Korea 2020

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process supports energy policy development and encourages the exchange of international best practices. By seeing what has worked – or not – in the "real world", these reviews help identify policies that deliver concrete results. Since 2017, the IEA has modernised the reviews by focusing on the key challenges in today's rapidly changing energy markets.

Korea has been actively involved in international discussions on energy as a member of the IEA since 2002. We greatly value its engagement with the Agency and our work, and I have much appreciated my in-depth conversations in recent years with Minister of Trade, Industry and Energy Sung Yun-mo on national, regional and global energy issues.

Korea's energy sector is characterised by the dominance of fossil fuels in the energy mix and a strong dependence on energy imports. To accelerate the transition to low-carbon energy, the government is prioritising innovation in demand-side management and the pursuit of a clean and safe energy mix.

In 2015, Korea became the first country in North East Asia to introduce a nationwide emissions trading system that sets a best practice example for other countries in the region. Yet, more needs to be done to reduce the carbon intensity of Korea's energy supply, which is higher than the IEA average because of the high share of coal-fired power generation.

Recent plans by the government to permanently close coal-fired plants that have been operating for over 30 years reflect growing concerns among the population over climate change and local air pollution. The government can draw on this support to swiftly introduce its planned environmentally friendly energy tax programme that will complement other policy efforts.

Korea's Green New Deal, announced as part of the government's Covid-19 recovery plans, builds on the country's commitment to significantly increase the share of renewable energy in the energy mix, currently the lowest among IEA countries. A higher share of renewable energy will also contribute to reducing energy imports. However, using the opportunities offered by innovation and digitalisation to foster the energy transition and ensuring energy security requires more flexible energy markets and active consumer engagement.

It is my hope that this in-depth review will support Korea in its energy transition and help it achieve the energy policy goals of providing affordable, secure and clean energy to its population as it adapts to a fast-changing global energy landscape.

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ENERGY INSIGHTS

ENERGY SYSTEM TRANSFORMATION

ENERGY SECURITY

ANNEXES

LIST OF FIGURES, TABLES AND BOXES

Figures

Tables

Boxes

1. Executive summary

Korea's energy sector is characterised by the dominance of fossil fuels, which in 2018 accounted for 85% of total primary energy supply (TPES), a strong dependence on energy imports at 84% of TPES, and the dominance of industrial energy use at 55% of total final consumption, the highest share among IEA countries. In 2018, Korea had the lowest share of energy from renewable sources in energy supply among all IEA countries.

The Korean government is committed to advance the country's energy transition by increasing the share of renewable electricity to 20% by 2030 and to 30-35% by 2040, to gradually phase-out coal and nuclear from the energy mix while significantly improving energy efficiency, and by fostering the country's nascent hydrogen industry. Under the Paris Agreement, Korea is committed to limit its emissions to 536 million tonnes carbon dioxide equivalent (Mt CO_2-eq) in 2030; in 2018, emissions were 709 Mt CO_2-eq.

Reaching these ambitious targets will require Korea to substantially enhance decarbonisation efforts across all energy sectors, address regulatory and institutional barriers, introduce flexible market designs, and make use of the country's advanced technologies and innovative capacity. The government's announcement of a Green New Deal in July 2020 as part of its post Covid-19 recovery package is a significant step towards accelerating Korea's energy transition.

Korea's energy transition and the Green New Deal

In its 3rd Energy Master Plan (EMP), the government has confirmed its intention to gradually phase-out nuclear power generation, expected to be completed in the last quarter of the century. Korea is also committed to phase-out coal-fired generation. Together, this amplifies the need to ensure system reliability and adequacy of supply at all times when the share of variable renewables increases. To facilitate greater deployment of renewable electricity, closer engagement with local communities through the creation of frameworks for more active consumer engagement are necessary.

A key aspect of Korea's Green New Deal is the decarbonisation of the industry sector and the decoupling of the sector's energy consumption from its economic activity, all the while maintaining the country's strong industrial export base. The Korean government is committed to leverage the benefits of the Fourth Industrial Revolution not only for economic development, but also to support the energy transition by harnessing the opportunities offered by digitalisation to foster the energy transition. The proposed measures include the creation of a big data platform, industrial convergence with 5G networks and artificial intelligence, and the promotion of smart working and low-carbon industrial complexes.

In 2015, Korea became the first country in North East Asia to introduce a nationwide Emissions Trading System (ETS) which sets a best practice example for other countries in the region. As over 90% of the emissions trading certificates are still provided for free,

the ETS resulted in a limited emissions reduction of 2% in 2019 of all ETS sectors taken together, and 8.6% in the power generation sector.

It is important that the government finds a good balance between mandatory and voluntary policy to ensure the contribution of the industry sector in meeting Korea's ambition for energy efficiency. Moreover, it is also essential to raise the awareness of the industry players that reducing energy intensity can not only make the industry sector more resilient to energy supply disruptions, but will also contribute to sustainable growth and maintaining competitiveness.

Transport is the second-largest energy-consuming sector and also has the second-highest emissions. The share of public transport use in Korea has been stagnating, while the use of individual motorised transport has been steadily increasing. The government is aiming to apply solutions from the Fourth Industrial Revolution to the transport sector such as "mobility as a service" and intelligent transport systems. Implementing the necessary changes to the infrastructure requires coherent co-ordination among all of the relevant authorities at the central and local levels and the involvement of local communities.

Korea also has strong ambitions for the creation of a hydrogen economy, and especially for the deployment of hydrogen in the transport sector. To ensure the smooth roll-out of the hydrogen transport network, the government should intensify its dialogue with affected communities that have expressed concerns about the safety of hydrogen fuelling stations and their siting.

Overall, reaching the ambitions of the 3rd EMP and the Green New Deal requires greater collaboration at all levels of government, enhanced responsibilities for local governments, and a proactive engagement with and of industry and civil society.

Taxation

The IEA welcomes Korea's commitment to move towards an environmentally friendly energy taxation system starting with the power sector (where in 2018, taxes on imported gas were reduced by 80% and those for coal were increased by 30%), to ensure that the price of each fuel adequately reflects the environmental costs related to its use, with a special focus on particulate matter. The IEA urges Korea to expedite the consultation for and introduction of the planned rational taxation system of transportation fuels. This would complement the government's other policy efforts to reduce greenhouse gas emissions and to reflect the external costs of energy use.

Local air pollution

There are increasing concerns in Korea about local air pollution and fine dust and they have become major social and economic issues. The Seoul Metropolitan Area is among the most polluted cities in the world, and in 2017 Korea had the highest fine particulate matter among OECD member countries. In 2018, the government implemented a breakthrough policy towards addressing the issue by giving local governments the authority to temporarily suspend the operation of coal-fired plants if air pollution and fine dust exceed the legal limits set by the government. To improve the levels of air pollution, the government is further committed to permanently close old coal-fired plants that have been operating for over 30 years.

Korea's population appears keenly aware of the severity of the local air pollution problem and is demanding fast, and perhaps even drastic, actions. The government could leverage

these concerns by pushing forward its agenda to reduce local air pollution while simultaneously preparing the ground for the fast implementation of other elements of its energy transition policy.

Broadening energy security parameters

Korea has traditionally maintained a high level of oil and gas security, although the country hardly has any domestic production and no cross-country oil and gas pipelines. It has consistently been in compliance with the IEA 90-day oil stock holding requirement. Korea has successfully diversified the number of its oil and gas suppliers by taking advantage of changing international markets. As dependence on oil and gas supplies from the Middle East in 2018 was still 70% and 43% respectively, the government is committed to pursue diversification further.

Moving forward with the Green New Deal, energy security will increasingly be assessed against a broader set of parameters. Since the last in-depth review in 2012, Korea has significantly accelerated the deployment of both wind and solar PV. However, as Korea started off from a very low base, the share of electricity generated from variable renewable sources was just under 4% in 2018. Reaching the 2030 and 2040 targets (shares of 20% and 30-35% respectively) requires a resilient and much more flexible electricity system, capable of accommodating the growing share of variable and decentralised renewables.

Korea's electricity sector is operated as a mandatory pool with a single buyer; wholesale and retail prices are not set by the market, but by the government. The role of Korea's Electricity Regulatory Commission is largely advisory, with all important decisions taken by the government. Failure to open the electricity sector and introduce true competition and independent regulation along the electricity value chain can become major impediments for Korea's energy transition.

The government is proactively addressing emerging threats to energy security potentially stemming from increasing digitalisation of the energy supply chain and the overall energy system. The IEA congratulates Korea on the issuance of its first National Cybersecurity Strategy in 2019, which sets a best practice example for other IEA countries.

Key recommendations

The government of Korea should:

- Elevate the status of the Korean Electricity Regulatory Commission as the regulator of the electric power industry. Its responsibilities in areas such as setting tariffs and monitoring of the market should be strengthened, and the commission's staff strength should be increased in line with the additional responsibilities.
- In addition to the clean energy targets, the Korean government should develop performance-driven regulatory frameworks for energy efficiency and renewable energy deployment, but also for competitive electricity and gas markets, in order to attract and facilitate investments in clean energy with new business opportunities.
- Ensure that the energy taxation of all fuels reflect their external costs, including carbon content and air pollution, to accelerate the switch to lower emission technologies.
- Ensure efficient infrastructure roll-out to support the clean mobility targets.

2. General energy policy

Key data

(2018)

TPES: 282.3 Mtoe (oil 39.1%, coal 28.5%, natural gas 16.9%, nuclear 12.3%, bioenergy and waste 2.5%, solar 0.4%, wind 0.1%, hydro 0.1%, geothermal 0.1%), +24.3% since 2008

TPES per capita: 5.5 toe/cap (IEA average: 3.9 toe/cap)

TPES per unit of GDP: 133.9 toe/USD million PPP (IEA total: 88.2 toe/USD million PPP)

Energy production: 45.2 Mtoe (nuclear 76.9%, biofuels and waste 15.6%, solar 2.3%, oil 1.8%, coal 1.2%, natural gas 0.6%, hydro 0.6%, wind 0.5%, geothermal 0.5%, heat 0.1%), +1.1% since 2008

TFC: 182.2 Mtoe (oil 51.9%, electricity 25.1%, natural gas 12.3%, coal 5.2%, district heat 3.0%, biofuels and waste 2.3%, geothermal 0.1%), +24.0% since 2008

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Country overview

Korea is located in the southern half of the Korean peninsula. It occupies 98 480 square kilometres (km²), slightly larger than Portugal, and shares a 238 km land border with the Democratic People's Republic of Korea. Geographically, there are many hills and mountains, covering almost 70% of the total territory. Most of the population is concentrated in the lowland areas. About 82% of the total population of close to 52 million lives in an urban area. Korea used to have a milder climate with hot and humid summers and cold, dry winters, but the climate has become more tropical in recent years.

Korea ("Daehan Minguk" in Korean) is a democratic republic that follows a presidential system and shares powers among the president, legislature and judiciary. The president is the head of the executive branch and is elected by direct popular vote for a single five-year term. The current President, Mr. Moon Jae-in, from the Democratic Party of Korea, took office in 2017. Seoul is the capital, with over 10 million residents, while the Seoul Metropolitan Area accounts for over 22 million residents. Other major cities include Busan (3.6 million); Daegu (2.7 million); Incheon (1.5 million); Gwangju and Deajon, each with 1.4 million inhabitants; and Ulsan, the smallest metropolitan city with 1.1 million (Gone2Korea, 2020) (Figure 2.1).

Sejong, a newly constructed city about 120 km south of Seoul, is the administrative capital of Korea. The gradual relocation of 36 government ministries and the Prime Minister's office to Sejong began in 2012 with a view to reduce the political and economic dominance

of Seoul and to spread economic development opportunities more evenly across Korea. However, the parliament and the president's office have remained in Seoul. In addition to the government ministries, large government-owned corporations and agencies have also relocated their headquarters outside of Seoul and are now situated across the country.

Figure 2.1 Map of Korea

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.

Korea has experienced remarkable economic growth in just a few decades and in 2018 was the 12th-largest economy in the world (by nominal gross domestic product [GDP]), and the fourth-largest economy in the Asia Pacific region, after the People's Republic of China (hereafter, "China"), Japan and India. This is even more remarkable given Korea's

geographical position and the country's lack of natural resources. Korea's economy is strongly export-oriented; exports contributed 44% of GDP in 2018 (World Bank, 2020).

Industry accounted for just over 35% of GDP and employed just under 25% of the workforce in 2018. The main industries include petrochemicals, textile, steel, car manufacturing, shipbuilding and electronics. Korea is the world's largest producer of semiconductors (Societé Générale, 2020). The share of high-technology exports of total manufactured exports was 36% in 2018 (World Bank, 2020). However, with limited natural resources, Korea depends on the import of raw materials, including energy, to sustain its strong industrial and export base.

Services is the largest and fastest growing economic sector, accounting for 53.5% of GDP in 2018 and employing 70% of the workforce. Tourism is increasingly important to the Korean economy, with the highest number of tourists coming from neighbouring China and Japan (Societé Générale, 2020). The agricultural sector plays a marginal role, contributing just 2% to GDP in 2018 (World Bank, 2020).

The government places the Fourth Industrial Revolution at the centre of its economic policy with a view to creating more high-skilled jobs, developing new technologies for export and reducing the country's import dependency on primary material. For example, Sejong City is designed as a test bed "smart city" for the implementation of the Internet of Things and employs innovative data and advanced technologies to facilitate the management of day-to-day activities. Korea is already one of the world's most technologically innovative countries and its population has fully embraced digital technology, with almost 100% of the population being connected to the Internet (World Bank, 2020).

However, the Korean economy has experienced a notable slowdown since 2017 as its export-driven economy and tourism sector were faced with the economic slowdown in China and regional trade tensions, as well as lower domestic demand. For 2020, Korea had unveiled the most expansionary budget since the 2008 global financial crisis. In a response to the Covid-19 crisis, the government has passed three supplementary budgets, the last one specifically including spending on digital and green industries (IMF, 2020) (see the section "Green New Deal and Digital New Deal"). The International Monetary Fund forecasts Korea's GDP growth to fall by 1.2% in 2020 and to return to positive growth in 2021 at 3.4% subject to a global economic recovery (Nordea, 2020).

Supply and demand

Korea's energy sector is characterised by the dominance of fossil fuels, which in 2018 accounted for 85% of total primary energy supply (TPES),[1] a strong dependence on energy imports at 84% of TPES, and the dominance of industrial energy use (55% of total final consumption (TFC), the highest share among IEA countries (Figure 2.2). Korea had the lowest share of renewable energy in TPES among all IEA countries in 2018.

Oil is the largest energy source, with 39% of TPES in 2018 and 52% of TFC[2] in 2018. Coal is the second-largest energy source in TPES, accounting for 29% in 2018. Most coal is used

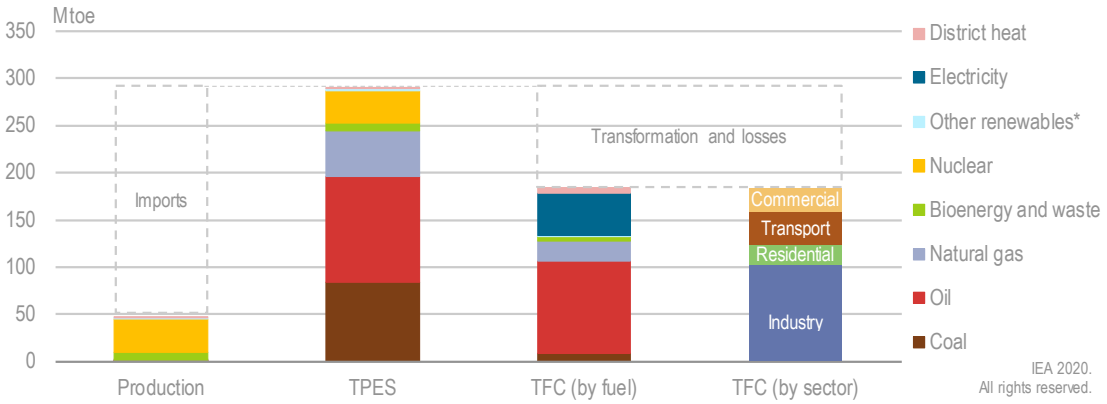
[1] TPES comprises: production + imports – exports – international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use.

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

in power generation, while use in final consumption is relatively small, at 5% of TFC in 2018. Natural gas demand has grown in recent decades, and in 2018 accounted for 17% of TPES. Nuclear accounted for 12%, bioenergy and waste for 3%, and other renewables for less than 1%. Due to the strong reliance on fossil fuels, Korea's energy intensity measured in TFC/GDP was the third highest among IEA member countries in 2018 (see Chapter 4).

In 2018, domestic energy production covered 16% of TPES. Of this, nuclear accounted for 77% of the total domestic production (note: nuclear feedstock is also imported), followed by bioenergy and waste with 16%. Other renewable energy sources, including solar, hydro, wind and geothermal, accounted for 4% of the production, and their shares have been growing slowly.

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



Both energy supply and demand in Korea are highly dominated by fossil fuels due to a strongly developed industry sector.

* *Other renewables* includes wind power, geothermal, hydro and solar energy.

Note: TPES = total primary energy supply. TFC = total final consumption.

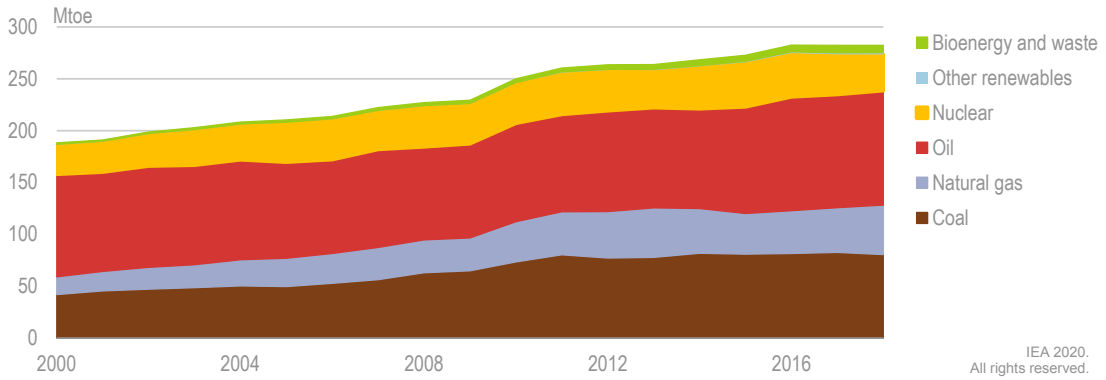
Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Primary energy supply

Korea's TPES has been growing steadily for decades, increasing from 188 million tonnes of oil equivalent (Mtoe) in 2000 to 282 Mtoe in 2018, a 50% growth (Figure 2.3). The expansion of fossil fuels drove most of the increase in total energy supply. From 2008 to 2018, oil supply in TPES grew by 23%, coal by 28% and natural gas by 50%. Use of natural gas and coal increased rapidly in power generation. The share of fossil fuels increased from 81% in 2008 to 85% in 2018; the tenth-highest among IEA member countries in 2018 (Figure 2.4).

Nuclear has continued to play an important role in Korea's energy supply since its first commercial operation in 1978, accounting for 12%, or 35 Mtoe, of TPES in 2018. Renewable energy is small, especially when measured in TPES (where thermal losses in power generation are included). In 2018, the share of renewables in TPES amounted to 5.5 Mtoe, or 1.9%, which was the lowest among IEA countries.

Figure 2.3 Total primary energy supply by source, 2000-18



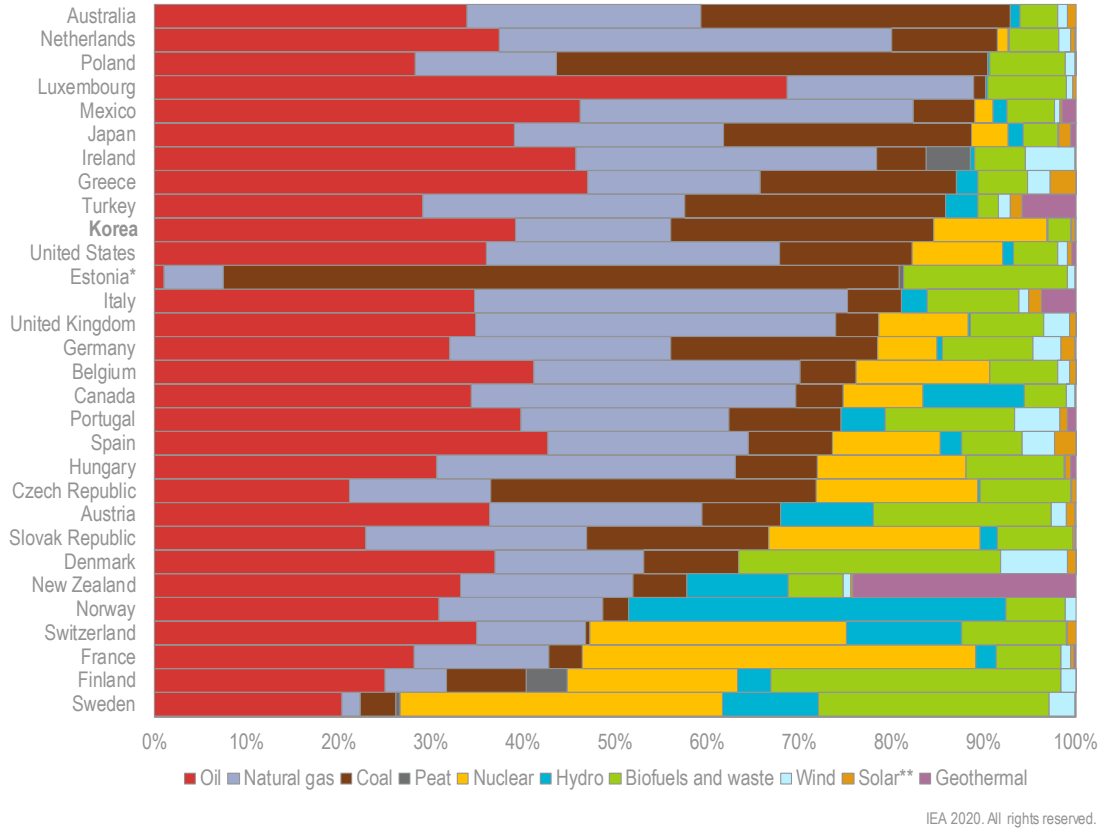
TPES has constantly increased since 2000, reaching 282 Mtoe in 2018, with most of the growth from fossil fuels.

* *Other renewables* includes electricity from wind, solar, hydro and geothermal.

Note: Electricity imports and exports are not shown in the chart.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Figure 2.4 Breakdown of total primary energy supply in IEA member countries, 2018



Fossil fuels accounted for 85% of TPES in Korea, which is above the IEA median (76%).

* Estonia's coal is represented by oil shale.

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

Note: the countries are ranked by share of fossil fuels in TPES.

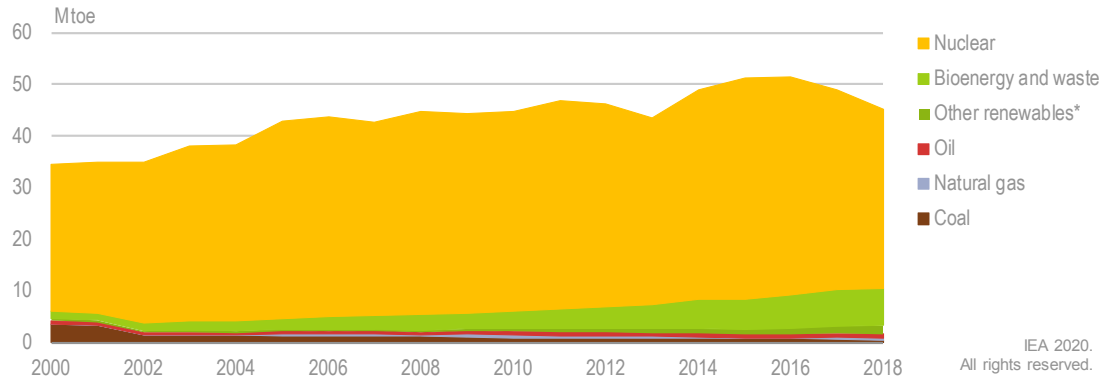
Source: IEA (2020), IEA World Energy Statistics and Balances (database), www.iea.org/statistics.

Energy production and import dependency

In 2018, domestic energy production in Korea was 45.2 Mtoe (Figure 2.5). Nuclear accounted for 77% of total domestic energy production (including thermal losses). Bioenergy and waste was the second-largest domestic energy source, producing 7.1 Mtoe of energy in 2018. The remaining amount was other renewable and fossil fuels, with around 4% each. Renewable energy production is growing, especially bioenergy and waste, which increased 136% over the decade 2008-18. Among other renewables, solar is the most prominent, and accounts for 2% of total domestic energy production as well as 2% of electricity generation.

For oil, natural gas and coal, domestic production covered only around 1% of total demand. Korea's high reliance on imported energy sources has led its energy policy to focus on the security of supply.

Figure 2.5 Energy production by source, 2000-18



Most of the energy production in Korea is met by nuclear, with an increasing amount of bioenergy and waste. However, the shares of fossil fuels and renewable energy are relatively small.

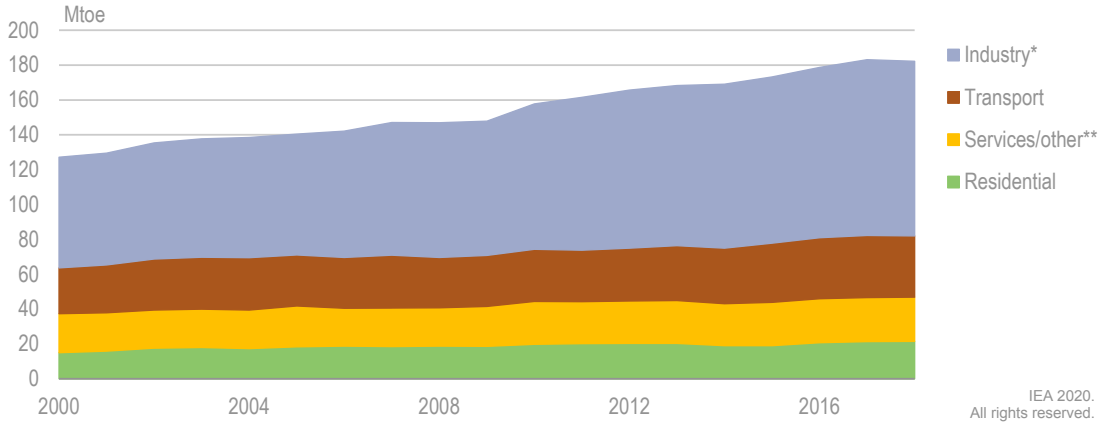
* *Other renewables* includes electricity from solar, wind, hydro, geothermal wind, solar and hydro (and a minor share of tide, wave and ocean).

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Energy consumption

Korea's energy demand is steadily increasing and TFC reached its highest level in 2017 at 184 Mtoe. It declined slightly in 2018, to 182 Mtoe, still up by 24% compared to 2008 (Figure 2.6). Industry has led overall energy demand growth in Korea and is the largest energy consuming sector at over half of total TFC, followed by transport (19%), services (14%) and residential (12%).

Figure 2.6 Total final conumption by sector, 2000-18



Energy consumption in Korea is on the rise due to fast-growing non-energy uses in the industry sector, and expansion of natural gas and electricity.

* *Industry* includes non-energy consumption.

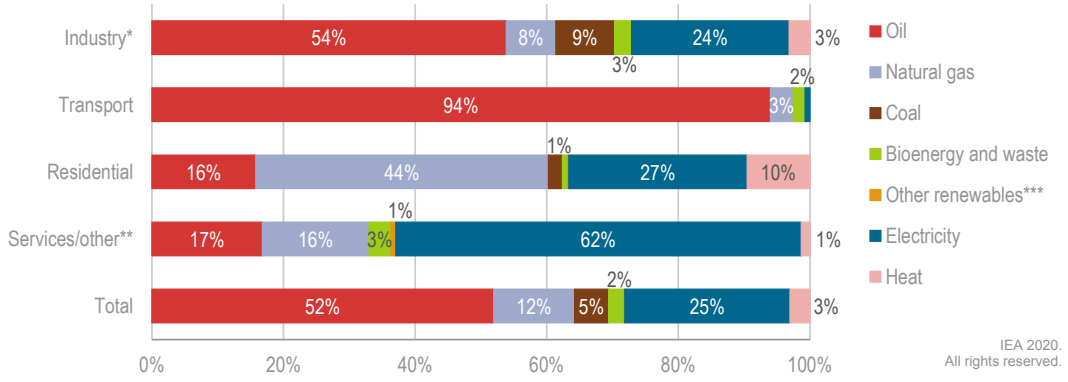
** *Services/other* includes commercial and public services, agriculture, and forestry.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

In the industry sector, more than half of the energy demand was from non-energy consumption, mainly oil products used in chemical processes (i.e. naphtha). The chemical and petrochemical industry is by far the largest industry sector in Korea, accounting for 18% of energy-related consumption in industry and 96% of non-energy use in the country.

Energy consumption in transport amounted to 35 Mtoe in 2018, an increase of 22% since 2008. Korea's transport sector is highly dependent on oil consumption, dominating with a share of 94% (Figure 2.7). In the services/other sector, electricity was the largest source of TFC, accounting for 62% in 2018. Almost half of the residential energy demand is provided by natural gas, mostly used for heating in buildings; electricity, the second primary source (27%), is mainly used for residential appliances.

Figure 2.7 Total final consumption by source and sector, 2018



Oil accounts for more than half of the TFC in Korea and dominates in transport and industry, while electricity is the largest source in services and natural gas in the residential sector.

* *Industry* includes non-energy consumption.

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

*** *Other renewables* includes solar heat and a minor share of geothermal.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Korea's sustainable energy transition

The Korean government is committed to a low-carbon energy transition by reducing the share of coal and nuclear in the energy mix, expanding the use of renewable energy, improving energy efficiency through the creation of markets for demand-side management, and fostering the country's nascent hydrogen industry. Combating climate change and local air pollution have become social and economic priorities in Korea and the government can build on a widening public support base for its energy transition ambitions in line with the country's commitment under the Paris Agreement.

The energy master plans (EMPs) guide Korea's national energy policy. They are drafted every five years, set long-term targets and provide the framework for sector-specific energy plans. The 3rd EMP was released in 2019 and covers the period 2019-40. It sets out five core initiatives to support the vision of "securing sustainable growth and improving people's life quality through energy transition" (MOTIE, 2019) (Table 2.1).

