster territorial cohesion by sharing knowledge and technologies with other EU countries. The government should use these collaborative partnerships to leverage the energy-related RD&D experience of the partner countries and institutions, especially in areas relevant to government policy goals where domestic RD&D expertise is limited.

Energy RD&D projects

Luxembourg supports numerous energy-related RD&D projects. The FNR supports energy RD&D research at the University of Luxembourg and LIST. The University of Luxembourg's Interdisciplinary Centre for Security, Reliability and Trust has a partnership with Creos (the electricity transmission system operator) and conducts research on smart

grid infrastructure, security of critical energy infrastructure, and smart and energy-efficient buildings and cities (UL, 2019a). The University of Luxembourg's Photovoltaics (PV) cluster, within the Physics and Materials Science Research Unit, conducts RD&D on PV material properties and thin film PV cells (UL, 2019b). The University of Luxembourg also co-operates with LIST on research on energy contained in wastewater and biomass.

The LIST Sustainable Energy Systems research group conducts RD&D on modelling tools (e.g. model-based control of grid integration measures); and performs simulation-based tests of new business models for demand-side flexibility, energy storage or virtual power plants, and data-driven learning algorithms (e.g. to valorise smart meter data). LIST is also conducting research related to bioenergy (LIST, 2019). Luxembourg has supported energy-related RD&D projects, including co-financing of a project with Kronospan Luxembourg S.A. to transition the company's wood products factory from natural gas to biomass (Government of Luxembourg, 2017).

Current energy RD&D projects cover a wide range of topics, including some that are relevant to government energy policies and goals. However, the FNR has noted that energy-related research capacity in Luxembourg is scattered across numerous institutions, without a discernible strategic focus on a national scale. It is also not clear if existing energy RD&D is being applied in Luxembourg's energy sector, especially in relation to high-impact pilot projects or key energy polices like e-mobility (see Chapter 7) and prosumer market participation. RD&D funding could be guided in a strategic manner to researchers, SMEs and starts-ups developing new products and services that support the transformation of Luxembourg's energy system.

Assessment

Luxembourg should consider creating an inter-ministerial structure to set energy-related RD&D priorities. Co-ordination of energy-related RD&D should be linked to policy priorities and focus on topics where the country can make a difference, taking into account its small research community and existing areas of expertise. The Third Industrial Revolution concept could be a guiding principle and give preference to research into integration of renewables, smart and flexible operation of the energy system, e-mobility and new transportation concepts. With co-ordinated direction of energy RD&D, Luxembourg could serve as a testbed for smart city concepts.

The review of RD&D policy being undertaken by the Ministries of the Economy, of Energy and Spatial Planning, and of Higher Education and Research should examine options for funding processes that would give more visibility and priority to supporting government energy policy and goals. This could include the introduction of calls for proposals implemented by the FNR and Luxinnovation to stimulate public-private collaboration in energy RD&D. The addition of eco-technology as a priority sector in RIS3 provides the government with a chance to incorporate energy RD&D funding into current selection processes.

Luxembourg is not participating in any of the IEA technology collaboration programmes. It is also not part of Mission Innovation nor the Clean Energy Ministerial. The government should consider participation in these innovation fora as they could support collaboration with experts in areas relevant to Luxembourg's energy policy goals, e.g. e-mobility, VRE integration, prosumer market participation and smart cities.

The IEA noted a lack of co-ordination between academic and applied research, and little attention to the benefits that start-ups and deployment projects can bring in relation to energy policies and goals. As a result, a few large incumbent companies dominate the energy sector as a whole, especially in areas related to renewables and energy efficiency, where notable innovation and new services are needed to achieve the government's targets. There is a risk that the newest technologies will have difficulties finding their way to market and that government tenders for renewable energy deployment attract a limited number of bidders, resulting in high operational aid (feed-in tariffs).

Recommendations

The government of Luxembourg should:

- Collect detailed data on energy RD&D spending by topic, from both the public and private sectors.
- Promote synergies between fundamental and applied research, and deployment of new technologies, to maximise the benefits of RD&D spending.
- Further promote RD&D funding programmes with regards to energy and climate policies of the government.
- Seek international leadership in developing market integration and prosumer concepts for smart cities, where all kinds of energy-related data assist people in energy-efficient behaviour at home, in transport and at work.

References

EC (European Commission) (2019), *Luxembourg Horizon 2020 Country Profile*, EC, Brussels, https://webgate.ec.europa.eu/dashboard/extensions/CountryProfile/CountryProfile.html?Country=Luxembourg.

EC (2018), *Smarter, Greener, More Inclusive? Indicators to Support the Europe 2020 Strategy – 2018 Edition*, EC, Brussels, https://ec.europa.eu/eurostat/documents/3217494/9087772/KS-02-18-728-EN-N.pdf/3f01e3c4-1c01-4036-bd6a-814dec66c58c.

FNR (National Research Fund) (2019a), *Research in Luxembourg*, FNR, Luxembourg City, www.fnr.lu/research-in-luxembourg.

FNR (2019b), *What We Do*, FNR, Luxembourg City, https://www.fnr.lu/what-we-do.

Government of Luxembourg (2019), *General Terms and Conditions Applicable to All Financial Aid for Research, Development and Innovation,* Government of Luxembourg, Luxembourg City, https://guichet.public.lu/en/entreprises/financement-aides/aides-recherche-developpement/rdi/conditions-generales-aides-rdi.html.

Government of Luxembourg (2017), *Excellence in Transforming Wood,* Government of Luxembourg, Luxembourg City, https://gouvernement.lu/dam-assets/fr/actualites/communiques/2017/05-mai/19-cdp-schneider/PresentationKronospan.pdf.

IEA (International Energy Agency) (2014), *Energy Policies of IEA Countries: Luxembourg 2014 Review*, IEA, Paris, www.iea.org/publications/freepublications/publication/Luxembourg2014.pdf.

LIST (Luxembourg Institute of Science and Technology) (2019), *Sustainable Energy Systems*, LIST, Luxembourg City, www.list.lu/en/research/erin/environmental-sustainability-assessment-and-circularity/group/sustainable-energy-systems-group.

Luxinnovation (2019a), *About Luxinnovation,* Luxinnovation, Luxembourg City, www.luxinnovation.lu/about-luxinnovation.

Luxinnovation (2019b), *Funding Criteria,* Luxinnovation, Luxembourg City, www.innovation.public.lu/en/financer/competitivite/grants/principes-generaux/index.html.

ME (Ministry of the Economy) (2019), *Financial Aid for Research and Development Projects*, ME, Luxembourg City, https://guichet.public.lu/en/entreprises/financement-aides/aides-recherche-developpement/rdi/aides-rdi.html.

ME (2017), *Research and Innovation Smart Specialisation Strategy (RIS3)*, ME, Luxembourg City, https://meco.gouvernement.lu/dam-assets/publications/rapport-etude-analyse/minist-economie/ris3/luxembourg-research-and-innovation-smart-specialisation-strategy-2017.pdf.

OECD (Organisation for Economic Co-operation and Development) (2019a), *Gross Domestic Spending on R&D*, OECD, Paris, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm.

OECD (2019b), *OECD Economic Surveys: Luxembourg 2019*, OECD Publishing, Paris, https://doi.org/10.1787/424839c1-en.

UL (University of Luxembourg) (2019a), *Interdisciplinary Centre for Security, Reliability and Trust,* UL, Luxembourg City, wwwen.uni.lu/research/focus_areas/interdisciplinary_centre_for_security_reliability_and_trust_snt.

UL (2019b), *Physics and Materials Science Research Unit,* UL, Luxembourg City, wwwen.uni.lu/research/fstc/physics_and_materials_science_research_unit

6. Renewable energy (focus area)

Key data (2018 provisional)

Total supply: 0.29 Mtoe (7.5% of TPES) and 0.67 TWh (71.0% of electricity generation)

IEA average: 9.9% of TPES and 24.6% of electricity generation

Bioenergy and renewable waste: 0.25 Mtoe (6.4% of TPES) and 0.22 TWh (23.2% of electricity generation)

Wind: 0.02 Mtoe (0.5% of TPES) and 0.25 TWh (26.1% of electricity generation)

Solar: 0.01 Mtoe (0.3% of TPES) and 0.11 TWh (12.0% of electricity generation)

Hydro: 0.008 Mtoe (0.2% of TPES) and 0.09 TWh (9.9% of electricity generation)

Overview

The steady growth of renewable energy in Luxembourg is reducing greenhouse gas (GHG) emissions and increasing energy security. The share of renewables in total primary energy supply (TPES) more than doubled from 2008 to 2018, from 3.3% to 7.5%. Despite these gains, Luxembourg has one of the lowest shares of renewable energy in TPES among IEA member countries due to its extremely high energy demand in the transport sector (see Chapter 8). In 2018, Luxembourg's renewable energy supply came mostly from imported biofuels used in the transport sector and domestic sourced primary solid biofuels supporting heat production and electricity generation.

Renewable energy is the main source of domestic electricity supply, accounting for 71% of Luxembourg's electricity generation in 2018. From 2008 to 2018, there was rapid growth in generation from bioenergy (213% increase), wind (302% increase) and photovoltaics (PV; 460% increase). However, domestic generation covered only 14% of electricity consumption in 2018 and Luxembourg remains dependent on imported electricity.

In 2017, renewable energy covered 6.38% of Luxembourg's gross final energy consumption. Luxembourg will use renewable energy statistical transfers from Estonia and Lithuania under the EU co-operation mechanisms to cover any gap between domestic renewable consumption and the 2020 target of 11% renewables in gross final consumption.

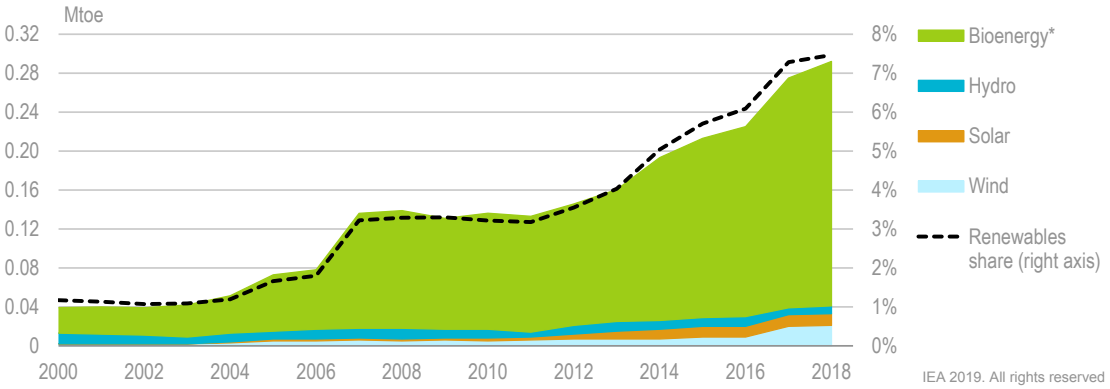
For 2030, Luxembourg has a target of 23-25% renewables in gross final consumption. Achieving this target requires a notable increase in the pace of renewable energy deployment. Luxembourg should develop scenarios supporting achievement of the 2030 renewable energy target and conduct a review of its renewable energy support schemes to see if government backing for renewables can be more effectively and efficiently targeted to drive the needed pace of renewables deployment.

Supply and demand

Renewable energy in TPES

The total supply of renewable energy in Luxembourg more than doubled from 2008 to 2018, from 0.14 to 0.29 million tonnes of oil equivalent (Mtoe) to reach 7.5% of TPES (Figure 6.1). Most of the growth in renewables came from increased use of bioenergy. In 2018, bioenergy accounted for 86% of renewable energy supply, with small contributions from wind (7.2%), PV (4.1%) and run of river hydro (2.7%).

Figure 6.1 Renewable energy and waste in TPES, Luxembourg, 2000-18



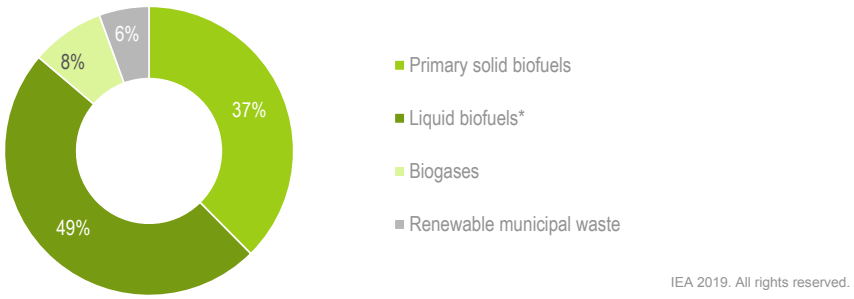
* *Bioenergy* includes solid primary biofuels, liquid biofuels, biogases and renewable municipal waste.

Notes: Mtoe: million tonnes of oil equivalent. TPES includes thermal losses for bioenergy used in combined heat and power plants (CHP). Data for 2018 are provisional.

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

In 2018, 49% of the bioenergy supply came from liquid biofuels used in the transport sector (Figure 6.2). Biofuels blended into diesel and gasoline covered 5.5% of transport sector energy demand in 2017; all biofuels are imported. Other bioenergy resources are domestically produced and include primary solid biofuels, which represented 37% of the bioenergy supply in 2018 and supported electricity generation and heat production in CHP plants. Small contributions also come from domestic renewable waste (6%) and biogas (8%).

Figure 6.2 Bioenergy supply by source, Luxembourg, 2018



* Liquid biofuels consist mainly of biodiesel and some biogasoline.

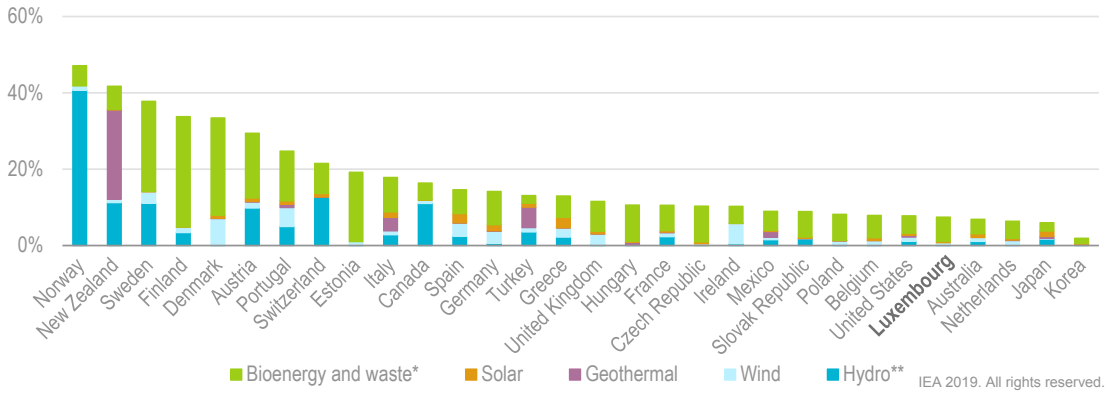
Notes: Total supply of bioenergy was 0.25 million tonnes of oil equivalent (Mtoe). In addition, there was 0.04 Mtoe of non-renewable municipal and industrial waste in Luxembourg's total primary energy supply in 2018. Data are provisional.

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

From 2008 to 2018, Luxembourg's biogas production increased by 169% to reach 3% of the total natural gas supply. Most biogas is consumed at the production site to fuel CHP plants or support the operation of wastewater treatment plants. Since 2011, a small share of biogas is upgraded to biomethane and injected into the natural gas grid. In 2018, grid-injected biomethane accounted for 0.7% of total natural gas consumption.

Despite the rapid growth of renewables in the last decade, Luxembourg's share of renewable energy in TPES was the fifth lowest among all IEA member countries in 2018 (Figure 6.3).

Figure 6.3 Renewable energy as a share of TPES in IEA member countries, 2018



* Includes solid biofuels, renewable waste, liquid biofuels and biogases.

** Includes hydropower (excluding pumped storage) and tidal, wave and ocean energy.

Note: Data are provisional.

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

Electricity from renewable energy

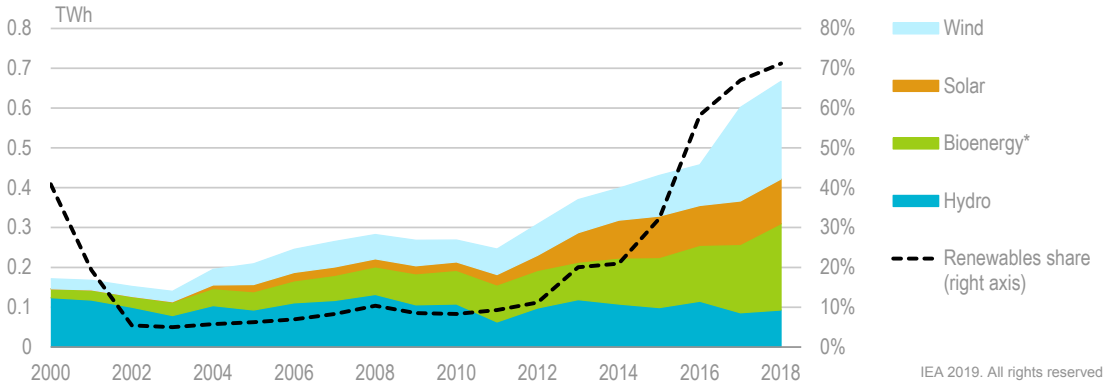
From 2008 to 2018, electricity generation from renewables increased from 0.28 terawatt hours (TWh) to 0.67 TWh and accounted for 71% of domestic generation[1] (Figure 6.4). However, domestic electricity accounted for only 14% of electricity demand in 2018 and Luxembourg remains reliant on electricity imports.

Generation from wind increased by 302% over the period 2008-18 to become the largest source of domestic electricity at 0.25 TWh and 26% of generation. Most of this growth occurred in 2017 when wind generation more than doubled, from 0.1 TWh to 0.23 TWh, with the commissioning of 60 megawatts (MW) wind capacity at the end of 2016. The growth in wind generation is partly due to repowering of existing wind farms and to the installation of new turbines in 2015 and 2016. Generation from bioenergy more than doubled over the same period and accounted 0.22 TWh (23% of generation) in 2018. Solid primary biofuels are the largest source of generation from bioenergy (10% of generation), followed by biogas (8%) and renewable municipal waste (5%). In contrast to wind, the growth in electricity from bioenergy has been relatively steady, with notable

[1] The fluctuation of renewable energy share in Luxembourg's electricity generation from 2000 to 2018 was driven primarily by the Twinerg natural gas plant, which entered operation in 2002 and was decommissioned in 2018. While in operation, this plant was often responsible for 90% or more of Luxembourg's domestic electricity generation (see Chapter 7).

increases every year from 2008 to 2018. This growth comes from the installation of new biomass CHP plants and the conversion of existing natural gas CHP plants to biomass.

Figure 6.4 Renewable energy in electricity generation, Luxembourg, 2000-18



* *Bioenergy* includes solid primary biofuels, liquid biofuels, biogases and renewable municipal waste.

Notes: TWh: terawatt hour. Data for 2018 are provisional.

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

PV was the fastest growing source of renewable generation over the period 2008-18, increasing by 460% to reach 0.11 TWh (12% of generation). The majority of the increase in PV generation occurred from 2012 to 2014, when it jumped from 0.038 TWh to 0.095 TWh, with only a slight increase since 2014. Run of river hydropower accounted for 0.09 TWh[2] and 10% of generation in 2018. Hydro generation has been relatively flat, averaging 0.1 TWh over the same period, and is not expected to grow significantly as the hydro resource potential is already almost fully exploited.

In 2017, Luxembourg had 442 MW of installed generation capacity, 65% of which was variable renewable energy (VRE) generation (wind, PV and run of river hydro) (Table 6.1). From 2007 to 2017, wind and PV capacity increased rapidly: wind grew from 40 MW to 121 MW and PV from 20 MW to 130 MW. Run of river hydropower capacity was stable at 38 MW. The 12 MW of biogas capacity comes from CHP plants using biogas produced from biomass, including the biodegradable fraction of waste from agriculture, silviculture and viticulture, along with biodegradable industrial and municipal waste and sewage sludge. The 21 MW of waste incineration capacity comes from a single CHP plant operated at Sidor, Luxembourg, which burns renewable and non-renewable waste (Creos, 2018).

CHP plants had 106 MW of capacity in 2017. Since 2003, CHP plants have been transitioning from natural gas to biomass. The Grand Ducal Regulation of 26 December 2012 on the generation of electricity based on high-efficiency cogeneration set a 2015 end date for a feed-in tariff supporting natural gas CHP. Qualifying natural gas CHP installations built before 2015 will continue to receive the feed-in tariff for a total period of 20 years (Government of Luxembourg, 2012). The government expects that whenever possible, remaining gas CHP plants will be converted to biomass and use of waste heat.

[2] The 0.09 TWh of hydropower generation includes only net generation from run of river hydropower plants. The pump-storage hydropower facility at Vianden, Luxembourg is excluded from these numbers as it is not a source of net generation and does not directly participate in Luxembourg's electricity system (see Chapter 7).

Table 6.1 Installed electricity generation capacity, Luxembourg, 2014-17

Megawatt (MW)				
	2015	**2016**	**2017**	**2018**
Photovoltaics	116	122	128	131
Wind	64	120	120	123
Hydro	33	34	35	34
Biomass	2	4	15	15
Biogas	12	12	12	12
Waste	17	17	17	17
Combined heat and power	480*	104	99	93
Total	**724**	**413**	**426**	**425**

* The 375 MW Twinerg combined cycle gas turbine, Luxembourg's largest natural gas combined heat and power plant, was permanently closed in 2016 (see Chapter 7).

Source: ILR (2019), *Key Figures of the Electricity Market Year 2018 – Part I,* https://assets.ilr.lu/energie/Documents/ILRLU-1685561960-667.pdf.

Institutions

The Ministry of Energy and Spatial Planning has most of the responsibility over renewable energy policy. Within the ministry, the Department of Energy formulates policies on renewable energy. Some responsibilities for renewable energy policies are shared with the Ministry of the Environment, Climate and Sustainable Development, which manages the system supporting private and municipal renewable energy investments. The Ministry of Mobility and Public Works is responsible for transportation policy, which plays an important role in relation to Luxembourg's renewable energy targets and policy.

MyEnergy is a public organisation under the authority of the Ministry of Energy and Spatial Planning; the Ministry of the Environment, Climate and Sustainable Development; and the Ministry of Housing. MyEnergy promotes awareness of renewable energy policy and provides information on renewable energy-related subsidies (including the Prime House programme, see below) to facilitate investments in renewable energy by all market participants.

Ownership of renewable generation assets in Luxembourg is concentrated among just a few companies. Enovos owns and operates the majority of domestic wind, PV, run of river hydro and CHP assets through direct ownership, controlling shares of the company Luxenergie and a 50% share in the company Soler, a joint venture with Société Électrique de l'Our S.A. (SEO) (Enovos, 2019). SEO separately operates the rest of the run of river hydro plants in Luxembourg (SEO, 2019).

Policy

Renewable energy targets

European Union (EU) directives are key drivers of Luxembourg's renewable energy targets and policy. Table 6.2 gives Luxembourg's 2020 and 2030 renewable energy targets and the 2017 status towards achieving these targets.

Table 6.2 Luxembourg's renewable energy targets, 2020 and 2030, and 2017 status

Renewable share by sector (%)	2017	Targets	
		2020	2030
Gross final consumption	6.38%	11%	23-25%
Electricity	8.05%	11.8%	33.6%
Heating and cooling	8.11%	8.5%	30.3%
Transport	6.44%	10%	25.9% (10% from biofuels)

Sources: MEFT (2010), *National Renewable Energy Action Plan*, https://www.iea.org/policiesandmeasures/pams/luxembourg/name-39515-en.php; MESP and MECSD (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

Luxembourg's 2020 renewable energy targets were set by the first EU Renewable Energy Directive (RED I), which established mandatory targets for each EU member state (EC, 2010). Luxembourg's National Renewable Energy Action Plan (NREAP) details the policies and measures supporting achievement of the 2020 targets (MEFT, 2010). RED I requires biannual reporting to the European Commission (EC) on progress towards the 2020 targets. Luxembourg will meet its overall 2020 target of 11% renewables in gross final consumption. In 2017, renewable energy covered 6.38% of gross final energy consumption and the remaining gap to reach the 2020 target will be covered through statistical transfers under the EU co-operation mechanisms.

In October 2017, Luxembourg and Lithuania became the first EU member states to sign an agreement on statistical transfers of renewable energy, one of the co-operation mechanisms established under the EU Renewable Energy Directive (EC, 2017a). The agreement covers 2018-20 and allows Luxembourg to purchase surplus renewable energy statistics from Lithuania, which has exceeded its 2020 renewable energy target. Transfers conducted under the agreement count towards Luxembourg's 2020 renewable energy target. In November 2017, Luxembourg and Estonia signed the second-ever agreement on statistical transfers, also covering 2018-20, and allowing Luxembourg to purchase surplus renewable energy statistics (EC, 2017b). In 2018, Luxembourg used statistical transfers from Estonia and Lithuania to comply with the 2017-18 EU-mandated renewable energy indicative trajectory. Luxembourg will use statistical transfers to meet its 2020 renewable energy target.

Luxembourg's 2030 renewable energy targets are derived from the EU Clean Energy Package (CEP), which set an EU-wide 2030 target to achieve a 32% share of renewable energy in EU gross final consumption along with EU-wide targets for GHG reductions and energy efficiency (EC, 2019a). The CEP does not define country-specific targets. Instead, each EU member state is required to submit a National Energy and Climate Plan (NECP) proposing contributions to the EU-wide 2030 targets for renewable energy, GHG reductions (see Chapter 3) and energy efficiency (see Chapter 4). In February 2019, Luxembourg delivered its draft NECP to the EC, proposing a 2030 target of 23-25% renewable energy in gross final consumption. The draft NECP indicates that 19.8% of gross final consumption would come from domestic renewables and EU flexible collaboration mechanisms would cover the remaining share of the 23-25% target (MESP and MECSD, 2019).

EU co-operation mechanisms include statistical transfers as well as jointly funded renewable energy projects and jointly funded renewable energy support schemes (EC, 2019b). The updated EU Renewable Energy Directive (RED II) established additional co-operation mechanisms to assist EU member states in achieving their 2030 renewable energy targets in a cost-effective manner. RED II maintained bilateral statistical transfers, but established the European Union Renewable Energy Platform as an additional option for the multilateral exchange renewable energy statistics between EU member states. RED II also calls for the establishment, by 2021, of the Renewable Energy Financing Mechanism, which would contribute funding to cost-efficient renewable energy projects across the EU to close any gaps in achieving the 2030 EU-wide renewable energy target. Luxembourg plans to use statistical transfers as available to support achievement of its 2030 renewables target, but aims to deepen co-operation with other EU member states on deployment of joint renewable energy projects.