Table 2.1 Korea's vision for the sustainable energy transition

VISION	Secure sustainable growth and improve people's life quality through the energy transition
Initiative 1 – Demand	**Shift the energy policy focus to innovation in demand management** ○ Improve energy intensity by 38% (2017 level) and reduce energy demand by 18.6% compared to "business as usual" by 2040. ○ Strengthen demand management by sector, revitalise the demand management market and rationalise the energy pricing system.
Initiative 2 – Supply	**Transition to a clean and safe energy mix** ○ Gradually reduce nuclear power and drastically reduce coal. ○ Expand the share of renewable energy generation to 30-35% by 2040. ○ Reduce fine dust* levels and implement the 2030 Greenhouse Gas Reduction Roadmap.
Initiative 3 – System	**Expand the decentralised energy system and ensure broad stakeholder engagement** ○ Expand the share of distributed power supply and improve the power grid resilience. ○ Promote power prosumers and strengthen the role and responsibility of local governments.
Initiative 4 – Industry	**Strengthen the global competitiveness of the energy industry** ○ Foster future energy industries such as renewable energy, hydrogen and efficiency-related industries. ○ Promote a higher value-added conventional energy industry and maintain the nuclear industry's ecosystem.
Initiative 5 – Infrastructure	**Secure the necessary infrastructure to accelerate the energy transition** ○ Improve the market system for power, gas and heat. ○ Build a comprehensive energy big data platform to promote the creation of new industries.

* *Fine dust* is the term used in Korea for particulate matter.

Source: MOTIE (2019), *Third Energy Master Plan*, www.keei.re.kr/web_keei/en_news.nsf/XML_Portal2/9CC1EC56D87E61FC492584A100209CCC/$file/Energy%20Master%20Plan_2019.pdf.

According to the 3rd EMP, Korea's final energy consumption, excluding feedstock consumption, will peak in 2027 at an unspecified level and then drop to 175.3 Mtoe in 2030 and to 172 Mtoe by 2040, which is 18.6% lower than the business as usual (BAU) case. For comparison, Korea's final energy consumption (excluding feedstock consumption) in 2017 was 176 Mtoe.

The largest reduction is expected to come from industry (-8.1%), followed by transport (-5.3%), with the remainder from the residential, commercial and public sectors (-5.2%). These are ambitious targets and will require close monitoring of the progress made and taking urgent corrective actions if needed. For example, energy efficiency policies in the industry sector rely to a large degree on voluntary measures, in addition to measures such as the expansion of factory energy management systems and the disseminiation of high-efficiency equipment. Furthermore, demand reductions in the transport sector are mainly expected to come from stricter fuel efficiency standards, in addition to measures such as the expansion of eco-friendly vehicles and transportation system innovation.

In August 2019, the Ministry of Trade, Industry and Energy (MOTIE)[3] announced an Energy Efficiency Innovation Strategy that is expected to achieve a reduction in total final energy consumption of 14.4% in 2030, compared to the BAU level.

The notable feature of the strategy is scaling up energy efficiency through the application of the country's most innovative technologies, such as information and communications technology (ICT) based factory energy management systems, intelligent transport systems and virtual power plants to allow efficient exchange of energy sources between major power plants.

With regard to the supply side, the Korean government is committed to a gradual reduction of nuclear power in the electricity generation mix. In 2018, nuclear power generated 23% of total electricity and accounted for 17% of total installed capacity. However, the ongoing construction of 7 000 megawatts (MW) of nuclear capacity will continue and nuclear capacity is expected to increase until 2022, before starting to slowly decline with the retirement of aging nuclear power plants. In 2030, the share of installed capacity is projected to be just under 12% (MOTIE, 2017). Korea will eventually halt electricity production from nuclear in 2083 at the latest; 60 years after the newest plants will come online.

In response to the lack of systematic assessment and monitoring of the 2nd EMP, MOTIE has set up a task force that will collaborate with other relevant ministries to monitor the implementation of the 3rd EMP from 2020 onwards. A non-governmental evaluation group consisting of energy experts in the private sector will carry out progress assessments at the end of each year and report to the government to facilitate quick corrective action to be taken, if needed. The IEA congratulates Korea for this initiative and, in particular, for integrating the private sector, which is expected to play an important role in meeting the targets set in the 3rd EMP.

On 14 July 2020, the Korean government announced the Korea New Deal, consisting of a "Green New Deal", a "Digital New Deal" and "Job Security". The Green New Deal increases Korea's ambition for the energy transition. For the first time, there is talk about establishing a zero-carbon society. The Green New Deal closely links to the Fourth Industrial Revolution to facilitate investments in the market for electric vehicles, energy

[3] Annex A provides detailed information on institutions and organisations with responsibilities related to the energy sector.

storage systems and smart grids, and intelligent transport systems, and broadly aims to establish an "Internet of Energy system". Part of the Green New Deal programme is integrated into the third supplementary budget for 2020 (see below).

Korean Green New Deal and Digital New Deal

The Korean government passed three supplementary budgets to address the consequences of the Covid-19 crisis on the economy. While the first two focused on the economic stimulation in general, the third, approved on 3 July 2020, includes a dedicated financial stimulus package of KRW 6.3 trillion (USD 5.4 billion)[4] for the "Korea New Deal" discussed above (MOEF, 2020a).

The Korea New Deal includes programmes for a total investment of KRW 160 trillion (USD 137 billion) by 2025, of which KRW 28.4 trillion is allocated for "Job Security" (MOEF, 2020b). Of the total KRW 160 trillion, the government expects that the local governments and the private sector will provide KRW 30.7 trillion for the Green New Deal and KRW 13.4 trillion for the Digital New Deal (MOEF, 2020b).

Table 2.2 Korea's Green New Deal and Digital New Deal (fiscal expenditure)

Green New Deal	**KRW: 42.7 trillion**
1. Implement a green transition for cities, spaces and infrastructure (KRW 12.1 trillion)	a. Facilitate zero-energy in public facilities. b. Restore the green ecosystem of land, ocean and cities. c. Build a clean and safe water management system.
2. Expand low-carbon and distributed energy (KRW 24.3 trillion)	a. Build smart grids for efficient energy management. b. Create a foundation for renewable energy deployment and support a just energy transition. c. Promote green mobility, such as electric and hydrogen vehicles.
3. Establish an innovative ecosystem for green industries (KRW 6.3 trillion)	a. Develop promising green enterprises and establish low-carbon and green industrial complexes. b. Create a foundation for green innovation in the R&D and financial sector.
Digital New Deal	**KRW: 44.8 trillion**
1. Strengthen the ecosystem for data, networks and artificial intelligence (KRW 31.9 trillion)	a. Build big data platforms and make them open to the public. b. Promote convergence with 5G and artificial intelligence in the 1st, 2nd and 3rd industries. c. Establish an intelligent government system based on 5G and artificial intelligence. d. Establish a Korean cyber quarantine system.
2. Digitalise educational infrastructure (KRW 0.8 trillion)	a. Build digital-based infrastructure in every elementary, middle and high school. b. Promote online education in universities and vocational training centres nationwide.

[4] Exchange rate (2019): 1 USD = 1 165.29 KWN.

Digital New Deal	KRW: 44.8 trillion
3. Develop non face-to-face (untact) industries (KRW 2.1 trillion)	a. Establish infrastructure for smart healthcare and caring service. b. Promote a remote working culture in small and medium-sized enterprises. c. Provide support for small online businesses.
4. Digitalise "social overhead capital"* (KRW 10.0 trillion)	a. Create a system to digitally manage the core infrastructure of transportation, underground structures, water management and disaster response. b. Spearhead digital innovation in cities and industrial complexes. c. Establish a smart logistics system.

* "Digitalizing social overhead capital [SOC] means making sectors such as transportation, urban and industrial complexes, and logistics smarter. SOC digitalization plans to build systems such as intelligent transportation system, railway IoT sensor system, 3D integrated map of underground structures, early response system for natural disasters, development of smart city solutions and expansion of smart city construction, nationwide smart logistics centre and e-commerce logistics."

Source: MOEF (2020b), *Government Announces Overview of Korean New Deal,* MOEF, Sejong City, https://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4940; information provided by the government of Korea.

Part of the budget for the Green New Deal is allocated to MOTIE to create new growth engines in the post Covid-19 economy. See Box 2.1 for a more detailed discussion of MOTIE's commitments.

Korea is to be commended for having developed such a comprehensive and integrated support package to include the green energy transition in the post Covid-19 economic stimulus programme. However, the financial support measures will need to be complemented by changes to the way the Korean energy markets function. The substantive financial endowment of Korea's New Deal offers an opportune moment to move forward with the electricity and gas market reforms that have long been under consideration. The 3rd EMP talks about the need to further open and liberalise the energy market also with a view to reflect the increasing environmental concerns.

Similarly, the existing regulatory and legal framework of the electricity market was not designed to accommodate the opportunities and challenges offered by the fast developing renewable energy technologies and digitalisation that allow for the creation of new business models, as well as a shift from consumers to prosumers. The 3rd EMP is committed to increasing the share of decentralised power generation to over 30% of total generation by 2040. The plan acknowledges that this will require increasing the flexibility of the national electricity system, which in turn requires a modernisation of the regulatory system. Korea is not alone in facing these challenges and could learn from the experiences of other IEA member countries and apply the lessons learnt moving forward.

In this regard, the government's commitment in the 3rd EMP to increase public participation in the process of establishing and implementing energy policies is laudable. Specifically, the intention is to establish conflict prevention and management systems to address environmental and land-use problems arising from the expansion of energy infrastructure for the energy transition. The lack of systematic co-ordination between the central and local governments, the energy generators, and the local population had been identified as a major barrier for grid access, grid expansion and maintenance.

Box 2.1 Summary of the Ministry of Trade, Industry and Energy's New Deal preparation

Expand low-carbon and distributed energy

I. Build smart grids for efficient energy management

- Smart grids: install advanced metering infrastructure for 5 million households residing in apartments to distribute power demand and save energy.
- Eco-friendly distributed energy: establish an eco-friendly power generation system to reduce emissions from diesel generators in 42 island regions.
- Underground power lines: replace overhead power and telecommunication lines with underground lines, beginning with school zones as a priority.

II. Create a foundation for renewable energy deployment and support a fair transition

- Wind power: analyse wind conditions, support feasibility studies and build test bed sites in phases in up to 13 regions to identify optimal locations for large-scale offshore wind farms.
- Solar PV: introduce participatory business models where profits can be shared with residents, increase loans for PV installation for farming communities and industrial complexes, and provide subsidies for the installation of renewable energy facilities for self-consumption of households and buildings.
- Just transition: provide support for regions where major businesses, such as coal power generation, are expected to suffer and help them transition into renewable energy businesses.

III. Promote green mobility, such as electric and hydrogen vehicles

- Electric vehicles: distribute 1.13 million electric vehicles, including passenger cars, buses and trucks, and build more charging infrastructure.
- Hydrogen vehicles: distribute 200 000 hydrogen cars, including passenger cars, buses and trucks; install 450 refuelling stations; and establish hydrogen distribution infrastructure, such as hydrogen production facilities.

Create an innovative ecosystem for green industries

I. Develop promising green enterprises and establish low-carbon and green industrial complexes

- Smart and green industrial complexes: build a micro grids-based smart energy platform to monitor and control power generation and consumption in real time.
- Eco-friendly manufacturing process: build smart ecosystem plants and clean factories.

II. Create a foundation for green innovation in the R&D and financial sector

- Greenhouse gas reduction: lay a foundation for the comprehensive demonstration and commercialisation of large-scale carbon capture, utilisation and storage.
- Promotion of resource circulation: develop remanufacturing technologies for aged electrical equipment as well as engines and exhaust systems of specialised vehicles while creating technologies to recollect and utilise rare metals.

Soucre: Information provided by the government of Korea.

Energy security and system resilience

Korea imports almost all of its fossil fuels and its nuclear feedstock. Its energy import dependency is over 90% (if nuclear energy is considered as domestic, energy import dependency declines to around 85%). Given the country's geographic location, Korea has no inter-country electricity and gas connections, which is an added challenge for ensuring energy security. The government is pursuing a policy to diversify its oil and gas supply sources, and engages with neighbouring countries for an eventual creation of inter-country gas pipeline and electricity connections.

Specifically, in the 3rd EMP, the government renews its commitment to the creation of a North East Asia Super Grid, to enhance not only energy security, but also the competitiveness of Korea's domestic renewable energy industry. Korea is also co-operating with China and Japan to improve the transparency and flexibility of the global liquefied natural gas (LNG) market.

Oil

The diversification of import sources of crude oil is a main pillar of Korea's oil security policy. The government's efforts to diversify import sources has brought new players into the oil trade in the last five years. In 2018, Kazakhstan and the United States accounted for 5% each of total crude oil imports, followed by Mexico and the United Kingdom with 3% each. The Middle East still accounted for more than 70% of total crude oil imports in 2018; however, this is the lowest share since 2003. The IEA congratulates Korea on this achievement and suggests that efforts for further diversification of oil import sources continue.

Korea complies with the IEA requirement to hold stocks corresponding to 90 days of the previous year's net imports. At the end of 2019, Korea held stocks equivalent to 185 days of net imports; well above the IEA obligation. Korea does not have estimates of potential savings for its demand restraint measures. It would be advisable to undertake volumetric saving estimates for the different demand restraint measures, as this would help identify the most efficient measures to be implemented in the event of a supply disruption.

The Korean government is to be commended for undertaking emergency response training exercises twice a year. This allows the concerned ministries, companies and other stakeholders to practice the emergency response procedures and new staff to become familiar with them.

Gas

Korea has no international gas pipeline connections and imports all natural gas as LNG. It was the third-largest importer of LNG in the world after Japan and China in 2018. Korea's gas import sources have become well-diversified over the last decade, although Qatar remained the largest gas exporter to Korea, accounting for 32% of total imports in 2018. Gas imports from Australia have increased significantly over the last five years, reaching 18% in 2018, and have significantly contributed to the reduction of Korea's long time dependency on gas from the Middle East. Under the 3rd EMP, Korea is committed to further diversify its LNG sources.

As the importance of natural gas in Korea's energy supply is increasing, the challenge for Korea is to ensure long-term access to a competitive gas feedstock from diverse supply sources in a context of growing gas consumption in Asia. Korea, jointly with other large

Asian LNG importers, is actively engaged towards increasing the flexibility and liquidity of the LNG trade by revisiting some of the contract terms that restrict the flexibility of LNG trade, such as fixed destination clauses.

The government obliges the national Korean gas company KOGAS to hold two types of gas reserves: mandatory inventory volume and preventive reserve volume. Those volumes are respectively 7 days and 30 days based on the average daily domestic sales volume of the last 24 months. The total volume is referred to as the natural gas inventory. Those safety stocks are used to handle any discrepancy between demand and supply which may arise from unexpected demand changes or sudden gas supply disruptions.

The Korean government introduced fuel-switching contracts in April 2018 to prevent gas supply disruptions during an emergency. For power generation companies, the largest users of natural gas, a regular survey is performed to check their inventories of alternative fuels. Co-generation[5] power plants are also required to include a mandatory provision to secure alternative fuels in their gas procurement contracts. In the city gas sector, fuel-switching contracts with industrial users started in 2019.

As in the oil sector, Korea holds biannual emergency exercises to test the gas emergency response measures and procedures.

Electricity

For long-term security of supply, every two years MOTIE establishes a “Basic Plan for Long-term Electricity Supply and Demand” (BPLE) to ensure the long-term security of electricity supply; the plan covers new generation installations, major transmission lines and substation facilities. The ongoing 8th BPLE targets a reserve margin of 19% between 2018 and 2025 (the margin was at its lowest at 7.7% in June 2018 and its highest at 23.1% in November 2018); this reserve margin will increase to 22% during the period from 2026 to 2031. The reserve margin consists of back-up generation facilities to meet future peak demand.

The reserve margin has two components: 1) a minimum reserve to address generation variabilities of the increasing share of variable power generation; and 2) a reserve for uncertainty to cover peak demand or mitigate risks due to delays during the construction of generation facilities.

As the government is committed to increase the share of renewable electricity generation to 20% in 2030 and to 30% in 2040, dispatchable generation and energy storage will become more important in providing security of supply. The market of energy storage systems (ESS), using batteries to store electricity, has been growing quickly, and in the first half of 2018 alone, 1.8 gigawatt hours (GWh) of ESS were installed, bringing the total to 4.9 GWh. Batteries are associated with small-scale photovoltaic power generation plants and frequency on the network is regulated by using the ESS. Since January 2017, the installation of an ESS is mandatory for newly built public buildings.

The government is also addressing emerging threats to energy security related to the increasing digitalisation of the energy supply chain and the overall energy system. The power system is also under the rising threat of cyberattacks due to the significant growth in instrumentation and automation at the level of the bulk power system. This allows the electricity system to operate more efficiently and provides the system operator with much

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

better situational awareness; it also improves grid reliability and resilience, but this added complexity can also introduce cybersecurity vulnerabilities.

The National Cyber Security Strategy of Korea was published in April 2019 by the National Security Office. Its objectives are: to safeguard people's safety, rights and interests against cybercrime; detect and block cyber threats to guarantee that the government's key operations continue; and foster cybersecurity talent and continue to support the development of the cybersecurity industry. The government is preparing a national cybersecurity basic plan to implement this strategy.

Assessment

Korea's energy sector is characterised by the dominance of fossil fuels, which in 2018 accounted for 85% of TPES; a strong dependence on energy imports at 84% of TPES; and the dominance of industrial energy use at 55% of TFC, the highest share among IEA countries. In 2018, Korea had the lowest share of renewable energy in TPES among all IEA countries.

The vision developed in the 3rd Energy Master Plan of 2019 is to "secure sustainable growth and improve people's life quality through energy transition". According to the master plan, there are three main challenges to address: 1) the transformation of the energy system in order to accelerate the low-carbon transition for the benefit of all; 2) the development of the global competitiveness of the energy industry; and 3) the creation of a more decentralised energy system while consolidating energy security.

Accelerating the low-carbon transition

Korea's 3rd Energy Master Plan is rightly giving priority to innovation in demand management and to a clean and safe energy mix. For this, improving energy consumption efficiency by 38% (based on the 2017 level) and reducing energy demand by 18.6% by 2040 (compared to a BAU scenario) can make a substantial contribution to reducing CO_2 emissions. For 2030, under the 2015 Paris Agreement, Korea has committed to reduce greenhouse gas emissions by 37% compared to the BAU scenario of 851 million tonnes carbon dioxide equivalents (Mt CO_2-eq), implying emissions will reach 536 Mt CO_2-eq in 2030, compared to 709 Mt CO_2-eq in 2017.

Energy efficiency is a powerful instrument used by many IEA countries for reducing emissions while at the same time boosting economic development and job creation. The energy efficiency challenge will require combining regulatory reforms and new technologies and mobilising finance.

The same logic is valid for promoting renewable energy. The political target of increasing the share of renewable power generation to 30-35% by 2040 is, taking into account the very low level today, a very challenging one that requires adequate measures to scale-up the penetration of renewable energy in the electricity market, including for system integration.

Enhancing the global competitiveness of the energy industry while moving towards a more decentralised energy system

Due to the dominance of industrial energy use, the government is fostering a link between the energy transition and the Fourth Industrial Revolution. In that context, a successful

decarbonisation for a cleaner and smarter industry should go hand-in-hand with the development of new technologies such as hydrogen, electric vehicles and smart grids. These innovative technologies can serve as a new growth engine and create high-quality jobs.

Korea is one of the most energy-intensive economies in the IEA and energy consumption has grown strongly over the last decades. In August 2019, MOTIE announced an Energy Efficiency Innovation Strategy to innovate the structure of energy consumption by 2030. The notable feature of the strategy is scaling up energy efficiency through the application of the country's most innovative technologies, such as the ICT technology-based factory energy management systems, intelligent transport systems and virtual power plants to allow efficient exchange of energy sources between major power plants. The government expects the strategy to achieve a reduction in total final energy consumption of 14.4% in 2030, compared to the BAU level.

In parallel, rapid decentralisation of the energy system will allow power consumers not only to consume, but also to produce, store and sell energy and become so-called "prosumers". The process will require close co-operation between municipalities and local utilities. It will also boost local jobs where small and medium-sized enterprises play an important role, particularly in the construction and engineering side of renewable energy development.

Consolidation of energy security

Due to the high and growing dependence on energy imports, the diversification of import sources and the expansion of the energy infrastructure, including storage, are key measures to ensure a stable security of supply.

The rapid increase of renewable energy generation will also contribute to improving energy security, together with energy savings. Installed nuclear capacity will increase until 2022 before gradually decreasing until 2083. In 2030, nuclear will account for 12% of total installed capacity and 24% of total generation.

The growing share of renewable energy will increase Korea's self-sufficiency in the energy sector. However, as a large share will be variable renewable energy, Korea will not only need to strengthen its infrastructure to accommodate this growth, but also adapt the existing legal and regulatory frameworks to be fit for the energy transitions that the government is committed too.

The Korean government is committed to leverage the benefits of the Fourth Industrial Revolution not only for economic development, but also to support the energy transition through the opportunities offered by digitalisation. The increasing digitalisation of the energy supply chain and the overall energy system, however, creates new emerging threats to energy security. The IEA congratulates Korea on the issuance of its first National Cyber Security Strategy in 2019, which sets a best practice example for other IEA countries.

Recommendations

The government of Korea should:

- In accordance with the 3rd Energy Master Plan for the low-carbon energy transition, enhance institutional co-ordination between ministries and between central and local governments, and encourage more proactive participation from the private sector in realising the ambitious targets set in that plan.
- In addition to the clean energy targets, the Korean government should develop performance-driven regulatory frameworks for energy efficiency and renewable energy deployment, but also for competitive electricity and gas markets, in order to attract and facilitate investments in clean energy with new business opportunities.
- Optimise the potential synergies between the energy transition and the Fourth Industrial Revolution, such as through the Energy Efficiency Innovation Strategy. This will facilitate more rapid development of new innovative technologies such as hydrogen; electric vehicles; carbon capture, utilisation and storage; and smart grids, as well as for energy efficiency, which will contribute to the decarbonisation of the industrial sector while reinforcing its competitiveness.
- Ensure energy security by pursuing further diversification of energy sources for both oil and gas, together with the development of energy infrastructure and storage, and fostering electricity security by creating market rules that value contributions from generators according to their ability to instantaneously balance supply and demand. Korea's competitiveness in advanced technologies should be utilised to enhance the country's energy resilience against emerging risks such as climate change and cyberattacks.

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3. Energy and climate change

Key data

(2017/18)

GHG emissions without LULUCF* (2017): 709.1 Mt CO_2-eq, +26.2% since 2005, +142.7% since 1990

GHG emissions with LULUCF* (2017): 667.6 Mt CO_2-eq, +31.5% since 2005, +162.4% since 1990

Energy-related CO_2 emissions:

CO_2 emissions from fuel combustion (2018): 605.8 Mt CO_2, +40.3% since 2000

CO_2 emissions by fuel (2018): coal 52.0%, oil 26.2%, natural gas 18.8%, other 2.9%

CO_2 emissions by sector (2018): power and heat generation 54.9%, transport 16.8%, industry 11.9%, other energy 6.8%, residential 5.7%, services and other 4.0%

CO_2 intensity per GDP (2018)**: 0.287 kg CO_2/USD (IEA median 0.206 kg CO_2/USD)

* Land use, land-use change and forestry

** Gross domestic product in 2015 numbers and PPP (purchasing power parity).

Key data sources: Greenhouse Gas Inventory & Research Center of Korea (2019), National greenhouse gas inventory report of Korea (1990-2017), http://www.gir.go.kr/eng/; IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

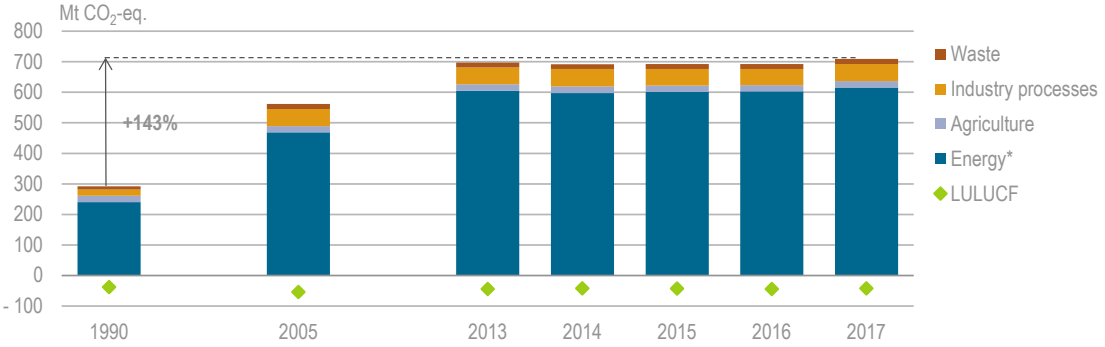
Overview

As the first country in North East Asia, Korea commenced the operation of a nationwide Emissions Trading System (ETS) on 1 January 2015. The ETS is designed to gradually deliver emissions reductions in the large industry and power generation sectors that account for around 80% of Korea's greenhouse gas (GHG) emissions. Yet, despite this proactive policy, Korea's GHG emissions continue to grow. In 2017, total GHG emissions in Korea were 709.1 million tonnes carbon dioxide equivalent (Mt CO_2-eq) (excluding LULUCF).[1] By 2017, GHG emissions had increased by 26% from 2005 and by 143% from 1990 levels (Figure 3.1). However, emissions have remained stable around 700 Mt CO_2 since 2013.

Most of the increase in GHG emissions came from the energy sector, which includes combustion in power generation, transport, industry and buildings. The share of energy-related emissions was 87% of total GHG emissions in 2017. Industry processes accounted for the largest share of non-energy related GHG emissions at 8%, followed by agriculture (3%) and waste (2%). The rest of this chapter will focus on energy-related CO_2 emissions.

[1] Land use, land-use change and forestry.

Figure 3.1 Greenhouse gas emissions by sector, 1990-2017



Total GHG emissions have increased by around 143% from the 1990 level, mainly driven by the energy sector, but emissions growth has slowed since 2013.

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

Note: LULUCF = Land use, land-use change and forestry.

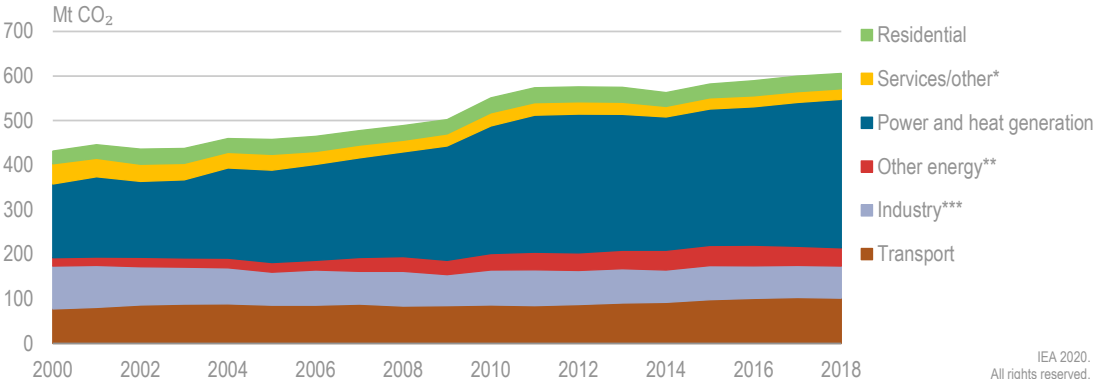
Source: Greenhouse Gas Inventory & Research Center of Korea (2019), *National greenhouse gas inventory report of Korea (1990-2017)*, http://www.gir.go.kr/eng/

Energy-related CO_2 emissions

Korea's energy-related CO_2 emissions were 606 million tonnes (Mt) in 2018, an increase by nearly 40% since 2000 and by 24% in the last decade. The main source of emissions, as well as of growth in emissions, is the power sector, where emissions have doubled since 2000, in line with the rapid growth in electricity generation (Figure 3.2). Since 2008, power sector emissions have increased by 42% while emissions in the transport sector have increased by 21%, other energy sectors by 23%, and the residential sector by 4%.

Emissions in industry have fallen by 7% since 2008 and by 25% since 2000, while emissions from services/other have declined by 8% since 2008 and by over 47% since 2000.

Figure 3.2 Energy-related CO_2 emissions by sector, 2000-18



Energy-related emissions are on the rise, most significantly in the power sector, whereas services and industry emissions have decreased in the last decade.

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

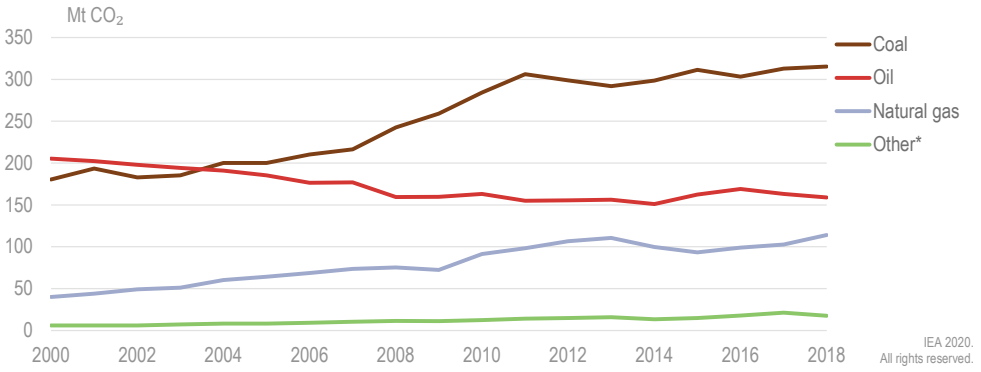
** *Other energy* includes emissions from oil refineries, blast furnaces and coke ovens, plus small shares in coal, oil and gas extraction.

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

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

By fuel, coal is the largest source of energy-related emissions after having surpassed oil in 2004 (Figure 3.3). In 2018, coal-related emissions were 315 Mt CO_2, representing 52% of total emissions. Natural gas-related emissions have also increased rapidly; their share of total emissions grew from 9% in 2000 to 19% in 2018. The growth in coal and natural gas emissions has mainly come from the power sector, which has driven the overall growth in emissions. Oil-related emissions have gradually declined since 2000 as oil demand in the power sector declined by one-fifth and in the services/other sector by just over 55% over the same period. However, they picked up again over the period 2014-16, and have seen a slight decrease since then. Around 62% of oil-related emissions comes from transport.

Figure 3.3 Energy-related CO_2 emissions by energy source, 2000-18



Coal-related emissions represent over half of total energy-related CO_2 emissions and continue to grow together with natural gas emissions, while oil emissions have stalled.

* Emissions from non-renewable waste.

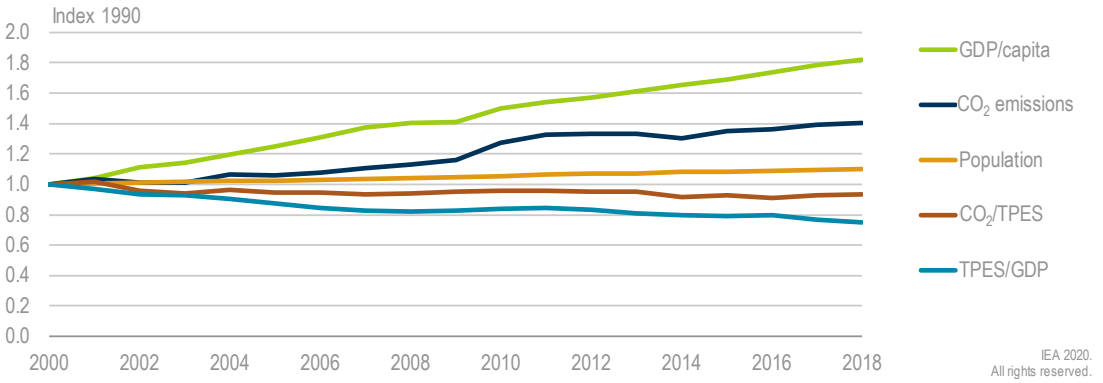
Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

CO_2 drivers and carbon intensity

Changes to total CO_2 emissions in a country are driven by changes in population and economic development (GDP/capita), along with changes in the energy intensity of the economy (measured as total primary energy supply [TPES] divided by gross domestic product [GDP]), and the carbon intensity of the energy supply (CO_2/TPES).

Between 2000 and 2018, Korea's economy (GDP/capita) grew by 82%, the population increased by 10% and CO_2 emissions grew by 40% (Figure 3.4). While Korea thus saw a gradual decline in the energy intensity of the economy (TPES/GDP), the carbon intensity of its energy supply (CO_2/TPES) has picked up again since 2014.

Figure 3.4 Energy-related CO_2 emissions and main drivers in Korea, 2000-18



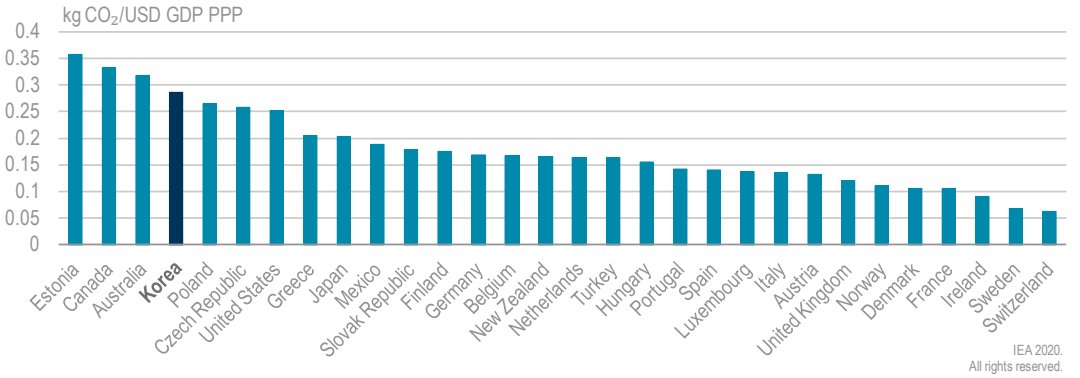
Korea's energy intensity of the economy has gradually declined since 2000. However, the carbon intensity of its energy supply started increasing again in 2014.

Notes: GDP = gross domestic product. TPES = total primary energy supply. Real GDP in USD 2015 prices and purchasing power parity (PPP).

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

In 2018, Korea had the fourth-highest CO_2 emissions per GDP among IEA member countries after Estonia, Canada and Australia (Figure 3.5).

Figure 3.5 Carbon intensity (CO_2/GDP PPP) in IEA member countries, 2018

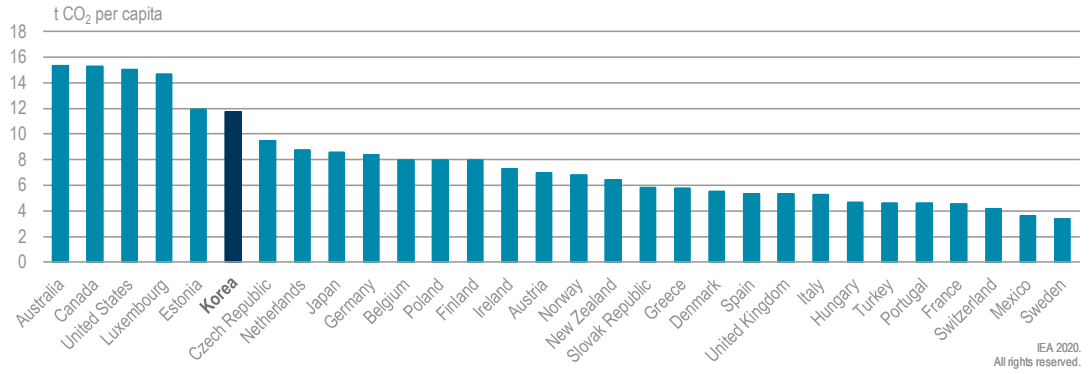


The Korean economy has the fourth-highest carbon intensity among IEA member countries.

Note: Real gross domestic product in USD 2015 prices and purchasing power parity (PPP).

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

Figure 3.6 CO_2 intensity (CO_2/capita) in IEA member countries, 2018

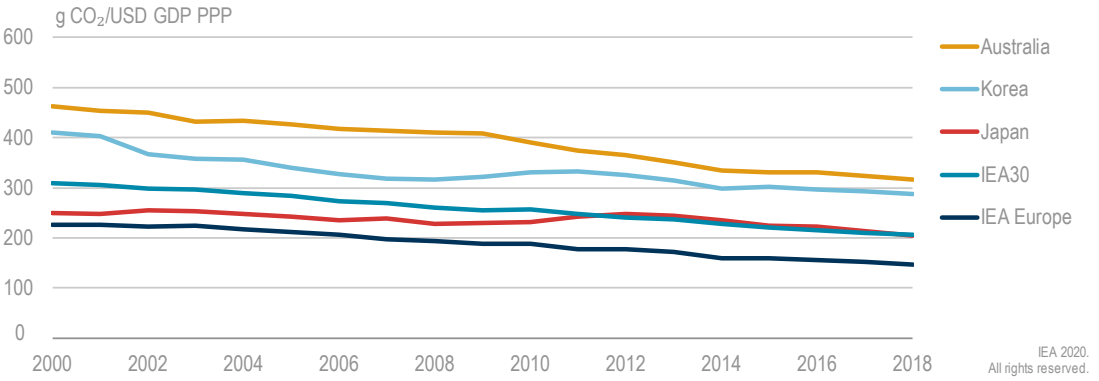


Korea has the sixth-highest CO_2 emissions per capita among IEA countries.

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

Korea's carbon intensity per unit of GDP (PPP) reduced by almost a third from 2000 to 2018. However, the IEA average has seen a similar trend, but at a steadily lower level (Figure 3.7).

Figure 3.7 CO_2 intensity per GDP in Korea and selected IEA member countries, 2000-18

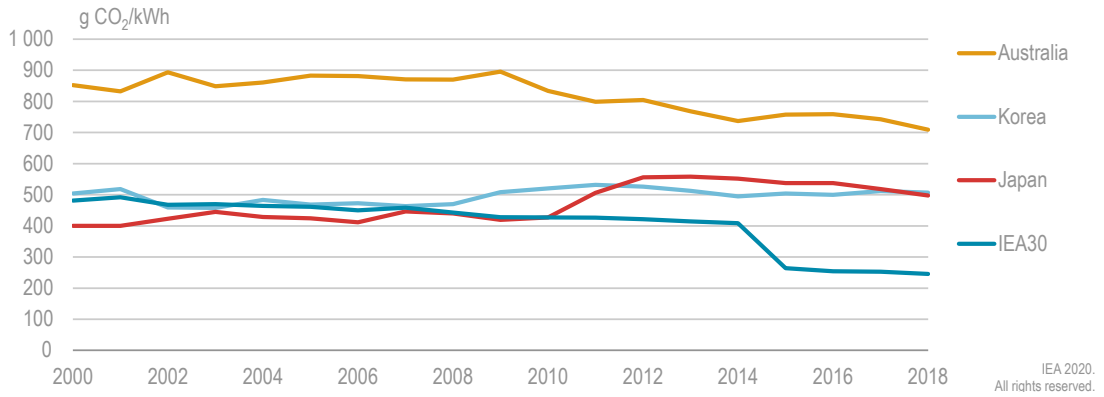


The CO_2 intensity of the Korean economy has decreased by 30% compared to 2000.

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

The main explanation for Korea's high CO_2 intensity per GDP is the emissions per kilowatt hour (kWh) of heat and power. Korea's CO_2 intensity of power and heat generation reached its lowest level in 2003, with 457 g CO_2/kWh, but went up again to around 507 g CO_2/kWh in 2018. This compares to an average of 246 g CO_2/kWh for the IEA as a whole in 2018 (Figure 3.8). The main reason for the increase in CO_2 intensity of power and heat generation is the continuous growth of Korea's coal-fired power plants in both absolute volume and by share in electricity generation, despite growth in natural gas and renewables. The share of fossil fuels in Korea's power generation was 73% in 2018, of which coal accounted for 44%.

Figure 3.8 CO_2 intensity of power and heat generation in Korea and selected IEA member countries, 2000-18



Korea's carbon intensity of power generation has rebounded since 2007 and is above the IEA average, mainly caused by the expansion of fossil fuel-fired generation, especially from coal.

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

Climate policy framework and targets

In the 2010 Framework Act on Low Carbon, Green Growth Korea set a voluntary GHG reduction ambition for 2020. The act created the legal framework for Korea's mid- and long-term emissions reduction targets, including the introduction of an ETS and a GHG and energy target management system (TMS), and the expansion of new and renewable energy. The act requires the government to establish and implement a national strategy, roadmaps and action plans, as well as a detailed plan covering a 20-year period that is to be rolled-over every 5 years, to address the various aspects of climate change mitigation and adaptation (NLCI, 2010).

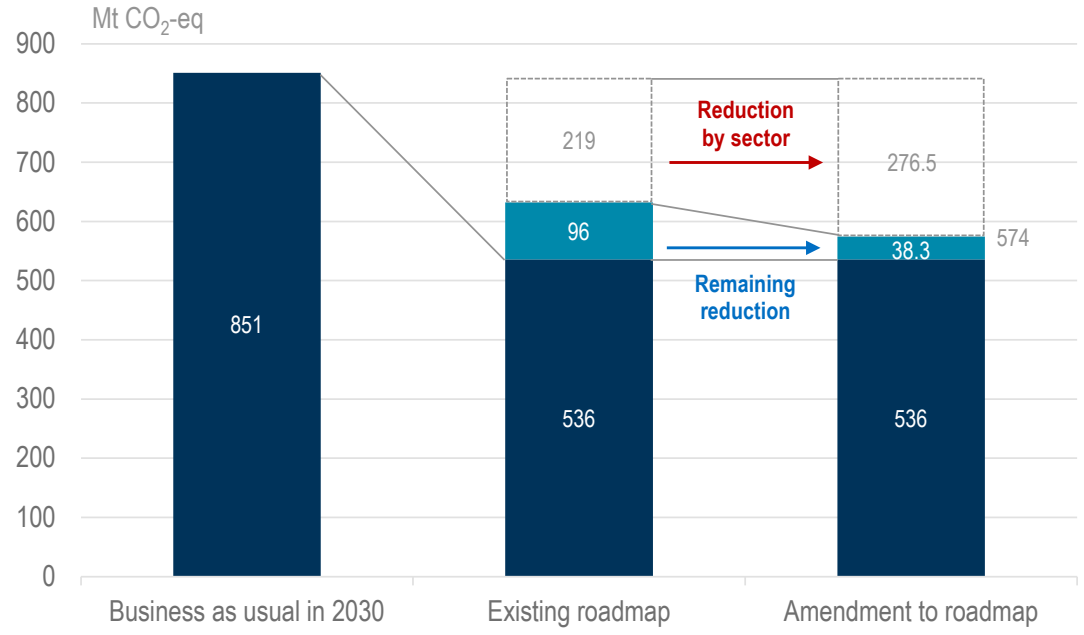
Under the 2010 act, Korea aims to reduce GHG emissions in 2020 by 30% against the business as usual (BAU) scenario of 776.1 Mt CO_2-eq (NLCI, 2010). In 2017, emissions were not on track to meet the ambition of 543 Mt CO_2-eq; in fact, at 709 Mt CO_2-eq, they were 30% higher than the 2020 target. The 2016 Enforcement Decree of the 2010 Framework Act clarified that the target for 2020 is now merely part of the pathway towards the 2030 target. However, missing the 2020 target by a wide margin will require Korea to substantially boost efforts towards meeting the 2030 mandatory GHG emissions reduction target.

For 2030, under the 2015 Paris Agreement, Korea has committed to reduce GHG emissions by 37% compared to the BAU scenario of 851 Mt CO_2-eq, implying that emissions will reach 536 Mt CO_2-eq in 2030, which is only slightly lower than the 2020 target of 543 Mt CO_2-eq. Korea opted to set a single-year target for 2030 under its Paris commitment. In December 2016, Korea issued a GHG Reduction Roadmap, which lays out detailed strategies and sectoral policy tools to reach the 2030 target. Of the 37% reduction target, almost 26% is to be obtained through domestic measures, while the remainder is to be met through internationally transferred mitigation outcomes resulting from voluntary co-operation of the Parties under Article 6 of the Paris Agreement, the rules of which are to be established by COP26 that is now scheduled to take place in 2021.

In the 2018 revision of the roadmap, the Korean government took its emissions reduction commitment a step further by voluntarily committing to shift from using relative to absolute

sectoral emissions reduction targets and by significantly increasing the share of emissions reductions to be obtained through domestic measures. The roadmap was revised to ensure that it is aligned with the new policy targets set in the 2030 Renewable Implementation Plan and the 8th Basic Plan for Long-Term Electricity Supply and Demand, which aim to increase the share of renewable electricity generation to 20% in 2030 and to reduce coal-fired power generation (see Chapters 7 and 10). The revised roadmap also reflects the fine-dust mitigation measures[2] that were approved in 2018 (see section below and Chapter 10).

Figure 3.9 Greenhouse gas reduction targets in 2030



Source: IEA, based on information provided by the Korean government.

Compared to their respective BAU scenario emissions, the residential and services sector is expected to reduce emissions by 32.7% (64.5 Mt); the transport sector by 29.3% (30.8 Mt); the industry sector by 20.5% (98.6 Mt); the power and heat sector by 17.3% (57.8 Mt); the other sectors (waste, public, agriculture, fugitive emissions) by 21.6% (14.6 Mt); the new energy industry and carbon capture, utilisation and storage (CCUS) sector by 1.2% (vs. national BAU) (10.3 Mt); and the forest and overseas sector by 4.5% (vs. national BAU) (38.3 Mt).

In the amended roadmap, Korea plans to reduce 38.3 Mt CO_2-eq of emissions through forest offsets and international co-operation (compared to 96 Mt CO_2-eq in the existing roadmap), which together corresponds to a 4.5% reduction of the BAU emissions in 2030, or 12.2% of the total reduction of 314.8 Mt CO_2-eq in the same year. Since the implementation of the Act on the Management and Improvement of Carbon Sinks commenced in 2013, Korea has undertaken substantial investments to maintain and increase the capacity of forests to absorb carbon (UNFCCC, 2018).

[2] The Korean government usually uses the term "fine dust" for airborne particles and pollutants such as $PM_{2.5}$.

The effective reduction of GHG emissions is one of the three strategies of the 3rd Five-Year Plan for Green Growth (2019-23). The policies under the 3rd Five-Year Plan include strengthening evaluation and verification of GHG reductions, and preparing a long-term low greenhouse gas emissions development strategy to 2050 that needs to be submitted to the United Nations Framework Convention on Climate Change in 2020. The long-term strategy is under preparation and will be introduced to parliament in the second half of 2020. It will set out the long-term vision and strategy rather than specific GHG reduction targets.

Emissions reduction policies and measures

Under the 2010 Framework Act, Korea introduced two key policy mechanisms to reach the 2020 target: a national ETS and the GHG TMS.

The 2010 Framework Act prescribes mandatory annual GHG emissions reporting to the government, and the establishment of an integrated information management system for GHG monitoring. Both instruments continue to play an important role in Korea's energy and climate policy and are continuously evolving in line with new policies.

The government is implementing a large number of programmes to provide financial and management support for the industry, public, transport and buildings sectors to reach their targets under either the ETS or the GHG TMS. Those programmes are discussed in more detail in Chapters 4 and 5.

Korea's Emissions Trading System

As the first country in North East Asia, Korea commenced the operation of its mandatory nationwide ETS on 1 January 2015. The ETS is designed to deliver emissions reductions in the industry and power generation sectors. The 2012 Act on the Allocation and Trading of Greenhouse-Gas Emission Permits and Enforcement Decree provides the details of the ETS such as scope, target type, allowance allocation method, registry and management, and operation of the carbon-trading houses.

The ETS is implemented in three phases; the first phase (2015-17) focused on firmly installing the ETS, while Phases II (2018-20) and III (2021-25) are intended to build on the experiences made and resolve any issues encountered during the implementation of the preceding phase. Phase III and beyond is focused to actively and effectively reduce GHG emissions (Ministry of Environment, 2019).

Participation in the ETS is mandatory for individual facilities with annual emissions above 25 000 Mt CO_2 and companies with annual emissions above 125 000 Mt CO_2. The ETS covers direct and indirect emissions from the electricity sector, as well as six types of GHGs covered under the Kyoto protocol, namely CO_2, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The ETS covers 5 sectors and 26 subsectors (Table 3.1).

Table 3.1 Sectors and subsectors covered under the Korean Emissions Trading System

Sector	Subsector
Conversion	Power generation, collective energy
Industry	Mining, food and drink, petroleum, wood, paper, petrochemicals, refining, oil, glass, ceramics, cement, steel, non-ferrous, machinery, semi-conductor, display, electrical electronics, automobiles, shipbuilding telecommunication, industrial complexes
Buildings	Buildings
Transportation	Aviation
Public sector and waste	Water supply, waste

ETS Phase I: 2015-17

All emissions allowances were allocated for free. The total carbon budget of 1 686 Mt CO_2 for the three years of the first phase included a reserve of 5%, equivalent to 89 Mt CO_2. Within this reserve, 33 Mt CO_2 were set aside for new entrants, 41 Mt CO_2 for early action and 14 Mt CO_2 for market stabilisation measures. Unallocated allowances and withdrawn allowances were also allocated to the reserve. Almost 85% of the reserve allocation, equivalent to 76 Mt CO_2, was used. The annual emissions allocation increased each year during Phase I, from 540 Mt CO_2-eq in 2015 to 585 Mt CO_2-eq in 2017.

At the end of Phase I in 2017, 591 of Korea's largest emitters were covered under the ETS, and more than three-quarters of the companies were from the energy sector and manufacturing industry. The total amount of allocated emissions allowances in Phase I covered just over 80% of national GHG emissions.

Two methods were used to allocate the free emissions permits. The so-called grandfathering method allocated permits based on the previous three-year average of GHG emissions. This method was applied to all subsectors except for the grey clinker, oil refining and aviation sectors. Emissions permits for those sectors were allocated using the so-called benchmark method, which used the activity data of each concerned entity from the base year.

ETS Phase II: 2018-20

The two major changes in the second phase of the ETS are the auctioning of 3% of allowances for non-energy intensive industry and the fixed annual emissions allocation for all years at 548 Mt CO_2-eq compared to the annual increase of emissions allocations in Phase I (ICAP, 2020).

So-called energy-intensive and trade-exposed sectors still receive all of their allowances for free, while power generation, telecommunications, domestic aviation and other are now required to purchase 3% of their allowances through monthly auctions.

Energy-intensive and trade-exposed sectors are defined as having either additional production costs of more than 5% and a trade intensity of more than 10%, or having either more than 30% additional production costs or a trade intensity above 30%. The production costs increase is determined by multiplying the average GHG emissions by the average price of the allowances for the reference period divided by the total value added for the same period. This implies that the desired increase in ETS prices does not necessarily result in companies investing in technologies to reduce their emissions, but instead, the

increasing ETS price potentially rewards companies that maintain existing technologies. In light of the increasing emissions in Korea, this condition may need to be revised for the third phase of the ETS and be replaced by measures that support economic competitiveness while simultaneously addressing the country's growing emissions.

Phase II of the ETS still covers the same 6 sectors, which were further disaggregated into 64 subsectors covering 610 entities in 2018, an increase of 2.1% compared to Phase I.

The first auction was held in January 2019. Only companies that must purchase part of their allowances were eligible to participate. No single bidder can buy more than 30% of the allowances of one auction and the allowances are subject to a minimum price.

The emissions cap for Phase II is 1 796 Mt CO_2, of which permits for just under 548 Mt CO_2 are available annually for companies covered under the ETS. Permits for around 134 Mt CO_2 are set aside for new entrants under Phase II while 14 Mt CO_2 are set aside in a market stability reserve for auctioning and 5 Mt CO_2 for a "market maker reserve". The market maker reserve is a new mechanism put in place by the government to address phases of low market liquidity (see the section on flexibility measures below).

Another significant change is the expansion of the benchmark-based allocation mechanism to a larger number of companies. The share of sector-specific benchmarking is set to reach 50% of the GHG emissions covered by ETS at the end of Phase II (ICAP, 2020).

ETS Phase III: (2021-25)

The government is in the process of developing the detailed rules for Phase III. However, it is already certain that less than 90% of the allowances will be distributed for free in Phase III, though energy-intensive and trade-exposed sectors will continue to benefit from free allowances. The government is also considering increasing the share of companies subject to sector-specific benchmarking for the allocation of free allowances to 70%. It is further being considered to introduce a stricter total annual emissions cap (ICAP, 2020).

Flexibility measures

The Korean ETS includes a number of flexibility measures within and between phases. Banking allowances is permitted across phases, but only within certain limits. Any banked allowances in excess of the limit between Phase I and Phase II was deducted from the allocation for the next phase. From Phase II to Phase III, banking is allowed at the higher limit, with two available options: either the net annual amount of allowances sold in Phase II, or with company and facility-specific limits (ICAP, 2020). However, borrowing of allowances is permitted only within each phase and with a specific limit set for each year until 2018. Since 2019, the limit on borrowing is determined by the total borrowing of an entity in earlier years (ICAP, 2020).

Entities under the ETS also have the possibility for offsets and credits. The quantitative limit for offsets in Phases I and II is a maximum of 10% of the compliance obligation of each entity. In Phase II this can include up to 5% of international offset credit and in Phase III this will likely increase to 10%.

In Phase I, only domestic credits could be earned and only from GHG emissions reduction activities by non-ETS entities. In Phase II, the trading of international clean development

mechanism projects developed by entities covered under the Korean ETS were also included when meeting a specific set of criteria.

To ensure market stability, the auction of allowances in the stability reserve is subject to an auction reserve price. Under certain circumstances, an allocation committee is charged with implementing market stabilisation measures. In June 2019, the Korean Development Bank and the Industrial Bank of Korea were officially designated as market makers and were authorised to draw on the government-held reserve of 5 million allowances to ensure market liquidity if needed.

ETS prices and investment of revenues

ETS prices increased by 54% between 2015 and 2018, when they reached KRW 22 237, approximately USD 20. Prices peaked in September 2019 at around USD 33, and reached around USD 25.5 in April 2020 (ICAP, 2020). However, ETS prices do not yet seem to noticeably influence the role of coal in the electricity mix, which reached a record at 44% in 2018 (see Chapter 7). As the final rules for Phase III are under consideration, this may be an opportunity to design them in such a way as to further increase the effectiveness of the ETS system.

Auction revenues in 2019, the first year in which auctions were carried out, totalled USD 199.4 million. Revenues from auctions of the reserve for market stability measures in 2016 and 2018 raised an additional USD 99.6 million (ICAP, 2020).

The government is in the process of deciding on eligible investments of ETS auction revenues. A final decision will be taken once the rules of Article 6 of the Paris Agreement are completed. Options under consideration by the government include support for funding of mitigation equipment projects, innovation, and technology development of the entities subject to the ETS.

GHG Target Management System

The GHG TMS was implemented in 2012 to set and achieve GHG reduction and energy conservation targets for small companies that consume substantial amounts of energy but that are not subject to the ETS. Companies with three-year annual average GHG emissions above 50 000 t CO_2-eq or with energy consumption above 200 terajoules (TJ), and facilities with three-year annual average GHG emissions above 15 000 t CO_2eq or energy consumption above 80 TJ are subject to the GHG TMS.

The “Guidelines for Greenhouse Gas and Energy Target Management and Operation”, provide details of the TMS, including designation and supervision on management plants; methods for reduction target setting and management; systems for accounting, reporting and verification of emissions; annual reporting and compliance systems; identification of early action; management of registry; and designation and management of designated verification entity.

In 2018, the last year for which data are available, 366 companies were covered under the GHG TMS and over half of these companies were in the energy and manufacturing industry. The GHG target of the 168 companies subject to the TMS in the industry and power generation sector in 2018 was 4 310 246 t CO_2, and actual emissions were 4 036 438 t CO_2 (KEA, 2020). The annual GHG reduction and energy saving targets are set for each obliged entity based on the annual average GHG emissions and energy

consumption over the preceding three years. The government supports industries through tax deduction and subsidies to achieve the targets. The investments in environmental conservation facilities are tax deductible and in addition up to 50% of the cost of the installation of best available technology facilities or manufacturing process improvements is eligible for subsidies. The details of the GHG TMS are discussed in Chapter 4.

Air pollution and fine dust

Local air pollution and fine dust have become major social and economic issues in Korea. The Seoul Metropolitan Area is among the most polluted cities globally and in 2017, Korea had the highest fine particulate matter ($PM_{2.5}$) among OECD member countries (OECD, 2020a). The number of days with a high concentration of $PM_{2.5}$ increased from 92 days in 2016 to 158 days in 2018 (MOTIE, 2019).

In 2018, the government implemented a breakthrough policy towards addressing the issue, the Special Act on Fine Dust that aims to combat particulate matter pollution. Specifically, the act aims to significantly reduce domestic fine dust emissions by more than 30% and to reduce the number of days with bad air, defined as exceeding 50 microgrammes per cubic metre (μg m^3), by 70%, from 258 days in 2016 to 78 days in 2022. At the core of the 2018 act is an innovative provision that gives local governments the authority to temporarily suspend the operation of coal-fired plants if air pollution and fine dust exceed the legal limits set by the government (Yonhap News Agency, 2019).

In November 2019, the Ministry of Environment issued a new Fine Dust Management Masterplan 2020-2024 that aims to reduce fine dust/$PM_{2.5}$ by 35% in 2024 compared to 2016 levels.

The forced closure of 15 coal-fired power plants from 1 December 2019 to 29 February 2020 and the reduction of output to 80% of capacity of all other coal-fired plants is said to have reduced fine dust from coal-fired generation by up to 44% compared to the previous winter (AFP, 2019; Regan, 2019). The government is also committed to permanently close ten coal-fired plants between 2017 and 2025 that have been operating for over 30 years and that account for 3 345 megawatts (MW) of generation capacity, as part of the gradual exit from coal-fired power generation (see Chapter 10).

In addition to the domestic measures, the policy underscores mid- and long-term international co-operation, since part of Korea's air pollution and fine dust originates from neighbouring countries and is hence beyond the control of the Korean government. The government has plans to enhance co-operation with the People's Republic of China (hereafter, "China") on this matter. According to a study undertaken by the National Institute of Environmental Research, 48% of the ultrafine particulate matter measured from May to June 2016 in the air of the project area was caused by foreign factors (OECD, 2020b).

The 2018 act includes specific instruments for all energy sectors. Measures targeting the power sector are reflected in the 8th Basic Plan for Long-term Electricity Supply and Demand (MOTIE, 2017). They include a mixture of closing seven old coal-powered plants that are at the end of their lifetime, the conversion of four coal plants to liquefied natural gas (LNG) and the upgrading of five coal plants to higher emission standards (see Chapter 10), and the expansion of renewable energy (see Chapter 5). Despite this commendable package, coal-fired generation in Korea is set to expand until 2022 under the Third Energy Master Plan before starting to decline marginally by 2030 (MOTIE, 2019) (see Chapters 7 and 10).

Among other policy measures is the expansion of regulations of local air pollution emissions from the currently limited geographical coverage for application to the entire country, while the emissions standards for fine dust from large industrial facilities such as steel and petroleum are to be strengthened. Moreover, the government plans to introduce new regulations for a cap on fine dust emissions from industrial facilities.

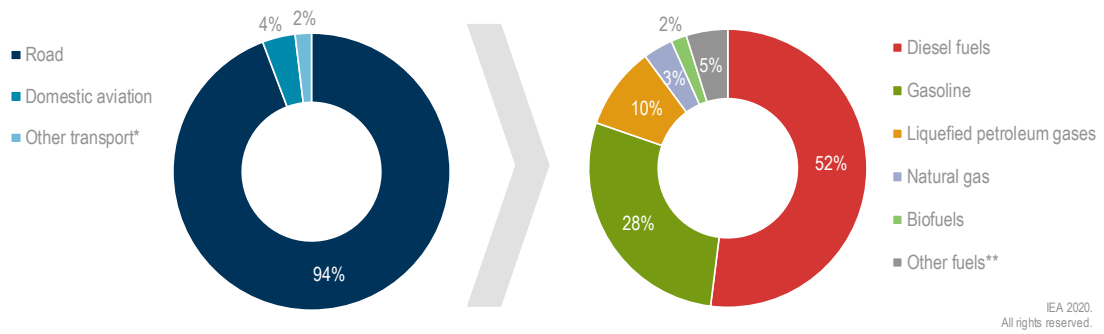
Measures targeting fine dust emissions from the transport sector focus primarily on the removal of old diesel vehicles. The government aims to reduce the number of old diesel engine vehicles by 2.86 million vehicles by 2022. This implies taking 77% of diesel vehicles built before 2005 off the roads. In addition, the current financial incentives for the purchase of new diesel vehicles will be stopped to avoid technology lock-in. Moreover, the existing restricted access of diesel vehicles to certain zones in Korea's metropolitan areas will be expanded to other parts of Korea. These policy measures are complimentary to the government's overall shift towards a transition of the transport sector to clean fuels (see next section).

Transport

Transport is the second-largest emissions sector in Korea. In 2018, close to 60% of emissions in transport were due to diesel, while gasoline accounted for just over 29% and liquefied petroleum gas for 9% (Figure 3.10).

Korea has a diesel-blending mandate of 3% for biofuels; there is no blending obligation for petrol. Around 60% of the feedstock for blending with diesel is imported. The 40% of domestically sourced feedstock consists largely of used cooking oil and soybean oils. Korea does have some potential to use waste for blending with transport fuels. Research and development in this area is ongoing.

Figure 3.10 Transport energy demand by transport mode and fuel, 2018



Road transport is the dominant mode of transport and diesel is the dominant fuel.

* *Other transport* includes domestic navigation, rail and pipeline transport.

** *Other fuels* include kerosene and other aviation fuels, electricity, and fuel oil.

Note: Excluding international aviation and navigation.

Source: IEA (2020b), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

The government has no immediate plans to increase the biofuel blending mandate, but instead privileges the roll-out of electric vehicles (EV) and EV infrastructure, and hydrogen/fuel cells vehicles and the relevant infrastructure.

From a basis of 60 000 EVs in 2018, including both battery electric vehicles and plug-in hybrid electric vehicles (PHEV), the target is to reach 350 000 EVs in 2022 and 3 million in 2030, while the fast-charging infrastructure is set to increase from 5 200 stations in June 2019 to 10 000 by 2022. Given this commendable ambition, the government should ensure it has effective EV battery recycling and disposal policies in place.