On 18 June 2019, the EC published its assessment Luxembourg's draft NECP. The EC welcomed Luxembourg's renewable energy targets, but requested more detail on policy measures to support achievement of the targets and a clear indication of how the 2020 target of 11% renewables in gross final consumption will be maintained as a baseline for achieving the 23-25% target for 2030. The EC noted the need for an indicative trajectory of renewables deployment that meets EU reporting requirements and details on measures to meet the renewables target for transportation. It also requested clarification on the frameworks for self-consumption of renewable electricity and energy communities (EC, 2019c).

The EC also requested a comprehensive assessment of the investment needed to achieve Luxembourg's energy sector targets (including renewable energy) as well as information on the financial sources to be mobilised for implementing existing and planned policies and measures. Luxembourg and all other EU member states must submit their final NECPs addressing the EC's comments by the end of 2019 (EC, 2019c).

Achieving the 2030 targets will require a notable increase in the pace of renewable energy deployment in all sectors. Luxembourg should develop clear scenarios on renewable energy deployment that support the ambitious 2030 renewable energy target.

Renewable energy support mechanisms

Luxembourg has numerous measures supporting deployment of renewable energy projects. The majority of these measures target electricity generation from renewables, including a feed-in tariff, premium tariff, investment subsidies, tenders for PV projects and a tax exemption for self-consumption of electricity from renewables. Some of these mechanisms also indirectly support renewable energy in heating by encouraging CHP plants based on renewable energy. The government also directly supports renewable energy in heating and cooling with a number of investment subsidies. Luxembourg has a biofuels quota supporting renewable energy in transport. The e-mobility initiative also aims to increase the renewable energy share in transport through electric vehicles (EVs) and electrified public transportation powered with electricity from renewable energy (RES Legal, 2019a).

Luxembourg should conduct a review of its renewable energy support schemes to see if government backing for renewables can be more effectively and efficiently targeted to drive the needed pace of renewables deployment. The impact of existing measures should be evaluated to see if they have been effective and newly introduced measures need to

be monitored to determine if they are driving the needed level and type of renewables deployment. Reducing/streamlining the large number of renewable support schemes would result in a simpler/more coherent system that would be easier to manage, monitor, and explain/promote to residents and companies receiving support.

A review of subsidies could also examine the upcoming introduction of carbon pricing, which would drive deployment by making renewables more cost competitive versus traditional fossil fuel options. Carbon pricing could also offer a simple mechanism to drive behaviour that supports achievement of the renewable energy targets and allow a recalibration of the current support schemes to areas where subsidies are the most effective.

Support for renewables in electricity generation

The Grand Ducal Regulation of 1 August 2014 on the production of electricity based on renewable energy sources established a feed-in tariff that supports generation from wind, PV, hydro, biogas and biomass. The tariff paid to a renewable generation asset depends on the technology and the year of commissioning, with tariffs set annually according to formulas accounting for changes in technology cost (Government of Luxembourg, 2014).

For projects commissioned in 2019, feed-in tariffs were EUR 91-92 per MWh for wind, EUR 151-165 per MWh for PV, EUR 152-191 per MWh for biogas, EUR 124-179 per MWh for hydro and EUR 80-162 per MWh for biomass. Smaller capacity projects receive higher tariffs; projects above certain capacities are not eligible for the feed-in tariff (500 kW for PV, 2.5 MW for biogas, 6 MW for hydro, and no limit for wind and biomass). The feed-in tariff is guaranteed for 15 years (20 years for biogas in special cases) and is funded via a surcharge paid by all electricity customers. The government needs to ensure that feed-in tariffs offer a clear incentive to drive investment at a level that will meet 2030 targets. However, feed-in tariffs should be adjusted on a regular basis to reflect declining renewable deployment costs and ensure efficient use of government funds.

Growth in PV generation has slowed notably since 2014. In May 2019, Luxembourg raised the feed-in tariffs for PV to accelerate deployment of distributed PV systems with capacities of 500 kilowatt (kW) or less. Tariffs for PV generation increased by 11-36%, with systems below 10 kW receiving the highest increase. In addition, new feed-in tariffs were created for PV systems of 30-500 kW deployed by co-operatives (RES Legal, 2019b).

In 2016, Luxembourg introduced a premium tariff supporting generation from wind, PV, hydro, biogas and biomass. The premium tariff applies in cases of direct sales of electricity produced from renewable energy sources. The premium tariff is mandatory for renewable installations above 500 kW and optional for installations between 200 kW and 500 kW, which may choose the feed-in tariff. For wind parks, the premium tariff is mandatory for projects with three or more turbines or if the project capacity is equal to or above to 3 MW. Wind projects below these limits may choose the feed-in tariff.

In contrast to the feed-tariff, the premium tariff provides some incentive for plant operators to respond to market conditions. The amount of the premium tariff (PT) results from the sum of the direct sales (PVD) and the difference between a technology-specific reference

remuneration (PRR) and the monthly market price (PMM[3]): PT = PRR – PMM + PVD. The PRR is adjusted on annual basis to account for changes in technology costs.

For 2019, the PRR was EUR 91 per MWh for wind, EUR 125/MWh for PV, EUR 152-178/MWh for biogas, EUR 124-178/MWh for hydro and EUR 117-161/MWh for biomass. The PRR is higher for smaller capacity projects; projects above certain capacities are not eligible for the premium tariff (200 kW for PV, 2.5 MW for biogas, 6 MW for hydro, and no limit for wind and biomass). The premium tariff is guaranteed for 15 years (RES Legal, 2019c). The feed-in premium is funded via the same surcharge paid by all electricity customers that is used to fund the feed-in tariff.

In 2018, the government issued its first tender for renewable energy projects, requesting bids for 20 MW of PV capacity. The bids were restricted to PV projects with a capacity greater than 500 kW deployed on industrial sites and buildings. The tender resulted in eight proposed projects with a total capacity of 15 MW. The average bids for premium tariffs were EUR 89/MWh for PV on industrial sites and EUR 120/MWh for PV on buildings. Once commissioned these projects will receive 15-year contracts with payment for generated electricity based on the premium tariff. The majority of the 15 MW awarded in the 2018 tender went to a single company, with certain projects planned as joint ventures.

The government issued a PV tender in 2019 for 40 MW of capacity and plans to define a strategy for yearly PV tenders with increasing capacity so that about 100 MW per year will be installed from 2025 onwards. The government should evaluate the tender process and look at ways to increase competition on PV projects to ensure that future tenders result in competitive bids that reflect falling PV deployment costs.

Since 2017, PV systems of up to 30 kW installed on private homes are eligible for an investment subsidy under the government's Prime House support scheme. The subsidy covers 20% of system costs, subject to a cap of EUR 500 per kW of system capacity (equal to EUR 15 000 for the maximum capacity of 30 kW) (RES Legal, 2019d). Since 1999, there has been a PV investment subsidy covering 50% of equipment and installation costs for PV systems installed by municipal governments (RES Legal, 2019e).

Luxembourg also has investment subsidies for renewable energy projects deployed by companies in the commercial sector (since 2004) and the industrial sector (since 2017). These subsidies support wind, hydro, geothermal, biogas and biomass projects and cover 40-65% of eligible project costs (in conformity with European State aid regulations) subject to caps. The exact amount depends on numerous factors, including the technology and the size project and the company; higher rates are paid to smaller companies. All renewable energy investment subsidies are funded by the government and managed by the Ministry of the Economy in co-operation with the Ministry of Energy and Spatial Planning (RES Legal, 2019f; 2019g; 2019h).

According to the Grand Ducal Regulation of 1 August 2014 on the production of electricity based on renewable energy sources and the Law of 15 December 2017 regulating investment subsidies for the protection of the environment, eligible renewable energy projects can receive both investment subsidies and the feed-in tariff or premium tariff.

[3] The market price (PMM) is based on the MW Epex value, which represents the average value of hourly contracts concluded for each renewable technology on the spot market of the EPEX Spot SE electricity exchange.

In 2018, the government introduced a law to support self-consumption of renewable electricity and encourage active market participation by consumers. Under the new law, the portion of renewable generation self-consumed at the generation site will be exempt from grid fees and taxes.

Support for renewables in heating and cooling

The Grand Ducal Decree of 23 July 2016 stipulates that from 1 January 2017 onwards, new buildings in Luxembourg must meet a Nearly Zero Energy Building (NZEB) standard (Government of Luxembourg, 2016). Renewable energy used for hot water and space heating and cooling can contribute to meeting the NZEB standard. Support for renewables in heating and cooling in Luxembourg comes from four investment subsidies that are funded by the government and cover municipalities and the residential, commercial and industrial sectors (Res Legal, 2019i).

The Prime House investment subsidy scheme supports renewables in heating and cooling in the residential sector. The subsidy covers air and ground source heat pumps as well as solar thermal installations and wood-burning boilers. The level of support depends on the technology and type of residence and ranges from 25% to 50% of total costs with caps of EUR 2 500-30 000 for systems installed between 1 January 2017 and 31 December 2020 (RES Legal, 2019j).

Since 2017, deployment of renewable heating and cooling in the industrial sector has been supported by an investment subsidy covering biogas, biomass, geothermal, solar thermal and water-sourced heat pumps. Air-sourced heat pumps are excluded. The subsidy covers 45-65% of eligible investment costs depending on the technology and the size of the company; smaller companies receive higher subsidies (RES Legal, 2019k).

Since 2004, deployment of renewable heating and cooling in the commercial sector has been supported by an investment subsidy covering biogas, biomass, geothermal, solar thermal, and water- and air-sourced heat pumps. The subsidy covers 40-50% of investment costs depending on the size of the company; smaller companies receive a higher subsidy. An additional 10% subsidy is available if the project allows for self-sufficient supply of heating or cooling (RES Legal, 2019l).

Since 1999, Luxembourg has supported municipal governments with an investment subsidy supporting heat pumps (up to 150 kW), solar thermal, and biomass or biogas-based heat production, and CHP. The support level varies from 30% to 50% on investment costs depending on the technology (RES Legal, 2019m).

Under the Grand Ducal Regulation of 23 December 2016 implementing an aid regime for the promotion of the rational use of energy and the enhancement of renewable energies in the housing sector, the construction of smaller district heating (DH) networks supplying at least two residential buildings can benefit from an investment subsidy covering up to 30% of the eligible investment costs (with a cap of EUR 7 500). The subsidies require that at least 75% of the heating network supply comes from renewable energy (RES Legal, 2019n).

The Law of 31 May 1999 created a fund supporting investments in environmental protection by Luxembourg municipalities. This fund supports the construction of DH networks by covering 40% of investments costs, including equipment and installation costs. The DH network must use at least 80% renewable energy to receive the subsidy. (RES Legal, 2019o).

Luxembourg's Chamber of Trades (Chambre des Métiers) provides training programmes for installers of renewable energy installations. The training costs EUR 675 and takes place over a three- or four-day period depending on the technology. As of 2017, installers can be certified for the following technologies: solar thermal, heat pumps, PV, and wood-fuelled stoves and boilers (RES Legal, 2019p).

Support for renewables in transport

The government of Luxembourg supports renewable energy in the transport sector. The Law of 18 December 2009 requires companies selling petrol and diesel to fulfil a quota of biofuels in annual fuel sales. In 2019, the mandated share of biofuels increased from 5.7% to 5.85% (based on the energy content). In addition, 35% of the quota must come from second-generation biofuels (after applying the double counting rule as specified under EU directives). Fuel suppliers failing to fulfil the quota pay a pollution tax of EUR 1.2 per litre based on the volume of biofuels below the amount required by the annual sales quota (RES Legal, 2019p).

Luxembourg also supports renewable energy in transport through its e-mobility initiative, which aims to power individual mobility and public transportation with electricity from renewable energy. To help achieve this goal, the draft NECP contains a target for 2030 for 49% of vehicles registered in Luxembourg to be electric vehicles (EVs). Another goal for 2030 is for RGTR, the regional bus company, to have a 100% electric bus fleet (MMPW, 2018).

Luxembourg subsidises EVs purchased by private individuals and companies. The amount of the subsidy is based on the type of vehicle: EUR 5 000 for battery electric vehicles (see Chapter 7) and fuel cell electric vehicles, EUR 2 500 for plug-in hybrid electric vehicles, EUR 500 for electric motorcycles, and EUR 300 for electric bikes. The subsidy was introduced in January 2019 and replaced an EV tax credit established in 2017, as the level of EV deployment under the tax credit did not meet the government's expectations (Government of Luxembourg, 2019a). Luxembourg is also supporting EV deployment by investing in a public EV charging network and aims to have 800 public charging stations installed by the end of 2020: 400 in park and ride stations and 400 in other public spaces. Each charging station has two 22 kW charging points and is operated using an open software format allowing any company to provide charging services (MESP and MECSD, 2019). To encourage EV charging at private residences and commercial properties, Luxembourg requires new buildings to be prepared to support 22 kW EV charging. To help EV charging align with electricity from renewables, these properties are also prepared for deployment of PV systems.

Luxembourg also supports e-mobility by encouraging a shift from private vehicles to electrified public transportation. Supporting measures include the introduction of free public transport on all modes except first-class rail by March 2020 (Government of Luxembourg, 2019b). Luxembourg's Strategy for Sustainable Mobility (Modu 2.0) includes a goal to increase the number of public transport users by 50% from 2017 to 2025, and defines measures to increase the level and quality of electrified public transport, e.g. investment in park and ride centres linked to a major reworking of bus and train infrastructure (MSDI, 2017).

Achieving Luxembourg's e-mobility goals will result in a significant increase in electricity demand. In order for e-mobility to contribute to Luxembourg's renewable energy targets for transport, there will need to be a corresponding increase in domestic renewable electricity generation to power EVs and electrified public transport.

Climate Pact

In 2012, Luxembourg created the Climate Pact programme in co-operation with municipalities to collaborate on climate, renewable energy and energy efficiency. Under the pact, the government provides technical advice and funding to support a broad range of climate actions. The pact defines 79 specific measures (including renewable energy projects) that can be undertaken by municipalities and includes a process that awards certifications to municipalities based on the number of implemented measures (PacteClimat, 2019). The pact has been signed by all 102 municipalities and as of 2018, 88 municipalities had received certification (Government of Luxembourg, 2018). The government is working to improve the design of the pact to reward more quantitative results and extend it past 2020.

Third Industrial Revolution Strategy

In November 2016, Luxembourg launched the Third Industrial Revolution Strategy, which provides a comprehensive set of measures to transition Luxembourg to a smart, circular economy by 2050. Under the strategy, renewables would be the primary energy source and provide 100% of electricity generation (TIR, 2016). The strategy includes focus areas on energy, mobility, buildings, food, industry and finance. In relation to renewable energy, the strategy provides a wide range of potential policy, market and regulatory measures focusing on the transformation of the energy system by 2050. The government is using the strategy as a guiding document for its overall economic development plans and has implemented, or is the process of implementing, numerous policy proposals from the strategy, including an e-mobility initiative pushing for electrification of transport with renewable energy.

Regional co-operation

Since 2010, Luxembourg has participated in the North Seas Countries' Offshore Grid Initiative (NSCOGI) with Belgium, Denmark, France, Germany, Great Britain, Ireland, the Netherlands, Norway, Sweden and the European Commission. This initiative prioritises discussions on electricity network infrastructure supporting the expansion of offshore renewable energy in the North Sea. The main objective of the initiative is co-ordination and facilitation of cost-effective use of renewable offshore energy, in particular wind energy, and the safeguarding of a sustainable, secure and accessible energy supply in the North Sea countries through enhanced and more effectively co-ordinated offshore wind power stations and potential joint projects (NSCOGI, 2019).

Luxembourg should leverage its participation in the NSCOGI to encourage deployment of offshore wind capacity. Luxembourg's draft NECP calls for a flexible collaboration mechanism to meet a notable share of the country's 2030 renewable energy targets. Offshore wind projects could be an attractive option for joint projects under the EU flexible collaboration mechanisms.

Assessment

From 2008 to 2018, the share of renewables in TPES more than doubled in Luxembourg. Most of the growth in renewables came from increased use of bioenergy. In 2018, bioenergy accounted for 86% of the total renewable energy supply with small contributions from wind (7.2%), PV (4.1%) and run of river hydro (2.7%). Nearly half of the bioenergy was imported liquid biofuels, mainly biodiesel, used in the transport sector. The other bioenergy resources are domestically produced primary solid biofuels, renewable waste and biogas, which are used in CHP plants or directly for heating in buildings and industrial processes.

The electricity sector has seen significant growth in generation from renewable energy. Generation from wind increased by 302% from 2008 to 2018 to cover 26% of domestic generation. Generation from bioenergy grew 213% over the same period and accounted for 23% of generation in 2018. Solid primary biofuels are the largest source of generation from bioenergy, followed by biogas and renewable municipal waste. PV was the fastest growing source of renewable generation from 2008 to 2018, increasing by 460% to reach 12% of generation. Hydro generation has been relatively flat and is not expected to grow significantly.

The renewable energy share in gross final consumption of heating and cooling reached 8.11% in 2017, based mainly on heat production from 12 biomass-fired CHP plants and the conversion of three CHP plants from gas to wood pellets. Another eight gas-fired plants are in the pipeline to be converted to biomass and in 2017, two large biomass power plants started operating. The feed-in tariff for gas-fired CHP plants is expiring and the government expects that all remaining gas CHP plants will be converted to biomass. There are investment grants available for the construction of district heating (DH) networks using renewable energy, and subsidies to connect residential households and non-profit associations to DH networks.

Luxembourg has a 2020 target to increase the share of renewables in gross final consumption to 11%; in 2017, it had achieved 6.38%. Statistical transfers of renewable energy from Estonia and Lithuania under the EU flexible collaboration mechanism will be used to cover any gap to reach the 2020 target. Luxembourg's draft NECP sets a 2030 target of 23-25% renewables in gross final consumption. The draft NECP indicates that 19.8% would come from domestic renewables and EU flexible collaboration mechanisms would cover the remaining share. The NECP also defines specific targets for the share of renewables in the gross final consumption of electricity (33.6%), heating and cooling (30.3%), and transport (21.9% with 10% coming from biofuels). There is ongoing consultation with the EC on the draft NECP. Luxembourg must submit a finalised NECP to the EC by the end of 2019.

The draft NECP defines a variety of plans and policies to support achievement of Luxembourg's renewable energy targets, including an ambitious e-mobility initiative supporting electric vehicles and electrified public transport powered by renewable energy. The draft NECP estimates deployment of renewable energy technologies needed to meet the 2030 targets, including a tenfold growth in PV generation, a fivefold increase in wind generation and a tripling of biomass generation compared to 2016. The NECP also estimates that meeting the 2030 target would require a tenfold increase in the total capacity of heat pumps, a tripling of biomass use in district heating systems and a doubling of direct biomass use for heating. The NECP notes that meeting transport sector renewable energy

targets would require significant growth in the use of advanced biofuels, as the use of food-based biofuels in Luxembourg is expected to decrease towards 2030.

The NECP does not provide details on whether the envisaged increase in PV generation can be achieved through a mix of rooftop PV deployment including building mounted PV and PV on shade structures (the government's preferred option due to the scarcity of land in Luxembourg) or if utility-scale PV projects are required. Sites for wind power development in line with the NECP projections have not been fully identified. There is uncertainty on what share of renewable heating and cooling for the residential and commercial sectors could be supplied through DH. There are large differences in the projected electricity demand from e-mobility. In addition, the socio-economic impacts of these NECP targets have not been analysed. The share of renewable energy in the various energy sectors will be highly dependent on future electricity and fuel demand, which could significantly change if any major industrial company enters or exits Luxembourg, or if the share of transport fuel demand substantially decreased.

The growth in renewables has been supported primarily through a feed-in tariff and a premium tariff for electricity generated from renewable energy, as well as an increase in the mandatory share of biofuels in diesel and gasoline sales from 2% in 2012 to 5.85% in 2019. The government also has a wide range of investment subsidies in place to support renewable energy projects deployed by residents, municipalities and private companies. These investment subsidies conform to European State aid rules and cover a range of eligible investment costs depending on the technology, project size and numerous other factors.

In 2018, the government introduced its first tender for renewable energy projects. The tender was for 20 MW of PV capacity and restricted to PV projects with a capacity greater than 500 kW deployed on industrial sites and buildings. The tender was undersubscribed and resulted in eight proposed projects with a total capacity of 15 MW. The government is expected to issue a second tender for larger capacity PV projects in 2019 and intends to define a plan for yearly PV tenders with increasing capacity that will reach about 100 MW per year in 2023.

Although PV capacity per capita is relatively high compared to other EU member states, the number of rooftop PV systems is still significantly below the government's expectations. In 2019, the government increased feed-in tariffs for solar PV systems. New feed-in tariffs were also created for PV systems of 30-500 kW deployed by co-operatives. The feed-in tariff scheme is not well aligned to support PV deployment by small and medium-sized enterprises, as most of them would prefer to build systems larger than 30 kW but lack the resources to compete in government PV tenders, which in 2018 required projects with capacities greater than 500 kW. To address this issue, the government has opened upcoming tenders to projects with capacities greater than 200 kW.

All 102 municipalities within Luxembourg have signed the Climate Pact, a co-operative agreement though which the government supports municipalities on a variety of climate-related projects, including electricity generation and heating and cooling from renewable energy. Through the pact, the government also assist municipalities with improving their permitting processes for renewable energy projects and the promotion of renewable energy within their community.

Luxembourg's Third Industrial Revolution Strategy provides a comprehensive set of measures to transition Luxembourg to a smart, circular economy by 2050. Under the strategy, renewables would be the primary energy source and provide 100% of electricity generation. The Ministry of Energy and Spatial Planning is working under the broad objective to achieve a climate-neutral economy by 2050, but has not translated this objective into energy scenarios for this time period.

The government intends to publish an online map (solar cadastre) where residents can examine the potential for rooftop solar PV. It has also proposed a new law to exempt residential self-consumption from grid charges and taxes and is exploring additional measures to support self-consumption and renewable energy communities. The revised codes for buildings developed after 2017 require a certain percentage of renewable power generation to be integrated in all new buildings. It is the Public Building Administration's goal that each new public building will be constructed with a maximally sized PV system and that existing public buildings will be analysed to determine options for PV installations or the expansion of existing PV systems.

The industrial sector accounts for around 50% of electricity consumption, with the major consumers supplied through a privately operated electricity network that is separate from the national electricity grid (see Chapter 7). There is technical potential for substantial renewable generation on this network that could directly supply industrial consumers, but current regulations do not allow for this. The government and industrial players are exploring options to support renewable power purchase agreements, possibly across borders, to supply industry with renewable electricity.

There are only a limited number of companies active in renewable energy in Luxembourg. Two private companies and their partly owned subsidiaries generate almost 100% of wind power, a significant share of the hydropower, and own most of the biomass CHPs plants. These companies also own all the PV projects being developed under the 2018 tender. Only a few other companies provide renewable electricity. The government should examine measures to increase the number of companies developing renewable energy projects in Luxembourg. This would drive competition, resulting in lower costs, new services and more innovation among renewable project developers.

Recommendations

The government of Luxembourg should:

- Develop scenarios on how to achieve the ambitious renewable energy targets for 2030, including expectations for regional renewable energy deployment, for the different end-use sectors, and for centralised and decentralised options.
- Use its Climate Pact 2.0 to facilitate municipalities in developing detailed local plans for renewable energy deployment, including opportunities for deployment of wind power and PV, and options to develop district heating and cooling systems.
- Develop a dedicated strategy together with energy-intensive industry to increase the share of renewable energy within their operations.

References

Creos (2018), *Scenario Report 2040*, Creos, Luxembourg City, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

EC (European Commission) (2019a), *Clean Energy for all Europeans Package Completed: Good for Consumers, Good for Growth and Jobs, and Good for the Planet,* EC, Brussels, https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en.

EC (2019b), *Cooperation Mechanisms,* EC, Brussels, https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive/cooperation-mechanisms.

EC (2019c), *United in Delivering the Energy Union and Climate Action: Setting the Foundations for a Successful Clean Energy Transition,* EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285.

EC (2017a), *Agreement on Statistical Transfers of Renewable Energy Amounts Between Lithuania and Luxembourg,* EC, Brussels, https://ec.europa.eu/info/news/agreement-statistical-transfers-renewable-energy-amounts-between-lithuania-and-luxembourg-2017-oct-26_en.

EC (2017b), *Second Agreement on Statistical Transfers of Renewable Energy Amounts between Estonia and Luxembourg*, EC, Brussels, https://ec.europa.eu/info/news/second-agreement-statistical-transfers-renewable-energy-amounts-between-estonia-and-luxembourg-2017-nov-13_en.

EC (2010), *European Union Renewable Energy Directive*, EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028.

Enovos (2019), *Enovos Luxembourg Annual Report 2018*, Enovos, Luxembourg City, www.encevo.eu/content/download/233610/2627481/version/3/file/Annual+Report+Enovos+2018.pdf.

Government of Luxembourg (2019a), *New Vehicle Bonuses*, Government of Luxembourg, Luxembourg City, https://transports.public.lu/fr/contexte/initiatives/primes.html.

Government of Luxembourg (2019b), *Free Public Transport*, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/fr/actualites/toutes_actualites/communiques/2019/01-janvier/21-bausch-transport.html.

Government of Luxembourg (2018), *Climate Bank and Sustainable Housing Package*, Government of Luxembourg, Luxembourg City, http://luxembourg.public.lu/en/actualites/2017/01/05-klimabank/index.html.

Government of Luxembourg (2016), *Grand Ducal Regulation of 23 July 2016*, Government of Luxembourg, Luxembourg City http://legilux.public.lu/eli/etat/leg/rgd/2016/07/23/n8/jo.

Government of Luxembourg (2014), *Grand Ducal Regulation of 1 August 2014 on the Production of Electricity Based on Renewable Energy Sources*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/rgd/2014/08/01/n1/jo.

Government of Luxembourg (2012), *Grand Ducal Regulation of 26 December 2012 on the Generation of Electricity Based on High-efficiency Cogeneration*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/rgd/2016/06/22/n2/jo.

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

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

ILR (Institut Luxembourgeois de Régulation) (2019), *Key Figures of the Electricity Market Year 2018 – Part I,* ILR, Luxembourg City, https://assets.ilr.lu/energie/Documents/ILRLU-1685561960-667.pdf.

MEFT (Ministry of the Economy and Foreign Trade) (2010), *National Renewable Energy Action Plan*, MEFT, Luxembourg City, https://www.iea.org/policiesandmeasures/pams/luxembourg/name-39515-en.php.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

MMPW (Ministry of Mobility and Public Works) (2018), *Electrification and Extension of the Nordstad-Bus Line 512*, Government of Luxembourg, Luxembourg City, https://mmtp.gouvernement.lu/fr/actualites.gouvernement%2Bfr%2Bactualites%2Btoutes_actualites%2Bcommuniques%2B2018%2B10-octobre%2B01-electrification-rgtr512.html.

MSDI (Ministry of Sustainable Development and Infrastructures) (2017), *Modu 2.0 Strategy for Sustainable Mobility*, Government of Luxembourg, Luxembourg City, https://environnement.public.lu/dam-assets/actualites/2019/04/modu2-fr-brochure.pdf.

NSCOGI (North Seas Countries' Offshore Grid Initiative) (2019), *North Seas Countries' Offshore Grid Initiative*, NSCOGI, Brussels, www.msp-platform.eu/practices/north-seas-countries-offshore-grid-initiative-nscogi.

PactClimate (2019), *Climate Pact (PacteClimat),* Government of Luxembourg, Luxembourg City, www.pacteclimat.lu/fr.

RES Legal (2019a), *Legal Resources on Renewable Energy*, EC, Brussels, www.res-legal.eu/en/search-by-country/luxembourg.

RES Legal (2019b), *Feed-in Tariff*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/feed-in-tariff-9/lastp/163.

RES Legal (2019c), *Premium Tariff* (*Prime de marché*), EC, Brussels, http://www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/premium-tariff-prime-de-marche/lastp/163.

RES Legal (2019d), *Subsidy I*, *PRIMe House*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/subsidy-i-regime-daides-pour-la-promotion-de-lutilisation-rationelle-de-lenergie-et-la-mise-en/lastp/163.

RES Legal (2019e), *Subsidy IV, Environmental Protection Fund* (*Fonds pour la protection de l'environnement*), EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/subsidy-iv-fonds-pour-la-protection-de-lenvironnement/lastp/163.

RES Legal (2019f), *Subsidy II, Support Scheme for Environmental Protection and Rational Use of Natural Resources* (*Régime d'aide à la protection de l'environnement et à l'utilisation rationnelle des ressources naturelles*), EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/subsidy-ii-regime-daide-a-la-protection-de-lenvironnement-et-a-lutilisation-rationnelle-des/lastp/163.

RES Legal (2019g), *Subsidy III, Support Scheme for the Middle Class*, (*Régime d'aide en faveur des classes moyennes*), EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/promotion/aid/subsidy-iii-regime-daide-en-faveur-des-classes-moyennes/lastp/163.

RES Legal (2019h), *Biofuel Quota*, EC, Brussels, www.res-legal.eu/en/search-by-country/luxembourg/single/s/res-t/t/promotion/aid/biofuel-quota-9/lastp/163.

RES Legal (2019i), *RES-H&C Promotion in Luxembourg*, EC, Brussels, www.res-legal.eu/en/search-by-country/luxembourg/single/s/res-t/t/promotion/aid/biofuel-quota-9/lastp/163.

RES Legal (2019j), *Subsidy I, PRIMe House – Heating*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/promotion/aid/subsidy-i-regime-daides-pour-la-promotion-de-lutilisation-rationelle-de-lenergie-et-la-mise-en-1/lastp/163.

RES Legal (2019k), *Subsidy II, Support Scheme for Environmental Protection and Rational Use of Natural Resources* (*Régime d'aide à la protection de l'environnement et à l'utilisation rationnelle des ressources naturelles*) – *Heating*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/promotion/aid/subsidy-ii-regime-daide-a-la-protection-de-lenvironnement-et-a-lutilisation-rationnelle-des-r/lastp/163.

RES Legal (2019l), *Subsidy III*, *Support Scheme for the Middle Class* (*Régime d'aide en faveur des classes moyennes*) – *Heating*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/promotion/aid/subsidy-iii-regime-daide-en-faveur-des-classes-moyennes-1/lastp/163.

RES Legal (2019m), *Subsidy IV, Environmental Protection Fund* (*Fonds pour la protection de l'environnement*)– *Heating*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/promotion/aid/subsidy-iv-fonds-pour-la-protection-de-lenvironnement-1/lastp/163.

RES Legal (2019n), *Support of RES-H Infrastructure I*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/policy/aid/support-of-res-h-infrastructure-10/lastp/163.

RES Legal (2019o), *Support of RES-H Infrastructure II*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/policy/aid/support-of-res-h-infrastructure-11/lastp/163.

RES Legal (2019p), *Training Programmes for Installers (Formation et certification dans le cadre de la directive 2009/28/CE)*, EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-hc/t/policy/aid/training-programmes-for-installers-16/lastp/163.

SEO (Société Electrique de l'Our) (2019), *Hydropower Stations*, SEO, Luxembourg City, www.seo.lu/fr/Activites-principales/Laufwasserkraftwerke/Presentation.

TIR (Third Industrial Revolution Consulting Group) (2016), *The 3rd Industrial Revolution Strategy Study*, TIR, Bethesda, www.troisiemerevolutionindustrielle.lu//wp-content/uploads/2016/11/TIR-CG_Luxembourg-Final-Report_Long-Version.pdf.

7. Electricity (with e-mobility focus area)

Key data (2018 provisional)

Electricity generation: 0.9 TWh (bioenergy and waste 31.4%, wind 26.1%, natural gas 20.7%, PV 12.0%, run of river hydro 9.9%), -66% since 2008

Electricity net imports: 6.2 TWh (imports 7.6 TWh, exports -1.4 TWh)

Installed capacity (2017): 0.4 GW, excluding 1.3 GW pumped hydro

Electricity demand (2017): 6.4 TWh (industry 49.8%, commercial 33.6%, residential 14.6%, transport 2.1%)

Overview

Luxembourg is highly dependent on imported electricity, a unique situation among IEA countries. In 2018, imports accounted for 86% of Luxembourg's electricity supply. The country's electricity system in divided into two separate grids. Creos, Luxembourg's transmission system operator (TSO), operates the national grid. Most residential and commercial customers and most domestic generation are linked to the national grid, which covers most of the country and is interconnected with Belgium and Germany. A separate, privately operated grid covers heavy industry demand (primarily from steel production) in the south of the country and is interconnected with Belgium and France.

In 2016, the only large thermal generation plant in Luxembourg, a 375 megawatt (MW) combined cycle gas turbine (CCGT), was permanently closed. The only remaining large generation asset, a 1.3 gigawatt (GW) pumped storage hydro plant, is connected to the German grid, and does not directly participate in Luxembourg's electricity system. Excluding the pumped hydro facility, Luxembourg's generation capacity in 2017 was 442 MW, over 50% of which was based on variable renewable energy (VRE) from wind, solar photovoltaics (PV) and run of river hydro.

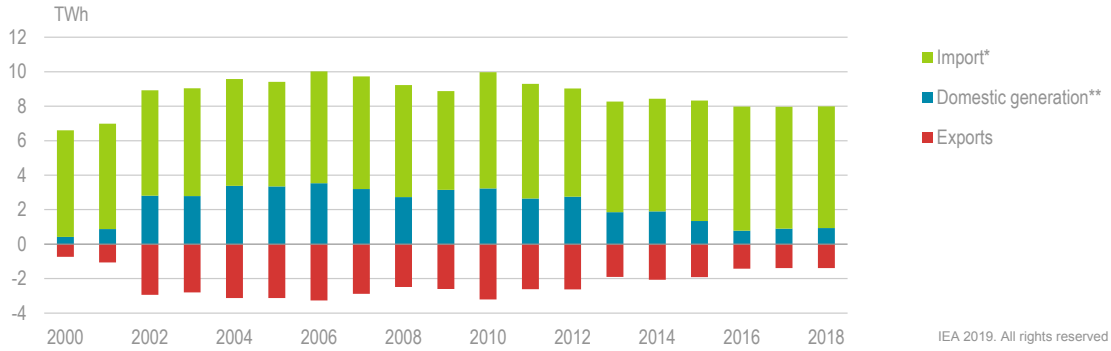
Traditionally, fluctuations in industrial production have driven Luxembourg's electricity demand. Looking to the future, Luxembourg expects rising population, economic growth and new demand sources like electrification of transport (e-mobility) and large data centres to drive electricity demand. The combination of import dependence, growing demand and increasing VRE generation in Luxembourg and neighbouring countries mean that robust and smart grid infrastructure, and strong regional grid and market integration are key to maintaining secure operation of the electricity system. Luxembourg should continue to build on the collaboration it has with neighbouring countries and look to innovative technology and market solutions to establish a highly efficient and flexible electricity system.

Electricity system

Electricity imports

Electricity imports covered 86% of Luxembourg's electricity demand in 2018. Net imports have grown by 55% over the last decade to reach 6.2 terawatt hours (TWh) in 2018 (7.6 TWh imports and 1.4 TWh exports) (Figure 7.1). The largest share of imports comes from Germany, followed by France and Belgium (Figure 7.2).

Figure 7.1 Electricity supply by source, Luxembourg, 2000-18



* Total imports minus around 0.5 TWh per year of pumped hydro net consumption (see Box 7.1).

** Excludes pumped hydro generation (1.2 TWh in 2017)

Notes: TWh: terawatt hour. Data for 2018 are provisional.

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

Figure 7.2 Electricity net imports and exports by country, Luxembourg, 2000-17

* Excludes around 0.5 TWh of pumped hydro net consumption (see Box 7.1).

Note: TWh: terawatt hour.

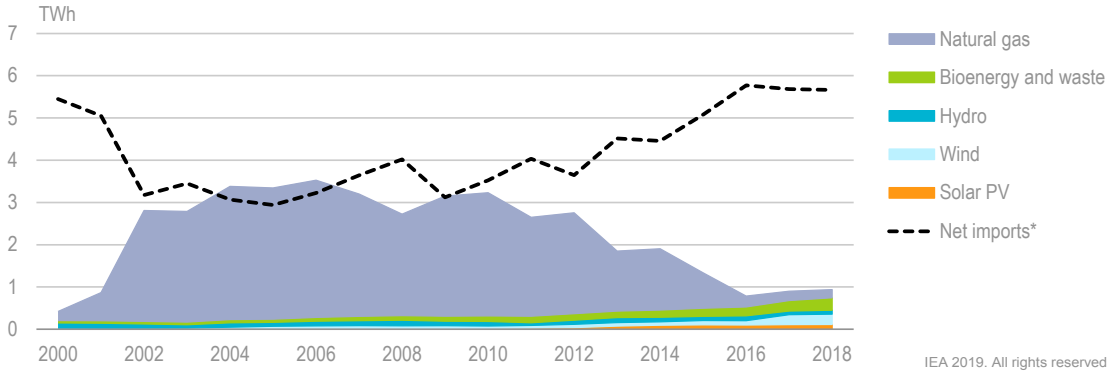
Source: IEA (2019b), *Electricity Information 2019*, www.iea.org/statistics.

Electricity generation

In 2018, total electricity generation was 0.9 TWh, covering 14% of Luxembourg's electricity demand. The largest source of electricity generation comes from biomass used in combined heat and power (CHP) plants (31%), followed by wind (26%), natural gas (21%), solar PV (12%), and run of river hydro (10%) (Figure 7.3). The reduced use and decommissioning of the Twinerg CCGT caused a dramatic drop in the share of natural gas in Luxembourg's electricity supply. Natural gas continues to play a major role in supporting CHP plants. In comparison, wind and PV generation have increased rapidly

over the past decade (from 0.06 TWh in 2008 to 0.25 TWh in 2018 for wind and from 0.02 TWh to 0.11 TWh for PV over the same period). Generation from run of river hydro has been stable around 0.1 TWh.

Figure 7.3 Electricity supply by source, Luxembourg, 2000-18



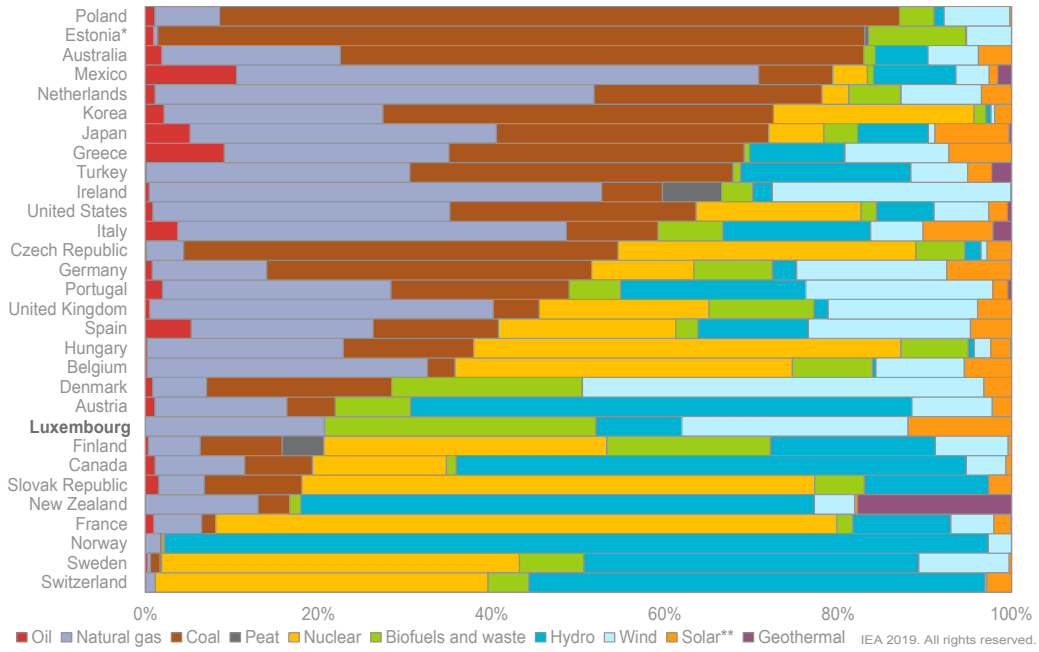
* Excludes around 0.5 TWh per year of pumped hydro net consumption (see Box 7.1).

Notes: TWh: terawatt hour. Data for 2018 are provisional.

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

From 2002 to 2016, natural gas was the dominant fuel in Luxembourg's generation mix, and the country consistently ranked among IEA member countries with the highest share of fossil fuels in electricity generation. However, after the 2016 closure of the Twinerg CCGT, Luxembourg's share of renewables in electricity generation rose to the fourth highest in the IEA in 2018 (Figure 7.4).

Figure 7.4 Electricity generation by source in IEA member countries, 2018



* Estonia's coal represents oil shale.

** Includes solar PV, solar thermal power, wave and ocean power, and other power generation (e.g. fuel cells).

Note: Countries are ranked by share of fossil fuels in electricity generation.

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

Installed capacity

Luxembourg had 442 MW of installed generation capacity in 2017 (Table 7.1). This capacity excludes the 1.3 GW pumped storage hydro plant, which is connected to the German grid and does not directly participate in Luxembourg's electricity system (see Box 7.1). This also excludes the 375 MW Twinerg CCGT, as this plant exported electricity to the Belgian grid. The Twinerg plant owners chose to permanently close the plant in 2016 (EMP, 2016) and it was demolished in 2019 (MD, 2019).

From 2007 to 2017, wind and PV capacity increased rapidly; wind grew from 40 MW to 121 MW and PV from 20 MW to 130 MW. Run of river hydropower capacity has been stable at 38 MW. Combined VRE generation (wind, PV and run of river hydro) accounted for 65% of installed capacity in 2017. In the same year, CHP plants had 106 MW of capacity, the third largest share (24%). Since 2003, CHP plants have been transitioning from natural gas to biomass. The 21 MW of waste incineration capacity comes from a single CHP plant operated at Sidor, Luxembourg. The 12 MW of biogas capacity comes from methane production at wastewater treatment plants (Creos, 2018).

Table 7.1 Installed electricity-generating capacity, Luxembourg, 2014-17

Megawatts (MW)

	2014	2015	2016	2017
PV	114	119	125	130
Wind	57	64	121	121
Hydro	38	38	38	38
Biomass	0	3	3	14
Biogas	11	11	12	12
Waste	21	21	21	21
Combined heat and power	107	108	106	106
Total	**348**	**364**	**426**	**442**

Source: Creos (2018), *Scenario Report 2040*, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

Electricity demand

Luxembourg's electricity demand declined from a historic peak of 6.7 TWh in 2007 to 6.2 TWh in 2014, but increased again to reach 6.4 TWh in 2017 (Figure 7.5). Over this period, industry demand declined by 11%, residential demand increased by 10% and commercial demand was relatively stable, with the exception of a notable increase in 2017. Transport electricity demand has shown small but steady growth, primarily from increased use of electrified rail as well as growth in electric vehicles (EVs). In 2017, electricity demand had the following mix by sector: industry (50%), commercial (34%), residential (15%) and transport (2%). The steel industry alone accounted for 40% of electricity demand.

Box 7.1 Vianden pumped storage hydro power plant

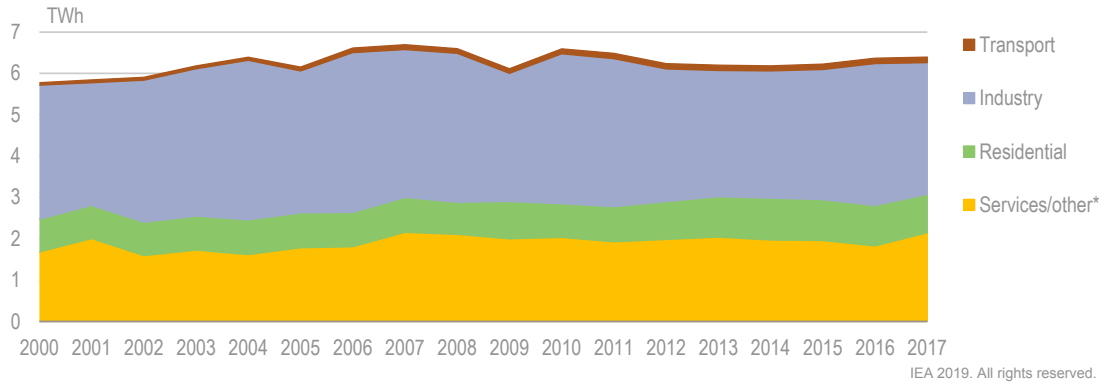
Luxembourg is home to one of Europe's largest pumped storage hydropower plants, located in Vianden near the German border. The plant is connected to the German electricity system and dispatches in the joint German-Luxembourg control zone of the German transmission system operator, Amprion. Société Électrique de l'Our S.A.

(SEO) operates the plant under a contract with the German electricity producer RWE. Luxembourg and RWE own controlling shares of the plant. In 2014, a major upgrade installed an eleventh 200 MW pump generator and expanded the capacity of the upper reservoir by 500 000 cubic metres. This increased generation capacity to 1.3 gigawatts and storage capacity to approximately 5 000 megawatt hours (SEO, 20, 2019a).

The Vianden plant's large power output, high storage capacity and ability to switch rapidly from generating to storing electricity allows it to provide a wide range of services. The plant traditionally provided large-scale and fast backup capacity for thermal plants, notably for the German coal-fired power plants in the Rhine area. While it continues to support thermal generation, plant operations have been shifting to provide a wider range of services supporting system flexibility and integration of variable renewable energy (VRE) generation from wind and photovoltaics. This includes managing VRE generation gradients, compensating for VRE generation forecast deviations and storing VRE generation that would otherwise be curtailed. The plant is also a critical provider of balancing and reserve services supporting flexible and efficient grid operations.

Growing VRE generation in the German grid entails increased need of the Vianden pumped storage plant. Injections of electricity from the plant into the Amprion control zone have increased by 33% since 2008 and 15% since the 2014 plant upgrade to reach 1.2 terawatt hours in 2018. With the expected phasing out of both coal and nuclear generation in the German electricity system and the likely increase of VRE generation, demand for balancing and storage capacity from the plant will likely continue to grow. Luxembourg should continue to co-operate with Germany and Amprion to ensure that the Vianden plant supports effective integration of VRE generation in the joint German-Luxembourg control area, as this will contribute to Luxembourg's security of supply and could allow for greater deployment of VRE generation in Luxembourg.

Figure 7.5 Electricity demand (TFC) by sector, Luxembourg, 2000-17



* Services/other includes commercial and public services, agriculture and forestry.

Notes: TWh: terawatt hour. Excludes electricity consumed in the energy sector, mainly for pumped hydro.

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

Peak annual electricity demand has been growing steadily, from 763 MW in 2010 to 795 MW in 2016. In 2017 and 2018, a portion of the industrial grid demand was supplied by the Creos grid, pushing demand up to 828 MW in 2018.[1] Although domestic installed

[1] 30 MW of load can be temporarily switched from the industrial Sotel grid to the Creos grid; this mainly occurs in response to emergencies. As of October 2019, the Sotel interconnection to the Belgian grid is out of service due to a

capacity increased 21% from 2014 to 2017, the share of peak demand covered by imports has been increasing, from 81% in 2015 to 85% in 2018. The high share of imports results from the misalignment of peak demand, which normally occurs on the coldest days in December or January, and peak domestic generation, which is driven by variable wind and PV generation, and peaks midday in February or March (Creos, 2018).

Electricity transmission and distribution

Luxembourg's electricity system has two separately operated transmission grids. Creos operates the national grid in a joint control area with the German TSO Amprion (MESP and MECSD, 2019). The national grid covers the whole country and serves all the residential customers and most of the commercial and industrial consumers. The majority of Luxembourg's generation capacity is connected to the national grid, but most electricity is imported through interconnections with Germany. A new interconnection between the national grid and the Belgian grid has been operating in a test phase since October 2017; commercial operation is expected to start in the near future (see Box 7.2). A second grid serves heavy (steel) industry demand in the south of the country and is operated and maintained by the private industrial grid operator, Sotel. The Sotel grid is interconnected with Belgium and since 2013 with France. There are no significant generation assets in the Sotel grid and most electricity has been imported from France since the interconnection was commissioned in 2013.

Both the national and industrial grids rely on 220 kilovolt (kV) cross-border interconnections to link electricity demand centres to generation assets in neighbouring countries. 220 kV and 65 kV lines provide internal electricity transmission (Figure 7.6). The two grids are, in general, not physically connected. However, for mutual assistance, a part of the Sotel load (30 MW) can be switched to the Creos grid.

Given its high import dependence and limited domestic generation, Luxembourg maintains significant electrical interconnection capacity with neighbouring countries. Accounting for N-1 security, current interconnection capacity of the national grid is around 135% of 2017 peak load (MESP and MECSD, 2019). Creos operates the following interconnections for the national grid:

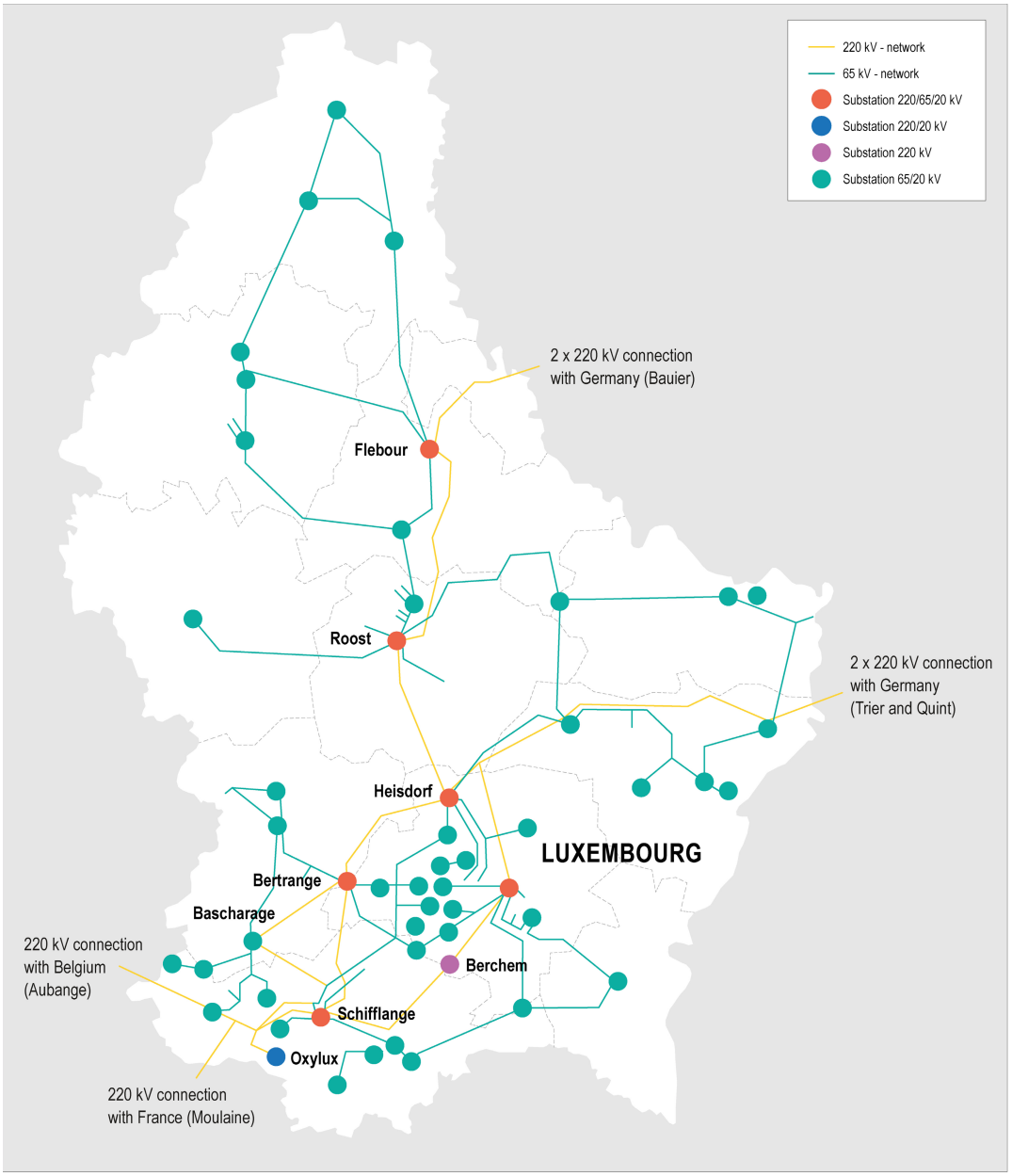
- Trier/Quint to Germany: 2 x 220 kV = 980 mega-volt amperes (MVA)
- Bauler to Germany: 2 x 220 kV = 980 MVA
- Aubange to Belgium: 220 kV = 400 MVA.

Sotel operates the following interconnections for the industrial grid:

- Aubange to Belgium: 220 kV = 360 MVA
- Moulaine to France: 220 kV = 450 MVA.

tornado in early August 2019. In response, 30 MW of the Sotel load is being provided by the Creos grid until the interconnection is repaired.