Korea supports the increased uptake of EVs with a number of measures, including subsidies and rebates on national and local vehicle purchase taxes, and reduced highway toll fees and public parking fees. It also gives priority to low-emissions vehicles in public procurement programmes. Tax rebates per EVs are capped at a maximum of KRW 5.3 million (USD 4 500) to promote sales of smaller, more efficient EVs. The number of low-carbon vehicles that benefited from subsidies that are available on top of the tax rebates increased from 32 000 vehicles in 2018 to 57 000 in 2019. Subsidies per battery electric vehicle are capped at a maximum of KRW 19 million (USD 16 400), up from KRW 14 million (USD 12 000) in 2018. Subsidies for plug-in hybrid electric vehicles are capped at KRW 5 million (USD 4 300).

In terms of charging infrastructure deployment, the government targets the installation of 10 000 fast EV chargers by 2022. The deployment of chargers will benefit from subsidies of KRW 3.5 million (USD 3 000) for publicly accessible slow chargers and KRW 1.3 million (USD 1 200) for private chargers, which was originally set to expire at the end of 2019. For fast EV chargers, an employer can benefit from a maximum of 50% of the total cost.

In addition, the government is providing substantial support for the roll out of hydrogen and fuel cell cars and infrastructure, and aims to have 67 000 units on the road by 2022 and 2.9 million vehicles by 2030 and will also roll-out the required filling infrastructure. In 2018, Korea had 889 hydrogen fuel cell electric vehicles and 14 hydrogen refuelling stations. Fuel cell electric vehicles benefit from a purchase subsidy of a maximum of KRW 36 million (USD 30 190). Korea plans to deploy hydrogen-fuelled public buses in seven major cities, including Seoul and Ulsan, and to expand the fuelling stations to 310 by 2022 (see Chapter 6 for a detailed discussion). There are also plans to strengthen pollution measures for old machinery and vehicles used in the construction sector and for ships; however, the details have yet to be developed.

The share of public transport in Korea has stagnated since 2013 at around 42%. The government plans to revitalise public transportation, primarily by extending the intelligent transport systems' infrastructure. However, no further details have yet been developed (MOTIE, 2019).

Taxation

By comparison among IEA members, energy tax rates in Korea are low and are currently not steering consumer behaviour (see Chapters 7, 8 and 9). The government is committed to introduce an environment-friendly energy tax system to reflect external costs of the different fuels used for power generation.

In 2019, the government adjusted the relative taxes for coal and LNG used for power generation. Until 2018, total taxes for natural gas were slightly higher than for coal (on an energy basis) and did not reflect the environmental benefits of gas-fired power over coal-fired power. In July 2018, the government announced a major tax reform to adjust the relative taxes for coal and LNG used for power generation.

In 2019, the import duty on natural gas was reduced by 85% and the consumption tax by 80%, while the consumption tax for coal increased by 30%. Korea does not put a levy on the imports of thermal coal. As a result, the total tax on coal is now five times higher than the tax for natural gas. The government hopes that the tax adjustment will help to reduce fine dust/$PM_{2.5}$ and will also change the merit order dispatch in the electricity sector (see Chapters 7 and 10).

Adapting to climate change

According to the Ministry of Environment, the average annual temperature in Korea has risen around 0.18°C every ten years for the past century, which is faster than the warming trend in the rest of the world. Moreover, extreme weather events such as heatwaves and heavy rainfall are becoming more frequent as well. The Ministry of Environment is therefore building adaptive capacity at the national level to quickly adapt to these changes. Targeted action plans are in place for different sectors and industries. The ministry is also working on enhancing climate-resilient infrastructure for cities, where most of the population lives (Ministry of Environment, 2020).

The 2010 Framework Act requires the Ministry of Environment to prepare and implement five-year plans every five years, containing measures for adapting to climate change. The act established the national integrated information management system for GHGs. The first National Climate Change Adaptation Plan (2011-15) was issued in 2010 and the second plan (2016-20) in 2015. Preparations for the third plan for the period up to 2025 are ongoing.

The ongoing second plan briefly discusses the energy sector's adaptation under the objective of "reinforcing the competitiveness of industries using climate change as an opportunity". The plan proposes the establishment and implementation of energy plans considering the impacts of climate change, and the expansion of distributed electricity systems in the islands. Targeted support is provided to small and medium-sized enterprises that have developed climate change adaptation technologies that are assessed to have high growth potential. Targeted adaptation measures are also developed for industrial complexes, a geographical unit comprising several industrial entities, and the government provides support for the implementation of the identified measures. External experts also assist individual companies located within the targeted industrial complexes to assess their specific vulnerability to climate change, then support the establishment of adaptation measures.

However, more recent energy plans, such as the 8th Basic Plan for Electricity Supply and Demand and the 3rd Energy Master Plan, still have limited discussion on climate change adaptation. Most of the climate-related discussions are focused on limiting temperature rise through mitigation efforts, such as decarbonisation and efficiency improvement in power generation. Adaptation to the increasing impacts of other climatic changes, such as increasing variability in precipitation and intensification of extreme weather events (e.g. typhoons, heatwaves, wildfires) is rarely discussed.

The 3rd National Climate Change Adaptation Plan and the 9th Basic Plan for Electricity Supply and Demand are currently under preparation. The government should consider including a discussion of measures for climate change adaptation, given the increasing adaptation needs in the energy sector.

As Korea is highly dependent on imported fuels and the electricity sector is operated as an isolated island system, energy security is of particular importance. The island of Jeju is used as a test bed for technologies and measures to eventually ensure independence in the electricity sector. An island-wide smart grid has been established and the government is expanding distributed electricity generation sources around the island to ensure stable supply in the event of severe weather events. Distributed electricity systems are expanding in islands not only to reap adaptation benefits, but also to increase the deployment of renewables and energy storage systems.

It should be noted that the assessment of the impact of climate change on energy infrastructure and demand and supply is carried out only qualitatively, and is not supported by quantitative modelling.

Assessment

In 2017, Korea's total GHG topped the 700 Mt CO_2 mark for the first time, reaching 709.1 Mt CO_2. The 2.4% increase in total GHG emissions compared to 2016 was largely due to the increased use of coal in electricity production, as more capacity came on-stream than old capacity was retired. In 2017, energy-related CO_2 emissions accounted for 86.8% of the total, equivalent to 615.5 Mt CO_2.

Power and heat generation is by far the largest source of energy-related CO_2 emissions in Korea. In 2018, the sector accounted for 55% of total energy-related emissions, followed by transport (17%), industry (12%), other energy industries (7%), residential (6%) and services (4%). Korea's carbon intensity of power generation was 507 g CO_2/kWh in 2018, much higher than the IEA average of 246 g CO_2/kWh. Although Korea's carbon intensity of the economy has declined by 33% since 1990, it was still the fourth highest among the 30 IEA member countries, at 0.290 g CO_2/kWh (2015 PPP), in 2018.

Emissions targets and strategy

The Korean government is cognisant of the challenge to address GHG emissions and to prepare for the transition of the energy system from its high reliance on fossil fuels towards new and renewable energy sources. The Framework Act on Low Carbon, Green Growth of 2010 made a pledge to reduce GHG emissions in 2020 by 30% against the business as usual scenario of 776.1 Mt CO_2-eq. In 2017, emissions were 30% higher than this voluntary and non-binding target of 543 Mt CO_2-eq. The 2020 voluntary target is understood as the pathway to the 2030 target.

For 2030, Korea is committed under the Paris Agreement to reduce GHG emissions by 37% against the BAU scenario of 851 Mt CO_2-eq using domestic measures and international market mechanisms. In 2018, the government revised the emissions targets, shifting from relative to absolute emissions reduction targets, implying a target of 536 Mt CO_2-eq in 2030. The government also announced that an increased share of emissions reductions will need to be obtained through domestic measures in order to minimise the impacts on international reductions. A detailed strategy for the buying of international off-set instruments is pending, due to the delayed finalisation of the market mechanism under the Paris Agreement. The government also plans to adopt a long-term strategy towards 2050.

Korea has made real progress in setting more ambitious and transparent targets for emissions reductions. But urgent corrective measures are needed in all sectors in order to

rectify the trajectory. The implementation of the proposed actions appears to rely in a large part on future voluntary contributions, especially in the industry and building sectors (see also Chapter 4). This does not reflect the urgency or the magnitude of the possible shortfall towards the climate targets. The continuous commitment to further emissions reductions in the long-term strategy by 2050 will facilitate implementation in those sectors, and help to meet the Paris Agreement's goals.

Emissions Trading System

In 2015, Korea became the first country in Asia to introduce a mandatory ETS for large industry. The IEA congratulates the Korean government for this achievement. The ETS is being implemented in three phases, the second of which is currently ongoing (2018-20). The second phase of the ETS covers 6 sectors (conversion, industry, building, public sector and other, waste, and transport) divided into 64 subsectors. The aviation sector is included in the transport sector, which is another commendable policy decision. The ETS covered 70% of Korea's total GHG emissions in the last year of the first phase. The third phase of the ETS will cover the years 2021-25.

The share of freely allocated allowances is progressively being reduced. From 100% in the first phase, the share was reduced to 97% in the second phase and will be lower than 90% in the third. Prices in the ETS increased by 54% between 2015 and 2018. However, power sector emissions are still increasing and the government should review the ETS mechanism to make it more effective in the third phase.

The government is discussing possible options for the investment of ETS auction revenues towards GHG emissions mitigation measures of companies under the ETS. These options include supporting mitigation equipment projects, innovation and technology development of the concerned companies. No specific criteria or rules for eligible investments have been identified; nor is the government currently considering the creation of a monitoring and evaluation system to track the investments made, or their outcomes. The IEA recommends that fuel-switching options to low- and zero-carbon energy be among the eligible investments.

The government is currently not undertaking regular and comprehensive monitoring of the effectiveness of the ETS system. It would be advisable to develop and implement such a monitoring system jointly with the development of a monitoring and evaluation system for the upcoming investments linked to ETS revenues.

Low-carbon transition in the transport sector

Transport is the second-largest emissions emitting sector and emissions have grown by 16.1% since the last in-depth review in 2012. Korea has set fuel efficiency standards for passenger cars in line with international trends. In addition, Korea is working towards the introduction of fuel efficiency standards for heavy-goods vehicles, again putting the country at the forefront of international efforts (see Chapter 4).

Korea has no aim to further expand the current diesel-blending mandate of 3% for biofuels, as almost two-thirds of the feedstock for blending is imported. The blending mandate does not extend to petrol. The IEA encourages the government to continue ongoing research into the potential of using waste as a feedstock and to explore the potential to identify possible implementation of cost-effective solutions, and evaluate in which sector the deployment of bioenergy will achieve the highest value.

Korea supports the increased uptake of EVs with a number of measures, including subsidies and rebates on national and local vehicle purchase taxes and privileges low emissions vehicles in public procurement programmes. The roll-out of charging infrastructure similarly benefits from a large number of support measures, including subsidies for public and private chargers. However, some of the support schemes were set to be suspended by the end of 2019 and replacement schemes have not yet been announced.

There are also some questions of whether the existing bundle of support measures is sufficient to achieve the desired targets. The environmental and emissions reduction benefits of the roll-out of EVs will partly be determined by the electricity fuel mix, and Korea's carbon intensity in the power sector is currently high, although the roll-out can help to mitigate local air pollution in cities.

The population is concerned about the safety of hydrogen fuelling stations and their siting which the government will need to address to facilitate the smooth roll-out of the network. These concerns need to be addressed through close dialogue with the population.

Air pollution

Air pollution is a major concern in Korea, with Seoul being one of the most polluted cities globally. Of particular concern is fine particulate matter. In 2018, the government took a substantial step towards addressing this issue by implementing the Special Act on Fine Dust that aims to combat particulate matter pollution, aiming to significantly reduce the number of days with bad air, defined as exceeding 50 μm m^3, from 258 days in 2016 to 78 days in 2022. The act gives authority to local governments to suspend the operation of coal-fired plants under certain circumstances.

Policy measures under the act cover all sectors and include the removal of support programmes for diesel vehicles, the scrapping of 77% of diesel vehicles built before 2005, the conversion of some coal-fired power plants to LNG and the closure of coal-fired plants more than 30 years old. These are ambitious targets and measures that will require determined implementation to meet the targets of the act.

Korea's population appears keenly aware of the severity of the local air pollution problem and is recognising the need for fast, and perhaps even drastic, actions. The government could leverage these concerns to push forward its agenda to reduce local air pollution while simultaneously preparing the ground for the fast implementation of other elements of its energy transition policy.

Taxation

Overall energy tax rates in Korea are low by international comparison and do not provide much incentive to steer behaviour towards less carbon-intensive energy, as evidenced by the lack of decoupling of economic growth from carbon intensity. Korea is committed to move towards an environment-friendly energy taxation system. In 2014, a tax on coal used for power generation was introduced, and increases annually. The government's objective is to ensure that each fuel used in power generation adequately reflects the environmental costs related to its use, with a special focus on particulate matter. In 2019, the government adjusted the relative taxes for coal and LNG used for power generation. As a result, the total tax on coal is now five times higher than that for natural gas.

Taxation is not yet a key policy mechanism to address emissions in the transport sector in Korea. Taxes on diesel fuel are substantially lower than taxes on gasoline. This appears to be in conflict with the government's policies and measures to reduce the share of diesel cars in the vehicle fleet and to move towards an environment-friendly energy taxation system. The IEA therefore urges the government to expedite the consultation for and introduction of the planned rational taxation system of transportation fuels. This would complement its other policy efforts to reduce GHG emissions and to reflect the external cost of energy use.

Recommendations

The government of Korea should:

- Examine the lessons learnt from Phases I and II of the Korean ETS, and of similar existing trading schemes around the world, and integrate them into the final design for Phase III before making it operational in 2021.
- Develop the criteria and rules applicable for eligible investments funded by revenues from the ETS. Establish a monitoring and evaluation system to track the investments made and the outcomes obtained.
- Define a clear trajectory for each sector (industry, transport, buildings, power) between the current situation and the 2030 GHG targets, and implement a regular monitoring system to track progress and identify and quantify the efforts needed in each sector. Ensure political ownership at all government levels and accountability to guide full and efficient implementation of the 3rd Energy Master Plan.
- Ensure that the energy taxation of all fuels reflects their external costs, including carbon content and air pollution, to accelerate the switch to lower emissions technologies.
- Ensure efficient infrastructure roll-out to support the clean mobility targets.

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4. Energy efficiency

Key data

(2018)

Total final consumption (TFC): 182.2 Mtoe (oil 51.9%, electricity 25.1%, natural gas 12.3%, coal 5.2%, district heat 3.0%, biofuels and waste 2.3%, geothermal 0.1%), +24.0% since 2008

Consumption by sector: industry 55%, transport 19.3%, commercial 13.9%, residential 11.8%

Energy consumption (TFC) per capita: 3.5 toe/capita (IEA average 2.9 toe/capita), +17.9% since 2008

Energy intensity (TFC/GDP): 86 toe/USD* million PPP (IEA average: 67 toe/USD* million PPP), -9.1% since 2008

* GDP data are in billion USD 2015 prices and PPP (purchasing power parity).

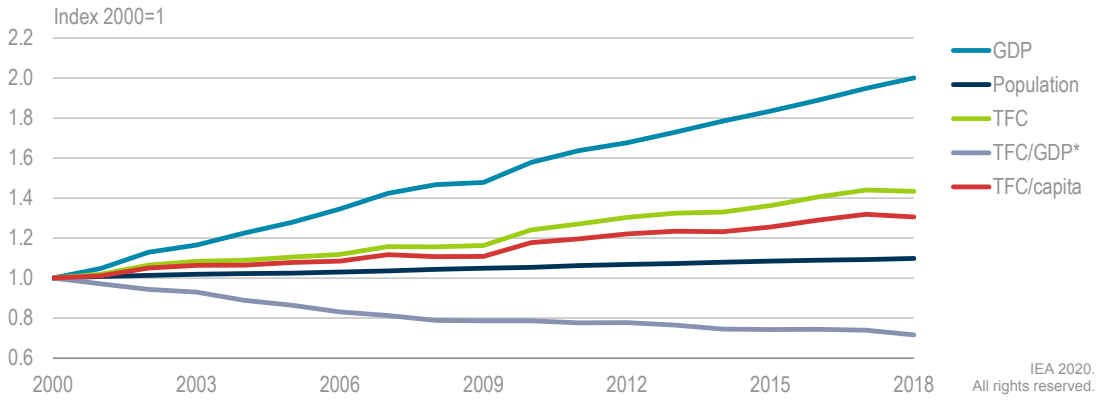
Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

Korea has a highly energy-intensive economy. In the period 2000-18, Korea's total final consumption (TFC) increased by 43% while its economy expressed as gross domestic product (GDP) in purchasing power parity (PPP) doubled, resulting in a 25% decline in energy intensity (TFC/GDP). Since the financial crisis in 2008, there has been little improvement in energy efficiency and ensuring decoupling of economic growth from energy consumption has become a more urgent issue (Figure 4.1).

Korea's 3rd Energy Master Plan (EMP) of 2019 well reflects this sense of urgency and shows the government's strong commitment to prioritise energy efficiency as the country's first energy source. Based on the plan, the government aims to reduce Korea's total final consumption by 18.6% in 2040 compared to the business as usual (BAU) case. The Energy Efficiency Innovation Strategy 2019 provides interim targets up to 2030 as well as specific measures to transform the domestic energy consumption pattern through the application of Korea's most innovative technologies, such as information and communication technology (ICT) for energy management in industry and intelligent transport systems. Strengthening the existing regulatory measures while applying new technology-driven innovation in energy efficiency can not only accelerate Korea's clean and safe energy transition, but can also help reduce its reliance on energy imports.

Figure 4.1 Energy supply and drivers, 2000-18



Korea's energy consumption is largely driven by economic growth and decoupling it from GDP growth has been very slow in the last decade.

* GDP data are in billion USD 2015 prices and PPPs (purchasing power parity).

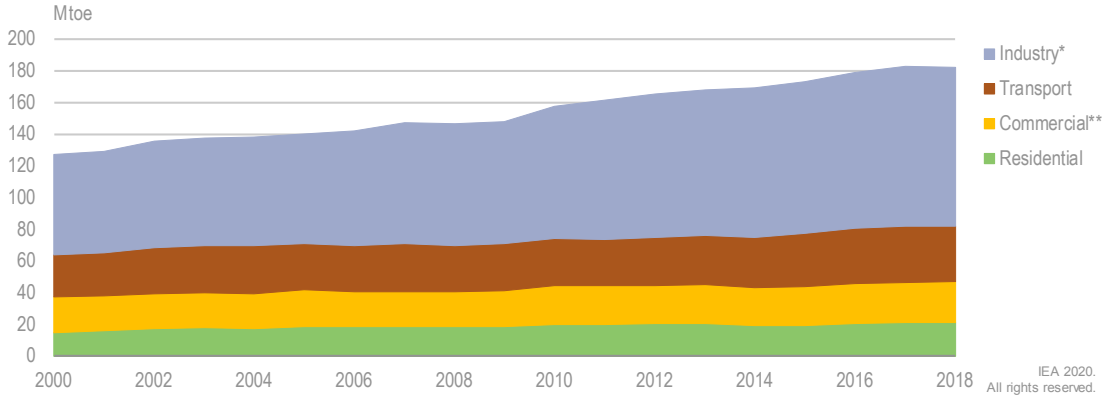
Note: GDP = gross domestic product. TFC = total final consumption.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Total final energy consumption

Korea's TFC was 182.2 million tonnes of oil equivalent (Mtoe) in 2018, slightly below consumption in 2017 (Figure 4.2). The industrial sector accounted for the largest share of TFC at 55%, followed by residential and commercial (25.7%), then transport (19.3%).

Figure 4.2 Final energy consumption (TFC) by sector, 2000-18



In Korea, industry is the largest energy consumer and the main driver of the increase in TFC.

* *Industry* includes non-energy consumption.

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

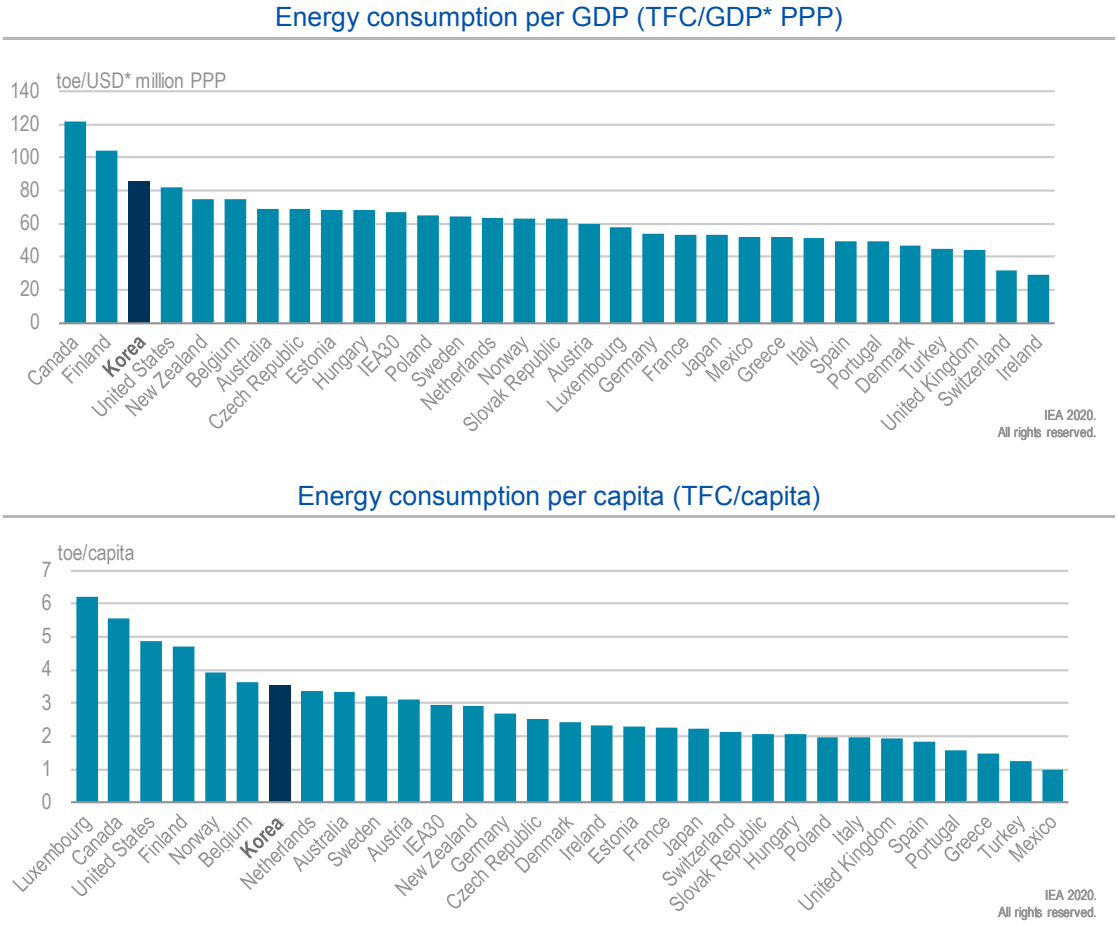
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

The industry sector is the main driver of TFC growth. In the period 2000-18, industrial energy consumption increased by 58%, mainly for non-energy use as petrochemical feedstock (see the industry section for more details). Energy demand in the other sectors also increased over the same period, with the residential sector showing the second-highest growth of 43%, followed by transport (34%) and the commercial sector (14%).

Energy intensity

Korea has one of the highest energy intensities among IEA member countries (Figure 4.3). In 2018, it ranked third highest in energy consumption per GDP at 86 toe/USD million PPP, which is 40% higher than the IEA average (67 toe/USD million PPP). In energy consumption per capita, Korea ranked the seventh highest at 3.5 toe per capita, 48% above the IEA median (2.9 toe per capita).

Figure 4.3 Energy intensity in IEA member countries, 2018



In IEA comparison, Korea has the third-highest final energy consumption per GDP and the seventh-highest consumption per capita.

* GDP data are in billion USD 2015 prices and PPPs (purchasing power parity).

Note: Energy intensity in total final energy consumption, not including the energy transformation sector.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Energy innovation

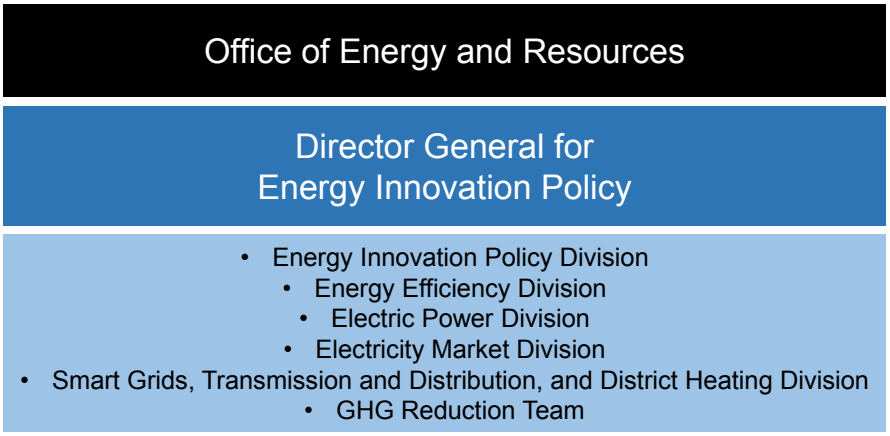
In February 2019, Korea made a major institutional change to its energy efficiency set up. The Ministry of Trade, Industry and Energy (MOTIE)[1] established a new Energy Innovation Policy Bureau directly managed by a director general, which revamps the previous structure where the Energy Demand Restraint Division was placed under the New and Renewable Energy Policy Bureau of MOTIE and was the principal body responsible for energy efficiency (Figure 4.4).

For the first time, an independent division was dedicated to improving energy efficiency, underlining the increasing prominence of energy efficiency in Korea's energy policy. It also reflects a shift towards demand-side management instead of merely energy conservation to improving the efficiency of energy consumption.

The main objective of the new office is to bring innovation to the centre of energy demand management with its five sub-divisions operating hand in hand. The Energy Innovation Policy Division is responsible for setting an overarching policy framework to transform Korea's energy consumption pattern, which is one of the 3rd EMP's primary targets. Acknowledging that such fundamental change requires a corresponding reform in energy pricing, markets and infrastructure, MOTIE placed three other divisions – Electric Power; Electricity Market; and Smart grids, Transmission and Distribution, and District Heating, as well as a Greenhouse Gas Reduction Team – under the same bureau.

The new organisational structure demonstrates Korea's strong commitment to bring innovative change to the country's demand-side management and could facilitate a successful implementation of the 3rd EMP. It also indicates a shift in Korea's energy policy's priority from security and affordability of supply to better demand-side management, including energy efficiency.

Figure 4.4 New organisational structure for energy efficiency under the Ministry of Trade, Industry and Energy, 2019



Source: MOTIE (2020), *Organizational Structure*, http://english.motie.go.kr/en/am/organization/organization.jsp.

[1] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

Energy efficiency policy and measures

Overview of national plan and targets

The Rational Energy Utilization Act sets the legal ground for all energy efficiency policies and legal obligations in Korea, including the minimum energy performance standards and labelling, and providing financial support for energy services companies (ESCOs). The act obliges major energy suppliers like Korea Electric Power Corporation (KEPCO) as well as large energy consumers to report their energy demand management plans to the Korea Energy Agency (KEA) (KEA, 2019). Large energy consumers are defined as having an annual energy consumption above 2 000 toe. In 2018, there were 4 694 such consumers in Korea.

The act also requires that MOTIE formulate a Basic Plan for Rational Energy Utilization every five years with clear national targets and specific measures to achieve them. The last 5th Basic Plan in 2013 proposed to reduce Korea's final energy consumption by 4.1% (9.3 Mtoe) below the BAU level by 2017, but the actual level in 2017 was about 1% higher than the BAU 2017 level, so the target was not met. The 6th Basic Plan, originally scheduled to be released in 2018, will now be released in 2020, and will be published on the basis of the 3rd EMP.

The 3rd EMP was released in June 2019 and provides the most updated, long-term energy efficiency targets, which are largely twofold (MOTIE, 2019a):

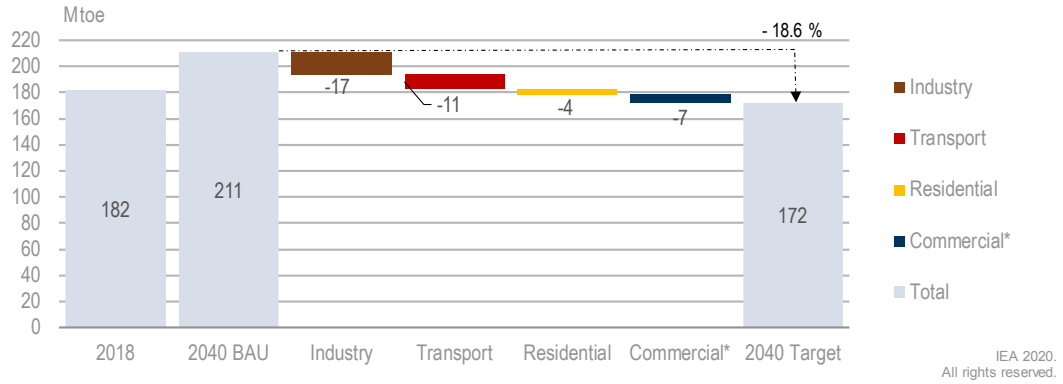
- Improve energy intensity (TFC/GDP) by 38% in 2040 compared to the 2017 level: If the target is achieved, Korea's energy intensity would decline from 0.113 toe/KRW million in 2017 to 0.070 toe/KRW million in 2040.

- Reduce Korea's final energy consumption by 18.6% in 2040 compared to the BAU forecast, which is equivalent to energy savings of 39 Mtoe.

The industry sector is expected to contribute the most to this potential energy saving and account for 8.1% out of the 18.6% target, which is equivalent to around 17 Mtoe energy saved. The transport sector saves 11 Mtoe, followed by commercial and public services (7 Mtoe), then the residential sector (4 Mtoe) (Figure 4.5).

In order to achieve the 2040 target, the 3rd EMP provides an overarching policy framework that consists of four main thematic tasks: 1) improve energy efficiency by sector; 2) promote the creation of a market for demand-side management; 3) rationalise the energy pricing mechanism; 4) optimise the use of non-electric energy sources (see energy efficiency policies per sector and cross-cutting sectors sections below).

Figure 4.5 Korea's final energy consumption reduction target, 2018-40



* *Commercial* includes public services

Notes: BAU = business as usual. Figures exclude feedstock consumption

Source. MOTIE (2019a), *3rd Energy Master Plan*, https://www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_seq_n=161753&bbs_cd_n=81.

Given the high ambitions, the government has acknowledged that simply reinforcing the existing energy efficiency measures is insufficient and that more needs to be done to scale-up the energy efficiency improvements. The Energy Efficiency Innovation Strategy was established to do just that (Box 4.1).