Figure 7.6 Luxembourg's electricity transmission system, 2018



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

Luxembourg's electricity distribution system is composed of 20 kV lines and additional infrastructure that delivers electricity from the transmission system to consumers. The majority of its electricity consumers are connected at the distribution level, with the exception of some industrial customers that are directly connected to the transmission system. Five distribution system operators (DSOs) maintain and operate the electricity distribution system. Creos, the TSO, is also the largest DSO and operates a distribution network that covers most of the country and provides services to the majority of electricity consumers in Luxembourg. The municipalities of Ettelbruck and Diekrich both have publicly owned and operated DSOs. Sudstroum is a publicly owned, privately operated DSO that runs a distribution network in the south of Luxembourg. Electris is a private DSO that operates a distribution network in the centre of the county (ILR, 2019).

Box 7.2 Interconnection to Belgium

To ensure a secure electricity supply, address expected electricity demand growth and contribute to the European electricity market integration, Luxembourg's transmission system operator (TSO) is working with the TSOs Elia (Belgium) and Amprion (Germany) on the BeDeLux interconnector project. This project is the first electrical interconnection between Luxembourg's national grid and the Belgian grid (Elia, 2019).

The first phase of the project was completed in October 2017 with the commissioning of a phase-shifting transformer in Schifflange, Luxembourg and the establishment of a 220 kV interconnection between the Luxembourg and Belgian transmission networks. This connection is currently operating in test mode. As soon as the needed technical and market requirements have been met, the interconnection will shift to commercial operation (MESP and MECSD, 2019). Although the date for commencing commercial operation is unknown, the test-mode operation has increased cross-border exchange and improved regional electricity security. During the winter of 2018-19, the BeDeLux interconnector supported 226 megawatts of electricity imports into Belgium (CREG, 2019). The BeDeLux interconnection currently does not support N-1 operation; however, Luxembourg is endeavouring to further strengthen this interconnection in the medium term (Elia, 2019).

While the primary goal of the BeDeLux interconnector is to increase Luxembourg's security of supply, this project opens the possibility of co-ordinating the flow of electricity between Belgium and Germany via the Luxembourg transmission network. This could have notable impacts on the Luxembourg grid, which already has to accommodate a high level of electricity imports. Following the trial phase of the interconnector, the market situation for the three TSOs (Amprion, Creos and Elia) will be reviewed along with the potential to connect the Belgian and German/Luxembourg bidding zones (Elia, 2019).

Electricity market, policy and regulation

Market overview

Luxembourg is integrated fully into the joint German/Luxembourg bidding zone and there is no separate domestic wholesale market. The wholesale electricity price used in Luxembourg is the day-ahead price for the joint bidding zone (SMARD, 2019). The absence of congestion on interconnections between Luxembourg and Germany allows market players trading electricity in Luxembourg to take advantage of the joint bidding zone's high liquidity (ACER, 2018). Electricity imports to the industrial grid operated by Sotel are supplied from the Belgian and French electricity markets through the interconnections of the Sotel grid with the grids of Elia (Belgian TSO) and RTE (French TSO). Sotel is restricted to serving its existing customers and cannot connect new customers to its network.

Luxembourg is part of the Core Capacity Calculation Region (CCR) project, which will combine the market regions of Central Eastern Europe (CEE) and Central Western Europe (CWE) to the enlarged European Core CCR, based on the decision by the Agency for the Cooperation of Energy Regulators (ACER) 06/2016 of 17 November 2016. The Core CCR will connect bidding zones in the following EU member states: Austria, Belgium, Croatia,

the Czech Republic, France, Germany, Hungary, Luxembourg, the Netherlands, Poland, Romania, the Slovak Republic and Slovenia. The 16 TSOs of these member states, including Creos, lead the Core project with the objectives of coupling the day-ahead and intraday markets and maximising efficient use of interconnection across the Core CCR (ACER, 2016).

Institutions

The independent regulatory authority, Institut Luxembourgeois de Régulation (ILR), regulates Luxembourg's TSO and DSOs as well as the industrial grid operator, Sotel. Transmission and distribution tariffs as well as ancillary services are regulated. Electricity prices are not. The ILR designates the electricity supplier of last resort every three years. Specific last-resort tariffs are proposed by the designated supplier of last resort and approved by the ILR. The ILR nominated Epex Spot as the electricity market operator for both the day-ahead and intraday transactions, and Nord Pool A.S. as the electricity market operator for the intraday transactions only (ILR, 2018a).

The Encevo Group plays a major role in Luxembourg's electricity sector. It has a 75% share in Creos, the TSO and largest DSO, and controlling shares in Enovos Services (the largest energy service company) and Enovos (the largest electricity supplier), which owns LEO, another electricity supplier. Encevo Group's holdings are legally unbundled, but not in terms of ownership. Luxembourg has been granted an exemption from the ownership unbundling requirement in the European directives (EC, 2019). ArcelorMittal, the world's largest steel manufacturer by volume, has its headquarters in Luxembourg City and operates the majority of the country's steel production facilities (WSA, 2019). ArcelorMittal owns 75% of the grid operator Sotel and controls ArcelorMittal Energy, the second-largest electricity supplier in the industrial sector (ILR, 2018a).

Generation

Ownership of generation assets in Luxembourg is concentrated among just a few companies. Enovos, through direct ownership of generation assets, controlling shares of Luxenergie and a 50% share in Soler (a joint venture with SEO), operates the majority of domestic wind, PV, run of river hydro and CHP assets (Enovos, 2019). SEO separately operates the rest of the run of river hydro plants in Luxembourg (SEO, 2019b).

Operators of generation plants, including those based on renewable energy, are entitled to grid connections without discrimination; the plant operator must pay all grid connection costs. Generation plant operators are generally entitled to use the grid by paying applicable usage fees, according to the principle of non-discrimination; however, operators of renewable energy plants are exempt from grid usage fees. Electricity from renewable sources has priority dispatch and, in contrast to plants generating electricity from conventional sources, renewable energy plants with capacity less than 10 MW do not require authorisation for generation (RES Legal, 2019).

Regional co-operation

To support a secure supply of electricity imports and promote an open and efficient European electricity market, Luxembourg maintains strong regional co-operation through numerous bodies and institutions. This includes the Pentalateral Energy Forum (PLEF), where Luxembourg works with Austria, Belgium, France, Germany, the Netherlands and Switzerland. The PLEF has launched initiatives to strengthen the internal energy market,

for example the introduction of regional energy security analysis in 2013 (MESP and MECSD, 2019). Under the Luxembourg presidency in 2019, the PLEF has defined a joint wording on regional co-operation to be included in the national integrated climate and energy plans (NECPs) of its member countries and launched the next ten-year common working programme. Luxembourg also co-operates on electricity market issues through the Benelux Union with Belgium and the Netherlands.

Retail market

As of July 2019, 22 companies were authorised by the ILR to supply electricity to customers in Luxembourg. Only 14 of these companies are active in the market and market shares are highly concentrated among just 3 of them. Enovos is the dominant retail supplier, with a 75% share by volume of the residential market, 57% of the commercial market (demand less than 2 GWh per year) and 51% of the industrial market (demand greater than 2 GWh per year). LEO (owned by Enovos) supplies 14% of the residential market, 30% of the commercial market and 5% of the industrial market. ArcelorMittal Energy supplies 39% of the industrial market. Aside from these three suppliers, the highest market shares by volume are supplied by Sudstrom in the residential market (7%) and Electris in the commercial market (5%); most of the other suppliers have market shares of 3% or less (ILR, 2019).

Retail electricity switching rates in Luxembourg are low. In 2018, switching rates for residential and commercial customers were less than 0.2% by volume of sales. Industrial customers have a higher switching rate, but this rate declined from around 2.8% of volume in 2017 to less than 1% in 2018 (ILR, 2019). The ILR runs a free online rate comparison portal providing consumers with an overview of electricity and gas tariffs to evaluate the potential savings of switching suppliers. The ILR has recommended more transparency in electricity supplier tariffs and services (MESP and MECSD, 2019).

Smart meters

Electricity DSOs are legally obliged to convert at least 95% of all electricity meters to smart meters by the end of 2019. The smart meter deployment has not been significantly affected by consumer acceptance problems, and as of June 2019, 84% of retail customers were equipped an electricity smart meter. A draft law presented in 2019 aims to establish the framework for operation of a national energy data platform that will collect and manage all smart meter data. The platform will be based on take-off and injection data from the electricity sector and withdrawal data for the natural gas sector. The platform will build on the common and interoperable national system for smart metering with the objective to simplify, standardise and manage market processes, including market communication, and to enable better management of electricity generation from renewable energy.

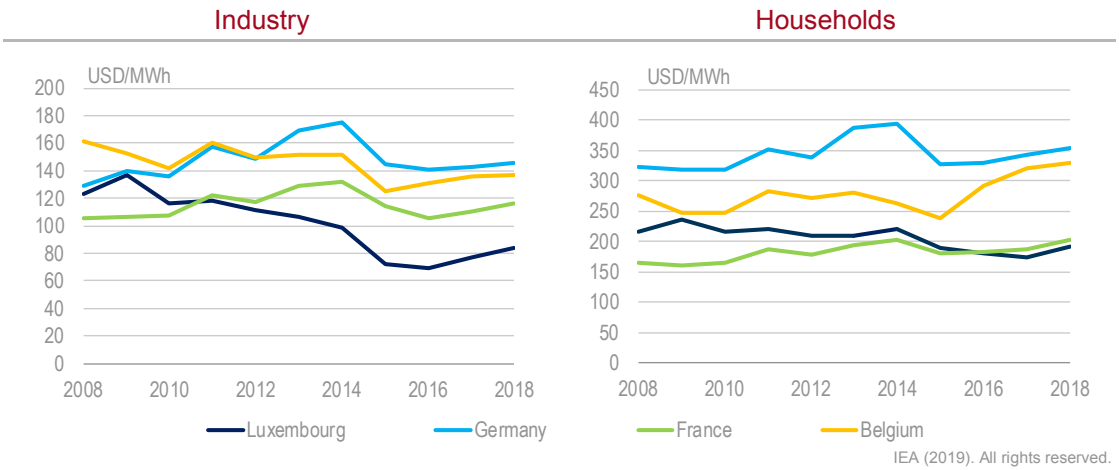
A key objective of the smart meter deployment is to allow electricity consumers to become active market participants (prosumers) through self-generation and self-consumption of electricity. To support this effort, Luxembourg requires newly constructed buildings to be prepared for PV systems. Luxembourg has prepared legislation to support self-consumption of renewable electricity and encourage consumers to be active market participants. Under the new law, which is supposed to enter into force in early 2020, electricity from renewable energy directly consumed at the generation site will be exempt from grid fees (ILR, 2018b). Smart meters allow for time-of-use pricing that could

encourage active consumer participation through demand-side management. Luxembourg is planning to investigate options for time-of-use pricing once the smart meter deployment is completed.

Electricity prices

Luxembourg's electricity prices have fallen notably since 2008, and are the lowest among the countries that trade electricity with Luxembourg (Figure 7.7). In 2018, industry consumers paid an average of 84 USD/MWh, a slight increase from 2016, but down 32% from 2008. In 2018, households paid 191 USD/MWh, a small increase since 2017, but still 11% lower than 2008. The lower prices in Luxembourg result primarily from significantly lower taxes on electricity, especially in comparison to Germany, Luxembourg's main source of electricity imports (Table 7.2). Among IEA member countries, Luxembourg had the fifth-lowest electricity prices for industry, while household electricity prices were close to the IEA average (Figure 7.8).

Figure 7.7 Electricity prices in Luxembourg and selected IEA member countries, 2000-18



Note USD: United States dollar; MWh: megawatt hour.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

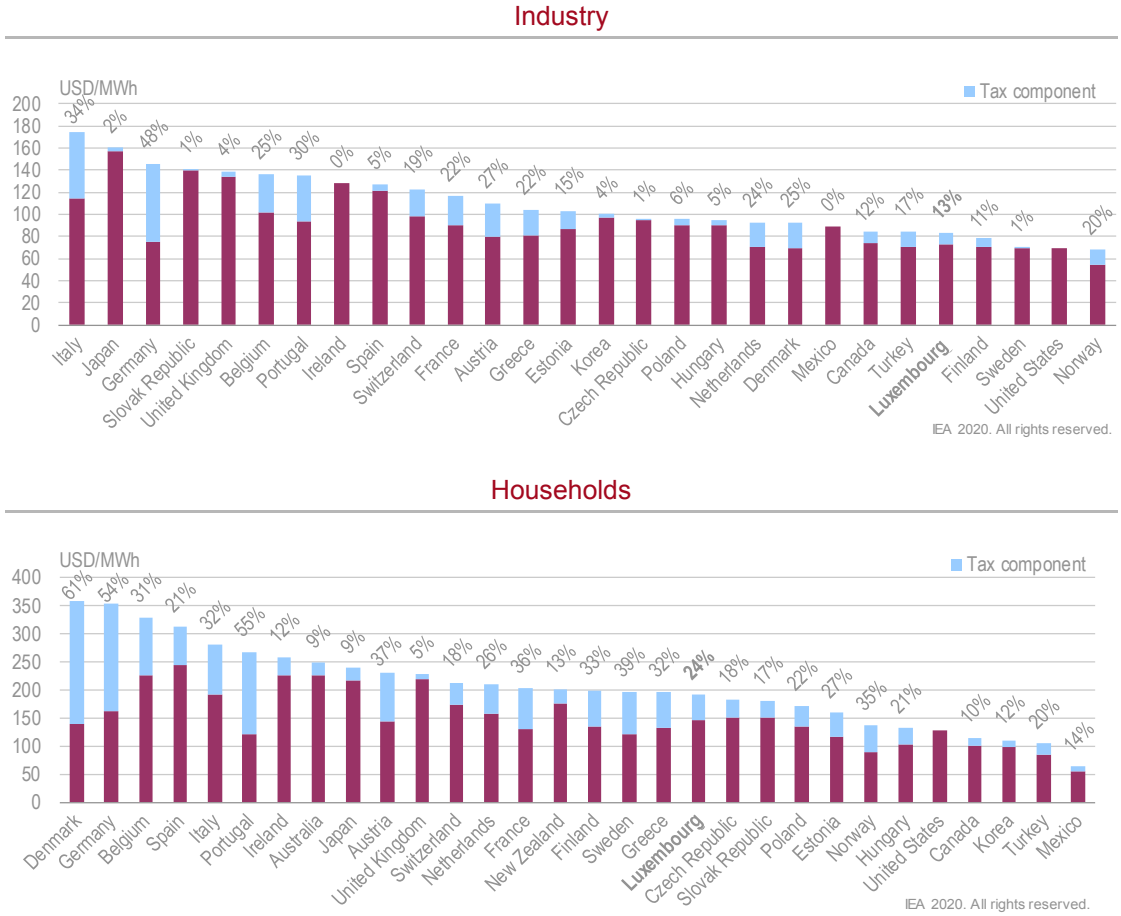
Table 7.2 Electricity prices in Luxembourg and neighbouring countries, 2018

Electricity prices (USD/MWh)	Industry				Households			
	Price	Pretax	Tax	Tax (%)	Price	Pretax	Tax	Tax (%)
Germany	145.40	75.00	70.40	48%	353.29	162.69	190.60	54%
Belgium	136.52	101.95	34.57	25%	328.66	225.56	103.11	31%
France	116.35	90.74	25.62	22%	202.37	129.78	72.59	36%
Luxembourg	83.49	72.40	11.09	13%	191.37	146.05	45.33	24%

Note USD: United States dollar; MWh: megawatt hour.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Figure 7.8 Electricity prices in IEA member countries, 2018



Notes: USD: United States dollar; MWh: megawatt hour. No industry prices data available for Australia and New Zealand. No tax information available for the United States.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Electricity demand and supply forecasts

Luxembourg expects sustained growth in electricity demand driven by increasing population, which is the fastest growing in Europe (OECD, 2019); increasing economic activity; and new demand sources, including e-mobility and large data centres. In 2018, the TSO developed a detailed electricity demand forecast in its *Scenario Report 2040*, which estimated that combined electricity demand in the industry, residential and commercial sectors (excluding e-mobility and large data centres) could push electricity demand close to 7.0 TWh by 2040, compared to 6.4 TWh in 2017. Additional demand from e-mobility and large data centres could push electricity demand over 9.0 TWh by 2040. The report forecasts a 12% growth in electricity demand by 2040 based on a 43% increase in residential demand, a 28% increase in commercial demand and a 5.7% decrease in industry demand (Creos, 2018).

The *Scenario Report 2040* also forecasts growth in peak electricity demand (MW). Excluding e-mobility and large data centres, peak electricity demand could grow from around 800 MW in 2017 to over 1 000 MW by 2040. Large data centres could add an additional 350 MW of demand by 2030, when it is expect that all large data centre projects will be in operation. New demand from e-mobility is estimated between 150 MW

projects will be in operation. New demand from e-mobility is estimated between 150 MW and 700 MW in 2040, depending on the level of electric vehicle adoption (see the e-mobility focus area below).

Taken together, these new demand sources, along with the expected demand growth from existing sectors, could double peak demand by 2030 and continue to increase peak demand through 2040 (Creos, 2018). This level of demand would have notable impacts on the electricity system and would require increases in domestic generation and transmission, distribution, and import capacity. The TSO indicates that the existing infrastructure can support about 1 000 MW of peak demand (Creos, 2018).

To support a secure electricity supply and reduce import dependence, Luxembourg aims to increase domestic renewable energy generation. The draft integrated National Energy and Climate Plan for Luxembourg (NECP) estimates an increase in installed generation capacity from 442 MW in 2017 to 1 225 MW in 2030 and 1 600 MW by 2040. The TSO's *Scenario Report 2040* estimates 2040 installed generation capacity at 1 200 MW. Both estimates assume all new capacity comes from renewables, primarily wind and PV. The draft NECP estimates that domestic generation could increase to 2 terawatt hours (TWh) by 2030 and 2.6 TWh by 2040, based mainly on increased wind, PV and biomass generation. It is estimated that this level of generation would reduce import dependence to 69% of annual electricity demand by 2030 and 60% by 2040.

The expected continued reliance on imports, the anticipated increases in both total (TWh) and peak (MW) electricity demand, and the expected increase in domestic VRE generation will require substantial investment in electricity infrastructure. The TSO regularly analyses the adequacy of existing infrastructure and proposed the following infrastructure investments in the *Scenario Report 2040*:

- replace existing 220 kV lines connected to the German grid at Trier/Quint with 400 kV lines
- reinforce existing 220 kV lines connected to the German grid at Bauler/Niederstedem
- possibly extend, in the long term, a new 400 kV grid to Belgium.

In addition, the TSO is considering infrastructure upgrades to support the expected increase in wind generation. This could require upgrading some 65 kV lines to 110 kV to allow adequate transmission capacity from the northern part of the country, where the best wind resources are located, to central and southern electricity demand centres. The government's policy is to consider authorising upgrades in capacity preferentially on existing pylons/corridors and, where necessary, using underground cables. The TSO also expects that increased PV generation could require investments in the low- and medium-voltage networks (Creos, 2018). The magnitude of these investments will depend on the future grid operation strategy in relation to the deployment of smart grid technologies such as smart meters, demand-side response, batteries and other energy storage options.

Electricity security of supply and emergency policy

Luxembourg maintains a high level of electricity security of supply. The last major loss of electricity supply on the 220 kV transmission system occurred in September 2004 (Government of Luxembourg, 2004). Luxembourg's performance on the key indicators for stability of electricity distribution network, unplanned SAIFI (average frequency of interruptions in electricity supply per customer) and SAIDI (average duration of interruption in the electricity supply in minutes per customer), reflect a secure electricity supply

(Table 7.3). In Europe, 2016 unplanned SAIFI including exceptional events was 0.08-4.35 interruptions per customer while unplanned SAIDI including exceptional events was 9-371 minutes per customer (CEER, 2018).

Table 7.3 Unplanned SAIFI and SAIDI* in Luxembourg, 2014-18

	2014	2015	2016	2017	2018
SAIFI	0.29	0.36	0.23	0.26	0.31
SAIDI	18.5	22.8	16.6	21.8	23.4

* SAIFI: average frequency of interruptions in electricity supply per customer; SAIDI: average duration of interruption in the electricity supply in minutes per customer.

Source: ILR (2019), *Key Figures of the Electricity Market Year 2018 – Part I,* https://assets.ilr.lu/energie/Documents/ILRLU-1685561960-667.pdf.

Under the modified Law of 1 August 2007 on the Organisation of the Electricity Market, the TSO and DSOs are responsible for ensuring the security, reliability and efficiency of electricity transmission and distribution, and the quality of electricity supply. This includes real-time electricity system monitoring; provision of emergency management resources, including control room back up; and implementation of appropriate emergency management practices, including over and under frequency load-shedding and restoration plans. The Government Commissioner for Energy is responsible for monitoring electricity security of supply and reports the results of this monitoring and any measures taken to manage electricity security to the European Commission (EC) and the ILR every two years (Government of Luxembourg, 2007).

According to Article 13 of the Law on the Organisation of the Electricity Market, the government can initiate temporary measures to address an electricity market crisis or a threat to security of supply, the electricity system, or the safety of persons. This action requires consultations with the Government Commissioner for Energy and the ILR and any measures taken must cause as little disruption as possible to the electricity market and should not exceed the scope that is strictly necessary to remedy the immediate crisis (Government of Luxembourg, 2007).

Emergency management and restoration activities are co-ordinated by the TSO from its dispatch control centre in Heisdorf, Luxembourg. The centre has an ISAM (interactive voice announcement management) uninterruptible telecommunication system, and analytical and real-time diagnostic tools (Creos, 2019). In case of a blackout, the Heisdorf control centre takes over DSO switching authority until grid operations are normalised (Creos, 2010).

The TSO and DSOs maintain an emergency response defence plan for the electricity system in agreement with EC Regulation (EU) 2017/2196 on establishing a network code on electricity emergency and restoration (EC, 2017). As there are insufficient emergency generation reserves, Luxembourg's defence plan relies on load shedding. In consultation with the DSOs, the TSO has developed a load-shedding plan for electricity outages that uses consecutive interruption of supply by customer category along with additional measures to limit deterioration of transmission or distribution system security, reliability and efficiency. The plan also includes a strategy for orderly restoration of electricity supply based on customer category (Creos, 2010).

E-mobility focus area

E-mobility goals and status

Luxembourg has embraced a broad e-mobility agenda aiming to reduce greenhouse gas emissions and fuel imports through electrification of transport. The draft NECP sets a goal for 2030 for 49% of vehicles registered in Luxembourg to be electric vehicles (EVs). The government has restricted purchases of state-owned vehicles to battery electric vehicles or plug-in hybrid electric vehicles and is working to increase the quality, availability and use of electrified public transportation (MSDI, 2017). This includes a goal for 2030 for RGTR, the regional bus company, to have a 100% electric bus fleet (MMPW, 2018).

Rail transportation in Luxembourg is almost completely electrified. In 2018, 262 km of Luxembourg's 271 km rail network was electrified (Statec, 2019a). The vast majority of trains operated by the national railway company, Société nationale des chemins de fer luxembourgeois (CFL), are electric and CFL continues to invest in electrification of rail lines and electric trains (CFL, 2018). Luxtram, a company owned by the government and Luxembourg City, deploys an electrified tramline system throughout the capital with planned expansions up to 2023 (Luxtram, 2019).

Compared to rail, electrification of road transportation is lagging. Of the 2 042 buses operating in Luxembourg in 2019, only 33 were electric (Statec, 2019b). This number has been increasing; in 2018, only seven electric buses were in operation. The government is aiming for 70 electric buses in the RGTR network by the end of 2019 (MMPW, 2018). EV deployment is rapidly growing: in 2010 there were only 21 EVs registered in Luxembourg (EAFO, 2019); in 2019, there were 3 624 EVs (1 827 battery electric vehicles and 1 979 plug-in hybrid electric vehicles) out of 496 326 registered vehicles (EAFO, 2019; Statec, 2019c).

Supporting policy

Luxembourg subsidises EVs purchased by private individuals and companies. The amount of the subsidy is based on the type of vehicle: EUR 5 000 for battery electric vehicles and fuel cell electric vehicles; EUR 2 500 for plug-in hybrid electric vehicles; EUR 500 for electric motorcycles; EUR 300 for electric bikes. The subsidy was introduced in January 2019 and replaced an EV tax credit established in 2017 (Government of Luxembourg, 2019a).

Luxembourg is investing in a public EV charging network called Chargy and aims to have 800 charging stations installed by the end of 2020; 400 will be installed in park and ride stations and 400 in other public spaces. Each charging station has two 22 kW charging points and is operated using an open protocol allowing any company to provide charging services (MESP and MECSD, 2019). The Chargy network also supports integration of privately funded EV charging stations that are installed for public use. As of May 2019, the Chargy network had 261 publicly funded stations, 40 privately funded stations and 14 companies providing charging services (Chargy, 2019).

To encourage EV charging at private residences and commercial properties, Luxembourg requires new buildings to be built to support EV charging in residential and professional buildings. Customers are encouraged to install chargers with a maximum capacity of 11 kW. The DSOs have established basic regulations governing the installation and operation of EV charging stations. Luxembourg is examining incentives

for charging stations at workplaces that would allow EV charging to be aligned with PV generation and in 2019 was finalising an EV fast-charging concept.

Luxembourg also supports e-mobility by encouraging a shift from private vehicles to electrified public transportation. Measures include the introduction of free public transportation for residents and non-residents on all modes except first-class rail by March 2020 (Government of Luxembourg, 2019b). Luxembourg's Strategy for Sustainable Mobility (Modu 2.0) includes a goal to increase the number of public transportation users by 50% from 2017 to 2025, and defines measures to increase the level and quality of electrified public transportation, e.g. investment in park and ride centres linked to a major reworking of bus and train infrastructure (MSDI, 2017).

E-mobility challenges and opportunities

The most relevant e-mobility goal for the electricity system will likely be the 2030 goal of a 49% EV share in registered vehicles, which would lead to a substantial increase in electricity demand. The increase in demand due to EV charging is difficult to predict as it depends on numerous factors, including EV adoption rates, evolving specifications of EVs and EV charging infrastructure, and the time of day when charging occurs. The TSO's *Scenario Report 2040* tries to account for these issues and gives estimates of EV charging demand for a range of EV adoption rates (Table 7.4). These estimates include demand from a 100% electric bus fleet (15-60 MW) and the Luxtram project (10-15 MW), and show that e-mobility could increase electricity demand by up to 695 MW (Creos, 2018). In comparison, 2017 peak electricity demand in Luxembourg was just over 800 MW.

Table 7.4 Estimated impact of e-mobility on electricity demand, 2040

Electric vehicle (EV) adoption rate	Number of EVs in 2040	Additional e-mobility demand in 2040 (EVs, buses and tram)
Light	111 000	147 MW
Medium	275 000	426 MW
High	477 000	695 MW

Note: MW: megawatt.