Box 4.1 Korea's Energy Efficiency Innovation Strategy 2019

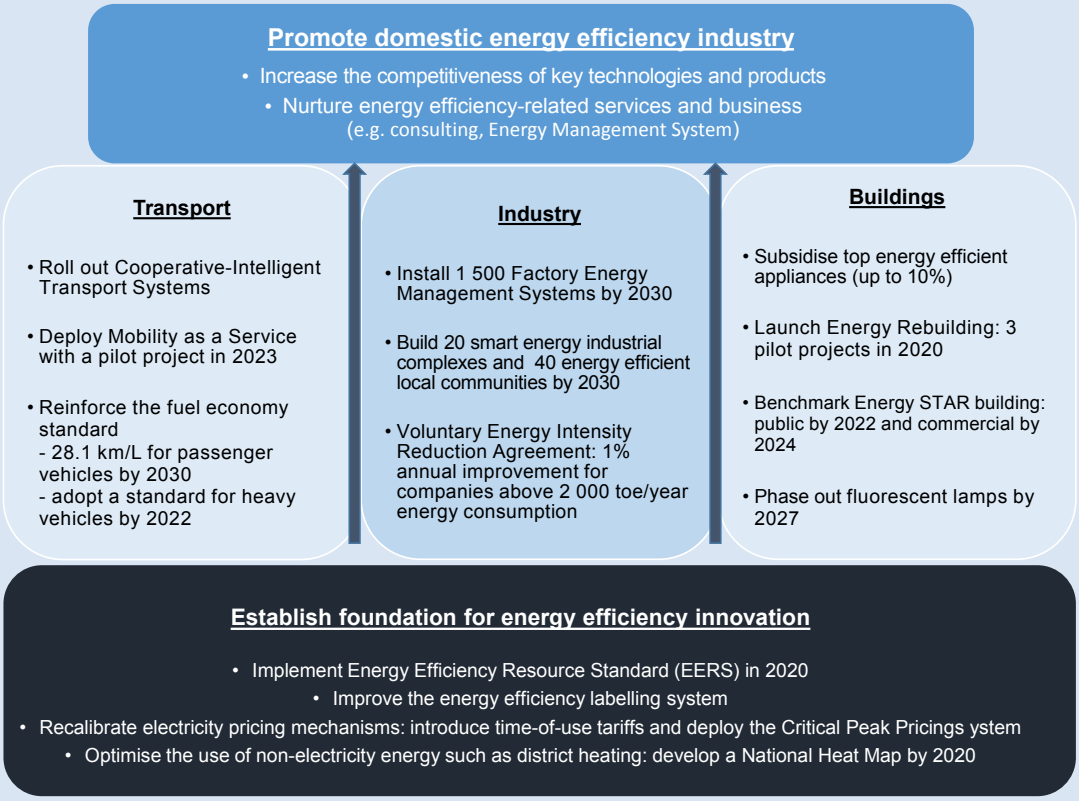
The Energy Efficiency Innovation Strategy (EEIS) was released in August 2019 to supplement the 3rd Energy Master Plan and to provide interim targets and measures up to 2030.

The strategy intends to use Korea's most advanced technologies such as the 5G network, artificial intelligence, big data and the Internet of Things as a major driving force of improving energy efficiency. This is in line with the country's Fourth Industrial Revolution initiative introduced in 2017, which emphasises the role of technology innovation and digitalisation to stimulate economic growth.

The EEIS anticipates reducing Korea's total final energy consumption by 14.4% in 2030 compared to a business as usual level, equivalent to 29.6 Mtoe of energy saved, and improve energy intensity by 27.4% compared to the 2017 level of 0.113 toe/KRW million. The reinforced implementation of the existing energy efficiency measures is expected to save around 10.7 Mtoe out of the targeted 29.6 Mtoe, while the new measures introduced in the EEIS will contribute the remaining 18.9 Mtoe of energy savings by 2030. The strategy's ultimate target is not limited to lowering energy demand, but to mutually reinforce two national agendas – the Fourth Industrial Revolution and energy efficiency innovation – to nurture a domestic energy efficiency industry that creates new jobs and businesses (Figure 4.6).

The Ministry of Trade, Industry and Energy anticipates that successful implementation of the strategy will reduce energy import costs by KRW 10.8 trillion (USD 8.9 billion) while creating 69 000 new jobs in the energy efficiency field.

Figure 4.6 Energy Efficiency Innovation Strategy framework



Source. MOTIE (2019b), *Energy Efficiency Innovation Strategy*, www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_cd_n=81&bbs_seq_n=161993.

Korea's EEIS illustrates an exemplary case of energy efficiency policy development promoted by the International Energy Agency: an integrated approach to promoting a diverse set of measures including incentives to increase investment, systematic data collection and assessment, market-based regulations, public engagement, and the application of advanced technologies to innovate the energy demand management (Sung and Birol, 2019).

Source: MOTIE (2019b), *Energy Efficiency Innovation Strategy*, www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_cd_n=81&bbs_seq_n=161993.

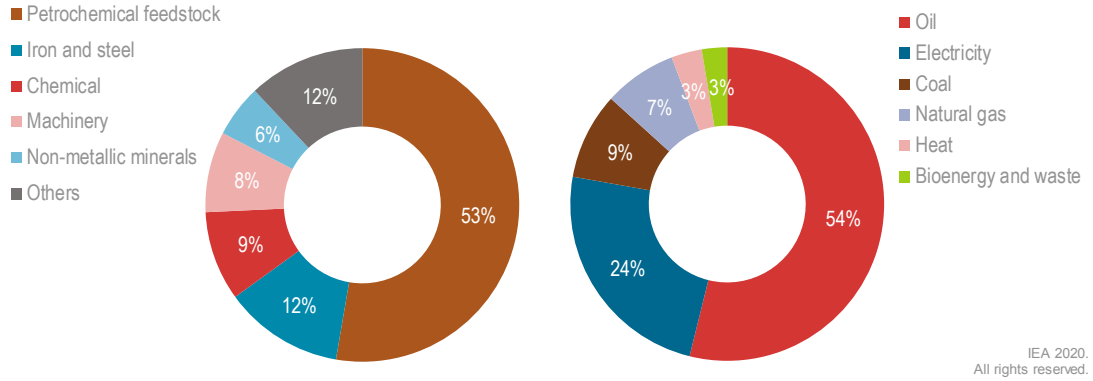
Energy efficiency policies by sector

Industry

The industry sector accounts for over half of total TFC in Korea and in 2018 reached just over 100 Mtoe. As one of the world's major petrochemical producers, Korea has a high share of petrochemical feedstock in total industrial energy consumption. In 2018, petrochemical feedstock accounted for 53% of total industrial energy consumption (Figure 4.7). Among the industrial subsectors, iron and steel accounted for the largest share with 12% of total industrial energy consumption, followed by chemical (9%), machinery (8%) and non-metallic minerals (6%).

Oil is the largest energy source used in the industry sector, accounting for 54% of total industrial energy consumption in 2018, followed by 24% for electricity, 9% for coal and 7% for natural gas. The rest were small shares of bioenergy and waste and district heating.

Figure 4.7 Industrial energy consumption by sector and fuel, 2018



Over half of Korea's industrial energy consumption is for non-energy use, primarily as petrochemical feedstock. Oil is the main source of energy for the industry sector.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Given the dominance of energy-intensive heavy industries in Korea's economy, decoupling industry's energy consumption from its economic activity has been the government's top priority.

The majority of the existing energy efficiency measures in industry are of a voluntary nature. The Energy Champion programme, introduced in 2015, is a typical example that employs incentives to elicit voluntary actions such as the purchase of high-efficiency equipment and improvements of operating processes. Under the programme, companies set their own annual voluntary targets and register with the KEA to be selected as energy champions following an assessment of their proposed voluntary actions.

After the establishment of an assessment framework and a pilot project in 2017, Energy Champion was enforced in 2018. The assessment framework is based on both a quantitative evaluation, with a maximum of 70 points, and a non-quantitative evaluation, with a maximum of 30 points of the activities undertaken in the previous year. Any company reaching a score of at least 80 points is accepted into the programme. The quantitative evaluation looks at the energy intensity improvements and the reduction of energy consumption, while the qualitative evaluation reviews the energy management effort and the practical actions for energy efficiency development.

In 2018, 31 companies registered with the KEA and 24 were nominated as energy champions. Of these, three were subsidiaries of KEPCO and the rest were private companies such as Posco and Korea Telecom, the major energy consumers in Korea. In 2019, the number of companies applying for inclusion under the programme increased to 35 companies; 25 were accepted. These 25 companies reduced their energy consumption by 2.5% (46.7 kilotonnes of oil equivalent [ktoe]) in 2018.

The champion title is valid for three years, during which the companies are exempt from the mandatory energy audits (see below). In addition, companies receive support for overseas energy training for their employees and receive an Energy Champion certificate and certification plaque.

Another voluntary scheme, the Energy Intensity Reduction Agreement, commenced in 2020. Unlike the Energy Champion programme, where the companies set their own voluntary targets, the Energy Intensity Redution Agreement encourages companies with an annual energy consumption over 2 000 toe to reduce their energy intensity by 1% per year. The government provides "Excellent Business" certificates to companies that meet the 1% target. A possible exception of these companies from the mandatory energy audit is under review by the government. In 2018, companies with an annual energy consumption above 2 000 toe accounted for 70.2% of total industrial energy consumption (KEA, 2019). The Energy Champion programme will eventually be integrated into the Energy Intensity Redution Agreement.

Energy management systems (EMS), an ICT-based monitoring and control system, play an essential role in optimising energy consumption through real-time data collection and analysis. In order to encourage more industry players to adopt EMS and build a solid EMS infrastructure in the country, the government has been providing technical, financial and operational support since 2014. Korea's EMS scheme follows a two-step process: 1) voluntary uptake of an international standard – ISO 50001;[2] 2) the government's evaluation of EMS implementation and its outcomes. The energy savings performance evaluation is undertaken for five years after the completion of the project implementation against a baseline. If implementation problems are discovered, the evaluation suggests improvement measures.

The government provides tailored consulting services for small and medium-sized enterprises (SMEs) in the heavy industry or power generation sector whose annual energy consumption exceeds 2 000 toe to adopt the EMS. Between 2014 and 2018, the government provided financial support of KRW 13.3 billion (USD 11.2 million) to 92 SMEs, which resulted in an accumulated energy savings of around 34 096 toe (KEA, 2019).

The ultimate objective of the EMS support scheme is to establish a nationwide, cross-sectoral EMS in Korea. For this, the government is currently promoting the deployment of factory energy management systems (FEMS) as part of the Energy Efficiency Innovation Strategy. The government is considering making the introduction of FEMS obligatory; however, no final decision has yet been taken.

SMEs with an annual energy consumption below 100 000 toe will be supported by MOTIE's Smart Factories initiative[3] initially, and the government expects that 3 000 FEMS will be installed in the SME sector by 2040. An obligation for a building energy management system (BEMS) is also planned to be enforced from 2025 onwards (see the section on buildings below).

[2] ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organisations to integrate energy management into their overall efforts to improve quality and environmental management (ISO, 2020).

[3] Smart Factory refers to a factory equipped with a collection of cutting-edge technologies such as artificial intelligence and the Internet of Things, supporting effective and accurate decision making in design, engineering and production operation process. The Manufacturing Innovation Strategy 3.0 (Strategy 3.0) is an initiative to advance Korea's manufacturing industry, including the setting up of 10 000 smart factories by 2020 (MCST, 2020).

The major regulatory type of energy efficiency measure in the industry sector is the Target Management System (TMS) linked to the greenhouse gas (GHG) emissions control. Companies whose average energy consumption level during the last three years exceeds 200 terajoules (TJ) and 50 000 tonnes of CO_2 equivalent (t CO_2-eq), and in the case of an individual business, 80 TJ and 15 000 t CO_2-eq, are obliged to set their own reduction targets for the following year in consultation with the government. Those targets are legally binding.

Concerned entities must submit their action plans to the KEA before the beginning of the target year. The KEA monitors progress and provides recommendations for reaching the targets during the target period. In 2018, 115 of the 168 entities controlled under the TMS of the industrial sector met their binding targets (KEA, 2020). In 2017, 100 companies out of the 149 registered met their self-set targets (KEA, 2019). However, no entity in the industrial sector was fined for missing their target, although the government is authorised to levy a fine not exceeding KRW 10 million. In case of non-compliance, the government can also order the concerned entity to make the necessary improvements. In 2017, 39 companies were ordered to improve their performance and 40 were in 2018, but the list of the concerned companies is not disclosed.

For SMEs subject to the Emissions Trading Scheme (ETS) (see Chapter 3), the government provides financial support for installing more efficient equipment and appliances such as light-emitting diode lamps, inverter compressors and waste heat recovery units. In 2017-18, 36 companies benefited from the subsidies; the government expects around 23.7 t CO_2-eq emissions reduction and positive awareness raised from this retrofit support scheme (KEA, 2019).

Companies with an annual energy consumption above 2 000 toe are obliged to undertake an energy audit every five years. Companies with an annual consumption above 200 000 toe have the option to either undertake a partial energy audit of their company every three years or a whole audit every five years. MOTIE appoints a certified auditor to carry out the on-site audits, who proposes a range of energy efficiency measures and reports back to the KEA. The audited companies are not obliged to comply with the outcome of the audit, but those that do not make progress within the three-year period are not eligible to apply for the government subsidy of 30% of the down payment for energy audits of SMEs at the time of their next mandatory energy audit.

Table 4.1 Outcome of mandatory energy audits, 2015-18

Year	Number of audited companies	Estimated annual energy reduction (toe/year)	Average reduction rate (%)
2015	825	520 893	3.9
2016	789	648 367	4.4
2017	682	562 753	4.2
2018	627	552 143	3.9

Source. KEA (2019), *KEA Energy Handbook 2020* (in Korean), https://www.energy.or.kr/web/kem_home_new/info/data/open/kem_view.asp?q=22049.

The falling average reduction rate in 2016-18 is likely due to the fact that Korea's mandatory energy audit system is in its third cycle and most of the low-cost, high-yield energy efficiency upgrades have already been implemented. In recognition of this, the

KEA has shifted to promoting the introduction of advanced ICT for the energy audits to identify additional opportunities. As a result, the preliminary average reduction rate for 2019 is assessed at 5.1%.

In 2018, the first energy efficiency resource standard (EERS) pilot project was executed by KEPCO, obliging an energy saving[4] equivalent to 0.15% of total electricity sales (measured in terawatt hours) compared to 2016. In the 2019 pilot project, the energy saving rate was raised to 0.2% compared to 2017 electricity sales. For the Korea Gas Corporation (KOGAS) and the Korea District Heating Corporation (KDHC), which were included under the EERS only in 2019, the saving rates were 0.02% and 0.15% of total gas and heating sales compared to 2017. The saving targets in 2020 were set at the same level as those in 2019 due to the pilot nature of the EERS. In the long term, the target for electricity and heat savings will be set at 1% and the target for gas at 0.5%. Targets will be adjusted every three years.

The first two years of the EERS pilot project brought mixed results. KEPCO met its savings target mainly by investing in high-efficiency power transformers, and has to start investing in customer facilities. KDHC met its 2019 savings target; KOGAS did not, but is taking measures to achieve it. Moreover, the pilot projects resulted in increasing customer awareness about the need for energy savings and saw a number of diverse end-use efficiency programmes being initiated. The experiences from the two-year pilot run will feed into the design for the legal obligation scheme. The full implementation of the EERS from 2020 onwards is expected to lower industrial energy consumption.

A potential barrier to the EERS is the long life cycle of industrial equipment that delays the adoption of efficient, advanced technologies. In 2017, the share of high- and premium-efficiency motors was only 5.6% in Korea (MOTIE, 2019a). To address this, the government will strengthen the minimum energy performance standards for key industrial equipment, including heat pumps, motors, boilers and other end-use devices under the EERS.

The government encourages active sharing of information and technology transfer among the industry players, particularly between the major multinational companies and SMEs, to maximise synergies for scaling up energy efficiency. The Green Growth Partnership has been partnering companies together since 2007, and in 2018, 31 large companies and 241 SMEs participated. The government reported that around 18 465 toe energy was saved in 2018 from the collaborative projects matched through the Green Growth Partnership (KEA, 2019).

The government anticipates that all the energy efficiency measures employed in the industry sector to be eventually incorporated into Korea's smart energy industrial complexes, whose entire operational chain, from production to distribution and sales, would be automated and connected (MCST, 2019). The government aims to build ten smart industrial complexes by 2022; sites for four of them have already been identified.

[4] Estimated amount of energy savings = annual energy sales of the two previous years (GWh or Gcal) * energy-saving targets (%) (KEA, 2019).

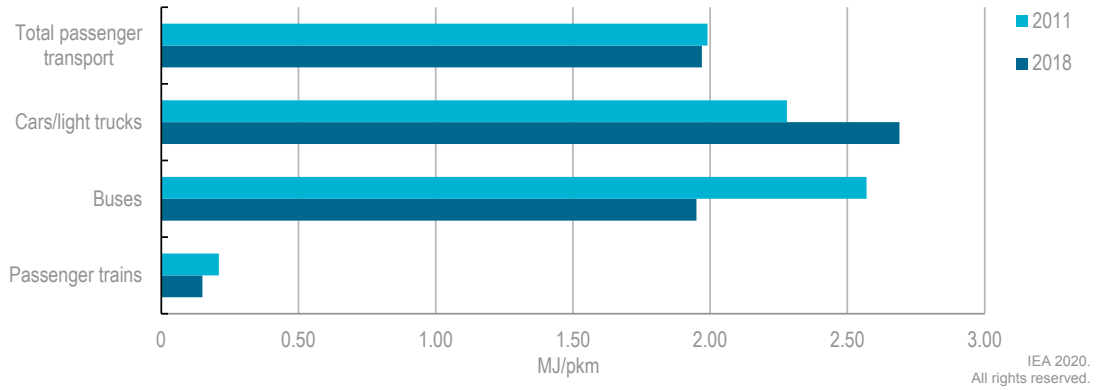
Transport

Korea's energy consumption in the transport sector has increased by 36% since 2000, to reach 36 Mtoe in 2017. After the 2008 financial crisis, transport energy demand picked up fast, growing by 20% in the period 2011-17. By mode, road transport accounts for 94% of total domestic transport energy demand, with the remainder coming from domestic aviation (4%), rail (1%) and others (1%). Oil fuels dominate in the transport sector, accounting for 94% of the total, followed by small shares of natural gas (3%), biofuels (1%) and electricity (1%).

Enforcement of fuel economy standards is the principal policy measure for promoting energy efficiency in the transport sector. The 3rd EMP acknowledged that limited progress was made on fuel economy standards in terms of both scope and stringency (MOTIE, 2019a).

From 2000 to 2018, the energy intensity of Korea's passenger transport improved by only 1%, mainly due to the growing energy intensity of passenger vehicles, which increased by 18% over the same period (Figure 4.8). The increased uptake of more energy-intensive vehicles like sport utility vehicles, more transport activity after lowering the special consumption tax rate on passenger vehicles and the relatively low fuel prices have offset the energy efficiency gains from passenger car technological improvements. On the other hand, the fuel intensities of buses and rail declined by 24% and 29% respectively.

Figure 4.8 Energy intensity of passenger transport by mode, 2011 and 2018



From 2011 to 2018, the energy intensity of Korea's passenger transport improved by only 1%, as cars and light trucks increased their energy intensity.

Notes: Energy intensity is expressed in megajoule per passenger kilometre (MJ/pkm).
Source: IEA (2020b), *Energy Efficiency Indicators 2020*, www.iea.org/statistics.

The Average Fuel Economy (AFE) scheme that obliges vehicle producers and importers to meet certain fuel efficiency levels has been in force since 2006 in Korea. All companies with annual sales over 4 500 vehicles are subject to the scheme and the standard varies between: 1) passenger vehicles with a seating capacity below 10 persons; and 2) passenger vehicles with a seating capacity up to 15 persons or freight vehicles that weigh less than 3.5 tonnes (KEA, 2019).

In 2012, the AFE was integrated with the transportation sector's carbon emissions regulation, allowing the obliged companies to meet either the fuel economy standard or the carbon emissions limit. Accordingly, both MOTIE and the Ministry of Environment set up the respective targets, but the Ministry of Environment is responsible for monitoring progress and imposing fines if the targets are not met.

The average vehicle fuel efficiency of light passenger vehicles (below 10 people) did not greatly improve between 2013 and 2017 and remained stagnant at around 17 kilometers per litre (km/l). The 2017 average fuel efficiency was 16.8 km/l, which is 6% below the target of 17.8 km/l. However, indicative data for 2018 show that vehicle fuel efficiency reached 17.8 km/l. According to the 3rd EMP, the AFE standard is set at 24.3 km/l for 2020, and will increase to 28.1 km/l in 2030 and 35 km/l in 2040 (MOTIE, 2019a). The government is confident that these ambitious targets can be met through a combination of penalties for non-compliance and support for the expansion of electric and hydrogen vehicles. The government may even revise up the final targets for 2030 and 2040.

For large passenger vehicles with a seating capacity up to 15 people and freight vehicles below 3.5 tonnes, the AFE standard is set lower compared to light passenger vehicles. The 2017 target was 14.5 km/l, but performance fell short at 12.3 km/l. The target for 2030 will be set in 2020, as will a target for larger passenger vehicles (buses) and heavy freight vehicles (trucks). To increase the effectiveness of the AFE scheme, the government is also exploring options for increasing penalties in the case of non-compliance.

There are no regulatory measures like the AFE imposed on heavy-duty vehicles, although they are much more energy-intensive than passenger vehicles. In 2017, the average fuel efficiency of heavy-duty vehicles stood at about 5.19 km/l (MOTIE, 2019a). This is likely to improve with the introduction of average fuel economy standards on heavy-duty vehicles, including buses and trucks, from 2023-24 onwards. The government anticipates that this new fuel economy standard and an accelerated growth of electric and hydrogen vehicles will substantially raise the average fuel efficiency of heavy-duty vehicles up to 7.5 km/l by 2040 (see Chapter 6 for details on electric and hydrogen vehicles).

Energy efficiency standards and labelling have played an essential role in helping consumers make smart choices, thereby motivating car manufacturers to invest more in efficiency technologies. All passenger and freight vehicles that weigh under 3.5 tonnes, except for some specially designed vehicles, are obliged to display energy efficiency labels certified by the government on the vehicle so that consumers can easily see and compare. Consisting of five levels, in 2020, the top tier label (level 1) is granted to vehicles with a fuel efficiency above 16.0 km/litre and the lowest (level 5) for those below 9.3 km/l. In December 2018, the share of vehicles with the lowest level (5) was the highest, at 29%, while that of level 1 was the lowest at 11% (KEA, 2019), which indicates that the efficiency limit for level 5 can be strengthened. Electric and hydrogen vehicles are not included in the five-level labelling system. Once the AFE for heavy-duty vehicles is established, the government plans to extend the energy efficiency standard and labelling to cover heavy-duty vehicles as well.

Overall, the government anticipates that in the transport sector, more stringent fuel economy standards on passenger and heavy-duty vehicles together with an accelerated shift to electric and hydrogen vehicles would contribute the most to reducing the transport sector's energy consumption in line with the 3rd EMP's target.

Despite a well-established, cost-competitive public transport system in Korea, modal shift to public transportation has been slow in the last decade, with its share hovering around 42% in 2013-16 (MOTIE, 2019a). Therefore, the EEIS proposed promoting a nationwide mobility as a service (MaaS) concept that allows travellers to use an application to plan and pay for a tailored mobility service. Korea has a good foundation to roll out MaaS as smartphone payments for public transport are prevalent and integrated payment between subways and buses has been in place since 2004. The emergence of diverse personal mobility options

such as shared bicycles and electronic scooters, and the infrastructural improvement to accommodate them could facilitate the deployment of MaaS.

In 2019, the first pilot project – the door-to-door service – was tested in Jeju Island, and since 2020, electronic scooters under the speed of 25 km/h were allowed on bicycle lanes. Based on its first demonstration project in 2019, the government is now focusing on developing an integrated payment system that facilitates seamless interconnection between the different public transport modes (MOLIT, 2019).

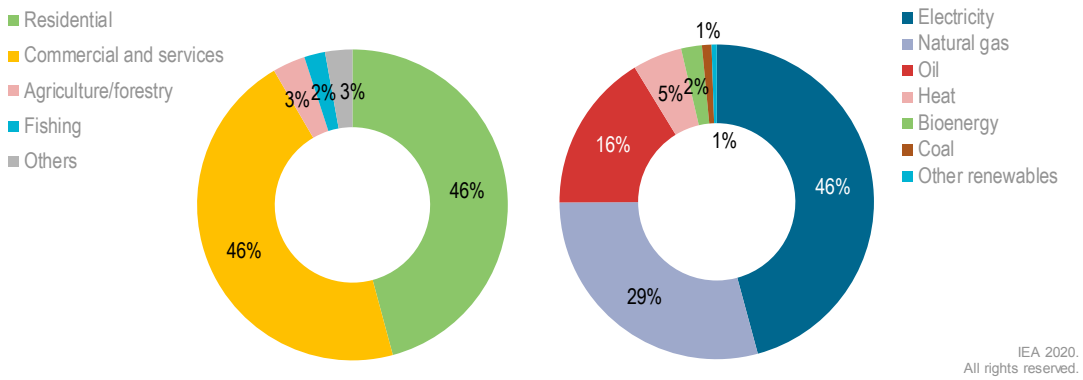
Another ambitious transport project highlighted in the EEIS is the Cooperative-Intelligent Transport System (C-ITS). The C-ITS's primary objective is to improve the road transport system's overall efficiency by fostering real-time traffic information sharing between the drivers, the so-called vehicle-to-vehicle, and between drivers and the traffic controller (vehicle-to-infrastructure). In 2014-17, a pilot project covering 87.8 km in the Daejeon-Sejong area, where all the major ministries are located, was carried out. The government plans additional demonstration projects in key areas like Seoul, Ulsan and Jeju Island by 2021 in an effort to scale C-ITS up to the national level (MOLIT, 2020).

The 3rd EMP noted that little energy efficiency policy development has been made outside the road transport sector, such as in aviation and shipping (MOTIE, 2019a). For that, the government plans to set up a voluntary scheme to encourage domestic airlines to improve their aircraft fuel efficiency by 0.1% annually and enhance the operational efficiency of air traffic controls for airports. For shipping, the government has been encouraging a fuel switch to liquefied natural gas (LNG), but there is no concrete plan on this front.

Residential and commercial

In 2018, the residential and commercial sectors[5] together consumed 47 Mtoe, a 25% increase since 2000. Growing rapidly over the same period, electricity became the largest energy source, accounting for 46% of total residential and commercial consumption in 2018 (Figure 4.9), followed by natural gas (29%), oil (16%), and heat (5%). Small shares of coal, bioenergy, solar and geothermal accounted for the remainder.

Figure 4.9 Residential and commercial sector consumption by sector and fuel, 2018



Most of the energy for the residential and commercial sectors comes from electricity and natural gas.

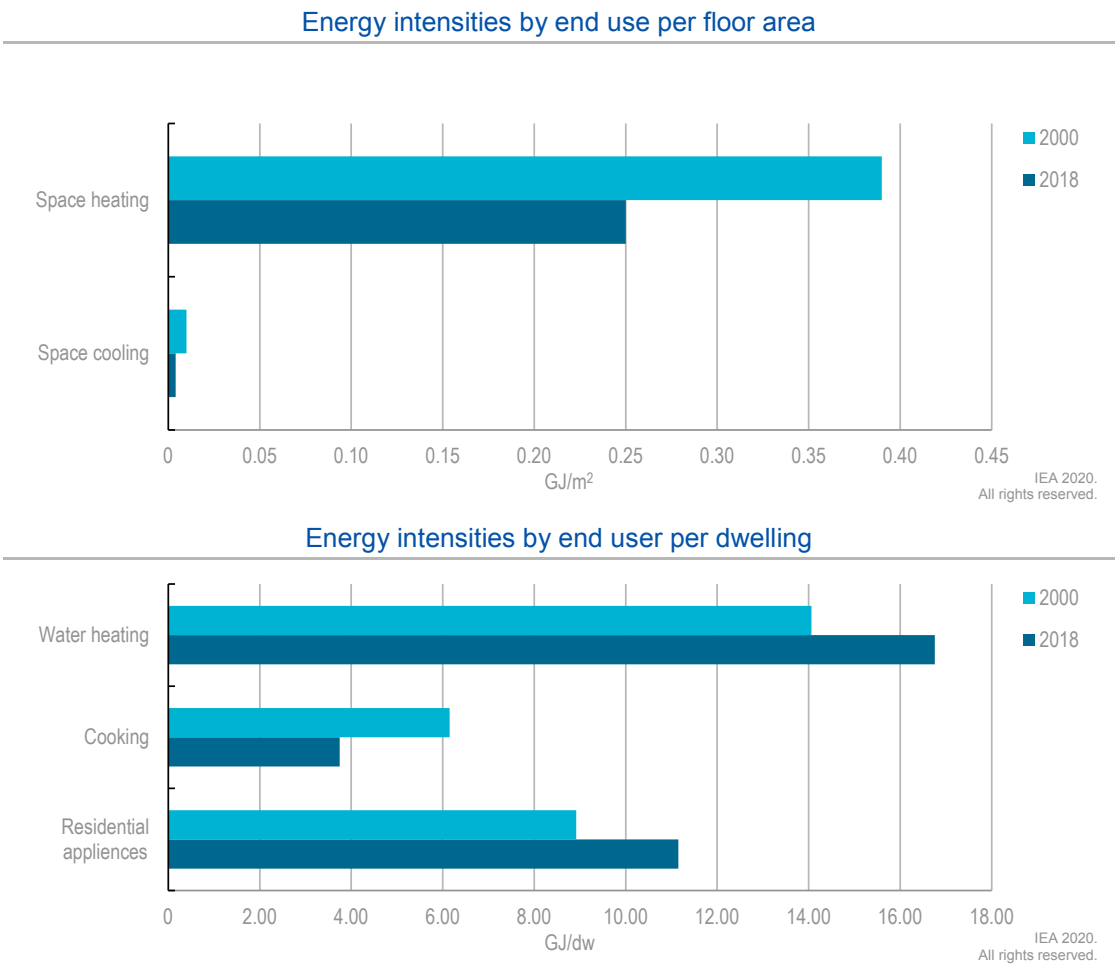
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

[5] The commercial sector includes commercial and public services, agriculture, and forestry.

Space heating is the largest energy user in the residential sector, accounting for 42% of the total residential energy consumption in 2018, followed by water heating (29%), appliances (19%) and cooking (6%) (Figure 4.10).

Space heating energy intensity fell from 0.39 gigajoule (GJ)/square metre (m^2) in 2000 to 0.25 GJ/m^2 in 2018, mainly thanks to energy efficiency gains from the continuous improvement in space heating technologies. The energy intensity of space cooling remained at very low values. Energy intensity of cooking per dwelling declined by around 39% over the period 2000-18, largely due to a change in Koreans' life style, with more frequent dining out and delivery. However, both water heating and residential appliances became 19% and 25% more energy intensive, respectively. A combination of various socio-economic factors, including the exponential increase in the use of electronic devices with more digitalised and modernised life styles have all contributed to increased intensities of residential appliances and water heating per dwelling.

Figure 4.10 Residential energy intensity by end use, 2000 and 2018



Energy intensities of space heating and cooking went down over the period 2000-18, while water heating and residential appliances became more energy intensive.

Notes: Energy intensity by end use per floor area is expressed in temperature corrected gigajoule per square metre (GJ/m^2). Energy intensity by end user per dwelling is expressed in gigajoule per dwelling (GJ/dw).

Source: IEA (2020b), *Energy Efficiency Indicators 2020*, www.iea.org/statistics.