Source: Creos (2018), *Scenario Report 2040*, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

Concentrating a high level of EV charging demand in a short period of time could affect the electricity system through increased wear and tear on infrastructure and the need for additional transmission, distribution and/or generation capacity. However, most EVs and EV charging stations in Luxembourg have the capacity to support smart charging that can control both the timing and the power (MW) of EV charging. Smart charging can prevent or greatly reduce the impacts of EV charging by ensuring that EV charging demand is not concentrated at times or locations that would strain the electricity system (IEA, 2019d).

Smart charging can also bring notable benefits for the electricity system. Aligning EV demand with Luxembourg's domestic renewable energy supply and with renewable generation from neighbouring countries would allow for greater integration of VRE generation. Smart charging also allows EVs to act as demand-side response (DSR) assets that can have many benefits for the electricity system, including more flexible and efficient operation and additional VRE integration. Realising these benefits requires co-ordinated

EV charging on a large scale. Luxembourg is taking steps that support smart charging, including smart meter deployment and preparing newly constructed buildings for EV charging and PV generation. The government should introduce smart charging for EVs in Luxembourg as soon as possible, before EV demand increases to the point where uncontrolled charging would negatively affect the electricity system.

EV smart charging can also require changes to the operation of electricity markets. Real-time electricity pricing can encourage customers to charge their EVs at times that do not place a strain on the electricity system. Policy makers and electricity suppliers can also develop options for direct control over large numbers of EV chargers. This requires investment in infrastructure allowing controlled EV charging on a mass scale, along with clear rules and regulation on who would control EV charging and how EV owners would be compensated. Luxembourg should investigate what legal and regulatory changes are needed to allow the introduction of widespread smart charging and develop clear concepts for introducing smart charging in the near future. The government is examining the potential for smart meters to allow the introduction of real-time pricing; this effort should include an analysis of how real-time pricing could be designed to encourage smart EV charging.

EVs can support vehicle to grid (V2G) systems, which allow EV batteries to support bidirectional electricity flows to and from the grid in a controlled manner. V2G systems could allow EV batteries to act as a large and highly responsive demand and supply side management tool supporting more efficient electricity system operations; greater integration of VRE generation; and greater system security. V2G systems are being tested in numerous countries at the pilot project level; however, there are technical, market, regulatory and behavioural challenges that need to be addressed before V2G can be adopted on a large scale (IEA, 2019d). The Chargy network, smart meter deployment and current level of EV deployment give Luxembourg the opportunity to develop its own V2G pilot projects that could provide useful information on how widespread use of V2G could be realised in Luxembourg.

Assessment

Looking to the future, Luxembourg will face increasing electricity demand, electricity import dependence, and growing shares of VRE in both domestic generation and the electricity supplies of neighbouring countries. This calls for a robust strategy to increase the regional electricity market and system integration. Luxembourg works with neighbouring countries and regional partnerships to support a well-functioning European electricity market. The government, the regulatory authority (ILR) and the TSO (Creos) are involved in the development of the European electricity market, particularly through co-operation with the PLEF, the Benelux Union and the Core CCR project.

In February 2019, Luxembourg assumed the chair of the Benelux Committee of Ministers and the 2019 presidency of the PLEF. It plans to use these leadership positions to strengthen the European market, digitalise the electricity system, increase generation from renewable energy and improve cross-border energy security (MESP and MECSD, 2019).

The PLEF provides opportunities to increase European electricity market and system integration and a more secure electricity supply for Luxembourg. A key example is the PLEF generation adequacy assessment carried out by the PLEF TSOs in 2015 and 2018.

The 2015 assessment provided the first probabilistic analysis of electricity security of supply in Europe conducted at regional level and the European Network of Transmission System Operators for Electricity (ENTSO-E) later used this methodology in its Midterm Adequacy Forecast (PLEF, 2018a). The 2018 assessment used an improved methodology with flow-based coupling and DSR measures to better model the PLEF regional electricity system. This improved the identification of potential generation adequacy problems and showed that DSR can have a clearly positive impact on generation adequacy in the PLEF region (PLEF, 2018b).

In June 2017, the Ministers for Energy of the PLEF countries signed a memorandum of understanding committing to implement key measures to improve regional co-ordination on electricity emergency response (PLEF, 2018b). In line with this memorandum of understanding, Luxembourg participated in a PLEF electricity crisis exercise in June 2018, which simulated a Europe-wide security of supply problem. The exercise showed a need for co-ordination mechanisms for government decisions and communication, and transparency in the preparation phase and during a crisis (Benelux, 2018).

The IEA encourages Luxembourg to leverage its PLEF and Benelux leadership positions to push for electricity market and system integration. Luxembourg should also incorporate the findings of the PLEF generation adequacy assessment and electricity crisis exercise into its electricity planning processes, especially the implementation of DSR measures, and push for PLEF generation adequacy assessment and electricity crisis exercises to be conducted on a regular basis.

In April 2019, the 16 TSOs supporting the Core CCR project (including Creos) finalised the Core CCR market design. Current planning foresees that flow-based market coupling in the Core CCR will start in the fourth quarter of 2020 (Eles, 2019). The IEA encourages Luxembourg to maintain its active role in the Core CCR project to ensure that its interests are taken into account and that Core CCR comes into full operation as soon as possible. In addition, the government should work to quickly bring the BeDeLux interconnection into commercial operation and clarify what role this interconnector and Luxembourg's electricity system will play in the Core CCR.

Although Luxembourg has some of the lowest SAIFI and SAIDI values in Europe, the ILR noted that the values have been increasing slightly since 2016. The government should monitor this situation and work with the TSO and DSOs to take appropriate steps to maintain a secure supply for all electricity consumers.

Luxembourg's reliance on electricity imports and increasing domestic and regional VRE generation mean that in addition to well-functioning markets, adequate interconnector and transmission capacity are important for a secure electricity supply. Accounting for N-1 security, network projects planned through 2030 would increase interconnection capacity of the national grid to 200% of 2017 peak electricity demand and provide greater transmission capacity to integrate wind or utility-scale PV generation. However, approval processes for new transmission lines can take several years, which could cause grid projects to lag behind demand increases and the expansion of VRE generation and possibly result in network congestion and curtailment of VRE generation.

The government should examine relevant planning processes and regulations to synchronise grid infrastructure construction with renewables deployment and electricity demand growth. Building an early-stage consensus between the different ministries, involved parties, local authorities and the public could favour a fast and co-ordinated

deployment of renewables and supporting infrastructure. There are currently no rules for VRE curtailment and its compensation. It might be sensible to not build new lines for every last MWh of generation, but instead set rules for curtailment.

From 2017 to 2019, the Creos grid regularly supplied electricity to meet 30 MW of demand in the Sotel grid. This demonstrated that Luxembourg's two grids can operate in a mutually beneficial manner. The government should examine increased co-operation between these grids as this could improve efficiency and flexibility in both systems. Infrastructure investment to better link the two grids could bring significant benefits, including access to additional electricity import capacity and more diversified supply options to improve security of electricity supply and regional integration.

Luxembourg should examine its current market structure, planning processes, regulations and grid codes to identify and address any barriers to the development of a smart, flexible electricity system that supports innovation; the introduction of new services; and the integration of high shares of VRE generation. Such a system will be necessary to support Luxembourg's goals on e-mobility and prosumer market participation.

Electricity planning processes should examine the full range of infrastructure options, including electricity storage and DSR measures as alternatives to and/or complements to investments in traditional transmission and distribution infrastructure. Battery storage and DSR can support a range of grid flexibility services, in particular in relation to the integration of VRE and distributed electricity generation from prosumers and especially since the cost of both technologies has been rapidly falling.

Luxembourg's smart meter deployment and development of a national database for smart meter data lays the groundwork for a wide range of DSR measures and electricity services that could support VRE integration and system flexibility. Smart meters could provide a market-based mechanism for reducing demand when electricity supply is limited, helping to improve system adequacy and security. Creos' smart meter pilot project "DataThings" examines possibilities for enhanced grid management, including DSR.

Smart meters can support a wide range of measures and services, including real-time pricing, DSR, prosumers and EV smart charging, but access to smart meter data is an important prerequisite to support these measures and facilitate the entry of new market players. The regulations for smart meter data collection and management should establish a clear legal framework that ensures fair and transparent data access that supports innovation and the creation of new electricity sector services. The ILR is currently carrying out a study of the grid fee system that will examine if existing rules allow prosumers to actively participate in the electricity market with appropriate sharing of the network costs. The IEA encourages Luxembourg to closely examine the results of this study and quickly implement any changes needed to realise the full potential of smart meters.

Luxembourg should examine the high level of market concentration in the electricity sector. Just a few companies control most electricity generation, distribution and supply. High market concentration could be limiting innovation and the introduction of new services needed for a smart, efficient and flexible power system. The government should consider measures that allow for more competition and the introduction of new services. The current method of unbundling in the electricity sector should be examined to see if it presents any barriers to competition and innovation.

The low price of electricity and high purchasing power of consumers in Luxembourg present a potential obstacle to development of a smart, flexible electricity system. Low prices limit customer interest in market participation and reduce the ability of energy service providers to develop profitable business models. The introduction of real-time pricing could be effective to drive changes in consumer behaviour and support the

introduction of services related to EV smart charging, DSR and prosumers. These services could lead to lower prices by supporting a more efficient electricity system and reducing the need for infrastructure investments. The introduction of real-time pricing and associated services needs to take into account social impacts, especially on low-income consumers who may not be able make the investments needed to take full advantage of such a scheme.

Luxembourg should develop a strategy to achieve the full benefits of e-mobility while avoiding potential negative impacts on the electricity system. This is particularly true in relation to the 2030 goal to have a 49% EV share in the vehicle fleet, and the need to update the electricity grid in a well-planned manner. The government should closely monitor EV deployment and adapt support of EVs and charging infrastructure to ensure a high EV adoption rate. The government needs to co-ordinate closely with the TSO and DSOs to monitor increasing EV charging and ensure that electricity system planning includes regular assessments of charging impacts on all voltage levels with clear options for infrastructure investments and market changes supporting increased EV adoption and secure system operations.

As imports will continue to play a major role in Luxembourg's electricity supply, the government needs to consider how e-mobility and other new demand sources (like data centres) will drive the need for additional interconnection and transmission capacity. Luxembourg plans to take advantage of its presidency of the PLEF to address cross-border EV charging infrastructure and regional sector coupling. The IEA encourages this effort and suggests that Luxembourg leverage its participation in regional institutions to develop an e-mobility and strategy with neighbouring countries.

Recommendations

The government of Luxembourg should:

- Finalise a legal framework allowing smart meters and their energy data to support the active participation of consumers in the electricity and natural gas markets, facilitate new service providers, and enhance security of supply.
- Examine which rules, procedures and investments are necessary to integrate the envisaged share of 49% electric vehicles into the grid to enable smart charging at homes and at workplaces; and carry out timely long-term distribution grid planning.
- Reconsider the adequacy of approval procedures for electricity infrastructure, establish rules to evaluate alternatives to grid extension and consider whether it would be necessary to establish rules for congestion management and curtailment compensation in relation to VRE.
- Examine whether the current electricity market structure, including the method of unbundling, is best suited to facilitate market entry of new participants and innovative business models.
- Given Luxembourg's high dependence on electricity imports, co-ordinate with neighbouring countries (especially Germany and Belgium) to continuously monitor electricity security implications.

References

ACER (Agency for the Cooperation of Energy Regulators) (2018), *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017*, ACER, Brussels, www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20ELECTRICITY.pdf.

ACER (2016), *Decision of the Agency for the Cooperation of Energy Regulators 06/2016 of 17 November 2016*, ACER, Brussels, www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual%20decisions/ACER%20Decision%2006-2016%20on%20CCR.pdf.

Benelux (2018), *Pentalateral Energy Forum PENTEX2018 – First Pentalateral Electricity Crisis Exercise*, Benelux, Brussels, www.benelux.int/nl/kernthemas/holder/energie/pentalateral-energy-forum.

CEER (Council for European Energy Regulators) (2018), *CEER Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply*, CEER, Brussels, www.ceer.eu/documents/104400/-/-/963153e6-2f42-78eb-22a4-06f1552dd34c.

CFL (Société nationale des chemins de fer luxembourgeois) (2018), *Integrated Report 2018,* CFL, Luxembourg City, https://groupe.cfl.lu/fr-fr/strategy.

Chargy (2019), *Integration of Terminals – Chargy OK*, Chargy, Luxembourg City, https://chargy.lu/fr/entreprises.

CREG (Commission for Electricity and Gas Regulation) (2019), *Study on the Analysis of the Market Reaction of Electricity as a Result of the Unavailability of Several Nuclear Reactors in Belgium During the Period from October 2018 to February 2019*, CREG, Brussels, www.creg.be/sites/default/files/assets/Publications/Studies/F1950FR.pdf.

Creos (2019), *Annual Report 2018*, Creos, Luxembourg City, www.creos-net.lu/fileadmin/dokumente/downloads/rapport_annuels/pdf/gb_creos_annual_report_2016.pdf.

Creos (2018), *Scenario Report 2040*, Creos, Luxembourg City, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

Creos (2010), *National Load Shedding Plan*, Creos, Luxembourg City, www.creos-net.lu/entreprises/electricite/plan-de-delestage.html.

EAFO (European Alternative Fuels Observatory) (2019), *Luxembourg Country Data*, European Commission, Brussels, www.eafo.eu/countries/luxembourg/1743/summary.

EC (European Commission) (2019), *Proposal for a Directive of the European Parliament and of the Council on Common Rules for the Internal Market in Electricity*, EC, Brussels, http://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ITRE/DV/2019/01-23/5-provisional-agreement-karins-directive-on-electricity-EN.pdf.

EC (2017), *Commission Regulation (EU) 2017/2196 of 24 November 2017 Establishing a Network Code on Electricity Emergency and Restoration*, EC, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2196&from=EN.

Eles (2019), *Flow-Based Market Coupling to Be Implemented in the Core Capacity Calculation Region*, Eles, Ljubljana, www.eles.si/Portals/0/Novice/avkcije/CEE/Core_Market_Communication_Kickoff_FINAL3.pdf.

Elia (2019), *Interconnector BeDeLux*, Elia, Brussels, https://www.elia.be/en/news/press-releases/2019/03/20190329_update-on-the-interconnector-between-elia-and-creos-icbedelux.

EMP (Energy Market Price) (2016), *ENGIE to Close the Door of Twinerg Combined-cycle Gas Turbine*, EMP, Martigny, www.energymarketprice.com/energy-news/engie-to-close-the-door-of-twinerg-combined-cycle-gas-turbine.

Enovos (2019), *Enovos Luxembourg Annual Report 2018*, Enovos, Luxembourg City, https://www.encevo.eu/content/download/233610/2627481/version/3/file/Annual+Report+Enovos+2018.pdf.

Government of Luxembourg (2019a), *New Vehicle Bonuses*, Government of Luxembourg, Luxembourg City, https://transports.public.lu/fr/contexte/initiatives/primes.html.

Government of Luxembourg (2019b), *Free Public Transport*, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/fr/actualites/toutes_actualites/communiques/2019/01-janvier/21-bausch-transport.html.

Government of Luxembourg (2007), *Law of 1 August 2007 on the Organization of the Electricity Market*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/loi/2007/08/01/n13/jo.

Government of Luxembourg (2004), *Preliminary Report Blackout of 2 September 2004*, Government of Luxembourg, Luxembourg City, https://gouvernement.lu/dam-assets/fr/actualites/articles/2004/09/09krecke/rapport.pdf.

IEA (2019a), *World Energy Balances 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019b), *Electricity Information 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019c), *Energy Prices and Taxes 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019d), *Global EV Outlook 2019*, IEA, Paris, https://www.iea.org/publications/reports/globalevoutlook2019.

ILR (Institut Luxembourgeois de Régulation) (2019), *Key Figures of the Electricity Market Year 2018 – Part I,* ILR, Luxembourg City, https://assets.ilr.lu/energie/Documents/ILRLU-1685561960-667.pdf.

ILR (2018a), *Electricity and Natural Gas Annual Report 2017*, ILR, Luxembourg City, https://www.ceer.eu/documents/104400/6319351/C18_NR_Luxembourg-NL.pdf/19d6ae0c-2e6e-1a45-9ddd-b167e2a80b22.

ILR (2018b), *Activity Report 2018*, ILR, Luxembourg City, https://assets.ilr.lu/Documents/ILRLU-1797567310-203.pdf.

Luxtram (2019), *A Multimodal Route,* Luxtram, Luxembourg City, www.luxtram.lu/fr/la-ligne.

MD (Martens Democon) (2019), *Construction Yard: Total Demolition of the Twinerg Steam and Gas Plant*, MD, Genk, www.martensdemocom.com/en/projecten/total-demolition-of-the-twinerg-steam-and-gas-plant/24.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

MMPW (Ministry of Mobility and Public Works) (2018), *Electrification and Extension of the Nordstad-Bus Line 512*, Government of Luxembourg, Luxembourg City, https://mmtp.gouvernement.lu/fr/actualites.gouvernement%2Bfr%2Bactualites%2Btoutes_actualites%2Bcommuniques%2B2018%2B10-octobre%2B01-electrification-rgtr512.html.

MSDI (Ministry of Sustainable Development and Infrastructures) (2017), *Modu 2.0 Strategy for Sustainable Mobility*, Government of Luxembourg, Luxembourg City, https://environnement.public.lu/dam-assets/actualites/2019/04/modu2-fr-brochure.pdf.

OECD (Organisation for Economic Co-operation and Development) (2019), *Luxembourg Country Data*, OECD, Paris, https://data.oecd.org/luxembourg.htm.

PLEF (Pentalateral Energy Forum) (2018a), *Pentalateral Energy Forum Support Group 2 Generation Adequacy Assessment*, PLEF, Brussels, www.benelux.int/files/1615/1749/6861/2018-01-31_-_2nd_PLEF_GAA_report.pdf.

PLEF (2018b), *Memorandum of Understanding of the Pentalateral Energy Forum on Emergency Planning and Crisis Management for the Power Sector*, PLEF, Brussels, www.benelux.int/files/7515/1749/6862/Penta_MoU_emergency_planning_and_crisis_management_in_power_sector_signed.pdf.

RES Legal (2019), *Use of the Grid,* EC, Brussels, www.res-legal.eu/search-by-country/luxembourg/single/s/res-e/t/gridaccess/aid/use-of-the-grid-30/lastp/163.

SEO (Société Electrique de l'Our S.A.) (2019a), *Centrale de Vianden*, SEO, Luxembourg City, www.seo.lu/fr/Activites-principales/PSW-Vianden/Presentation.

SEO (2019b), *Hydropower Stations*, SEO, Luxembourg City, www.seo.lu/fr/Activites-principales/Laufwasserkraftwerke/Presentation.

SMARD (2019), *Wholesale Prices*, SMARD, Berlin, www.smard.de/en/wiki-article/5884/5976.

Statec (2019a), *Length of Lines and Tracks in Operation (in km) 1939-2018,* Government of Luxembourg, Luxembourg City, https://statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13519&IF_Language=eng&MainTheme=4&FldrName=7&RFPath=7048.

Statec (2019b), *Type of Fuel by Category of Vehicles 1997-2019,* Government of Luxembourg, Luxembourg City, https://statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13502&IF_Language=eng&MainTheme=4&FldrName=7&RFPath=7049%2c13899%2c13898%2c13901.

Statec (2019c), *Road Motor Vehicles Registered By Type of Vehicle 1936-2019,* Government of Luxembourg, Luxembourg City, https://statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13499&IF_Language=eng&MainTheme=4&FldrName=7&RFPath=7049%2c13899%2c13898%2c13901.

WSA (World Steel Association) (2019), *Top Steel-producing Companies 2018,* WSA, Brussels, www.worldsteel.org/steel-by-topic/statistics/top-producers.html.

8. Oil

Key data (2018)

Domestic oil production: none

Net imports of crude oil: none

Domestic oil products production: none

Net imports of oil products: 63.3 kb/d, +5% since 2008

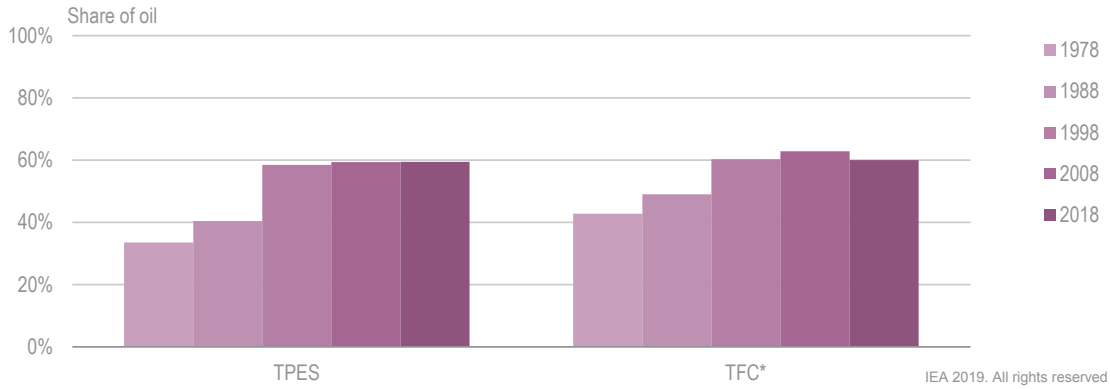
Share of oil: 59.5% of TPES and 0% electricity generation

Consumption by sector (2017): 2.9 Mtoe (transport 84.5%, residential 7.8%, commercial 5.5%, industry 2.1%, heat and power generation 0.05%)

Overview

Oil is Luxembourg's dominant energy source. The share of oil in total primary energy supply (TPES) and in total final consumption (TFC) has remained largely unchanged over the last few decades (Figure 8.1). In 2018, Luxembourg had the highest share of oil in TPES (59.5%) and in TFC (60%) among IEA member countries. It does not have any crude oil production or oil refining capacity. The country imports 100% of its oil products supply, mostly diesel, jet fuel and kerosene for the transport sector. Imports come primarily from Belgium, with smaller contributions from France, Germany and the Netherlands. Luxembourg's oil demand has shown strong growth since 2016, and in 2018 surpassed a pre-financial crisis level to reach 63.3 kb/d (thousand barrels per day).

Figure 8.1 Share of oil in TPES and TFC, Luxembourg, 1978-2018



* Latest TFC data are from 2017.

Note: TPES: total primary energy supply; TFC: total final consumption.

Source: IEA (2019a), *World Energy Balances 2019 First Edition*, www.iea.org/statistics.

In 2017, Luxembourg's oil consumption was 2.2 million tonnes of oil equivalent (Mtoe), 85% of which was from road transportation. Refined oil fuels covered 94% of transport energy consumption in 2017, with 78% coming from diesel and 16% from gasoline. Luxembourg's role as a European transport hub and its low fuel taxation in comparison to neighbouring countries (see Chapter 2) contribute to the high consumption of the transport sector. Around two-thirds of transport fuel consumption come from non-residents refuelling in Luxembourg, including transiting freight trucks and about 200 000 daily cross-border commuters. In an effort to reduce fuel consumption in line with climate targets, the government raised tax rates on gasoline and diesel in 2019.

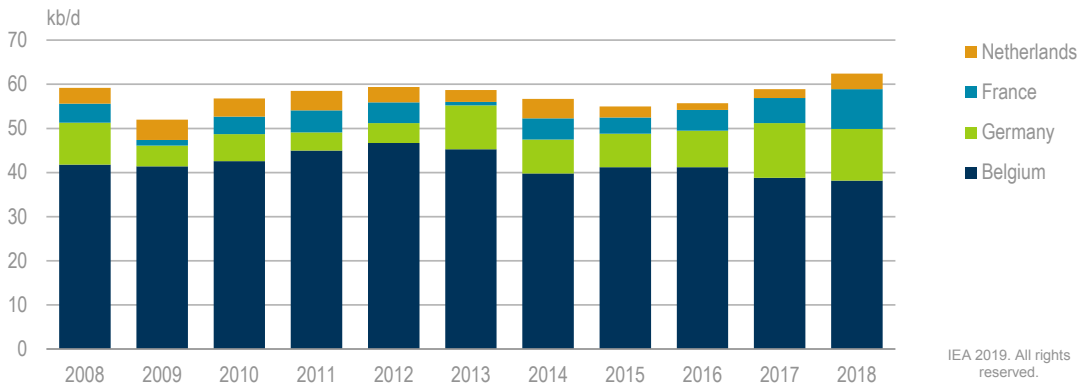
Security of oil supply is promoted through diversification of oil products import sources and modalities, optimal use of oil storage capacity, and compulsory oil stocks for the oil-importing industry. In 2018, Luxembourg's oil products supply chain faced a major challenge due to historic low water levels on the Rhine River (a significant source of oil imports) and the yellow vest movement in Belgium, which blocked access to oil depots relevant to Luxembourg. Consequently, the stockholding obligation of affected importers was temporarily reduced. This incident pointed out the importance of maintaining at least the current level of domestic oil storage capacity to enable operational flexibility for fuel supplies and ensure security of supply.

Supply and demand

In 2018, Luxembourg had the highest share of oil in TPES (59.5%) of any IEA member country. The average for IEA member countries was 34.3%. Luxembourg has neither domestic oil production nor oil refining capacity and is entirely reliant on oil products imports.

In 2018, Luxembourg imported 63.3 kb/d of oil products from four neighbouring countries (Figure 8.2). Belgium was largest source of oil products imports, accounting for 61% of imports, followed by Germany (19%), France (14%) and the Netherlands (6%).

Figure 8.2 Oil products imports by country, Luxembourg, 2008-18



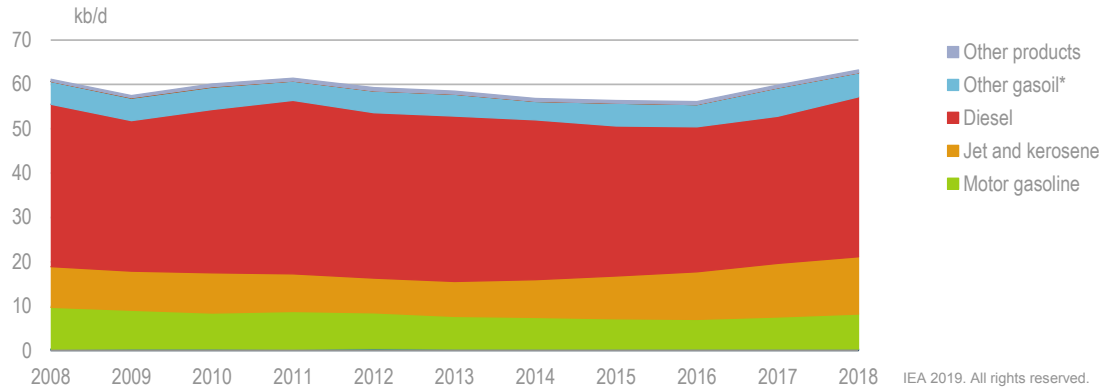
Notes: kb/d: thousand barrels per day. The graph shows total imports, excluding negligible amounts of exports on an occasional basis.

Source. IEA (2019b), *Oil Information 2019*, www.iea.org/statistics.

Luxembourg's oil demand declined for most of the past decade. However, in 2016 oil demand started increasing, with an average annual growth rate of 6% (Figure 8.3).

Transport demand for diesel and jet and kerosene are the principal drivers of the recent growth. Diesel has been the dominant fuel in Luxembourg's oil demand for the last decade. In 2018, diesel accounted for 57% of oil consumption, followed by jet and kerosene (20%), motor gasoline (13%), other gasoil (primarily heating oil) (9%), and other oil products (1%).

Figure 8.3 Oil consumption by product, Luxembourg, 2008-18



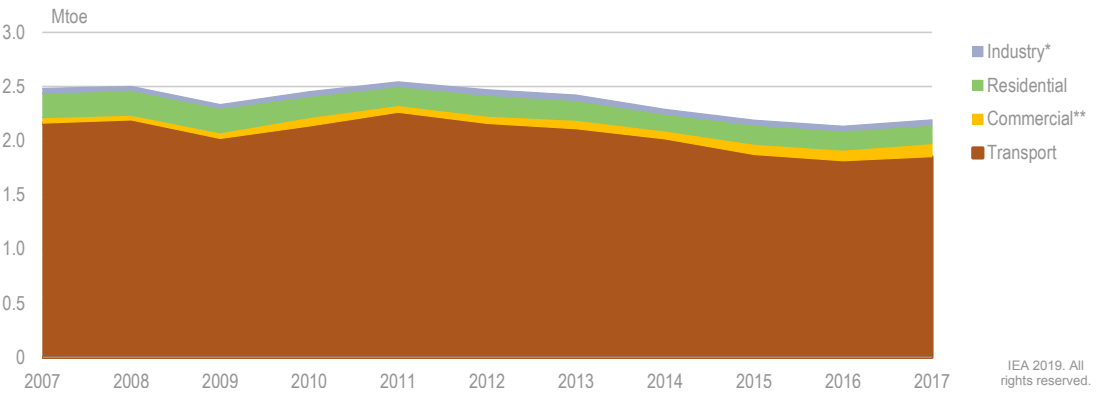
* *Other gasoil* includes light heating oil, marine diesel and diesel used in rail traffic.

Note: kb/d: thousand barrels per day.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics.

Transport is by far the largest oil consuming sector in Luxembourg, accounting for 85% of oil consumption in 2017, followed by the residential (8%), commercial (6%) and industry (1%) sectors (Figure 8.4). Around two-thirds of transport oil consumption comes from non-residents refuelling in Luxembourg. Transiting freight trucks were responsible for almost half of diesel consumption in 2017. Heating oil continues to play a major role in Luxembourg's oil consumption, covering 33% of residential energy consumption and 25% of commercial energy consumption. The commercial share of oil consumption grew by 11% per year over the last decade, driven by an overall increase in commercial sector energy demand and an increase in the share of commercial heating demand covered by heating oil.

Figure 8.4 Oil consumption by sector, Luxembourg, 2000-17



* *Industry* includes non-energy use.

** *Commercial* includes agriculture, forestry and fishing.

Note: Mtoe: million tonne of oil equivalent.

Source: IEA (2019a), World Energy Balances 2019 First Edition, www.iea.org/statistics.

Biofuels blended into diesel and gasoline covered 6% of transport TFC in 2017. Luxembourg's biofuels quota requires all transport fuel suppliers to have a certain share of biofuels in their total annual fuel sales. In 2019, the mandated share of biofuels increased from 5.7% to 5.85%, based on energy content (RES Legal, 2019). The biofuels quota is one of Luxembourg's main policy measures to support achievement of transport sector renewable energy targets. Luxembourg's draft National Energy and Climate Plan (NECP) calls for a 21.9% renewable energy share in transport gross final consumption by 2030, with 10% coming from biofuels and the rest from electrification of transportation (MESP and MECSD, 2019).

Prices

In the second quarter of 2019, Luxembourg had the seventh-lowest diesel price and the ninth-lowest gasoline price among IEA member countries (Figure 8.5). Its low prices are mainly due to lower value-added tax and excise duties on oil products. Total fuel tax revenues, including sales to residents and non-residents, amounted to about EUR 1 billion in 2017, roughly 5% of state revenues.

Luxembourg has the lowest automotive fuel pump prices and taxes among its neighbouring countries (Table 8.1). The low fuel prices are a key driver for the high share of oil in Luxembourg's energy system, as they encourage freight trucks and Luxembourg's 200 000 daily foreign commuters to fuel their vehicles in Luxembourg. In line with the government's policy priority to reduce this fuel consumption to achieve its climate goals, it increased the excise duties on diesel by EUR 0.02 per litre and on gasoline by EUR 0.01 per litre on 1 May 2019. Between February and April 2020, the government is considering another increase in excise duties of up to EUR 0.05 per litre for diesel and up to EUR 0.03 per litre for gasoline.

An inter-ministerial committee of the Ministries of Finance; the Economy; Environment, Climate and Sustainable Development; and Energy and Spatial Planning is charged with analysing the factors affecting fuel sales and monitoring the impact of government measures on fuel sales (including the recent increase in excise duties).

Table 8.1 Fuel prices in Luxembourg and neighbouring countries, Q2 2019

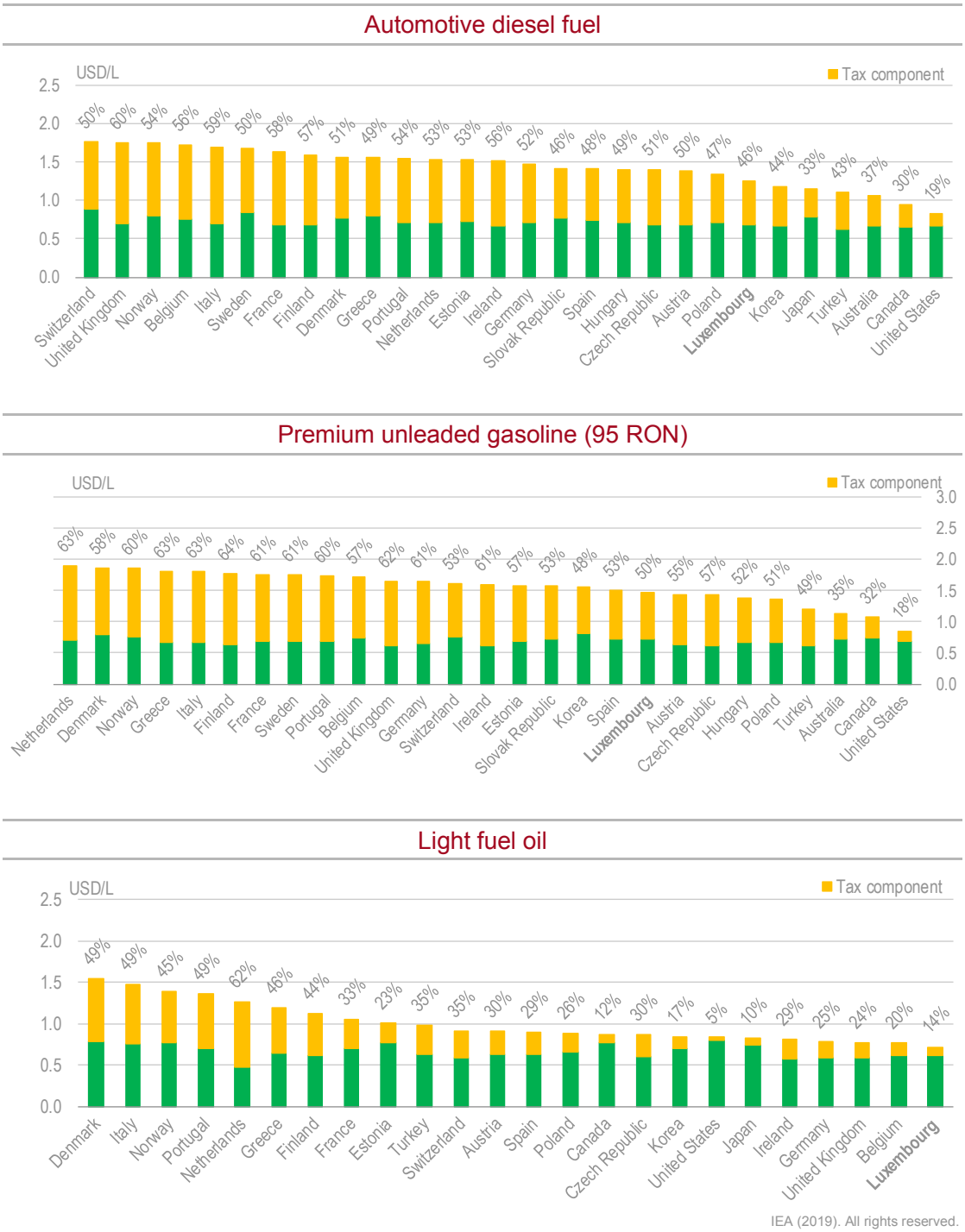
Fuel type	Fuel price (USD per litre)	Luxembourg	France*	Germany	Belgium*
Automotive diesel	Total price	1.25	1.64	1.47	1.72
	Tax component	0.57 (46%)	0.96 (58%)	0.76 (52%)	0.97 (56%)
Unleaded gasoline	Total price	1.47	1.75	1.65	1.71
	Tax component	0.74 (50%)	1.1 (61%)	1.0 (61%)	0.97 (57%)

* Belgium and France provide partial refunds of diesel excise duties for fuel purchased by international transportation companies and bus line operators that are registered in the European Union. In 2018 and 2019, the refund was EUR 0.18-0.22 per litre in France and EUR 0.25 per litre in Belgium. There are restrictions on the types of vehicles that qualify and it can take over a year to receive the refund (Eurovat, 2019).

Notes: Quarterly price data are based on national average weekly prices as reported to the IEA by member countries. Luxembourg and Belgium maintain maximum price-setting mechanisms for oil products (including diesel and gasoline). France and Germany do not set fuel prices. In Belgium, France and Germany, the actual price paid can vary from the average value.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Figure 8.5 Oil fuel prices in IEA member countries, Q2 2019



Notes: Diesel data are not available for Mexico and New Zealand. Premium unleaded gasoline data are not available for Japan, Mexico and New Zealand. Light fuel oil in Australia, Hungary, Mexico, New Zealand, the Slovak Republic and Sweden.

Source: IEA (2019c), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Luxembourg maintains a maximum price-setting mechanism for oil products through a signed agreement between the government and oil-importing companies. This mechanism sets a maximum price for oil products sold to the end consumer, including gasoline, automotive diesel, heating oil and liquefied petroleum gas. The maximum price

calculation is based on price quotations of oil products plus a standard cost of transport from Antwerp to Luxembourg, a standard distribution margin for the market actors, and estimated costs for holding emergency stocks (OECD, 2019). The price-setting mechanism limits consumer choice; such regulations have long disappeared in most IEA member countries, resulting in a dynamic retail market for transport fuels. The government should consider abolishing this system.

In 2018, there were ten companies importing finished products into Luxembourg. These importers are also the main retailers and operated the majority of the approximately 225 retail sites in Luxembourg. The national oil company association, Groupement Pétrolier Luxembourgeois, represents the interests of the oil importers and retailers.

Infrastructure

Luxembourg has limited oil infrastructure: there are no oil refineries, only one pipeline and six oil storage sites (Figure 8.6).

Pipeline

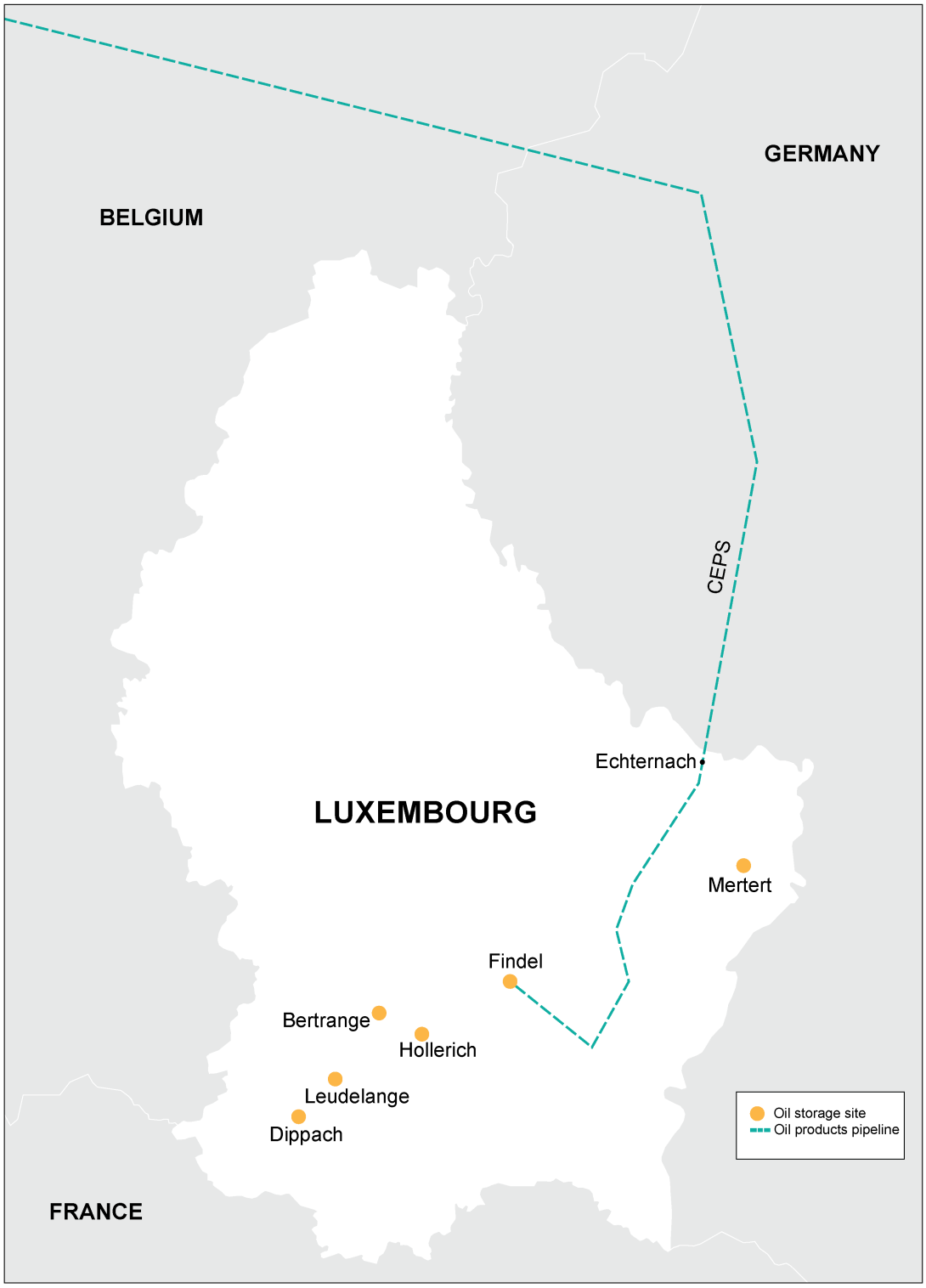
Luxembourg has only one oil pipeline, which is connected to the Central European Pipeline System and supplies the Luxembourg international airport in Findel with aviation kerosene. The pipeline's length within Luxembourg is 36 km and it has a maximum theoretical flow capacity of 96 cubic metres per hour (around 15 kb/d). There are no interconnection capacities and the flow is not reversible.

Oil storage

In 2019, there were six oil storage facilities in Luxembourg. These facilities have a total storage capacity of 177 000 cubic metres (around 1 million barrels) and store mainly diesel, heavy gas oil, two grades of gasoline (95 and 98) and kerosene. The permits for oil storage depots, representing about two-thirds of national oil storage capacity, were renewed in 2019.

With these permits renewed and tanks completely full, Luxembourg's total available oil storage capacity could potentially supply around 17 days of domestic consumption (63.2 kb/d as of 2018). The government plans to conduct a study in order to evaluate needed storage capacities on national territory in line with the NECP, which includes mid-term demand projections (2015-40) for fuels in the transport sector based on a reference scenario.

Figure 8.6 Oil infrastructure in Luxembourg, 2019



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

Emergency response policy

Security of supply is promoted through diversification of oil products import sources and import routes and modalities, optimal use of oil storage capacity, and compulsory oil stocks for oil importers. These measures allow the oil supply chain to respond flexibly and adapt to potential supply disruptions. The primary response policy for an oil supply disruption in Luxembourg is the release of emergency stocks.

Luxembourg's response to oil supply shortages is governed by the provisions of the 2015 Law on the Organization of the Market for Petroleum Products (Government of Luxembourg, 2015), which implements all relevant modifications to the emergency system required by EU Directive 2009/119/EC (EC, 2009) and obliges all oil-importing companies to hold petroleum products stocks equivalent to at least 93 days of net average daily imports of the previous year. These compulsory stocks are typically commingled with commercial stocks.

As of May 2019, Luxembourg held stocks at the level of 97 days of net imports. Domestically held stocks accounted for only 10 days; 87 days of the stocks are in the form of tickets held abroad. Belgium (51%) and the Netherlands (48%) are the principal holders of these tickets, 1.6% of tickets are held in France. Of the stocks held abroad, 60% are crude oil (crude tickets are usually the least expensive), followed by middle distillates (30%), residual fuel oil (6%) and gasoline (4%). All stocks held in Luxembourg are finished products as there are no refineries in Luxembourg (IEA, 2019d).

According to the Law on the Organization of the Market for Petroleum Products, at least 40 days of compulsory stocks shall be in the form of finished oil products that reflect the share of products imported in the previous year. Each importer must also respect requirements, determined by a Grand Ducal regulation, for minimum stock levels to be held nationally and regionally, defined as within 230 km of the geographic centre of Luxembourg.

As all of Luxembourg's emergency stocks are compulsory industry stocks, the release of emergency stocks onto the market would be implemented by reducing company stockholding obligations. The location from which the stocks would be released depends on the type of crisis. For example, stocks of finished products located in Luxembourg might be released during a local crisis and stocks of crude oil held abroad might be released during an international or a regional collective action.

In May 2018, the government decided to develop an emergency plan (*plan d'intervention d'urgence*, PIU) to define how demand restraint measures would be used during an oil supply crisis. The PIU will determine crisis management bodies and emergency measures, and establish the emergency alert procedures necessary to implement demand restraint measures. As of 2019, the draft PIU was in the finalisation process; however, the government has not conducted robust studies showing what volumetric savings can be achieved through demand restraint measures.

According to the government, such a study is difficult, as the professional transport sector dominates Luxembourg's oil consumption and non-residents account for around half of automotive fuels sales. Setting a maximum sales volume per consumer at fuel stations, notably for truck drivers, would likely have the most impact among the measures being considered for the PIU. The IEA recommends that the government

develop solid estimates for volumetric savings from demand restraint measures, most preferably in close co-operation with neighbouring countries.

In 2018, the supply chain of oil products into Luxembourg faced major challenges due to the historic low water levels on the Rhine River and the yellow vest movement. The low water levels of the Rhine River reduced barge transport capacities from Germany by up to 70% and led to significant increases of oil transport costs (barge and train). The refineries along the Rhine River had to reduce production, which lowered the availability of oil products. At the same time, the yellow vest movement disrupted the operation of oil depots relevant to Luxembourg at Feluy and Wandre in Belgium. These depots were temporarily inaccessible due to demonstrations and the refusal of some importers to send trucks to these depots due to safety concerns.

Oil importers were affected by these events and had to apply for stock releases. Thirteen individual waiver decrees were issued over a period of six months and the level of compulsory stocks of affected importers was reduced temporarily, between one to four days depending on the company's specific circumstances. Other actions taken by the importers included: sourcing oil products from different depots in Belgium and the Netherlands; exchanges with importers not affected by the supply crisis; and setting maximum sales volume per customer at certain retail stations. Affected companies reported their operational responses to the crisis to the government on a daily basis. Communication between industry and the government functioned well during this supply disruption. There were no major shortages at affected depots or retail stations and Luxembourg was compliant with its IEA obligation throughout the period. However, this incident shows that there is reason to revisit the adequacy of national stockholding locations and composition. Luxembourg should maintain the current level of storage capacity and consider increasing the amount of oil products held domestically to enable operational flexibility and ensure security of fuel supply.

Assessment

Oil is the dominant energy source in Luxembourg, accounting for 59.5% of TPES in 2018, the highest share among all IEA countries. The large share of oil in TPES corresponds to the dominance of the transport sector in energy consumption.

With neither oil production nor oil refineries, Luxembourg is entirely reliant on oil product imports from neighbouring countries. Oil demand has been increasing since 2016. Diesel and jet and kerosene were the principal drivers of recent growth, accounting for 57% and 20% of oil consumption respectively in 2018.

Luxembourg imports oil by road (47%), rail (22%), pipeline (18%), and barge (13%). There is only one pipeline, a branch of the Central Europe Pipeline System, which supplies kerosene to Luxembourg's international airport. Luxembourg has six oil storage facilities with a total capacity of around 1 million barrels, which could potentially supply around 17 days of Luxembourg's domestic consumption if the tanks were totally filled. The permits for oil storage depots, representing about two-thirds of national oil storage capacity, were renewed in 2019. The government plans to evaluate oil storage adequacy in line with 2040 transport fuel demand projections from the NECP.

Oil consumption in the heating sector is quite high, 33% of residential TFC and 25% of commercial TFC come from heating oil. The government should take active measures to effectively reduce heating oil consumption in residential and commercial heating, including a proactive fuel boiler replacement programme.

Fuel prices in Luxembourg are low compared to neighbouring countries, mainly due to the lower VAT and excise duties on transport fuels. Consequently, Luxembourg has long generated important fuel sales to non-residents, raising additional fuel tax revenues but also fuel emissions relative to its small population. Total fuel tax revenues, including sales to residents and non-residents, amounted to about 1 billion euros in 2017, roughly 5% of state revenues. Luxembourg slightly increased taxes on gasoline and diesel on 1 May 2019, although further increases are needed to reduce the gap with taxes in other countries and to reduce fuel exports. Another increase, to take place between February and April 2020, is under consideration.

Luxembourg maintains a maximum price-setting mechanism for oil products, which regulates the distribution margin. Consequently, most retailers price their products according to the prevailing maximum price. This limits consumer choice between prices. Most IEA member countries abolished such regulations a long time ago, resulting in a dynamic retail market for transport fuels. The government should consider abolishing this system.

Oil emergency response

Luxembourg seeks to maintain security of oil supply by diversifying import sources in terms of country of origin and mode of transport. There is no domestic production and Luxembourg doesn't have any refineries, so the use of emergency oil reserves is central to its emergency response policy. Luxembourg meets its entire IEA and EU stockholding requirements by placing a minimum stockholding obligation on industry. All oil-importing companies are obliged to hold petroleum products stocks equivalent to at least 93 days of the net average daily imports of the previous year. Currently there are ten companies importing finished products into Luxembourg.

The 2015 Act on the Organization of the Market for Petroleum Products is the key legislation regulating oil emergency response. In the case of an emergency, the Department for Energy in the Ministry of Energy and Spatial Planning would be the focal point, acting as the country's National Emergency Strategy Organisation.

As of May 2019, Luxembourg held 97 days of net imports. Domestically held stocks only covered ten days; most of the stocks (86%) are in the form of tickets held abroad. Belgium and the Netherlands are the principal holders of these tickets. A small portion of tickets are also held in France. By fuel type, the majority of these stocks held abroad are crude oil (crude tickets are usually the cheapest), followed by middle distillates, residual fuel oil and motor gasoline. Of all compulsory stocks, at least 40 days should be in the form of refined products that reflect the composition of product types imported in the previous year.

The PIU that is currently under development will allow for co-ordination at the national level in the case of an oil supply crisis. It will determine crisis management bodies, emergency measures (including implementation of demand restraint) and establish emergency alert procedures. Restraint measures being considered for the PIU include maximum sales volume per consumer at fuel stations and allocation of oil products to

priority customers. The government has not conducted robust studies on volumetric savings from demand restraint measures, which is complicated as the professional transport sector dominates oil consumption in Luxembourg and around half of all automotive fuels are sold to non-residents.

In 2018, Luxembourg faced challenges to its oil products supply due to the historic low water levels on the Rhine River and the yellow vest movements in Belgium blocking access to the main oil depots (in Feluy and Wandre) relevant to Luxembourg. The stockholding obligations on oil importers were lowered, depending on the degree to which they were affected. Operational responses to the crises were reported to the government by the affected companies on a daily basis and communication between industry and government proved to function well during this supply disruption.

Recommendations

The government of Luxembourg should:

- Use the 2040 demand forecast study to evaluate the adequacy of domestic oil storage capacity to ensure security of supply.
- Evaluate the composition of stocks held abroad, especially to assess whether physical finished products held in Luxembourg should be increased and whether having a high share (60%) of crude oil tickets impacts the security of supply, as the country doesn't have any refineries.
- Conduct a study into volumetric savings of demand restraint measures, especially the maximum sales volume per consumer (notably truck drivers) set at fuel stations.
- Take active measures to reduce heating oil consumption in domestic heating.

References

EC (European Commission) (2009), *Council Directive 2009/119/EC of 14 September 2009 Imposing an Obligation on Member States to Maintain Minimum Stocks of Crude Oil and/or Petroleum Products*, EC, Brussels, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:265:0009:0023:EN:PDF.

Eurovat (2019), Excise Duty Belgium, Eurovat, Brussels, www.eurovat.eu/en/diesel-tax-reclaim#slideshow-1.

Government of Luxembourg (2015), *Law of 10 February 2015 on the Organization of the Petroleum Products Market*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/loi/2015/02/10/n3/jo.

IEA (International Energy Agency) (2019a), *World Energy Balances 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019b), *Oil Information 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019c), *Energy Prices and Taxes 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019d), *Oil Imports* (database), IEA, Paris, www.iea.org/netimports.

IEA (2014), *Energy Supply Security: The Emergency Response of IEA Countries 2014*, IEA, Paris, https://webstore.iea.org/energy-supply-security-the-emergency-response-of-iea-countries-2014.

MESP (Ministry of Energy and Spatial Planning) and MECSD (Ministry of the Environment, Climate and Sustainable Development) (2019), *Draft Integrated National Energy and Climate Plan for Luxembourg*, Government of Luxembourg, Luxembourg City, https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lu_necp.pdf.

OECD (Organisation for Economic Co-operation and Development) (2019), *OECD Inventory of Support Measures for Fossil Fuels*, OECD, Paris, http://stats.oecd.org/wbos/fileview2.aspx?IDFile=01a8a1ce-1930-40ee-afe2-27b8714aad14%20%20.