Compared to the industry sector, energy efficiency measures in the buildings sector are more regulative, with more mandatory obligations imposed. Nonetheless, rather loose energy performance standards and limited coverage of energy efficiency policies on new and public buildings have been a major setback in promoting energy efficient buildings in Korea (MOTIE, 2019a).

The TMS implemented in the industry sector is also applied to buildings as the Building Energy & GHG target management scheme. Large buildings whose last three months' average energy consumption level exceeds 200 TJ (or 50 000 t CO_2-eq), and in the case of small to medium buildings 80 TJ (or 15 000 t CO_2-eq), are obliged to set their own 2-year reduction targets and submit action plans to achieve them to the KEA. The difference between the industry TMS and the Building Energy & GHG target management scheme is that there is penalty for the latter. Incorrect reporting and/or non-disclosure of the KEA's recommendations to meet the targets, or failing to meet the recommendations in three years' time can result in a maximum fine of KRW 10 million (USD 8 252). In 2018, 46 buildings participated in practice, resulting in a reduction of approximately 203 000 t CO_2-eq (KEA, 2020).

Another mandatory measure are energy audits. New buildings with a floor area of over 500 m² are required to submit their energy consumption plan to be audited by one of the six audit institutions designated by the Ministry of Land, Infrastructure and Transport. Only buildings that achieved an energy performance index score of over 65 for commercial buildings and 74 for public buildings can obtain a construction approval. The three key assessment criteria are: 1) building codes, e.g. insulation, rooftop; 2) appliance and equipment, e.g. efficient heating and cooling system, lighting; 3) installation of distributed energy technologies, including solar and geothermal systems. In 2018, around 17 314 new buildings were audited (KEA, 2019).

There is no system for regular audits on existing buildings. Instead, a voluntary buildings energy efficiency certification scheme, under which the government issues certificates for highly energy efficient buildings, has been open to all buildings since 2013. In 2013-19, 10 782 buildings received the certificate from the government.

To accelerate the energy efficiency improvement of existing buildings, the government plans to introduce the energy efficiency evaluation system for all existing public office buildings from 2022 and for commercial buildings consuming over 2 000 toe from 2024. It would become mandatory to stipulate standard energy intensity by building type and disclose the outcome of the energy efficiency evaluation for any real estate transactions. A survey on buildings' energy consumption will be conducted every three years to prepare efficiency indicators that reflect operational characteristics and the results will feed into the national data platform for the energy efficiency evaluation system. Based on this, the government will set up and provide certified marks for outstanding energy efficient buildings as part of an effort to benchmark the US ENERGY STAR building programme initiative. Preparations of the programme will commence during 2020.

The 3rd EMP has a particular focus on reinforcing two measures to scale-up buildings' energy efficiency up to 2040: zero-energy buildings (ZEBs) and BEMS. A ZEB[6] is broadly

[6] In Korea, the ZEB rating is divided into five grades depending on the building's "energy self-sufficiency (%)" measured as: energy demand (kWh)/renewable energy supply (kWh) per floor unit. The highest ZEB grade 1 certificate is given to buildings whose energy self-sufficiency rate is over 100% and the lowest grade 5 is given to those whose self-sufficiency rate is between 20% and 40% (KEA, 2020).

defined as a building that produces enough renewable energy to meet its own energy consumption requirements and that is equipped with active and passive energy efficient technologies. Since 2017, newly constructed or extended educational, research and office buildings of over 3 000 m² and owned by market-type public corporations are obliged to be constructed as ZEBs. Quasi-market type public corporations were added in 2018. In 2020, the obligation was extended to include all newly constructed, reconstructed and extensions of public buildings of over 1 000 m^2, except for multi-unit dwellings. The government aspires to have all new buildings of over 500 m^2, both public and commercial, constructed as ZEBs by 2030 (MOTIE, 2019a).

All new public buildings over 10 000 m² are required to install a BEMS, which is an integrated, computerised system that monitors and controls the building's energy consumption for optimal energy use. The government provides incentives for the installation of these systems in the form of tax exemptions (7% for small companies, 3% for medium-sized companies and 1% for large companies), and exemptions of the energy audit. The expansion of this obligation to new private sector buildings is under discussion by the government, but a decision has not yet been reached.

Over the period 2012-15, Korea had almost 44 000 buildings larger than 10 000 m^2, less than 1% of the total building stock, but they accounted for 31.4% of total building energy consumption. The average energy consumption of these buildings was 2 620 megawatt hour (MWh) per building, or 225 toe (KCL, 2017). The government provides a tax deduction or exemption from the energy audit to building owners that install a KEA certified BEMS.

Energy efficiency labelling and standards and high-efficiency equipment certifications have been in place on appliances and equipment for more than 20 years and remain well-established. Rating criteria are reviewed and updated periodically. The minimum energy performance standards have been strengthened continuously, in line with technological advancements, but the government stresses the need to reinforce the coverage and stringency of the standards on major home appliances such as air conditioners, refrigerators and washing machines.

Against this background, the 3rd EMP plans to bring more energy efficient and high-quality appliances onto the market and increase their market shares in an effective manner. Specifically, the production and sales of fluorescent lamps are set to be phased out by 2027 with the roll-out of smart lighting.[7] The government aspires to increase the domestic market share of smart lighting to 60% by 2040 by mandating all new public and commercial buildings to install smart lighting from 2020 (MOTIE 2019a).

Additionally, the Top Energy Efficient Appliances programme was implemented in 2019. It provides a maximum of a 10% reimbursement to consumers for purchasing government-certified energy-efficient appliances. MOTIE anticipated that this programme could obtain around 15 095 MWh worth of annual energy savings; but the programme in effect overachieved expectations, resulting in 15 800 MWh of savings (Jang, 2019). In 2020, the government expanded the programme as part of the stimulus package from the Covid-19

[7] Smart lighting can optimise its energy consumption by adapting light intensity according to various environmental elements such as natural light, occupancy, etc. (Smart Lighting Alliance, 2020).

impacts, by increasing the type of appliances eligible for reimbursement from seven to ten[8] and multiplying the total amount of government subsidy by almost four, up to KRW 150 billion (USD 123 million) in 2020 (Ministry of Interior Safety, 2020).

Owners of public sector buildings can contribute to creating energy efficient supply chains. Prioritising high efficiency products in public procurement, subsidies for the procurement of high efficiency products from the Energy Use Rationalisation Fund, mandatory use of high efficiency appliances like LEDs, and the waiver of retrofit consulting fees are some of the main measures in place to promote energy efficiency in public buildings.

Energy efficiency in cross-cutting sectors

In addition to promoting energy efficiency measures by sector, the government highlighted the urgent need to address the fundamental barriers of a low electricity tariff, a lack of public awareness and energy efficiency services, and inefficient heating and cooling systems, and has included these concerns as three of the four main tasks of the 3rd EMP.

Promote the creation of a market for demand-side management

Korea's approach to promoting the creation of a demand-side management market is based on three key initiatives: 1) invigorating energy efficiency related services including ESCOs; 2) boosting technological capacity linked to the Fourth Industrial Revolution to enable real-time demand management; 3) promoting a business case of demand management to attract more private investment.

Energy services companies

The ESCO programme was introduced in 1992 to extend the government's energy conservation polices and measures to the private sector. Initially, ESCO projects had been limited to co-generation[9] facilities and high efficiency lighting systems, but the coverage was extended to include waste heat recovery, cooling and heating systems, and operating process improvements. Thanks to support from the government, mainly tax deductions, the ESCO market had grown rapidly up to 2013, when the total investments peaked at KRW 309.7 billion (USD 250 million) with 227 projects. However, the market has sharply declined since and in 2018, there were only 31 ESCO projects, for a total amount of KRW 53.7 billion (USD 43 million) (KEA, 2019). The main reason for Korea's dwindling ESCO market was a decline in investments in energy facilities due to continued low oil prices and restrictions on government support for large companies. At the end of 2018, there were 317 ESCOs operating in Korea; the number dropped to 296 by the end of 2019.

The government plans to revive the role of ESCOs by engaging them in EERS and mandatory energy audits, which under the 3rd EMP are expected to expand greatly in both the industry and buildings sectors. For instance, companies that use the results of the mandatory energy audits to undertake energy efficiency improvements through ESCOs could receive extra points when applying for government funding. The anticipated growth of Korea's public demand restraint market could also provide abundant business opportunities for ESCOS (see below).

[8] In 2020, ten home appliances were eligible for reimbursements: televisions, refrigerators, Kimchi refrigerators, air conditioners, washing machines, cooling and heating equipment, electronic rice cookers, vacuum cleaners, air cleaners, and dehumidifiers.

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

Promoting technology and business for demand-side management

The Korean government has made substantial investments in developing key technologies like the ESS and smart meters as part of a broader effort to accelerate the energy transition. However, it is difficult to assess the practical impact of these new technologies on demand-side management. For instance, solar PV-linked ESS instalment on buildings has expanded significantly in the last decade thanks to the government's strong push to promote variable renewables (see Chapter 5). But assessing its potential as a measure for demand-side management is time consuming, and the government find the same to be true for EVs (MOTIE, 2019a). To account for this, multiple vehicle-to-grid projects – connecting EVs to the national power grid as a battery to ensure network stability – have been implemented since 2015, and the government plans to carry out a project allowing the users of solar PV-linked ESS to sell electricity at EV charging stations in 2020 (MOTIE, 2019a).

Such efforts to promote business models for demand-side management could facilitate the government's plan to establish a public demand restraint market, where the energy end users and relevant small business can participate in the demand restraint market as sellers. In 2018, the first pilot project included the participation of 45 000 consumers, 6 private companies and the Korea Power Exchange (KPX) (MOTIE, 2018). In preparation for the full launch of a public demand restraint market, the government plans to install 22.5 million advanced metering infrastructure in households by the end of 2020 and is currently exploring financial incentive options to scale-up the private sector's participation.

Recalibrate the energy pricing mechanism

One of the fundamental barriers to promoting energy efficiency in Korea are the low, administratively set, electricity tariffs that have proven to reduce the financial attractiveness of energy efficiency investments. The 3rd EMP pointed to rationalising the energy pricing structure as a crucial step towards meeting the 2040 targets and announced a plan to introduce cost-based pricing mechanisms (see Chapter 7).

Following the roll out of advanced metering infrastructure in households, the government is considering the introduction of specific pricing measures, like critical peak pricing that applies premium tariffs during energy demand peak hours. The current time-of-use tariff system – differentiated pricing by season and time – applied on high-voltage (over 100 kW) energy use would also be restructured once the advanced metering infrastructure become more prevalent and mature, but there is no specific time frame for this plan yet.

Optimise the use of non-electricity energy sources

Co-generation, referred to as "collective energy" in Korea, has not yet been widely adopted and the share of heat in Korea's TFC has remained low. The government estimated that in 2015 around 1.2 Mtoe of heat energy from power generation and waste treatment was not properly used (MOTIE, 2019a). In 2017, district heating supplied just under 17% of total heating supply (KEA, 2019). To address this, the government is currently drafting a National Heat Map that outlines the supply and demand of heat in the country and ways to optimise the use of heat. The map is expected to be released in 2021 and will serve as a basic policy framework for co-generation development as well as for district heating.

As of 2018, there were 37 district heating companies operating in Korea, mainly in urban areas, and who own exclusive heat supply rights within their districts. They are obliged to ensure the security of supply and the government has issued a "heating cost ceiling"

regulation to protect consumers from any possible abuse of the monopoly. The majority of Korean homes use gas for heating but electricity is steadily gaining ground. The relatively high cost of liquefied natural gas compared to that of coal and nuclear power generation has been a major factor for the slow district heating deployment in Korea. However, as fuel cells are classified as new and renewable energy and benefit from financial support from the government (see Chapter 5), there has been an increase in the use of them in district heating in the last five years (MOTIE, 2019a). Additionally, with an accelerated shift towards more distributed energy systems, the government is exploring ways to promote co-generation in a more decentralised manner at the regional and local levels through better institutional co-ordination and integrated planning.

Assessment

Korea has one of the highest energy intensities among IEA member countries. Its total final energy consumption increased by 43% between 2000 and 2018 while its economy doubled, resulting in a 25% decline in energy intensity (TFC/GDP). Yet, Korea had the third-highest energy consumption per GDP at 86 toe/USD million PPP among IEA countries.

Industry is the largest energy consumer and the main driver of the increase in TFC in Korea. In 2018, the industrial sector accounted for more than half of TFC, followed by the transport, commercial and residential sectors. By energy source, oil remains the dominant fuel, used mainly for transport and industry, mostly as petrochemical feedstock for non-energy use. However, electricity and gas consumption have increased substantially over the last decade.

With limited natural energy resources and growing energy demand, security of supply has been Korea's number one energy policy priority. Demand-side management was considered complementary and its focus was to conserve energy by using less, rather than improving the efficiency of energy consumption.

The 3rd Energy Master Plan of 2019 demonstrates the government's strong commitment to change the course of Korea's energy policy and make energy efficiency the first energy source by bringing innovation to the heart of demand-side management. It underpins four main tasks to achieve the target of reducing Korea's final energy consumption by 18.6% by 2040 compared to the business as usual level: 1) improve energy efficiency by sector; 2) promote a market for demand-side management; 3) rationalise the energy pricing mechanism; and 4) optimise the use of non-electric energy sources. For this, the Ministry of Trade, Industry and Energy has established a new Energy Innovation Policy Bureau within the ministry that includes energy efficiency as one of its four divisions. The IEA commends the government for this strategic move to align its organisation with the new action plan and for creating a dedicated division on energy efficiency.

The IEA also welcomes the Energy Efficiency Innovation Strategy that was released soon after the 3rd EMP to ensure that Korea is on track to achieve the long-term target by setting interim targets and policy measures for energy efficiency.

In order to reduce Korea's total final energy consumption by 14.4% in 2030 compared to the business as usual level, the EEIS plans to employ the key technologies of Korea's Fourth Industrial Revolution, such as the 5G network and artificial intelligence, as major driving forces of innovation in energy efficiency. Cutting-edge projects like the Cooperative-Intelligent Transport System proposed by the EEIS are indeed noteworthy. It

will be critical that the government supports the full value chain of technology development, from research to demonstration and deployment through a balanced use of regulations and incentives. In this regard, it is noted that Korea plans to fully utilise the resources available from the energy suppliers and other private sector actors to advance the EEIS. It is also crucial that the new, high-tech measures introduced in the EEIS do not overshadow the importance of reinforcing the existing measures in each sector.

Industry

Despite the industry sector being the largest energy consumer in Korea, the government has mainly encouraged industrial sector consumers to participate in voluntary schemes, which has resulted in rather weak participation and hence a continuous growth of industrial energy consumption over the last decade.

In this regard, the reinforced measures introduced in the 3rd EMP, such as the full implementation of the EERS on Korea's largest energy utilities like KEPCO from 2020 is an excellent step forward. Korea's effort to integrate individual energy efficiency measures as a building block of smart energy industrial complexes sets an exemplary case for well co-ordinated and strategic planning.

If industry is expected to contribute 17 Mtoe of energy savings by 2040, 17% below the busines as usual scenario, it is critical that the government employs a good balance of mandatory and voluntary measures to engage all stakeholders. It is also essential to raise the awareness of industry players that reducing energy intensity can make the industry more resilient to energy supply disruptions in the long run, not to mention the fact that energy efficiency itself could develop into a profitable industry that creates clean energy jobs and boosts sustainable growth.

Transport

Korea has well-established fuel economy standards that are complemented by a standardised labelling system. These two measures have played an essential role in keeping Korea's transport sector efficient and competitive. However, the average passenger vehicle fuel efficiency level remained stagnant in 2013-17 and missed the target set for 2017. Given the slow progress, meeting the 2020 target looks challenging. Reaching the more ambitious 2030 and 2040 targets will hence rely even more on achieving the ambitious targets for the roll-out of EVs and hydrogen vehicles. While raising penalties for non-compliance can help, the government should make efforts to disclose all relevant information, annual targets *vis-à-vis* outcomes, to the public and the market to keep track and respond accordingly.

One of the most notable improvements expected in the transport sector is the introduction of fuel economy standards on heavy-duty vehicles by 2023-24. The IEA applauds this new initiative, which would make Korea one of the early adopters of the scheme, and encourages the government to set up a concrete action plan to ensure that all relevant stakeholders adapt to the change in a constructive manner.

Korea is also leading an innovative change in the transportation system itself, with projects like mobility as a service and the Cooperative-Intelligent Transport System already having entered the demonstration stage. Given that these initiatives require an infrastructural change to the system, coherent co-ordination among all the relevant authorities at the central and local levels and the involvement of local communities would be critical to scale the current regional projects up to the national level.

The majority of the implemented and planned energy efficiency measures are concentrated on road transport. However, in the long term, energy efficiency efforts should be extended to aviation and shipping as well, particularly against the outlook of their increasing energy demand. It is commendable that the government already acknowledges this in the 3rd EMP. To put this into action, the government could explore ways to use international initiatives like the new International Maritime Organisation 2020 regulation and ETS on aviation as an opportunity to illicit more proactive participation. It is essential that the government adopts a long-term perspective and already starts exploring various policy options from regulations to incentives and capacity building in order to sustain the competitiveness of Korea's aviation and shipping industries.

Buildings and appliances

The energy efficiency measures in Korea's buildings sector have been mainly limited to new buildings. No regulatory policy has been enforced on existing residential and other non-public sector buildings, with only financial incentives and voluntary schemes like efficiency certification in place. Against such a background, the anticipated increase in the coverage and stringency of existing regulatory measures such as ZEBs or the BEMS is very much welcome, and the IEA encourages the government to continue to push for more inclusive and stringent regulations.

The government's effort to learn from international best practices is also highly commendable. Korea should also proactively share its own experience and lessons learnt in international fora like the IEA.

On appliances, minimum energy performance standards and labelling have been well maintained and effective for the last 20 years. Korea is now targeting to phase out fluorescent lamps by 2027. The new Top Energy Efficient Appliances programme that provides up to a 10% reimbursement for purchasing certified high-efficiency products would help to lower the intensity of growing energy demand for home appliances.

As energy efficiency investments in buildings and appliances are largely affected by external factors like electricity price, public awareness, and availability of relevant information and services, the government should continue to make efforts to address these fundamental issues in parallel to the energy efficiency improvements in the buildings sector.

Energy service companies

ESCOs in Korea are highly reliant on government support. The strongly reduced investments in energy facilities due to a combination of low oil prices and restrictions on the eligibility for government support for large companies have resulted in a sharply contracting ESCO market since 2013. The 3rd EMP suggests reviving the role of ESCOs by engaging them in the EERS and mandatory energy audits, which are expected to expand in both industry and buildings. The anticipated growth of Korea's demand restraint market could also provide abundant business opportunities for ESCOs. However, since there is a substantial lead time for new opportunities to become available, the government should consider reversing some of the budget cuts and continue to support ESCOs until the domestic energy efficiency service market becomes more mature.

Recommendations

The government of Korea should:

- Clarify how the Innovation Strategy will be financed in order to increase the credibility of project implementation and attract more private investment.
- Promote energy efficiency and emission reductions in industry based on well-funded and effective incentive programmes, international benchmarking, and mandatory regulations.
- Incentivise companies to implement cost-effective improvements identified in the mandatory energy audits.
- Develop a strategy to improve the energy efficiency of the existing building stock, both in the residential and commercial sectors.
- Establish mandatory energy labels for all buildings and continue to improve the performance-based energy code.
- Continue to upgrade minimum standards and the labelling of appliances, and examine the adaption of the labels to other product types, while increasing the visibility of the financial benefits of such appliances.
- Explore ways to introduce energy efficiency policies for aviation and shipping to create a first mover advantage for Korean industries.
- Promote the ESCO model by creating visibility and providing sufficient budget to ignite new efficiency projects.
- Strengthen the public sector as a role model through procurement policies for energy efficient buildings and appliances.

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5. New and renewable energy

Key data*

(2018)

Total supply:** 5.5 Mtoe (1.9% of TPES; IEA median 12%); 23.0 TWh (3.9% of electricity generation; IEA median 33%)

Bioenergy:** 4.0 Mtoe (1.4% of TPES) and 7.5 TWh (1.3% of electricity generation)

Solar: 0.8 Mtoe (0.3% of TPES) and 9.2 TWh (1.6% of electricity generation)

Wind and ocean*:** 0.3 Mtoe (0.1% of TPES) and 3.0 TWh (0.5% of electricity generation)

Hydro: 0.3 Mtoe (0.1% of TPES) and 3.4 TWh (0.6% of electricity generation)

Geothermal: 0.2 Mtoe (0.1% of TPES) and 0 TWh

* All key data according to the IEA definition of renewable energy.

** Includes bioenergy: primary solid biofuels, renewable municipal waste, liquid biofuels and biogas; excludes non-renewable municipal waste and industrial waste.

*** Includes tide, wave and ocean energy.

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

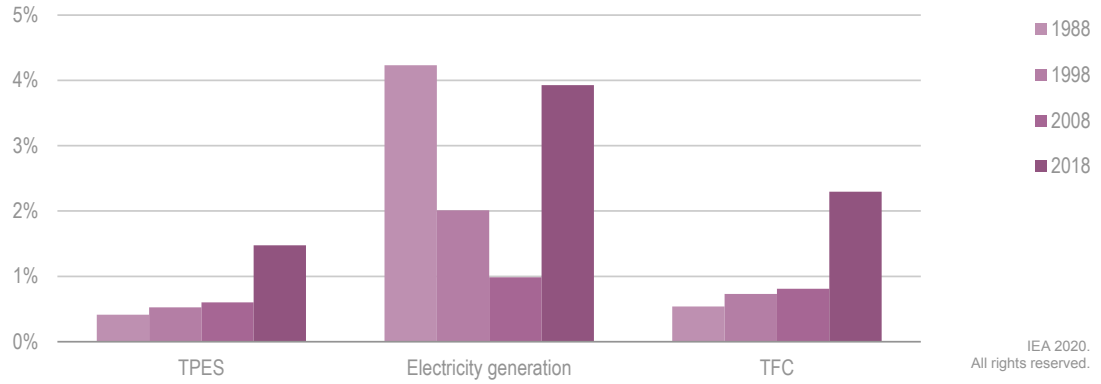
Promoting energy from renewable sources is at the core of Korea's energy transition.[1] Over the last decade, renewable energy in both total primary energy supply (TPES) and electricity generation has expanded significantly with the government's strong support. However, the country's mountainous topography, high population density and the absence of transborder interconnections creates challenges for Korea to accelerate renewable energy deployment. In addition, Korea had the lowest share of renewable energy among IEA countries in 2018

Korea is committed to increasing the share of renewables in power generation up to 20% by 2030 to be on track to meet the long-term target of 30-35% in 2040. For this, addressing the institutional barriers that have stalled renewable energy development, such as engagement with local communities, and establishing a coherent policy framework, systematic monitoring-based incentive schemes and flexible market design are essential.

[1] Korea refers to renewable energy as "new and renewable energy", where "new energy" includes hydro, fuel cell and energy converted from fossil fuels, like integrated gasification combined cycle. Until October 2019, Korea also included non-renewable waste energy (i.e. waste, wood pellet, by-product gas, etc.) in the definition of "renewable energy". As a result, there could be differences in numbers or percentages between the renewables data published by the Korean government and those published by the IEA. For instance, renewable figures used by the Korean government for setting relevant targets are for new and renewable energy.

Korea can also benefit from its advanced technology and innovation capacity to lead the development of new technologies like tidal and floating offshore wind power and further scale up decentralised energy systems, which in turn will enhance energy security in Korea, which is highly dependent on fossil fuel imports.

Figure 5.1 Shares of renewable energy in Korea's energy system, 1988-2018



Renewable energy supply and demand have increased substantially over the last decade after a long period of slow renewable energy growth.

Notes: TPES = total primary energy supply. TFC = total final consumption. TFC includes direct use of renewable energy and indirect use of electricity and heat produced from renewable sources.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

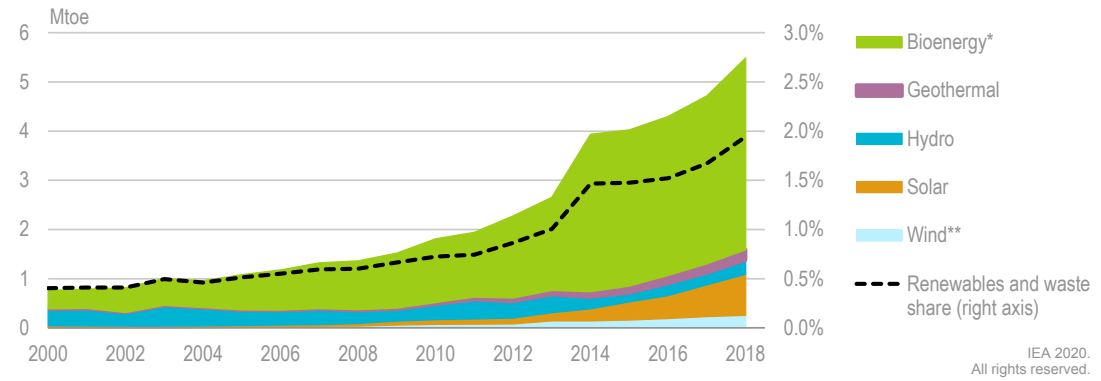
After a long period of slow growth, the shares of renewables in TPES and TFC soared between 2008 and 2018 (Figure 5.1). The sharp fall in the share of renewables in electricity generation between 1988 and 2008 is not due to declining use of renewable energy, but the exponential increase in Korea's electricity generation, which more than quadrapled. With the demand for electricity slowing down and renewables growing over the last decade, the proportion of renewables in electricity generation jumped from 1.0% in 2008 to 3.9% in 2018.

Supply and demand

Renewable energy in total primary energy supply

In the period 2008-18, the share of renewable energy in TPES more than tripled, from 0.6% to 1.9% (Figure 5.2). Bioenergy was the main driver of this growth measured in absolute amounts, but solar and wind also made a remarkable jump. Solar, in particular, showed the strongest growth of around a fourteen-fold increase over the last decade. In 2018, bioenergy accounted for 1.4% of TPES, followed by 0.3% of solar; 0.1% of each hydro, wind and ocean; and geothermal. Despite the significant growth of renewables since 2013, Korea still had the lowest share of renewable energy in TPES among the 30 IEA member countries in 2018.

Figure 5.2 Renewable energy in total primary energy supply, 2000-18



The share of renewables in TPES has more than tripled in the last ten years, but still covers only 1.9% of TPES, with bioenergy accounting for most.

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

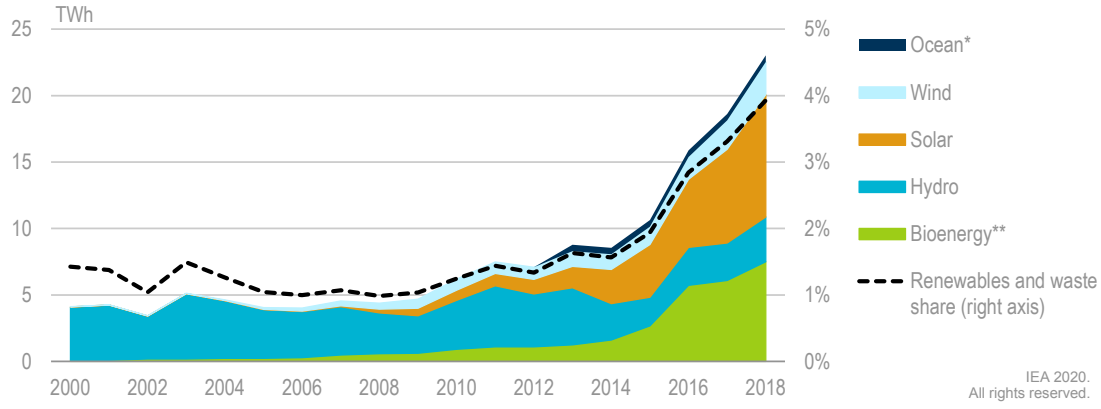
** *Wind* includes also tide, wave and ocean power.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Renewables in power generation

Over the last decade, Korea's renewable electricity generation has more than quadrupled, to 23 terawatt hours (TWh) and accounting for 3.9% of total electricity generation in 2018 (Figure 5.3).

Figure 5.3 Renewable energy in electricity generation, 2000-18



Renewable electricity has more than quadrupled over the last decade in Korea; solar power is the fastest-growing and the largest renewable energy source for electricity generation.

* *Ocean* includes tide, wave and ocean energy.

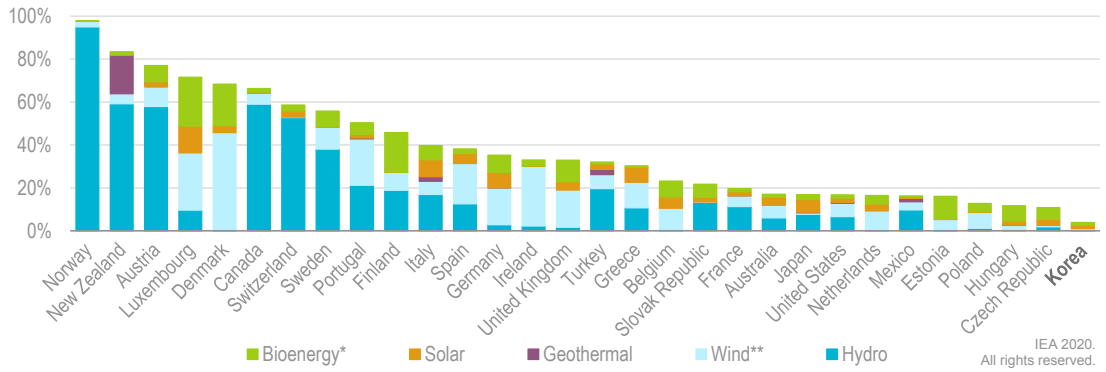
** *Bioenergy* includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Solar power is the fastest-growing and the largest renewable energy source, accounting for 1.6% of total power generation in 2018, followed by bioenergy (1.3%), hydro (0.6%), wind (0.4%) and ocean (0.1%). The role of hydropower has substantially decreased since 2000, notably after 2013-15, when generation almost halved, but it has been recovering slowly since.

Korea is one of four IEA member countries (along with France, Canada and the United Kingdom) that produce ocean energy for power generation and is the second-largest producer among them. Korea has been producing tidal power since 2013, and in 2018 it reached 485 gigawatt hours (GWh). Despite this commendable growth, Korea still had the lowest share of renewable electricity among the 30 IEA member countries in 2018 (Figure 5.4).

Figure 5.4 Share of renewables in electricity generation in IEA member countries, 2018



Despite its commendable growth in the last decade, Korea's share of renewables in electricity generation still ranked the lowest in an IEA comparison in 2018.

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

** *Wind* includes tide, wave and ocean energy.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Renewables in industry, transport and buildings

Renewable energy has been growing in various end-use sectors, although its share remains marginal. Renewables, almost entirely bioenergy, accounted for 1.5% of total industry energy consumption in 2017. If biofuels and waste are considered, the share jumps to 7%. This indicates that a significant amount of non-renewable municipal waste and industrial waste is fed into industry, particularly paper, non-metallic minerals, and increasingly the chemical and petrochemical sectors.