RES Legal (2019), *Biofuel Quota*, EC, Brussels, www.res-legal.eu/en/search-by-country/luxembourg/single/s/res-t/t/promotion/aid/biofuel-quota-9/lastp/163.

9. Natural gas

Key data (2018 provisional)

Production: Luxembourg has no gas production

Imports: 0.78 bcm, -38% since 2008

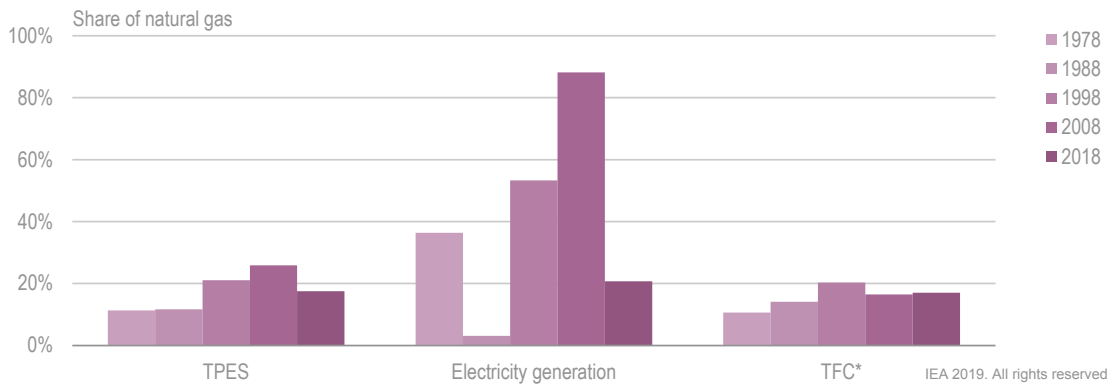
Share of natural gas: TPES: 17.5%, electricity: 20.7%, TFC: 17.1% in 2017

Gas consumption by sector (2017 data): 0.80 bcm total (industry 39.2%, residential 34.1%, commercial 16.0%, heat and power generation 10.7%)

Overview

Luxembourg has no domestic natural gas production; 100% of natural gas is imported, mostly from Norway and the Russian Federation ("Russia"). Natural gas is the second-largest energy source after oil in Luxembourg's total primary energy supply (TPES) and total final consumption (TFC) (Figure 9.1). There has been a significant reduction in natural gas consumption since 2008, mainly driven by decreased gas demand for power generation because of the closure of the country's only large thermal power plant in 2016 (see Chapter 7). The share of natural gas in domestic electricity generation fell from 88% in 2008 to 21% in 2018, while the share of natural gas in TPES fell from 26% in 2008 to 17% in 2018. The share of natural gas in TFC remained more stable around 17%.

Figure 9.1 Share of natural gas in TPES, generation and TFC, Luxembourg, 1978-2018



* Latest TFC data are from 2017.

Notes: TPES: total primary energy supply; TFC: total final consumption. Data for 2018 are provisional.

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

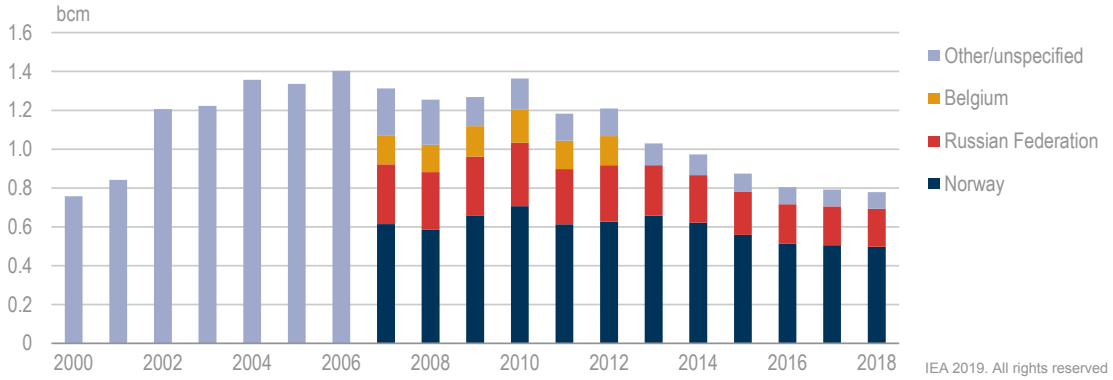
Luxembourg's policies to reduce greenhouse gas (GHG) emissions, improve energy efficiency and increase the share of renewable energy are expected to reduce natural gas demand. Accordingly, Luxembourg will further develop biogas production and in parallel substitute an increasing share of natural gas usage with other renewable energy sources. Luxembourg does not have any plans to add new natural gas entry points into the country and does not intend to expand its gas transmission or distribution networks, other than densifying existing distribution networks where applicable. In 2015, Luxembourg phased out a feed-in tariff for new natural gas combined heat and power (CHP) plants. The government is not planning for any new subsidies for natural gas and expects that whenever possible remaining gas CHP plants will be converted to biomass and use of waste heat. In light of falling gas demand, the government should assess what role natural gas and gas infrastructure could play in supporting Luxembourg's energy transition goals.

Well-functioning emergency response procedures are crucial to maintain a stable and secure supply of natural gas in Luxembourg. As Luxembourg has neither natural gas storage nor substantial line pack in its transmission grid, there is little supply flexibility within the country to compensate for gas supply disruptions. As there is no domestic production or storage, Luxembourg's load-shedding plan is the only measure to safeguard supply to protected customers in emergency cases. In 2018, protected customers represented 34% of total gas consumption.

Supply and demand

Luxembourg does not have any domestic natural gas production and is reliant on imports (Figure 9.2). Natural gas imports fell from 1.36 billion cubic metres (bcm) in 2010 to 0.78 bcm in 2018. Norway and Russia have been the main sources of gas imports over the last decade. In 2018, 64% of imports came from Norway and 25% from Russia.

Figure 9.2 Luxembourg's natural gas imports, 2000-18



Notes: bcm: billion cubic metres. No details on imports by country available before 2007. Data for 2018 are provisional. Imports from Belgium are not a primary source but refer to liquefied natural gas.

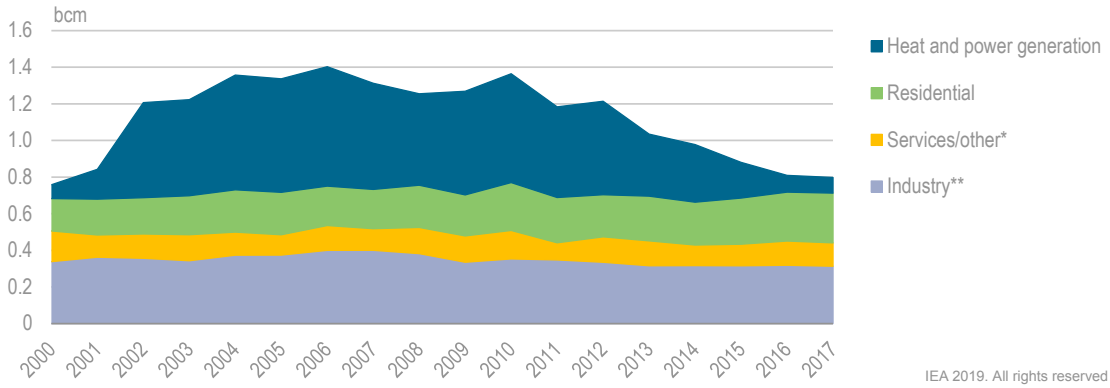
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Luxembourg produces a small amount of biogas from biomass, including the biodegradable fraction of waste from agriculture, silviculture and viticulture, along with biodegradable industrial and municipal waste and sewage sludge. From 2008 to 2018, Luxembourg's biogas production increased by 169% to reach 0.025 bcm (3% of the total

gas supply). Most biogas is consumed at the production site to support electricity generation and heat production in CHP installations, as well as the operation of wastewater treatment plants. Since 2011, a small share of biogas is upgraded to biomethane and injected into the natural gas grid. In 2018, grid-injected biomethane accounted for 0.7% of total natural gas consumption (see Chapter 6).

Natural gas consumption in Luxembourg has gone through major changes in the last decade (Figure 9.3). From 2007 to 2010, natural gas consumption was relatively stable at around 1.3-1.4 bcm per year. By 2017, gas consumption had declined by over 40% to 0.8 bcm. This drop resulted mainly from the reduced used and decommissioning of Luxembourg's only large thermal generation asset, the Twinerg combined-cycle gas turbine (CCGT) plant in 2016 (EMP, 2016). The plant closure reduced heat and power generation gas consumption by 85%, from 0.6 bcm in 2007 to just 0.01 bcm in 2017. Industrial gas demand declined 22% over this period, from 0.4 bcm to 0.3 bcm. Industrial demand has been flat in recent years. Commercial sector gas demand grew by 8% to reach 0.1 bcm in 2017. The main growth in gas consumption came from a 27% increase in residential sector consumption, driven by increasing population and some fuel switching from heating oil to natural gas. In 2017, residential gas consumption was 0.3 bcm. Most residential and commercial gas demand is for building heating.

Figure 9.3 Luxembourg's natural gas consumption by sector, 2000-17



* *Services/other* includes public and commercial services, agriculture, and fishing.

** *Industry* includes chemicals and petrochemicals as well as non-energy use.

Note: bcm: billion cubic metres.

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

Infrastructure

Gas network

In 2018, Luxembourg had a 2 110 km natural gas network providing gas access to an estimated 76% of households in 60 of Luxembourg's 102 communes (Figure 9.4). Creos, the transmission system operator (TSO) and largest distribution system operator (DSO), operates most of the gas network. The DSO Sudgaz and a DSO owned by the municipality of Dudelange operate distribution networks in the south of Luxembourg. There are no gas compressor stations in Luxembourg; all network pressure is provided by stations abroad. The network is not designed to support transit flows to other countries. Network line pack capacity is approximately 320 000 cubic metres.

Natural gas is supplied to Luxembourg via three entry points: Remich from Germany and Bras and Pétange from Belgium (Table 9.1). The combined maximum flow capacity of the three entry points is 6.26 million cubic metres per day (mcm/day). Peak gas demand was 6.0 mcm/day in 2018. On 1 October 2015, the common Belgium-Luxembourg (BELUX) gas market area entered into force. Implementation of the BELUX market ended reservation of entry capacities through a gas entry point with France. However, the capacity of this entry point was very limited, and it never supplied a significant share of gas to Luxembourg (ILR, 2018).

Table 9.1 Major natural gas entry points, Luxembourg, 2017

Entry point	Maximum technical capacity	Delivery pressure	Technical capacity per day	2017 market share (%)
Bras (Belgium)	110 000 Nm^3/hour	40 bars	2.46 mcm/day	39%
Remich (Germany)	100 000 Nm^3/hour	30 bars	2.24 mcm/day	36%
Pétange (Belgium)	70 000 Nm^3/hour	32 bars	1.56 mcm/day	25%
Total	280 000 Nm^3/hour		6.26 mcm/day	

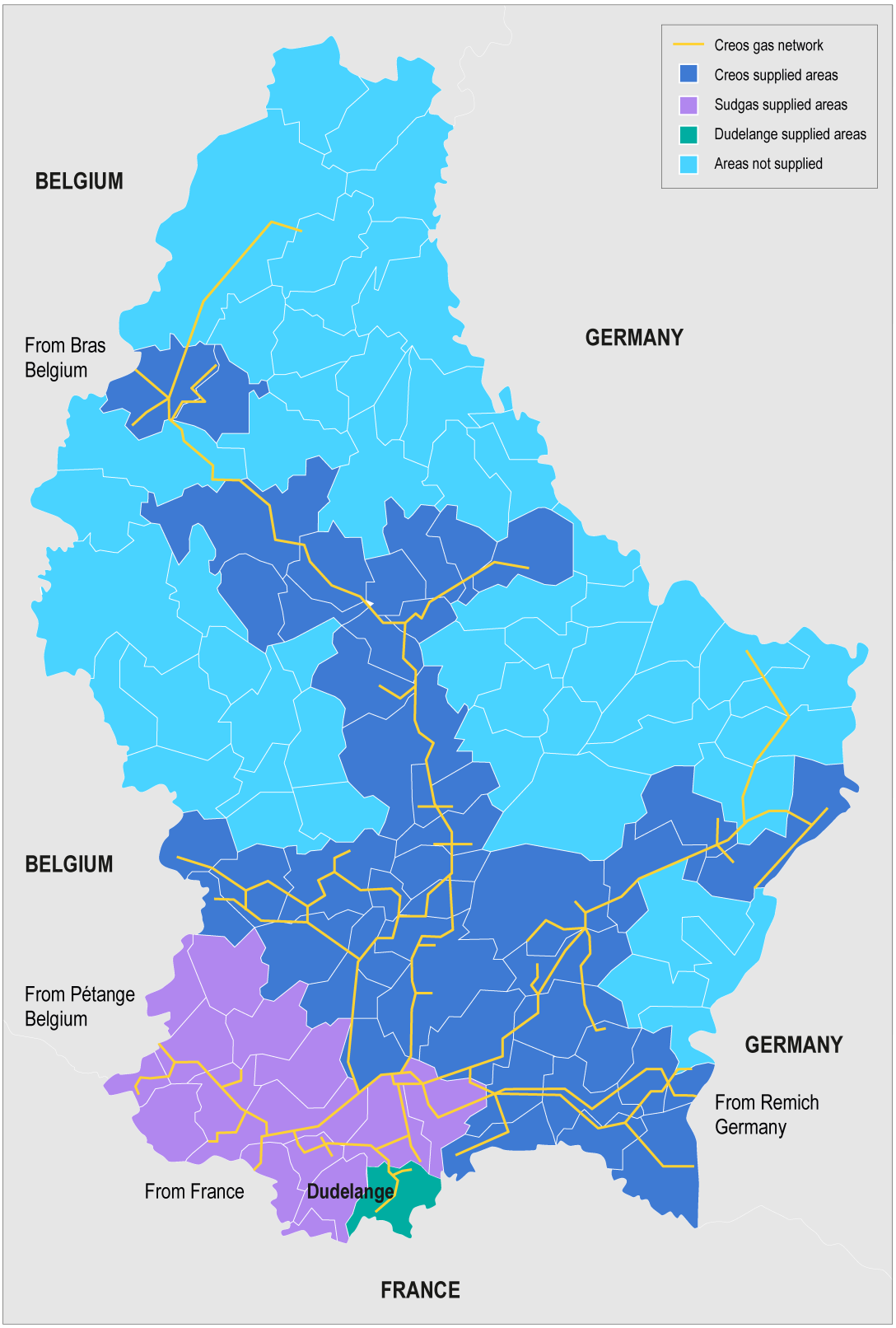
Note: Nm^3/hour: normal cubic metres per hour; mcm/day: million cubic metres per day.

Source: Creos (2018), *Scenario Report 2040*, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

In line with Luxembourg's energy transition goals, the government and the TSO expect decreasing use of the natural gas grid. There are no planned investments to extend the gas transmission grid. The TSO has noted that densification of the distribution grid may be considered in the medium term. An open-season process was launched in 2013 to assess interest in additional gas transmission capacity from France to Luxembourg. The market did now show any interest in building or financing new capacities. The TSO has indicated that no new entry points with neighbouring countries are planned (Creos, 2018).

The government should assess what role natural gas and gas infrastructure could play in supporting Luxembourg's energy transition goals. In the medium term, natural gas can help to support Luxembourg's decarbonisation, e.g. by reducing the high share of heating oil used in residential and commercial buildings. Gas infrastructure could be used to supply renewable gases such as biomethane or hydrogen produced with renewable energy. This would support sector coupling in line with Luxembourg's Third Industrial Revolution strategy and could increase renewable energy shares in sectors like heating and transport that are highly dependent on fossil fuels. Luxembourg is already injecting a small share of biomethane into the gas grid. This could be expanded through pilot projects that would help the government identify barriers to wider use of renewable gases in Luxembourg's gas infrastructure.

Figure 9.4 Luxembourg's natural gas network, 2018



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

Smart meters

A mass roll out of smart meters is taking place, and by the end of 2020 at least 90% of conventional meters will be replaced with smart meters. This could stimulate energy efficiency and ease market access for new suppliers. Non-discriminatory and transparent procedures are needed for accessing consumption data as well as data required for consumer switching. Validated historical consumption data should be made easily and securely available to final customers. As of June 2019, 56% of gas meters had been converted to smart meters (ILR, 2018). The government should ensure that the smart meter deployment proceeds on course and that the data from smart meters are made available in a secure and fair manner to support innovation, market competition and the creation of a flexible energy system.

Markets and regulation

Institutions

Creos is the natural gas TSO, the DSO with the highest number of connected consumers and the largest natural gas distribution network. Creos is legally unbundled from Enovos, the largest gas supplier, but both companies are owned by the Encevo Group. Creos is also the electricity TSO and the largest electricity DSO in terms of customers and network size. There are two other natural gas DSOs in Luxembourg: Sudgaz S.A. and the municipality of Dudelange. These DSOs are also natural gas suppliers, but are exempt from unbundling requirements because of their small size (ILR, 2018).

The Institut Luxembourgeois de Régulation (ILR), the national regulatory authority, has the following responsibilities over the natural gas market:

- conduct research as an input for tariff setting
- review and/or approve contract terms between regulated entities and market actors (e.g. approving transmission and distribution tariffs and fixing the methodologies how these tariffs are calculated)
- issue market guidelines and/or codes of conduct
- enforce compliance with industry standards and regulatory commitments
- issue sanctions and penalties
- mediate to resolve disputes between market actors.

Wholesale market

On 1 October 2015, Luxembourg and Belgium integrated their national gas markets into one common BELUX market/balancing zone. Creos, Luxembourg's gas TSO, and Fluxys, the Belgian gas TSO, jointly manage operation of the common market. Regulatory authority is shared by the ILR and CREG, the Belgian regulatory authority. Balansys SA, which was created jointly by Creos and Fluxys, is the designated market balancing co-ordinator for Luxembourg. Once Balansys obtains the needed authorisation from CREG and the Agency for the Cooperation of Energy Regulators (ACER), it will be the balancing co-ordinator for the entire BELUX zone. In the meantime, Fluxys continues to perform all market balancing tasks in Belgium (ILR, 2018).

Integration of the BELUX market removed entry-exit rights between Belgium and Luxembourg. The Zeebrugge Trading Point (ZTP) is the gas exchange point of the integrated zone. The commercial supply of Luxembourg is possible from any entry point or hub in the BELUX zone without reservation of intermediate transport capacity. The Remich entry point links the German balancing zone NetConnect Germany (NCG) with the ZTP hub. Creos provides a conditional capacity product for the transport of gas from the NCG zone to the BELUX zone, which is necessary to secure Luxembourg's supply on days of high consumption (ILR, 2018).

Retail market

Eight supply companies where active in Luxembourg's natural gas retail market in 2017. As with the electricity retail market, market shares in the natural gas retail market are highly concentrated among just a few companies. Following the 2017 exit of Electrabel from Luxembourg's natural gas retail market, industrial gas supply comes from only two companies: Enovos, which took most of Electrabel's market share, and ArcelorMittal Energy (ILR, 2018).

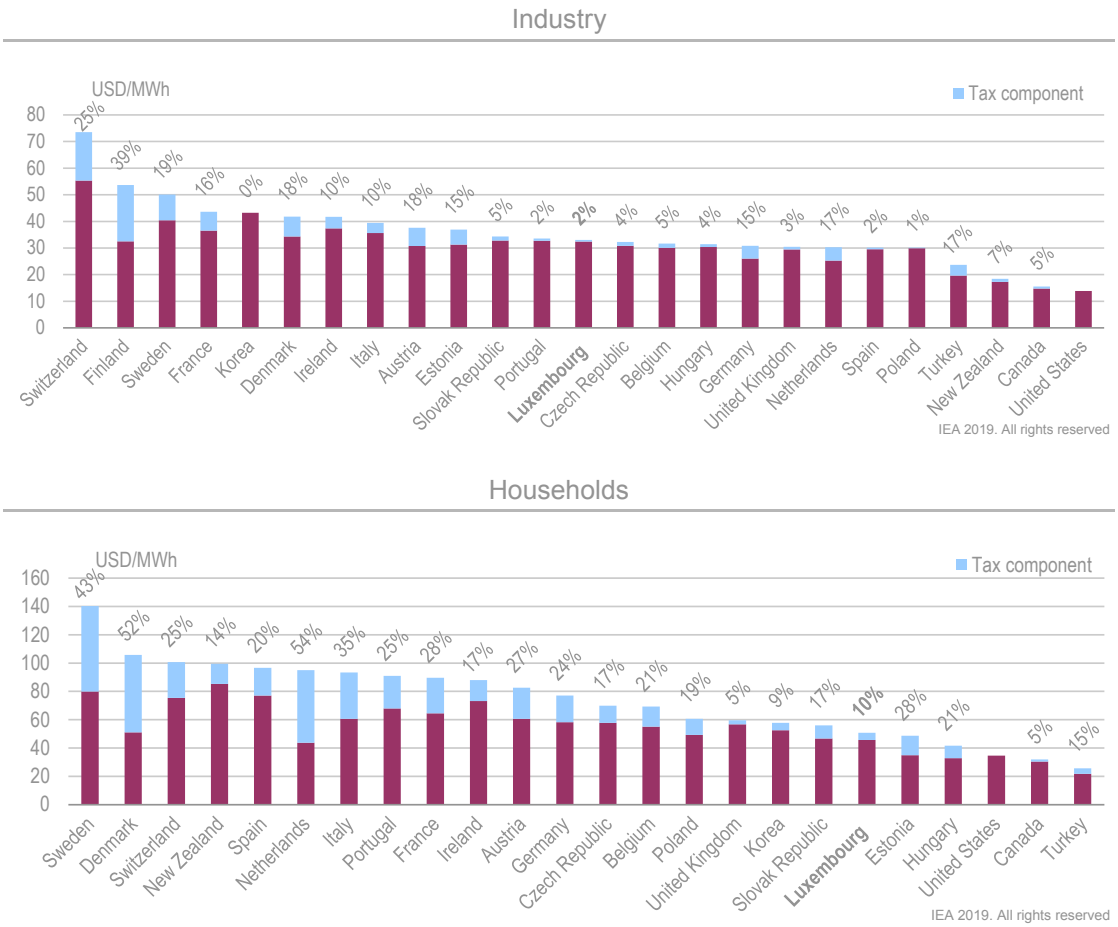
Enovos is the dominant retail gas supplier, with a 28% share by volume of the residential market, 35% of the commercial market (demand less than 280 gigawatt hours [GWh] per year) and 47% of the industrial market (demand greater than 280 GWh per year). LEO (owned by Enovos) supplies 33% of the residential market and 19% of the commercial market. ArcelorMittal Energy supplies 53% of the industrial market and 14% of the commercial market. Sudgaz supplies 39% of the residential market and 16% of the commercial market. Eni has a 5% share of the commercial market (5%). All the other suppliers have market shares of 1% or less (ILR, 2018).

As with the electricity sector, switching rates are low in Luxembourg's natural gas retail market. In 2017, switching rates by volume were 0.2% for the residential sector (same as in 2016) and 0.8% for the commercial sector (down from 0.9% in 2016). High industrial sector switching rates in 2016 (40%) and 2017 (20%) resulted from the exit of Electrabel and do not reflect normal market conditions. In addition, there are only five customers in the industrial segment of the natural gas retail market, defined by the ILR as companies with annual demand of greater the 280 GWh (ILR, 2018).

Prices

Luxembourg's natural gas market was fully opened to competition on 1 July 2007. Prices are not regulated (ILR, 2018). Three tariff components determine the price paid by customers connected to the distribution network: 1) the gas price determined by the customer's selected supplier; 2) fees for the use of the distribution network and ancillary services like metering; and 3) the energy tax and value-added tax. Gas retail prices in Luxembourg's industry sector are close to the median value among IEA member countries, but have one of the lowest tax rates (Figure 9.5). In 2018, industry gas price was 33.1 USD/MWh, of which 2% was taxes. The household gas price was the sixth lowest in an IEA comparison in 2018, at 50.7 USD/MWh, of which 10% was taxes. The household gas price was significantly lower than in neighbouring countries like Belgium, France and Germany.

Figure 9.5 Natural gas prices in IEA member countries, 2018



Notes: USD: United States dollar; MWh: megawatt hour. Tax information not available for the United States. Industry price data are not available for Australia, Greece, Japan, Mexico and Norway. Household price data are not available for Australia, Finland, Greece, Japan, Mexico and Norway.

Source: IEA (2019b), *Energy Prices and Taxes 2019*, www.iea.org/statistics.

Emergency response

The modified Law on the Organization of the Natural Gas Market of 1 August 2007 is the key legislation regulating natural gas emergency response in Luxembourg (Government of Luxembourg, 2007). According to Article 18 of the law, the system operators (TSO and DSOs) are obliged to take the necessary preventive measures in order to limit deterioration of the security, reliability and efficiency of the gas supply. Article 19 allows the government to take temporary measures to safeguard the gas supply after consultation with the Government Commissioner for Energy and the ILR.

The measures to eliminate or mitigate the impact of supply disruptions are described in the Emergency Plan and Preventive Action Plan established according to EU Regulation No. 994/2010 of the European Parliament and of the Council of 20 October 2010 on the security of natural gas supply. A new Emergency Plan and Preventive Action Plan elaborated pursuant to the new regulation (EU) 2017/1938 were finalised in 2019.

The Emergency Plan and Preventive Action Plan establish emergency alert procedures and stipulate operational measures, including the role of the competent authority (Minister for Energy), the composition of a crisis management body and the level of regional co-operation. The crisis management body is composed of two representatives appointed by the competent authority (Ministry for Energy and Spatial Planning), two representatives appointed by the ILR and two representatives appointed by the TSO. The Emergency Plan defines three crisis levels: 1) early warning; 2) alert; and 3) emergency. The crisis management body is required to announce a certain crisis level depending on the situation and to suggest any necessary emergency measures.

Industrial gas consumers do not have any legal obligation to maintain a stock of alternative fuel. Some industrial consumers, representing about 3% of total gas consumption, can switch from natural gas to oil or electrical heating during a crisis. A number of larger CHP plants are also able to switch from gas to other fuels, but the share of gas consumption of these plants is unknown.

Luxembourg has neither natural gas storage nor substantial line pack in its transmission grid and there are no procedures for emergency release of the limited line pack storage. Luxembourg is not a gas transit country and the three active entry points are exempt from the obligation to transport gas in both directions ("bi-directional capacity"). Luxembourg also has a derogation for the N-1 criteria pursuant to EU Regulation 2017/1938 (ILR, 2018). As such, there is little supply flexibility within the country to compensate for lost gas supplies; Luxembourg's natural gas emergency response relies mainly on the load-shedding plan (*plan de délestage*).