Biodiesel is the only renewable energy source used in transportation and only for road transport. Its use more than tripled between 2007 and 2017, up to 528 kilotonnes of oil equivalent (ktoe) to 1.5% of total road transport energy consumption in 2017. A small amount of geothermal and solar thermal energy is used for heating in the commercial and residential sectors, but bioenergy remains the primary new and renewable source, while heating oil still accounts for a large share in heating these sectors.

Legal and regulatory frameworks

The primary institutions involved in the renewable energy sector in Korea are the Ministry of Trade, Industry and Energy (MOTIE);[2] the Korea Energy Agency (KEA); the Korea Electric Power Corporation (KEPCO) and its six power generation subsidiary companies[3]; and the Korea Power Exchange (KPX).

Pursuant to the Act on Development, Use and Diffusion of New and Renewable Energy – the Renewable Energy Act – MOTIE formulates the basic national plan for the promotion of new and renewable energy every five years. Based on this plan, the minister establishes a detailed implementation plan on an annual basis to ensure that the country is on track to meet the set targets. MOTIE also oversees the regulations for renewable electricity generation, including the allocation of permits. For generation below 3 megawatts (MW) of capacity, local governments take the lead in project implementation.

The KEA, particularly the Korea New and Renewable Energy Center under the KEA, supports new and renewable energy promotion work, such as the issuance of renewable energy certificates (REC) that serve as a certified proof of renewable energy power generation (see the section "Overview of policy framework" for details).

As a public corporation that has a monopoly over the transmission, distribution and sales of electricity in Korea, KEPCO, also wields a significant influence over renewable power generation as its subsidiary companies are subject to renewable portfolio standards (RPS) – an obligation on power generators to generate a certain proportion of renewable energy (see the "Overview of policy framework" section for details). It is also in charge of making renewable energy-related investments like smart grids.

Korea's domestic power network builds on a single national grid and a single power-trading platform run by the KPX; private companies cannot directly purchase renewable electricity from the generators. Consequently, the private sector still plays a limited role in renewable energy development in Korea and as of December 2019, there were 20 independent power producers and 3 442 new and renewable energy power generators registered on the KPX. Private companies can invest in renewable energy facilities to benefit from some fiscal incentives.

As the operator of Korea's electricity market, the KPX manages the supply and demand of renewable electricity through grid connection and REC trading. All generated power is dispatched to the KPX to be traded except for very small generation and those generators on islands (see Chapter 7 for details).

Other legal frameworks relevant to new and renewable energy development in Korea are:

- The Act on the Allocation and Trading of Greenhouse Gas Emission Permits: businesses eligible for emission permits can use new and renewable energy projects to obtain emission permits.

[2] Annex A provides detailed information on institutions and organisations with responsibilities related to the energy sector.

[3] Korea Hydro & Nuclear Power (KHNP), Korea South-East Power, Korea Midland Power, Korea Western Power, Korea Southern Power and Korea East-West Power.

- The National Land Planning and Utilisation Act regulates all aspects of land use, including the authorisation of new and renewable projects and the required environmental impact assessment.

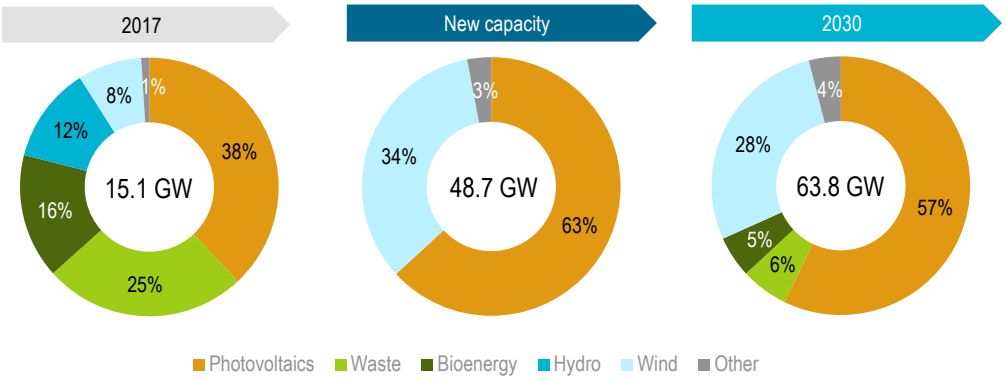
New and renewable energy targets, progress, and outlook

National new and renewable electricity targets

The 4th Basic Plan for New and Renewable Energies released in 2014 by MOTIE envisioned that by 2035 the share of new and renewable energy will reach 11% in total primary energy supply and 13.4% for power generation.

In December 2017, the government announced the Renewable Energy Implementation Plan 3020 (RE 3020), which set out an ambitious renewable target of producing 20% of total electricity from new and renewable resources by 2030. It specifies individual targets for each technology by production capacity, which altogether would increase from 15.1 GW in 2017 to 63.8 GW in 2030, mainly driven by accelerated growth in solar and wind power (Figure 5.5). Additionally, the RE 3020 mentions the government's commitment to aligning Korea's renewable definition in line with the international standard that excludes non-renewable wastes. The IEA applauds Korea for this commitment and its implementation in October 2019.

Figure 5.5 Korea's new and renewable energy targets, 2017-30



In 2030, Korea targets to generate 20% of total electricity from renewables. Of total additional new capacity, over 95% is expected to come from solar and wind.

Source. KEA (2017), *Renewable Energy Implementation Plan 3020*, www.energy.or.kr/web/kem_home_new/energy_issue/mail_vol77/pdf/issue_180_03_01.pdf.

In 2018, Korea had 19 027 MW of new and renewable power generation capacity, which is 21.2% more than in 2017 (KOSIS, 2020). Growth mainly came from solar photovoltaic (PV), that showed a strong increase of 2 367 MW and accounted for 42.6% of total new and renewable power capacity in 2018, followed by waste (20%) and biomass (16.1%).

The 3rd Energy Master Plan (EMP) released in 2019 set forth Korea's long-term renewable energy target: increase the share of renewable power generation up to 30-35% by 2040.

New and renewable electricity projects

Siting, particularly for large utility-scale projects, is one of the key barriers to promoting renewable power generation in Korea. Securing large pieces of flat land in Korea's mountainous terrain is difficult and utility-scale projects are mostly located far from major cities, which makes grid connection challenging and costly. Hence, most of the renewable power plants have been limited to 1 MW and some of the larger ones to 5 MW or less. Acknowledging the importance of grid connectivity, the government has been investing in expanding the network while encouraging the use of rooftops of industrial complexes, public facilities like schools, and even military bases by granting higher REC values for those projects (see more in the "Policies and measures" section).

Solar

With generous incentives and support from the government, solar power has shown the strongest growth out of all renewable energy over the last five years. Multiple projects currently in the pipeline indicate that solar PV will continue to be the key driver of renewable electricity development.

The most prominent solar project in Korea now is the Saemangeum project, which embodies the government's vision to build a renewable energy-based industrial cluster. By 2025, it aims to build a 2.4 GW solar PV farm in Gunsan – a high-tech industrial city located around 200 km south-west of Seoul, and 2.1 GW of this will come from Korea's first floating solar PVs (SDIA, 2020). Construction will commence in the second half of 2020 and if all goes according to plan, it would eventually become the world's largest floating solar farm.

On top of government support for installing smaller solar PV units in residential areas, some initiatives target scaling up solar PV at a city level. The Solar City Seoul project aims to power all public buildings and 1 million households in the Seoul area with solar by 2020 (see more in the "Policies and measures" section).

Wind

With a growing interest in offshore wind power generation, Korea's first offshore wind plant with a total capacity of 30 MW was completed in 2016 in Jeju Island (Tamra-owp, 2020). It generates 85 000 MWh of wind power annually, providing electricity to around 24 000 households and contributes to Jeju Island's Carbon Free Initiative. The Woljung plant (5 MW) is also operating in Jeju Island. The proposed Hanlim offshore wind project (100 MW) obtained environmental assessment approval in 2019, almost ten years after requesting the permit, and is expected to be commissioned in June 2023 (Kim, 2019).

Jeonnam Province and the Ulsan Metropolitan Area have both expressed their commitments to lead the promotion of offshore wind farms and contributing to meeting the country's national target of 17.7 GW of wind power capacity by 2030. A notable mega-size offshore wind project is taking place in Jeonnam Province located in the south-western tip of the Korean peninsula (Song, 2019). Currently in Phase 1, KEPCO is taking the lead on developing the first 1.5 GW. The project ultimately targets to build 8.2 GW of wind power capacity by 2029 in the form of a public-private partnership.

Ulsan also has ambitious plans to build a 6.0 GW floating offshore wind farm by 2030. The project would help make Ulsan the leading city of Korea's energy innovation, including

hydrogen and electric vehicles (EVs). However, the complicated and strict approval process has stalled multiple offshore wind projects to date.

Hydropower

Korea Hydro & Nuclear Power (KHNP), one of the six subsidiaries of KEPCO, owns and operates Korea's hydropower plants, with a generating capacity of around 607 MW and pumped storage power plants of 4 700 MW.

With Korea's potential for conventional hydropower generation almost fully exploited, its significance in renewable energy development has declined in the past decade and the government is investing more on tapping technologies like tidal power generation (Kim, Kim and Lee, 2019).

Ocean energy – tidal power generation

Korea is home to the world's largest tidal power plant situated in Shihwa Lake, Incheon City that has a total capacity of 260 MW and generates around 543 GWh annually.

With increasing pressure from the RPS, major utilities are exploring options to exploit the full potential of existing power plants. One such idea was to use the effluents from power plants located along the coast, where artificial water flows can be created at the outlet of a power plant's cooling system. Korea South East Power Co, a subsidiary of KEPCO, owns somne of the largest coal-fired plants, including the Yeongheung plant built on an island in Incheon City. The company has installed seven small ocean hydro plants at the outlets of the Yeongheung power plant, which amount to a total generation capacity of 12.6 MW (Jo, 2019).

Geothermal

Korea's share of geothermal energy is miniscule at 0.2% of renewable energy in 2018. However, geothermal heating, mainly ground-source heat pumps, is increasing in Korea. For instance, Sejong City, where the majority of government offices are located, installed around 20 MW of geothermal heating, which provides 38% of the city's cooling and heating demand (Lim, 2018).

Biomass

Co-firing biomass with coal for power generation has mainly been used by major power generators to meet their RPS obligations since 2012 (see the section "Policies and measures"). Korea is also increasingly reliant on imports of wood pellets, which raises questions about the sustainability and reliability of this energy source. According to KEA statistics, compressed organic matter or biomass generated 6 620 283 MWh of electricity in 2018, up 80 times from 2012. Biomass accounted for 12.5% of total electricity generated by renewable energy sources in 2018.

Fuel cell power generation

Fuel cell power belongs in the "new" energy category of the new and renewable energy in Korea. Hydrogen power generation has been growing in Korea, mostly as co-generation,[4] to deliver heat for district heating systems in addition to producing electricity. Built in 2013, the Gyeong-gi Green Energy (59 MW) is one of the world's largest fuel cell parks that has

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

a capacity to power around 140 000 homes. However, the actual power generation has dropped substantially in the last five years, from 454 GWh in 2014 to 352 GWh in 2017, resulting in the power company's financial difficulty (Kmib, 2018).

The world's largest secondary hydrogen fuel cell power plant, the Daesan Plant (50 MW), is located in the city of Seosan (Jeong, 2018). By using by-products (hydrogen) from the petrochemical process rather than liquefied natural gas, it enhanced the security of domestic supply. Korea East-West Power Co., together with Hanwha Energy and Doosan company, plans to expand it to a 1 GW hydrogen fuel cell power plant by investing a total of KRW 5.8 billion by 2030.

Outlook

According to the IEA *Renewables 2019* report (IEA, 2019), Korea's renewable power generation capacity is expected to double to 41 GW in 2024. The IEA expects the level of new and renewable power generation to increase up to 59 TWh over the same period, led by solar PV (31.4 TWh) and bioenergy (15 TWh) (IEA, 2019). The offshore wind market is expected to gain ground slowly over the forecast period, as the limited experience and slow permitting processes pose key challenges (IEA, 2019). Additional barriers are environmental issues and social acceptance by local communities that result in complicated wind farm constructions (IEA Wind TCP, 2018). The 3rd EMP in fact identifies the need to expand public participation and to effectively prevent conflicts through communication as key tasks and promotes supplementary strategies such as clarifications regarding planned sites (MOTIE, 2019a).

Other than a quantitative expansion of renewable electricity in Korea's energy mix, the government aims to shift the current bioenergy-dominant renewable electricity mix to a solar- and wind-centric one. In addition, the government promotes more decentralised deployment of renewables by engaging with local governments and individual suppliers.

Policies and measures

Overview of policy framework

Since 2001, Korea has employed feed-in tariffs as the primary instrument to promote renewables in the country. As the subsequent upsurge in solar PV installations placed a large burden on the government's national electricity industry infrastructure fund that supported the scheme as well as the network stability, the feed-in tariffs were replaced with the RPS scheme in 2012.

The current RPS obliges power generators with an installed capacity greater than 500 MW to increase their share of renewable generation up to 10% by 2023. As of 2020, the obligation rate is set at 7%. The government is considering gradually increasing the share of the RPS obligation by 2030. To meet the obligation, companies can either generate new and renewable energies themselves to receive proportionate RECs from the KEA or purchase RECs traded in the electricity market operated by the KPX (see Chapter 7). For REC trading, only entities sanctioned by the government and "bulk consumers" with an annual energy demand higher than 30 000 kilovolts per ampere (KVA) that obtained the required license from the KPX are eligible to directly purchase renewable electricity from generators. In practice, KEPCO, which has a monopoly over electricity retail in Korea, is the only entity approved by the government to directly purchase renewable electricity.

Failure to meet RPS obligations is subject to a maximum penalty of 150% of the average market value of each compliance certificate not obtained for the year in question. Based on the average certificate price in 2016, this equates to around 180 USD/MWh. The fulfilment rate of the RPS has continuously improved since 2012, from 64.7% (4 154 GWh) to 96.6% in 2018, with 21 power companies,[5] including KEPCO's 6 subsidiaries, generating a total of 22 886 MWh.

The weights of the RECs differ for technologies to ensure a balanced development of renewables. By granting RECs based on "the amount of power generation (MWh) + the differentiated REC weights", the government effectively addresses the concerns that many companies fulfil their RPS obligations with the cheapest option available, usually wood pellets and wastes, rather than investing in advanced renewable technologies. The highest REC weights at 5.0 are applied to advanced technologies like energy storages (ESS) linked to solar and wind, while biomass and waste energy are weighted only at 0.25 (Figure 5.6). As the REC weight for solar PV and storage is rather generous, Korea saw a boom in the installation of solar PV and storage for commercial installations in 2019 (IEA, 2019). The government issued amendments to the regulations on the issuance of RECs and the management of the REC market to ensure that the REC issuances and the actual supply of renewable energy are aligned.

The government has been working on improving the effectiveness of the RPS scheme by addressing key issues such as the complexity of the REC system, administrative setbacks and price volatility.

An integrated online RPS platform to share real-time information of the supply and demand, and relevant regulations, is currently being developed. To reduce the risks associated with the price volatility of RECs, the KEA introduced a system with fixed prices in long-term contracts for solar PV and wind in 2012. Power generators mandated with RPS can enter into a 20-year contract at a fixed price that is calculated based on "system marginal price (SMP) + REC price" through a bidding process. In 2019, KEPCO's subsiduaries approved multiple fixed-price contracts for 850 MW of solar PV. Wind power is also eligible for the fixed-price long-term contract system, but no contracts have been concluded yet. The government is also considering expanding the volume of the fixed-price long-term contract system.

The REC price in Korea has been falling rapidly over the last three years as more renewable generation came online to meet the RPS obligations. Notably, the exponential growth of solar PV exceeded the RPS quota. As a result, according to the KPX, the REC price dropped from KRW 130 000 (USD 107) in 2017 to KRW 42 543 (USD 35) as of March 2020. As the REC price is an essential element of renewable power generators' revenue, such a drop in the price has raised concerns for the renewable industry, particularly solar PV, whose price competitiveness is still much lower than that of biomass (Kim, 2020). In response, the Korean government is implementing a policy to differentiate the REC weight in order to increase the price competitiveness of solar PV. To address the issue, the Korean government expanded the capacity for fixed-price long-term contracting from 350 MW in the first half of 2019 to 1 200 MW in the first half of 2020, and is considering raising the RPS obligation rate from 8% to 9%.

[5] Korea Hydro & Nuclear Power Co., Ltd., Korea South-East Power Co., Korea Midland Power Co., Korea Western Power Co., Korea Southern Power Co., Korea East-West Power Co., Korea District Heat Corporation, Korea Water Resources Corporation, Posco Energy, SK E&S, GS EPS, GS Power, MPC Yulchon.

Table 5.1 Korea's New and Renewable Energy Supply Certificate weight, 2018

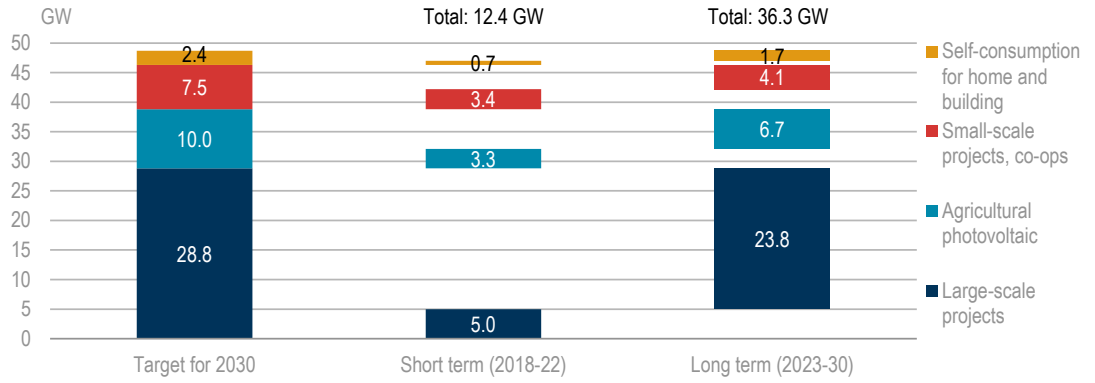
Division	Installation type	Supply certificate weight	Detailed criteria
Solar energy	Installing on a regular site	1.2	Less than 100 kW
	Installing on a regular site	1.0	From 100 kW
	Installing on a regular site	0.7	Above 3 000 kW
	Installing in the forest	0.7	-
	Using existing facilities, such as buildings	1.5	3 000 kW or less
	Using existing facilities, such as buildings	1.0	Above 3 000 kW
	Installing on floating surface, such as oil	1.5	-
	Trading electricity through private power generation facilities	1.0	-
	Energy storage system (linked to solar)	5.0	Year: 2018-20 (June)
	Energy storage system (linked to solar)	4.0	Year: July-December 2020
Other new and renewable energy	Bio-solid recovery fuel (Bio-SRF), integrated gasification combined cycle, gas by-products, waste energy (excluding non-renewable)	0.25	
	Landfill gas, wood pellets, wood chips	0.5	
	Other bioenergy (biogas, etc.), onshore wind, hydro, tidal power	1.0	
	Unused forest biomass, hydrothermal	1.5	
	Fuel cell, tidal, geothermal power, unused forest biomass	2.0	
	Tidal, geothermal	1.0-2.5	Fixed/variable type
	Offshore wind power	2.0	Connection distance less than 5 km
	Offshore wind power	2.5	Connection distance more than 5 km and less than 10 km
	Offshore wind power	3.0	Connection distance more than 10 km and less than 15 km
	Offshore wind power	3.5	Connection distance more than 15 km
	Energy storage system (linked to wind)	4.5	2018-20 (June)
	Energy storage system (linked to wind)	4.0	Year: July-December 2020

Source: KNREC (2018), *Korea's New and Renewable Energy Supply Certificate Weight,* https://www.knrec.or.kr/business/rps_guide.aspx.

Participatory business model for new and renewable energy development

In addition to improving the mix of renewables, RE 3020 also emphasises improving the mix of participation by engaging with diverse stakeholders (Figure 5.6).

Figure 5.6 Korea's new and renewable energy targets by project type, 2030



Korea will achieve its capacity addition target through a mixture of large-scale projects and small projects driven by the involvement of citizens.

Source. KEA (2017), *Renewable Energy Implementation Plan 3020*, http://www.energy.or.kr/web/kem_home_new/energy_issue/mail_vol77/pdf/issue_180_03_01.pdf.

Large-scale projects

The government envisages to substantially expand the number of large renewable energy projects above 3 MW, which has proven difficult due to space limitations as well as local community acceptance issues. The government is exploring the use of suspended nuclear and coal power plant sites, which are expected to increase as Korea accelerates its clean and safe energy transition. Additionally, the Renewable Energy Act that is currently under preparation will introduce a siting planning system to facilitate the environmental assessment process and multi-stakeholder communications with the local authorities from the planning stage onward (KEA, 2019). If a project succeeds in getting the local community's approval through efficient co-ordination, the government will grant an additional 0.1 REC (MOTIE, 2019b).

Agricultural PV

The government is keen on promoting solar agriculture, as it can effectively resolve the limited space issue while accelerating the clean energy transition in the agriculture sector. There are various incentives for installing solar PVs on agricultural farmland – so-called "agricultural PV", including low-interest loans, consulting services, and a streamlined process and priority for grid connection. The first solar agriculture project (100 kW) connected to the national grid was done by South-East Power Generation in Gyeong-nam Province in 2017. Currently, the KEA and South-East Power are collaborating on six pilot projects in the same province.

Small-scale projects consisting of co-operatives

To achieve 7.5 GW of small-scale renewable projects that engage local co-operatives by 2030, the government introduced a new scheme called the Korean style feed-in tariff

in 2018. It combines feed-in tariffs with RPS by making it mandatory for the six public power generators to purchase solar power from producers with a capacity below 100 kW. Any solar power generator below 30 kW can participate, while projects above 30 kW generation capacity can only benefit if they take the form of farmer or fisherman co-operatives. Solar power is purchased at a price (SMP + REC price) that is fixed for 20 years without a competitive bidding.

In 2018, the KEA awarded 250 MW of solar PV at an average price of 160 USD/MWh, which exceeds the global standards thanks to the generous RPS weights granted (IEA, 2018). The government anticipates that this new measure, which will initially run for five years, will help boost small-scale renewable power generation by ensuring more financial stability.

Self-consumption for buildings

The last core pillar of RE 3020 targets buildings. The electricity price offset scheme that remunerates the cost of excess electricity generated from solar PV has been central to deploying solar PVs in households since 2005. In 2016, the government expanded the scope of beneficiaries to include large commercial and public buildings as well as manufacturing facilities, and the total amount of electricity eligible for remuneration grew from 50 kW to 1 000 kW (MOTIE, 2016). The government remunerated the excess solar electricity generation by carrying the excess amount over to the following month and offset it from the next month's electricity bill. However, there have been issues raised with an accumulated delay in remuneration and the government is currently considering an option of direct cash payment instead of an electricity bill offset (KEA, 2017).

Incentives to promote new and renewable energy

The One Million Green Homes Initiative, now called the Housing Support Scheme, provides subsidies for using renewable heating or electricity in households. In 2013-14, the method to calculate the subsidy was revised to use installed capacity as a basis instead of upfront installation cost. Since then, the total amount of the subsidy has declined while the number of beneficiaries has increased (Table 5.2). In 2018, there was an upsurge in the scale of the subsidy.

Table 5.2 One Million Green Homes Initiative, 2010-18

Year	~2010	2011	2012	2013	2014	2015	2016	2017	2018
Household	73 684	35 602	52 356	31 658	14 304	15 665	27 448	42 955	115 117
Subsidy (hundred thousand KRW)	370 970	88 220	97 499	64 984	55 467	50 639	43 786	39 502	85 584

Source. KEA (2019), KEA Energy Handbook 2019, www.energy.or.kr/web/kem_home_new/energy_issue/mail_vol116/pdf/2019_07_201901.pdf.

The government announced a plan in 2017 to expand the discount on electricity bills linked to renewable energy generation and consumption. Previously, renewable energy producers and end users had been eligible for a minimum 10% discount on their electricity bills under the condition that the amount of green electricity produced or consumed exceeded 20% of the total. The new discounts will be equal to a value of up to 75% of the

renewable electricity generated and consumed. Tax deductions for investments made on energy-saving facilities and new and renewable energy facilities ended at the end of 2018.

The total amount of subsidies granted for new and renewable development increased from KRW 487 558 million (USD 4.1 million) in 2015 to KRW 590 500 million (USD 5.0 million) in 2018, most of which was spent on the feed-in tariff scheme. The 3rd EMP stipulates the creation of major renewable energy funds, including a renewable energy loan worth KRW 257 billion (USD 200 million). The mutual guarantee fund aims to support small and medium-sized new and renewable energy companies for a total of up to KRW 100 billion (USD 80 million) and the new and renewable plant and equipment fund of KRW 150 million (USD 120 million).

New and renewable transport and buildings

The Renewable Fuel Standard is the primary tool to promote renewable energy use in the transport sector. It obliges oil refiners, importers and exporters to blend a certain amount of biodiesel into transportation fuels. The blending obligation rate was set at 2.5% in 2015 and is bound to increase to 3% in 2020. In 2018, the biodiesel blending rate surpassed the target at 3.03%.

In the building sector, all existing and new public buildings larger than 1 000 m^2 are obliged to increase the share of renewables in their final energy consumption. The bar was set at a 10% minimum in 2011 and raised to 30% in 2020. There are initiatives at the city level as well. For example, the Solar City Seoul project aims to install a total of 1 GW solar PVs in 1 million households, around a quarter of Seoul residents, and on every public building with suitable space by 2022 (Seoul Metropolitan Government, 2019). As of 2019, more than 160 000 households were already using solar panels to generate their own electricity (Broom, 2019).

A solar PV rental scheme has contributed to boosting the solar PV deployment in major cities. Introduced in 2013 by the KEA, a number of certified companies provide solar PV rental services (installation, operation and maintenance of solar PVs) to households that pay a rental fee over a 7-15 year-long contract period (KEA, 2020a). Only those households or apartments with an average monthly electricity consumption more than 200 kWh are eligible and a minimum capacity to install 3 kW is required. This is a profitable business model that benefits both the solar PV companies and consumers. The households not only avoid the upfront installation cost, but also save money, as the sum of the rental fee and the new electricity bill has proven to be around 80% lower than what they used to pay on average. Companies can secure a solid and stable revenue stream from the rental service and also by selling the renewable energy points (REPs) to power generators obligated with the RPS. Similar to a REC, a REP is a type of government-approved certificate for renewable energy generation specifically created for the solar PV rental scheme; the rental service companies can receive 1 REP for each 1 kWh of electricity saved from using the installed solar PV and 1 000 REP is equivalent to 1 REC (Etnews, 2013). The interest and demand for solar PV rental service has increased since 2013 and as of August 2018, the number of customers had reached 48 000, with only 13 households ending the contract (Jeong, 2018).

Promoting decentralised energy systems

The 2nd EMP set a target to increase the share of distributed power generation[6] from 5% in 2014 to 15% by 2035. In 2017, the share had reached 12.2% of total electricity generation and the 3rd EMP raised the target to 30% by 2040.

The government focuses on major cities with the highest level of power demand to establish an effective decentralised energy system. The solar equipment rental/lease and installation project was introduced to encourage residents to rent solar PV equipment from the companies designated by the KEA as lease operators. Residents can benefit from lower energy bills while companies can secure a solid revenue stream. In 2017, around 16 000 households participated in the scheme, which amounted to 19.6 MW of total capacity. Additionally, the government has been emphasising the importance of "energy self-sufficient islands" for which micro grids are of critical importance. In 2013, a tiny island located in the southern part of Jeolla Province – Gasa Island – became Korea's first independent micro-grid based renewable island (KEPCO, 2014). Four wind turbines (400 kW) and 4 solar PV plants (296 kW) provide electricity to around 168 households (286 residents) and excess power generated is saved in installed energy storages (3 MWh). Funded by KEPCO and MOTIE, KEPCO plans to replicate the Gasa Island model on 86 other islands.

At the core of the decentralisation initiative is the development and deployment of smart grids and storages. The 3rd EMP laid out the Smart Grid City initiative, which will contribute to meeting the national roll-out of smart grid 2030 target (MOTIE, 2019a). Divided into two phases, Step 1 (2019-21) concentrates on building the infrastructure and regulatory framework to enable the deployment of smart grid technologies. One of the advanced technologies that Korea is promoting is to use electric cars equipped with vehicle-to-grid as a mobile energy storage facility that can be tapped in peak hours. Step 2 will begin in 2022 and will focus on real technology demonstrations in two metropolitan cities. Ultimately, the government aspires to turn Sejong City, home to all major governmental bodies, into an exemplary business case of a smart city.

Box 5.1 Energy storage system development in Korea

In Korea, energy storage systems (ESS) had primarily been used as an emergency response measure against potential power outages, ensuring grid security behind-the-meters. With more focus on system integration of variable renewables and deployment of a smart grid, ESS in the form of in-front-of-the-meters has grown rapidly since 2015 thanks to generous government support and fiscal incentives (Kim, Kim and Lee, 2019). Some major domestic companies, like Samsung SDI and LG Chemicals, now own large ESS production facilities in Korea.

In 2016, electricity from ESS became tradable through the Korea Power Exchange and in 2017 it became mandatory to install an ESS for all public buildings with a contracted power supply/demand of over 1 000 kW (KEA, 2020b). Public buildings with a lower power demand (<10 000 kw) are advised to install ESS by the end of 2020 and the ESS capacity

[6] According to the 7th and 8th Electricity Supply and Demand Basic Plans, distributed power generation includes small-scale power generation facilities below 40 MW nearby energy demand sites and power generation facilities below 500 MW. Includes new and renewable energy sources such as fuel cells.

should be at least 5% of the total power supply. Until the end of 2018, installing an ESS benefited from 1-6% of tax relief off the total cost. However, a series of fire incidents in 2018 created uncertainty about the safety of these systems and resulted in the suspension of almost half of all renewable energy linked ESS installed in Korea. The government is debating to offer various support measures to the affected installations, including an extension of the application period for the support schemes (Etnews, 2019; Lee, 2019).

The government is exploring ways to revive and further scale up ESS in Korea. One of the options includes recalibrating the tax benefits to encourage efficient use of renewable ESS as opposed to just installation. The government set the target to deploy around 1 700 MW of ESS domestically and account for around 30% of the global ESS market share by 2020 (MKE, 2011).

For the purpose of energy demand management, an online platform provides real-time power consumption data together with energy saving consulting services for both energy users and providers (see Chapter 4).

With a view to grid accessibility and stability, the Electricity Business Act ensures that all market participants be connected to the transmission and distribution network without discrimination. KEPCO bears the costs for the reinforcement or expansion of the network related to increases in new and renewable power generation when the contracted power is less than 1 MW and the customer carries the cost if it exceeds 1 MW. Approval for power generation and construction is governed by local governments.

A special measure prioritising renewable energy grid connection was introduced in August 2018 to account for the growing need for distributed energy deployment. However, smooth grid acceptance remains a challenge. As of January 2019, out of 56 657 applications (equal to 12.2 GW) for grid connection, around half (6.23 GW) was put on “standby” (MOTIE, 2019a). The Mid- to Long-term Distributed Energy Promotion Strategy Roadmap, which is scheduled to be released in 2020, will include detailed measures to address existing issues around variable renewables, including the delay in grid connection, ensuring sufficient capacity to connect renewable generation capacity as well as challenges related to the actual grid integration of variable renewables.