The load-shedding plan is established by the TSO and DSOs as a last resort to safeguard supply to protected customers in emergency cases, who represented 34% of the total annual gas consumption in 2018. The categories of interruptible customers with different priorities are defined in the load-shedding plan. Under the plan, the supply to industrial customers, some of which have the possibility to switch from gas to another fuel, will be interrupted first.

A supply disruption in Bras, the largest entry point of Luxembourg with a technical capacity of 2.46 mcm/day, would cause a supply deficit corresponding to 2.20 mcm/day during a phase of the peak demand (6.00 mcm/day). At times of peak demand, a significant reduction of capacity at one entry point would be difficult to compensate for from the other directions. Thus, given this absence of mutually complementary interconnections, and no domestic production or storage, the load-shedding plan is the primary option to address such a supply disruption. The other two entry points (combined capacity of 3.80 mcm/day), however, have enough capacity to cover the demand of the protected customers (52% of peak demand, i.e. 3.06 mcm/day). As such, the country fails to meet the N-1 assessment according to the EU regulation, but it can sustain supply to protected customers if the largest interconnector is interrupted. Although Luxembourg has been granted a derogation for the N-1 criteria pursuant to EU Regulation 2017/1938 concerning measures to safeguard the security of gas supply (ILR, 2018), the IEA encourages the government to investigate whether enhanced regional market integration could improve the cross-border capacity to ensure security of gas supply.

Assessment

There has been a sharp decline in natural gas consumption and power generation over recent years, mostly due to the decommissioning of the Twinerg CCGT plant in 2016. The industry sector and residential sector are the two largest gas-consuming sectors. Gas continues to play an important role in the industrial and residential sectors, but the government forecasts a reduced role for gas in the midterm. Luxembourg does not have any plans to add new natural gas entry points into the country and does not intend to expand its gas transmission or distribution networks, other than densifying existing distribution networks where applicable.

Due to the policies for GHG emissions, energy efficiency and renewable energy, the demand for gas is expected to further decline. This will especially take place in the electricity sector, where subsidies for natural gas CHP are being phased out.[1] In the residential sector, there is a potential for extra gas demand through fuel switching from heating oil, although the government has expressed a preference to move from heating oil directly to renewable heating sources.

There is no indigenous natural gas production in Luxembourg and all natural gas is imported, mostly from Norway and Russia. 3% of that natural gas supply is covered by biogas production from biomass, including the biodegradable fraction of waste from agriculture, silviculture and viticulture, along with biodegradable industrial and municipal waste and sewage sludge. In 2018, biomethane injected into the gas grids covered only 0.7% of total gas consumption.

There are three active entry points for the supply of natural gas to Luxembourg. Maximum flow capacity of these three active entry points is 6.3 mcm/day in total, compared to an anticipated peak demand of 6 mcm/day. The current gas system does not provide enough compensation for a disruption of the single largest entry point and fails to meet the N-1 assessment, for which Luxembourg has a derogation.

Other than line pack storage, Luxembourg does not have any gas storage facilities. Line pack capacity can cover the expected peak demand for around 90 minutes (without additional imports). Luxembourg's natural gas grid has a total length of around 2 110 km, there are no compressor stations and the grid does not allow transit flows to other countries. The government and TSO expect a lower use of the grid for transport and distribution of natural gas. There are no planned investments to extend the gas transmission grid in Luxembourg. The TSO has indicated that no extra interconnection with neighbouring countries will be needed.

Natural gas emergency response

The TSO and DSOs are responsible for ensuring the security and the quality of natural gas supply. As Luxembourg has no natural gas storage, emergency response relies solely on the load-shedding plan, which categorises interruptible customers with different priorities. In an emergency, supply to industrial customers, some of which have the possibility to switch

[1] The Grand Ducal Regulation of 26 December 2012 on the generation of electricity based on high-efficiency cogeneration set a 2015 end date for a feed-in tariff supporting natural gas CHP. Qualifying natural gas CHP installations built before 2015 will continue to receive the feed-in tariff for a total period of 20 years (Government of Luxembourg, 2012). The government expects that whenever possible remaining gas CHP plants will be converted to biomass and use of waste heat.

from gas to another fuel, will be interrupted first, while protected customers, who represent 34% of the total gas consumption, will be interrupted last (ILR, 2018).

EU Regulation 2017/1938 is the key European legislation regulating natural gas emergency response. The Government Commissioner for Energy is responsible for monitoring the general state of the networks and interconnections as well as the security of supply. The regulation obliges risk assessments and all measures necessary to safeguard an uninterrupted supply of gas. System operators are required to take the necessary preventive measures in order to limit the deterioration of the security and the quality of gas supply. The Emergency Plan and Preventive Action Plan establish emergency alert procedures and stipulate operational measures, including the role of the competent authority (Minister of Energy), the composition of a crisis management body and the level of regional co-operation.

Recommendations

The government of Luxembourg should:

- Assess the potential consequences of entry points failing to meet the N-1 standard, and investigate whether enhanced regional market integration could further improve cross-border capacity.
- Together with neighbouring countries, conduct on a regular basis joint exercises to assess cross-border risks and review emergency response procedures, including the creation of a solidarity mechanism under Article 13 of Regulation 2017/1938/EU.
- Investigate options to increase competition on the retail market, including alleviating entry barriers for suppliers, and by price comparison instruments.
- Establish a mid- to long-term perspective for the role of gas and gas infrastructure in light of the decarbonisation strategy. Take into account the role gas and gas infrastructure could play in sector coupling, and in reducing GHG emissions from the residential sector by substituting heating oil and increasing the share of biogas.

References

Creos (2018), *Scenario Report 2040*, Creos, Luxembourg City, www.creos-net.lu/fileadmin/dokumente/NEWS/pdf/2018/Scenario_Report_2040_2_2_2018.pdf.

EMP (Energy Market Price) (2016), *ENGIE to Close the Door of Twinerg Combined-cycle Gas Turbine*, EMP, Martigny, www.energymarketprice.com/energy-news/engie-to-close-the-door-of-twinerg-combined-cycle-gas-turbine.

Government of Luxembourg (2012), *Grand Ducal Regulation of 26 December 2012 on the Generation of Electricity Based on High-efficiency Cogeneration*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/rgd/2016/06/22/n2/jo.

Government of Luxembourg (2007), *Law of 1 August 2007 on the Organization of the Natural Gas Market*, Government of Luxembourg, Luxembourg City, http://legilux.public.lu/eli/etat/leg/loi/2007/08/01/n14/jo.

IEA (International Energy Agency) (2019a), *World Energy Balances 2019* (database), IEA, Paris, www.iea.org/statistics.

IEA (2019b), *Energy Prices and Taxes 2019* (database), IEA, Paris, www.iea.org/statistics.

ILR (Institut Luxembourgeois de Régulation) (2018), *Electricity and Natural Gas Annual Report 2017*, ILR, Luxembourg City, www.ceer.eu/documents/104400/6319351/C18_NR_Luxembourg-NL.pdf/19d6ae0c-2e6e-1a45-9ddd-b167e2a80b22.

ANNEX A: Organisations visited

Review criteria

The Shared Goals (see Annex C), which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews conducted by the IEA.

Review team and preparation of the report

The IEA's joint in-depth review and emergency response review team visited Luxembourg 2-7 June 2019. The review team met with government officials, energy suppliers, market participants, interest groups, consumer representative associations, research institutions, and other organisations and stakeholders. The report was drafted on the basis of the information obtained during these meetings, the review team's preliminary assessment of Luxembourg's energy policy, the Luxembourg government's response to the IEA energy policy questionnaire, and information on subsequent policy developments from the government and private sector sources. The members of the team were:

IEA member countries

Mr. Priit Enok, Estonia (team leader)

Mr. Herbert Krajenbrink, the Netherlands

Ms. Kristin Walter, Germany

Ms. Moa Forstorp, Sweden

European Union (EU)

Mr. Ruud Kempener

International Energy Agency (IEA)

Mr. Aad van Bohemen

Ms. Maki Yamaguchi

Mr. Peter Journeay-Kaler

The team is grateful for the co-operation and assistance of the many people it met with during the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable.

The team expresses its gratitude to Claude Turmes, Minister of Energy and Spatial Planning; Tom Eischen, Director General for Energy; Georges Reding, Director of Renewable Energy; Marc Lindner, Director of Energy Efficiency; and Marco Hoffmann, Director of Energy Markets for their time and encouragement. The team also thanks Georges Lanners, Advisor Oil Products Sector, and Vanessa Tarantini, Assistant to the Director General Energy, for their efforts in organising the team visit, their prompt responses to the team's many requests and their patience throughout the week.

The review was prepared under the guidance of Mr. Aad van Bohemen, Head of the Energy Policy and Security Division, IEA. Mr. Peter Journeay-Kaler managed the review and is the author of the report, with

the exceptions of the chapters on oil and natural gas, which were written by Ms. Maki Yamaguchi, Ms. Jihyun Selena Lee and Mr. Shuto Fukuoka.

Mr. Oskar Kvarnstrom, Ms. Jihyun Selena Lee, Ms. Lilly Lee and Ms. Michelle Lim prepared and drafted the sections relating to energy data contained in each chapter. Helpful comments, chapter reviews and updates were provided by the following IEA staff: Mr. Jean-Baptiste Dubreuil, Mr. César Alejandro Hernandez, Mr. Kieran McNamara, Mr. Gergely Molnar, Mr. Brian Motherway and Mr. Matthew Wittenstein.

Special thanks are extended to the IEA secretariat with regard to the data, publication and editing. Mr. Oskar Kvarnstrom, Ms. Jihyun Selena Lee, Ms. Michelle Lim and Ms. Astrid Dumond ensured the preparation of the design of the report with figures, tables and maps. Ms. Roberta Quadrelli and Mr. Faidon Papadimoulis provided support on statistics. Ms. Therese Walsh managed the editing process, Ms. Astrid Dumond managed the production process and Ms. Isabelle Nonain-Semelin finalised the layout. Mr. Jad Mouwad ensured the press launch.

Organisations visited

During its visit to Luxembourg City, the review team met with the following organisations:

Chambre des Métiers du Grand-Duché de Luxembourg

Creos

Eida

Electris

Fédération des Artisans

Fedil

Greenpeace

Groupement Pétrolier Luxembourgeois

Institut Luxembourgeois de Régulation

Lux Energie

Luxembourg Competition Council

Luxembourg National Research Fund

Ministry of Energy and Spatial Planning

Ministry of Mobility and Public Works

Ministry of the Environment, Climate and Sustainable Development

Ministry of the Economy

MyEnergy

Sotel

Société Electrique de l'Our

Société Luxembourgeoise des Énergies Renouvelables

Sudgaz

Union Luxembourgeoise des Consommateurs

University of Luxembourg

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2016	2017	2018p
TOTAL PRODUCTION		**0.00**	**0.03**	**0.06**	**0.13**	**0.16**	**0.19**	**0.21**
Coal		-	-	-	-	-	-	-
Peat		-	-	-	-	-	-	-
Oil		-	-	-	-	-	-	-
Natural gas		-	-	-	-	-	-	-
Biofuels and waste[1]		-	0.02	0.05	0.11	0.13	0.15	0.17
Nuclear		-	-	-	-	-	-	-
Hydro		0.00	0.01	0.01	0.01	0.01	0.01	0.01
Wind		-	-	0.00	0.01	0.01	0.02	0.02
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	-	0.00	0.01	0.01	0.01
TOTAL NET IMPORTS[2]		**4.44**	**3.37**	**3.34**	**4.09**	**3.54**	**3.58**	**3.70**
Coal	Exports	-	-	-	-	-	-	-
	Imports	2.44	1.11	0.11	0.07	0.05	0.05	0.04
	Net imports	2.44	1.11	0.11	0.07	0.05	0.05	0.04
Oil	Exports	0.01	0.01	0.02	0.01	0.01	0.03	0.03
	Imports	1.67	1.64	2.41	2.87	2.66	2.78	2.93
	Int'l marine and aviation bunkers	-0.05	-0.13	-0.32	-0.43	-0.51	-0.57	-0.59
	Net imports	1.60	1.49	2.07	2.44	2.14	2.19	2.32
Natural gas	Exports	-	-	-	-	-	-	-
	Imports	0.22	0.43	0.67	1.20	0.71	0.69	0.68
	Net imports	0.22	0.43	0.67	1.20	0.71	0.69	0.68
Electricity	Exports	0.07	0.06	0.06	0.28	0.12	0.12	0.12
	Imports	0.24	0.40	0.55	0.63	0.66	0.65	0.65
	Net imports	0.18	0.34	0.49	0.35	0.54	0.53	0.53
TOTAL STOCK CHANGES		**-0.01**	**-0.01**	**-0.05**	**0.02**	**-0.00**	**0.01**	**0.01**
TOTAL SUPPLY (TPES)[3]		**4.43**	**3.39**	**3.35**	**4.24**	**3.70**	**3.78**	**3.91**
Coal		2.44	1.11	0.11	0.07	0.05	0.05	0.04
Peat		-	-	-	-	-	-	-
Oil		1.60	1.48	2.02	2.46	2.14	2.19	2.33
Natural gas		0.22	0.43	0.67	1.20	0.71	0.69	0.68
Biofuels and waste[1]		-	0.02	0.05	0.15	0.23	0.27	0.29
Nuclear		-	-	-	-	-	-	-
Hydro		0.00	0.01	0.01	0.01	0.01	0.01	0.01
Wind		-	-	0.00	0.01	0.01	0.02	0.02
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	-	0.00	0.01	0.01	0.01
Electricity trade[4]		0.18	0.34	0.49	0.35	0.54	0.53	0.53
Shares in TPES (%)								
Coal		*54.9*	*32.8*	*3.3*	*1.6*	*1.4*	*1.2*	*1.1*
Peat		-	-	-	-	-	-	-
Oil		*36.1*	*43.7*	*60.1*	*58.0*	*57.8*	*58.1*	*59.5*
Natural gas		*4.9*	*12.7*	*20.0*	*28.3*	*19.2*	*18.4*	*17.5*
Biofuels and waste[1]		-	*0.7*	*1.5*	*3.5*	*6.2*	*7.2*	*7.4*
Nuclear		-	-	-	-	-	-	-
Hydro		*0.1*	*0.2*	*0.3*	*0.2*	*0.3*	*0.2*	*0.2*
Wind		-	-	*0.1*	*0.1*	*0.2*	*0.5*	*0.5*
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	-	*0.1*	*0.3*	*0.3*	*0.3*
Electricity trade[4]		*3.9*	*10.0*	*14.6*	*8.2*	*14.7*	*14.1*	*13.6*

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: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
TFC	**2.87**	**2.78**	**3.26**	**3.94**	**3.58**	**3.66**	**..**
Coal	0.98	0.53	0.11	0.07	0.05	0.05	..
Peat	-	-	-	-	-	-	..
Oil	1.46	1.48	2.01	2.45	2.14	2.19	..
Natural gas	0.18	0.42	0.61	0.68	0.63	0.62	..
Biofuels and waste[1]	-	-	0.02	0.11	0.16	0.18	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	0.00	0.00	0.00	..
Electricity	0.26	0.36	0.50	0.57	0.55	0.55	..
Heat	-	-	0.01	0.07	0.05	0.06	..
Shares in TFC (%)							
Coal	*34.0*	*18.9*	*3.4*	*1.7*	*1.5*	*1.2*	..
Peat	-	-	-	-	-	-	..
Oil	*51.0*	*53.2*	*61.8*	*62.3*	*59.7*	*60.0*	..
Natural gas	*6.2*	*15.1*	*18.6*	*17.1*	*17.7*	*17.1*	..
Biofuels and waste[1]	-	-	*0.7*	*2.7*	*4.4*	*4.9*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	*0.0*	*0.1*	*0.1*	..
Electricity	*8.9*	*12.9*	*15.3*	*14.4*	*15.3*	*15.0*	..
Heat	-	-	*0.4*	*1.8*	*1.5*	*1.6*	..
TOTAL INDUSTRY[5]	**2.09**	**1.33**	**0.79**	**0.79**	**0.71**	**0.68**	**..**
Coal	0.94	0.52	0.11	0.07	0.05	0.05	..
Peat	-	-	-	-	-	-	..
Oil	0.80	0.29	0.10	0.04	0.04	0.05	..
Natural gas	0.14	0.28	0.30	0.31	0.28	0.27	..
Biofuels and waste[1]	-	-	0.01	0.04	0.04	0.04	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	-	-	..
Electricity	0.20	0.24	0.28	0.31	0.30	0.27	..
Heat	-	-	-	0.01	0.00	0.00	..
Shares in total industry (%)							
Coal	*45.2*	*38.9*	*13.6*	*8.4*	*7.3*	*6.7*	..
Peat	-	-	-	-	-	-	..
Oil	*38.4*	*22.1*	*12.5*	*5.6*	*6.2*	*7.0*	..
Natural gas	*6.7*	*20.9*	*37.8*	*39.4*	*39.6*	*40.5*	..
Biofuels and waste[1]	-	-	*0.8*	*5.3*	*5.2*	*5.3*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	-	-	..
Electricity	*9.7*	*18.2*	*35.2*	*39.6*	*41.6*	*40.5*	..
Heat	-	-	-	*1.5*	*0.1*	*0.1*	..
TRANSPORT[3]	**0.23**	**0.88**	**1.61**	**2.19**	**1.92**	**1.98**	**..**
OTHER[6]	**0.55**	**0.57**	**0.86**	**0.97**	**0.95**	**1.00**	**..**
Coal	0.03	0.01	0.00	0.00	0.00	-	..
Peat	-	-	-	-	-	-	..
Oil	0.43	0.31	0.31	0.27	0.28	0.29	..
Natural gas	0.04	0.14	0.31	0.37	0.35	0.35	..
Biofuels and waste[1]	-	-	0.02	0.02	0.03	0.03	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	0.00	0.00	0.00	..
Electricity	0.05	0.11	0.21	0.25	0.24	0.27	..
Heat	-	-	0.01	0.06	0.05	0.06	..
Shares in other (%)							
Coal	*6.2*	*1.1*	*0.2*	*0.1*	*0.1*	-	..
Peat	-	-	-	-	-	-	..
Oil	*78.3*	*54.4*	*36.0*	*28.3*	*28.8*	*29.3*	..
Natural gas	*6.9*	*24.9*	*35.7*	*37.9*	*36.9*	*35.0*	..
Biofuels and waste[1]	-	-	*1.9*	*2.4*	*3.1*	*3.1*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	*0.1*	*0.2*	*0.2*	..
Electricity	*8.9*	*19.4*	*24.9*	*25.4*	*25.3*	*26.5*	..
Heat	-	-	*1.4*	*6.0*	*5.5*	*6.0*	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
ELECTRICITY GENERATION[7]							
Input (Mtoe)	0.44	0.19	0.11	0.57	0.17	0.20	..
Output (Mtoe)	0.12	0.05	0.04	0.28	0.07	0.08	0.08
Output (TWh)	1.39	0.62	0.42	3.23	0.79	0.90	0.94
Output shares (%)							
Coal	*58.8*	*76.4*	-	-	-	-	-
Peat	-	-	-	-	-	-	-
Oil	*27.6*	*1.4*	-	-	-	-	-
Natural gas	*10.2*	*5.4*	*51.3*	*90.3*	*32.9*	*24.6*	*20.7*
Biofuels and waste[1]	-	*5.4*	*13.4*	*4.1*	*26.8*	*27.7*	*31.4*
Nuclear	-	-	-	-	-	-	-
Hydro	*3.4*	*11.2*	*29.6*	*3.3*	*14.6*	*9.6*	*9.9*
Wind	-	-	*6.0*	*1.7*	*13.0*	*26.1*	*26.1*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	*0.6*	*12.7*	*12.1*	*12.0*
TOTAL LOSSES	**1.54**	**0.61**	**0.09**	**0.29**	**0.11**	**0.12**	**..**
of which:							
Electricity and heat generation[8]	0.32	0.14	0.06	0.22	0.05	0.05	..
Other transformation	1.08	0.41	-	-	-	-	..
Own use and transmission/distribution losses	0.14	0.06	0.03	0.06	0.07	0.07	..
Statistical differences	**0.02**	**-**	**0.01**	**0.01**	**0.00**	**0.00**	**..**
INDICATORS							
GDP (billion 2010 USD)	13.66	24.12	40.78	53.21	62.56	63.52	65.18
Population (millions)	0.35	0.38	0.44	0.51	0.58	0.60	0.61
TPES/GDP (toe/1 000 USD)[9]	0.32	0.14	0.08	0.08	0.06	0.06	0.06
Energy production/TPES	0.00	0.01	0.02	0.03	0.04	0.05	0.05
Per capita TPES (toe/capita)	12.63	8.87	7.67	8.34	6.33	6.32	6.42
Oil supply/GDP (toe/1 000 USD)[9]	0.12	0.06	0.05	0.05	0.03	0.03	0.04
TFC/GDP (toe/1 000 USD)[9]	0.21	0.12	0.08	0.07	0.06	0.06	..
Per capita TFC (toe/capita)	8.19	7.27	7.45	7.76	6.13	6.12	..
CO_2 emissions from fuel combustion ($MtCO_2$)[10]	17.5	10.8	8.1	10.7	8.5	8.6	-
CO_2 emissions from bunkers ($MtCO_2$)[10]	0.2	0.4	1.0	1.3	1.5	1.7	-
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-15**	**15-16**	**16-17**	**17-18**
TPES	-1.6	-0.1	2.4	-2.5	-1.0	2.1	..
Coal	-4.5	-20.6	-4.8	-6.1	6.1	-13.5	..
Peat	-	-	-	-	-	-	..
Oil	-0.4	3.1	2.0	-2.3	-2.5	2.7	..
Natural gas	4.0	4.6	6.0	-8.5	-7.8	-2.3	..
Biofuels and waste[1]	-	8.3	11.4	7.8	5.0	19.2	..
Nuclear	-	-	-	-	-	-	..
Hydro	2.4	6.2	-2.0	-	11.1	-30.0	..
Wind	-	-	9.6	12.5	-	122.2	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	29.7	-	9.1	..
TFC	-0.2	1.6	1.9	-1.9	0.1	2.1	..
Electricity consumption	2.0	3.4	1.3	-1.2	2.4	0.4	..
Energy production	12.4	8.1	7.2	4.1	5.8	17.8	..
Net oil imports	-0.4	3.3	1.7	-2.3	-1.6	2.2	..
GDP	3.4	5.4	2.7	2.8	2.4	1.5	..
TPES/GDP	-4.8	-5.2	-0.3	-5.2	-3.3	0.5	..
TFC/GDP	-3.5	-3.6	-0.7	-4.6	-2.4	0.7	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste 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. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.
3. Excludes international marine bunkers and international aviation bunkers.
4. Total supply of electricity represents net trade.
5. Industry includes non-energy use.
6. Other includes residential, commercial and public services, agriculture/forestry, fishing, and other non-specified.
7. Inputs to electricity generation include inputs to electricity, combined heat and power, and heat plants. Output refers only to electricity generation.
8. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 100% for hydro, wind and solar photovoltaic.
9. Tonne of oil equivalent per thousand US dollars at 2010 prices and exchange rates.
10. "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.

P: preliminary data; Mtoe: million tonnes of oil equivalent; TPES: total primary energy supply; TWh: terawatt hour; GDP: gross domestic product; toe: tonne of oil equivalent; TFC: total final consumption; $MtCO_2$: million tonne CO_2 equivalent.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases, this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. **The environmentally sustainable provision and use of energy** are central to the achievement of these shared goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the polluter pays principle where practicable.

4. **More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. **Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle, from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. **Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. **Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. **Co-operation among all energy market participants** helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 in Paris, France.)

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

ANNEX D: Glossary and list of abbreviations

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

Acronyms and abbreviations

CCGT	Combined cycle gas turbine
CEP	Clean Energy Package
CHP	Combined heat and power
DH	District heating
DSO	Distribution system operator
DSR	Demand-side response
EBR	Enhanced Building Renovation
EC	European Commission
EEA	European Environment Agency
EED	Energy Efficiency Directive (EU)
EEO	Energy efficiency obligation
EPBD	Energy Performance of Buildings Directive
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
EU	European Union
EV	Electric vehicle
FEDIL	Business Federation of Luxembourg
FNR	National Research Fund *Fonds National de la Recherche*
GDP	Gross domestic product
GHG	Greenhouse gas
IEA	International Energy Agency
IFSB	Building Sector Training Institute *Institut de Formation Sectoriel du Bâtiment*
ILR	Institut Luxembourgeois de Régulation
LGX	Luxembourg Green Exchange
LIST	Luxembourg Institute of Science and Technology
NECP	National Energy and Climate Plan
NEEAP	National Energy Efficiency Action Plan
NSCOGI	North Seas Countries' Offshore Grid Initiative
NZEB	Nearly zero-energy building
OECD	Organisation for Economic Co-operation and Development
PHEV	Plug-in hybrid electric vehicle

PIU	Emergency plan *Plan d'intervention d'urgence*
PLEF	Pentalateral Energy Forum
PV	Photovoltaics
RD&D	Research, development and demonstration
SME	Small and medium-sized enterprise
TFC	Total final consumption
TPES	Total primary energy supply
TSO	Transmission system operator
UNFCC	United Nations Framework Convention on Climate Change
V2G	Vehicle to grid
VRE	Variable renewable energy

Units of measure

bcm	billion cubic metres
GWh	Gigawatt hour
kb/d	Thousand barrels per day
kV	Kilovolt
kW	Kilowatt
mcm/day	Million cubic metres per day
MPA	Mega-volt amperes
$MtCO_2$-eq	Million tonne CO_2 equivalent
Mtoe	Million tonne oil equivalent
MW	Megawatt
Toe	tonne of oil equivalent
TWh	Terawatt hour

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Energy Policy Review

The 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 best practices and experiences.

Luxembourg experienced strong economic and population growth between 2008 and 2018. For most of that decade, energy demand and carbon dioxide emissions fell significantly, but they started to increase again in 2016. The government has adopted ambitious energy sector targets, including a 50-55% reduction of greenhouse gas emissions by 2030. Luxembourg faces challenges achieving those targets. Low energy prices for consumers are creating a barrier to the investments needed in energy efficiency and renewables. And the country has a fossil fuel-intensive energy mix driven by a high demand for transportation fuels, notably from transiting freight trucks.

Luxembourg is embedded in the European electricity market, a sector that is transforming swiftly as rising shares of variable renewable generation, such as wind and solar PV, put increased attention on security of supply. In this context, Luxembourg plans to expand and upgrade its electricity grids, but the country would benefit further from the deployment of measures to increase energy storage and demand-side response in its power system. It is also important to ensure competitive markets that foster innovation and new energy services.

In this report, the IEA provides a range of energy policy recommendations to help Luxembourg smoothly manage the transition to a smart, flexible and sustainable energy system.