Assessment

Renewable energy grew substantially from 2008 to 2018 in Korea’s energy system. The share of renewable energy in both TPES and electricity generation have both more than doubled, and the government is committed to accelerate this growing momentum. Yet, in 2018, Korea still had the lowest share of renewable energy in TPES and power generation among all IEA member countries, which is the same as in the last in-depth review of Korea (2012).

Some of Korea’s renewable energy projects, such as the Saemangeum project that aims to build a cluster of innovative renewable technologies with floating solar PVs, wind and fuel cells, demonstrate the country’s strong R&D capacity. Korea is also home to the largest tidal power plant and there are ambitious offshore wind power projects in the pipeline. While the recent developments are commendable, they need to be replicated at a larger scale and at an accelerated speed in order for Korea to meet its renewable energy

target. The lessons learnt from the long delays in offshore wind projects – low social acceptance, complicated project approval processes and limited private investments – can help to speed up and scale up the deployment of these new technologies.

Promoting renewables in end-use sectors such as industry and transport has been slow and is heavily driven by biomass and non-renewable wastes. The Renewable Fuel Standard is the primary instrument to promote renewables in transportation, and the targets have been met easily mainly because there were low-hanging fruits. The industry sector's renewable strategy is also essentially concentrated on blending biofuels and waste. The government has been highlighting electrification of end-use sectors as a breakthrough to deep decarbonisation, but renewables have a role to play in the transition of other sectors too, especially since Korea's large heavy industry is the biggest and most carbon-intensive energy consumer in Korea. With increasingly limited domestic supply of biomass (wood pellets), it is critical that the government provides clearer and longer term targets and policies to ensure a sustainable clean energy transition across all sectors.

Renewable energy has made a more advanced leap in the buildings sector thanks to a diverse set of policy tools, from fiscal incentives, like subsidies and tax relief, to mandatory obligations of minimum renewable energy consumption for public buildings. Various local initiatives like Solar City Seoul contributed to raising public awareness and creating momentum. However, a long-term target and an integrated policy framework are largely still missing. Questions around how to effectively involve commercial buildings and how to accommodate the emergence of prosumers as renewable use becomes more prevalent remain unclear. A thorough cost-benefit analysis of the existing measures and systematic monitoring of their effectiveness could help make the most value out of future investments.

Renewable electricity generation plays a key role in Korea's clean energy transition and the most distinguishable improvement from the last Korea in-depth review is indeed the growth of variable renewables like solar and wind in power generation. In 2017, the Renewable Energy Implementation Plan 3020 (RE 3020) set the national target to increase the share of new and renewable generation up to 20% by 2030, which equals 63.8 GW of renewable capacity. The 3rd EMP released in 2019 envisages to further increase the share up to 30-35% by 2040.

The RPS – an obligation on power generators (over 500 MW) to increase the share of renewable electricity generation to 10% by 2023 and gradually increasing further by 2030 – is the principal measure that has supported renewable electricity development in Korea since 2012, and will continue to be the main contributor to achieving the 2030 target. The obligated companies can either produce renewable electricity themselves or purchase RECs to meet their obligations. Under the current electricity market structure, companies cannot directly purchase renewable electricity from generators but must go through the KPX. In this regard, the IEA welcomes the government's ongoing deliberations to introduce direct power purchasing agreements between obliged REC entities and private renewable producers. The KEA introduced a "fixed-price long-term contract system" for solar PV and wind in 2017, which allows power generators obliged with RPS to enter into 20-year contracts.

Other than meeting the quantitative target, the government is committed to improving the diversity of the mix of renewable energy, and the REC supply weights have been the main driver for this. The allocation of higher REC weights to advanced technologies like solar, wind and ESS accelerated the shift from biofuels and waste to solar and wind. In this

regard, the IEA welcomes the amendment of the REC regulations to ensure that the issuance of RECs and the actual supply of renewable energies are aligned.

The most notable feature of RE 3020 is that it sets out a detailed method for Korea's unique profile and energy system. Korea's limited land availability, high urbanisation and population density, and the lack of transborder interconnection have proven challenging for Korea to deploy renewable energy, causing long delays for siting and local acceptance in particular. At the same time, Korea has a powerful manufacturing industry, supported by a strong R&D capacity, which can help develop creative and practical applications for renewables. Based on this, RE 3020 articulates four main pillars that the government will specifically target: 1) 28.8 GW of large utility-scale projects, including offshore wind farms and floating solar PV systems; 2) 10 GW of agricultural PV – deploying solar PVs on agricultural land; 3) 7.5 GW installed by small-scale local co-operatives; and 4) 2.4 GW generated for self-consumption by residential and commercial buildings.

Given the government's strong emphasis on public participation, setting up a new institutional framework like a siting planning system is commendable, but needs to be complemented with ground-level capacity building in order to make real progress in engaging local communities. Many neighbourhoods, particularly in rural areas, still find the current energy transition and government plans difficult to comprehend, causing delays in project development. In addition, for deploying new technologies like offshore wind, there is a need to strengthen the expertise ranging from project management to the facilitation of smooth environmental and social assessment processes. The new initiative by MOTIE and the KEA to strengthen their expertise by establishing a "Wind Power Generation Support Group" is commendable. Also, the government's initiative to apply best practice support schemes, modelled on the Danish experience, is a welcome initiative. More transparent information sharing, particularly on price developments, is also crucial to win social support and public acceptance.

Similarly, to expand the private sector's investments in renewable energy, it is necessary that measures take into account electricity prices and renewable energy generation costs in Korea. In the long run, enabling direct power purchasing agreements between private companies is necessary to stimulate proactive corporate participation, which requires a fundamental change in Korea's electricity market design (see Chapter 7).

The rigidity of Korea's current electricity market is making it difficult to accommodate the growing share of decentralised and variable renewable electricity. Moreover, renewable electricity generation in Korea is relatively costly compared to other IEA countries, while retail electricity prices are low. The government's efforts to lower the prices of renewable electricity generation through a variety of policy support measures are therefore welcome. The government is mulling over the recurrent suggestions to reform the electricity market design and recalibrate the support schemes accordingly. In doing so, a comprehensive review of existing measures and establishing clear assessment criteria can provide constructive policy insights.

On infrastructure, delays in access to the national grid remain a hurdle to the expansion of Korea's distributed power generation. With a strong push from the government, distributed power supply has grown exponentially in recent years. However, as the rate of renewable generation capacity additions outpaces the rate of grid expansion, obtaining grid connections has become a challenge, in particular for projects above 1 MW capacity. The Korean government is planning to provide incentives for distributed generation to solve

these problems. For this, it is promoting the construction of an intelligent power grid – an integrated solution underpinned by ICT-based network deployment and demand-side management. Some innovative R&D initiatives like vehicle-to-grid technology – using EVs as mobile energy storage – are highly encouraged. Korea has the capacity to lead such transformative changes and the ambitious targets for clean energy transition make these changes ever more urgent.

Recommendations

The government of Korea should:

- Identify and implement criteria to assess the progress made under the various incentive programmes towards meeting the renewable targets and take early corrective action if needed.
- Clarify and streamline the support mechanisms for renewable energy.
- Strengthen engagement with local communities to support the energy transition through effective communication, promote involvement in the agricultural PV villages, and in home and building self-consumption projects.
- Streamline permitting procedures for (offshore) wind energy deployment and develop new mechanisms to support technology development for wind turbines.

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6. Energy technology research, development, deployment and innovation

Key data

(2018)

Government energy RD&D spending: KRW 640 billion/USD 549 million (2019 prices and exchange rates)

Energy RD&D of GDP: 0.34 per 1 000 GDP units (IEA* median: 0.32)

Energy RD&D per capita: USD 10.6 (IEA* median: USD 14.0)

* Median of 27 IEA member countries for which 2018 data are available.

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

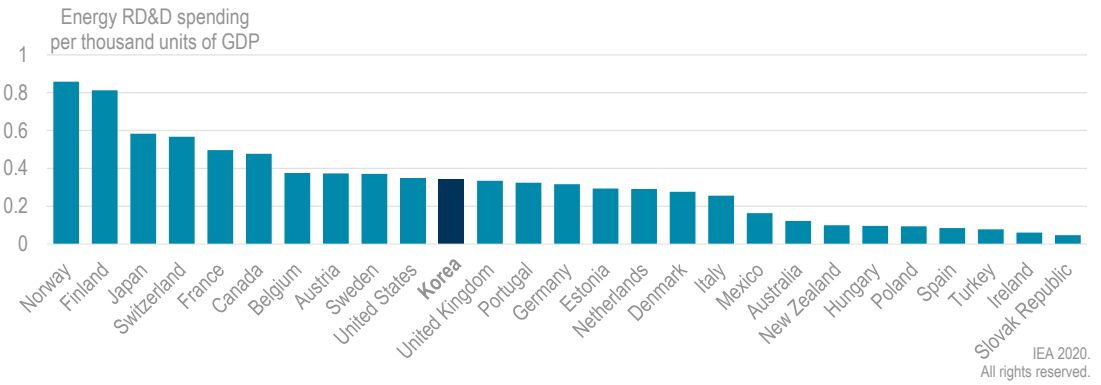
Korea's economic policy has a strong focus on technology innovation and development, including for the energy sector, which is reflected in its continuously high level of spending on research, development and demonstration (RD&D). Korea's public energy-related RD&D budget in absolute terms has been around three times as high as the median of IEA countries in the last decade, though spending has decreased since a peak in 2013. In 2018, the energy RD&D budget of the Ministry of Trade, Industry and Energy (MOTIE) was KRW 640 billion. Korea supports a diverse set of energy technology areas, with the objective to foster low-carbon technologies, ensuring energy security and reaping the benefits of the Fourth Industrial Revolution.

In 2019, the Korean government presented the 3rd Energy Master Plan (MOTIE, 2019a), which indicates a shift to larger scale R&D and demonstration projects. It includes enhanced R&D investments in areas supporting Korea's energy transition and strengthening energy industry competitiveness, such as energy efficiency, renewables and hydrogen energy. The government also aims to expand R&D co-operation between the government and public companies, and encourages private companies to conduct research into energy technology performed with big data, like artificial intelligence and the Internet of Things.

Public spending on energy RD&D

In 2018, Korea spent 0.034% of its gross domestic product (GDP) on public energy-related RD&D (Figure 6.1). This was the 11th-highest share among IEA member countries, close to the median.

Figure 6.1 Energy-related public RD&D spending per GDP in IEA countries, 2018



In 2018, Korea was the 11th-highest ranking energy RD&D investing country as a ratio of GDP, which was slightly above the IEA median level.

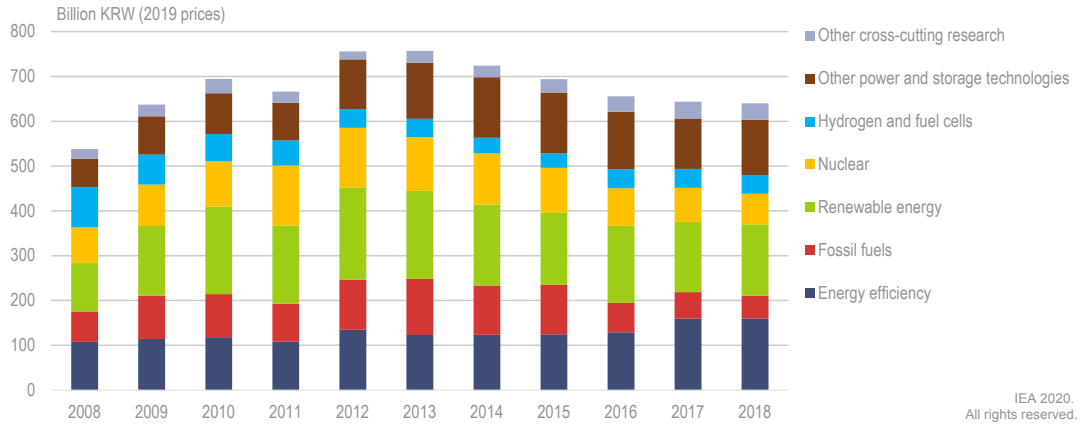
Note: Missing data for the Czech Republic, Greece and Luxembourg.
IEA (2020), Energy *Technology RD&D Budgets 2020*: *Overview*, www.iea.org/statistics.

In 2018, MOTIE spent KRW 640 billion (around USD 549 million) on public RD&D, up by 20% from 2008 (Figure 6.2). However, since its peak in 2013, MOTIE's overall RD&D investments had steadily decreased by 15% in 2018.

Low-carbon technologies received 95% of the total budget for energy-related RD&D in 2018. Energy efficiency and renewable energy received the largest shares at 25% each of the total budget. Energy efficiency funding was allocated to a diverse set of sectors including industry, transport and electric appliances. Renewable energy RD&D funding was allocated to solar, which received 40% of the total spending on renewables, followed by 22% to wind energy and 14% to biofuels, plus small shares to hydroelectricity, geothermal energy and ocean energy.

Power and storage technology accounted for 19% of the total budget, mainly for electricity transmission and distribution systems, and energy storage systems. Nuclear received 11% of total public funding, all of which went to fission research. Fossil fuel RD&D received only 8% of the total budget, one-third of which was for carbon capture, utilisation and storage (CCUS). Korea is also investing in hydrogen and fuel cells by allocating 7% of its total public funding. The remaining 6% goes to cross-cutting technology research.

Figure 6.2 Korea's national energy RD&D budget by technology, 2008-18



Korea has a diverse energy RD&D investment portfolio, but the total budget has fallen by 15% since its peak in 2013.

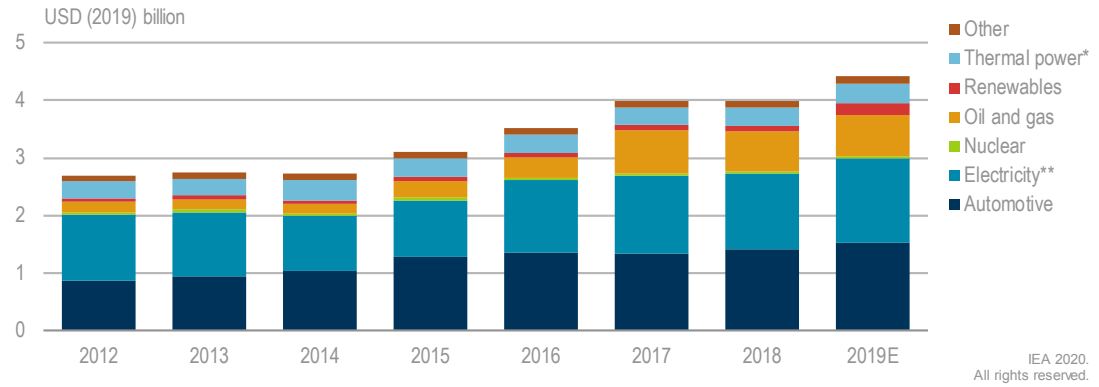
IEA (2020), Energy *Technology RD&D Budgets 2020*: *Overview*, www.iea.org/statistics.

In analysis undertaken for the 2020 *World Investment Report*, the IEA estimates that global listed companies headquartered in Korea spent about USD 4.4 billion on energy RD&D in 2019, a significant year-on-year growth (about 10%) after stagnating levels in 2018 (Figure 6.3). Current spending by private sector actors is about 60% above 2012 spending levels, with cumulative growth driven by automotive companies (40%) and oil and gas (30%), followed by electricity generation and networks (20%). The strong growth recorded from 2014 to 2019 warrants further examination in 2020, as corporate revenues are expected to decrease due to the unfolding Covid-19 crisis, thereby potentially affecting RD&D budgets in the short term.

In 2019, automotive and electricity generation and networks companies each accounted for about 35% of total corporate energy RD&D spending. About 60% of the total spending is estimated to have been spent in low-carbon energy technology areas. It should be noted that companies do not necessarily report in which country innovation activities take place.

While firms headquartered in Korea accounted for about 5% of global corporate energy RD&D in 2019, venture capital activity in the sector is much more limited. Similar to other regional economies which rely less on this type of financing for clean-tech start-ups than the United States or European economies, latest available data suggest that only a handful of clean-tech venture capital deals for energy start-ups take place each year in Korea. Venture capital activity is more developed in other sectors such as consumer goods, finance, services, and information and communications technology.

Figure 6.3 Estimated corporate energy RD&D spending by global listed companies headquartered in Korea



* *Thermal power* includes combustion equipment.

** *Electricity* includes networks.

Source: IEA analysis based on Bloomberg data for World Energy Investments 2020.

RDD&I strategy and policy framework

MOTIE[1] is in charge of energy-related RDD&I policy in Korea. It prepares an energy technology development plan (ETDP) every five years as a statutory requirement under the Energy Law. The ETDPs serve as the primary policy framework for energy technology development and lay down the R&D investment strategy for a ten-year period. The ETDPs include the range of technologies eligible for RD&D funding in the mid- to long term, facilitate the commercialisation of new technologies, assess the requirement for human resource development and lay out priorities for Korea's international RD&D co-operation. They are aligned with overall energy sector priorities as set out by the EMPs. The ETDPs take into account relative successes of previous programmes.

While MOTIE takes the lead in preparing the ETDPs in close co-operation with a broad range of stakeholders from academia, research institutions and the private sector, the Presidential Advisory Council on Science & Technology provides final approval. The Ministry of Science and Information and Communication Technology is responsible for overall basic research, including on energy, and also handles all related budget aspects.

The 4th ETDP, covering the period 2019-28, is currently ongoing. It has a strong focus on technologies that enhance the safety of energy use and on strengthening the technological capacity of future energy industries. It sets out four key tasks: 1) boosting energy-related emerging industries; 2) energy system restructuring towards high efficiency and low consumption; 3) supplying clean and safe energy; and 4) spreading decentralised energy (Pulse, 2019).

Those 4 tasks are further divided into 16 priority RDD&I areas that are promoting low-carbon energy technologies, including solar energy and wind power; hydrogen economy; energy efficiency in buildings, industry and transport; smart grids, energy storage; and energy safety and decommissioning of nuclear plants. A distinctive feature of the 4th ETDP is the inclusion of innovative themes as priority research areas, such as

[1] Annex A provides more information about institutions and organisations and agencies with responsibilities related to the energy sector.

resource development and resource circulation; big data and cybersecurity. Within these 16 priority RDD&I areas, the government has set 50 specific development goals (Jung, 2019).

A technology roadmap is developed in order to reach the specific development goals in the 16 core investment technologies. The technology roadmap sets out the milestones for concrete technology development for each of the 16 priority areas and contains staged action plans to deliver on the objectives and strategies set out in the 4th ETDP. A steering committee is tasked with the overall review and co-ordination of the roadmap, while a working group of around ten experts from industry, academia and research institutions is established for each core investment area to provide input to the roadmap.

Public energy RD&D funding is mainly channelled through the Korea Institute of Energy Technology Evaluation and Planning (KETEP). KETEP, which reports to MOTIE, is responsible for managing the entire RD&D process: policy development, planning, selection of applications, evaluation and management of RD&D projects, human resources development, energy technology diffusion and international co-operation. KETEP launches annual calls for bids that are not only open for research institutes and universities, but that actively encourage the private sector to participate.

Since 2018, KETEP operates a platform for R&D co-operation of public energy corporations on behalf of MOTIE. The main objective is to offer institutional support to large-scale projects in which several public co-operations jointly participate. KETEP also extends support for the commercialisation of RD&D and assists with the creation of suitable business models.

Selected policies and programmes

Smart grids

Smart grids are one area where Korea's investment in energy innovation is having particularly strong benefits. Korea is an international leader in the area of smart grid technology and implementation. It is a founding member of the International Smart Grids Action Network (ISGAN), and co-hosts, jointly with Austria, its Secretariat through the Korean Smart Grid Institute.

Korea was among the first countries to set up a test bed for smart grids and implemented the highly successful flagship test bed project on Jeju Island between 2009 and 2013. The Jeju Island test bed was designed as a launch pad for wider deployment within Korea, but also with a view to preparing Korean companies to be at the forefront of the early commercialisation of the technology and to open up export markets (GSMA, 2012). For example, Korean companies support the establishment of a smart distribution network in Peru, the creation of an energy-independent town in Myanmar and the roll-out of microgrids in Cambodia (MOTIE, 2019a).

The Jeju Island pilot project covered 13 projects in five areas:

1. smart grid infrastructure: the intelligent monitoring of demand, high level of fault tolerance and fast restoration in case of failure

2. smart electricity services: providing customers with electricity tariffs and services customised according to their needs
3. smart places: the use of intelligence at home and in businesses through, for example, smart appliances, real-time pricing and demand management
4. smart transport: introducing intelligent systems to manage the connections of electric mobility to the smart grid
5. smart renewables: connecting and using large and diverse sources of power to the grid.

The total project cost was USD 230 million, more than two-thirds (USD 160 million) of which came from the private sector. Building on the success of the Jeju Island project, the government expanded its smart grid activities to 16 city demonstration projects over the period 2016-19.

The government is now implementing a new initiative for two smart grid service demonstration towns with a total budget of KRW 27 billion (approximately USD 25 million) over the period 2019-22. The project aims to create smart micro-grids in cities and link those to newly created solar PV community pilot projects. The ultimate objective is to demonstrate and spread new business models based on the smart grid demonstration towns that will include new technologies to allow for the stabilisation of virtual power plant systems and demonstrate related trading platforms. To reach this objective, regulatory sandboxes will be rolled out in the smart grid demonstration towns that will introduce new energy service models (MOTIE, 2019a).

Hydrogen economy and fuel cells

Policy framework

In 2019, Korea first announced the Hydrogen Economy Roadmap and then the National Roadmap of Hydrogen Technology Development, with the vision to foster an ecosystem for a hydrogen industry and support all stages of technological development throughout the entire value chain, including electrolysers from development of source technology in hydrogen-powered vehicles, core components of fuel cells, and storage and transportation, to demonstration, commercialisation, and to eventually establish a broader hydrogen-based economy. The roadmaps set targets to 2040 for hydrogen vehicles and refuelling stations, and for power generation. The strategic objectives are to secure energy independence, reduce greenhouse gas emissions and fine dust, and assume a global leadership role in hydrogen technology (MOTIE, 2019b; Korea's Joint Ministries, 2019a).

The government has set out a two-stage RDD&I process to create a hydrogen market. Starting in 2021, the government will create a Hydrogen Industry Cluster to foster RDD&I co-operation between research institutes, industry and other organisations. The cluster will be a test bed for demonstrating innovative technologies. From 2022, four cities will act as national hydrogen test bed cities to eventually set up a model city where heating, cooling, transportation and the electricity needs of homes are met by hydrogen power (Netherlands Enterprise Agency, 2019; Kan, 2020).

In 2013, Korea became the first country to launch a commercial fuel cell electric vehicle and in 2015, its private sector POSCO Energy completed the world's largest fuel cell

manufacturing plant (Kan, 2020). In January 2020, over 3 200 passenger fuel cell electric vehicles and 7 hydrogen-fuelled buses were operating in Korea, with 24 refuelling stations at their disposal. In 2018, Korea already produced power from 307 MW of fuel cells, of which 7 MW was consumed in the residential sector (MOTIE, 2019b). However, the development of a viable market will require government support, at least initially.

Targets

The hydrogen economy roadmap plans to expand the production of hydrogen-powered fuel cell electric vehicles and the supply of fuel cells. Specifically, it outlines the following production targets for 2040:

- 6.2 million fuel cell electric vehicles with an interim target of 81 000 in 2022 and 100 000 in 2025 of which:
  - 60 000 hydrogen-fuelled buses with an interim target of 2 000 in 2022
  - 120 000 taxis
  - 120 000 trucks.
- At least 1 200 refuelling stations with an interim target of 310 stations by 2022.

Of the total 6.2 million vehicles to be produced in 2040, 3.3 million would be exported (MOTIE, 2019b). To achieve these targets, the government provides a subsidy of about 50% of the purchase price of a hydrogen passenger vehicle and subsidises up to 50% of the installation cost of refuelling stations. Additionally, the government will also streamline the permitting process (IPHE, 2020; Kan, 2020).

Table 6.1 Government subsidies for hydrogen vehicles, 2018-20

Scale of subsidy (in KRW)	2018	2019	2020
Central government	22.5 million	22.5 million	22.5 million
Local government	10-12.5 million	10-13.5 million	10-17.5 million
Number of vehicles	740 vehicles	4 000 vehicles	11 000 vehicles

Source: Information provided by the Korean government.

Hydrogen refuelling stations will be supplied with hydrogen produced from waste biogas to ensure economic feasibility. This project is implemented jointly with bus companies. It commenced on 1 May 2019 and will run for a period of 32 months. A key objective is to establish a business model that co-operates with local residents to enhance the acceptance of hydrogen among the population.

The use of pure hydrogen for power generation is not widespread globally and Korea presents an exception with its installed capacity and the deployment of larger fuel cell systems up to a size of 2.4 MW. Transforming the electricity sector towards more decentralised and variable renewable energy sources creates a growing market for fuel cells to provide the necessary dispatchable power and off-grid electricity.

The roadmap outlines an objective to create production capacity of 15 GW of fuel cells for power generation by 2040: 7 GW will be exported and of the 8 GW expected to be used

in Korea in 2040, 2.1 GW will be for stationary fuel cell applications in buildings, sufficient to power 940 000 households (Netherlands Enterprise Agency, 2019; Kan, 2020). The roadmap has set a total interim production target of 1.5 GW for 2022 with the distribution of fuel cells for homes expected to reach 50 MW in the same year (MOTIE, 2019b). However, it is worth noting that these are targets for fuel cells, not necessarily hydrogen.

Korea is supporting RDD&I related to solid oxide fuel cells and is developing the first solid oxide fuel cells system for buildings to allow for the commercialisation of manufacturing technology. The RDD&I project commenced in December 2016 and will run for 46 months.

Hydrogen supply

Korea aims to become the world's largest producer of hydrogen powered vehicles and fuel cells by 2030 and to eventually also develop hydrogen ships, trains and machinery. To realise this vision, Korea needs to sharply increase the supply of hydrogen and make it more affordable and greener.

In 2018, demand for hydrogen was 130 000 tonnes (t) and is set to increase to 470 000 t by 2022, 1.94 million tonnes (Mt) in 2030 and 5.26 Mt in 2040 in line with the targets set in the roadmap. Currently, by-product hydrogen, derived from petrochemical processes, is used for hydrogen fuel cell electric vehicles (EVs), while hydrogen extracted from natural gas is mainly used for other fuel cells. Production costs are high and are a barrier for greater deployment. Moreover, this hydrogen is produced from non-renewable sources, which undermines its potential environmental benefits (MOTIE, 2019b).

The government aims to use surplus renewable energy as an environmentally friendly method for production. Large-scale RDD&I for electrolysis and demonstrations using surplus renewable energy (power-to-gas) will begin by 2022 in co-operation with large-scale renewable energy generation complexes, such as those harnessing offshore wind and solar power.

As Korea has only limited domestic capacity of eco-friendly hydrogen production, the roadmap plans to establish overseas production bases for hydrogen production, import and supply from renewable and non-renewable sources. Imports of hydrogen are expected to commence in 2030. The target for 2040 is to meet 70% of domestic demand for hydrogen with eco-friendly, CO_2-free hydrogen from hydrogen electrolyses and overseas production and 30% by reformed hydrogen (MOTIE, 2019b).

To prepare for the production and import of large quantities of hydrogen by 2030, the government plans to develop related infrastructure starting in 2022, including research for liquefaction and liquid[2] technology, hydrogen transportation vessels, and liquefaction plants, and commence the construction of receiving bases for overseas hydrogen. A 200 km hydrogen pipeline will be connected to these receiving bases after 2025 as part of a nationwide supply network (MOTIE, 2019b).

The government expects that the strong hydrogen supply growth will reduce prices noticeably, reaching KRW 4 000/kg in 2030 and further falling to KRW 3 000/kg in 2040.

[2] Liquid technology RD&D aims to produce ammonia (NH3), methane (CH4) and LOHC (liquid organic hydrogen carrier), which is used as a hydrogen carrier.

The policy vision is complemented by the creation of a legal support system for the promotion and application of hydrogen. In January 2020, the National Assembly of Korea passed the "Hydrogen Law" (Hydrogen Economy Promotion and Hydrogen Safety Management Law). The law provides the legal basis for the enactment of special regulations for hydrogen safety management throughout the hydrogen supply chain and for the government's support schemes (IPHE, 2020; Kan, 2020).

Carbon capture, utilisation and storage

Given the importance of fossil fuels in Korea's electricity sector at over 70% of generation in 2018, Korea RD&D activities cover all aspects along the CCUS value chain. CCUS is one of the top four priories in Korea's 3rd Five-Year Plan for Green Growth (2019-23), that includes a three-step plan towards a CO_2 capture project in a 500 MW power plant and transport and storage facilities for 3 Mt CO_2/year (Korea's Joint Ministries, 2019b). CCUS is also one of the six essential climate technologies in the Climate Technology Roadmap (2017).

Capture

Korea promotes post-combustion CO_2 capture using advanced amine, dry solid sorbent and separation membrane technologies, pre-combustion capture linked to integrated gasification combined cycle and oxy-fuel combustion capture technology.

The government-owned Korea Electric Power Cooperation (KEPCO) is operating two post-combustion carbon capture pilot projects. The 10 MW CO_2 capture pilot plant at the Boryeong coal power station uses advanced amine, a proprietary CO_2 capture solvent, also known by its brand name KoSol, developed by KEPCO. The pilot has been operating since 2013 and captures approximately 200 t CO_2 per day. This technology accomplished a capture rate of over 90%, with over 99% purity from the initial 0.1 MW test bed. The CO_2 captured is currently being sold for welding and agriculture (such as strawberry cultivation) after cooling and compression.

In 2017, the pilot plant had achieved 5 000 hours of continuous operation with regeneration energy at 2.5 gigajoules (GJ)/t CO_2. KEPCO then prepared the complete package for the installation of a commercial size plant of 150 megawatt electrical (MW_e) capacity including CO_2 capture, compression and liquefaction. Testing for the continuous operation of over 10 000 hours is ongoing.

KEPCO is also testing other sorbents. A second 10 MW capture pilot using dry regenerable solid sorbent technology is operating at the Hadong thermal power station. This project was recognised by the Carbon Sequestration Leadership Forum in 2015. The pilot plant was commissioned in 2014 and can capture up to 200 t CO_2 per day. The installation of the CO_2 cooling and compression process at the Hadong plant is ongoing. The CO_2 captured from the two 10 MW pilot plants will eventually be stored underground.

The objective of the pilot is to demonstrate the feasibility of dry solid sorbent capture, prove long-term continuous operation at over 2 000 hours, achieve a capture rate of over 80% with 95% purity and reduce the capture cost to below USD 40/t of captured CO_2. In 2017, the pilot had completed 1 500 hours of continuous operation. KEPCO will use the outcome of this project to contribute to a Front-End Engineering Design Study of a 300 MW-scale dry-sorbent CO_2 capture facility that started in 2018. For this project, a long-term continuous operation for 2 000 hours including CO_2 compression and liquefaction is planned.

In addition to the two pilots discussed above, a 0.5 MW CO_2 capture pilot in the Taean coal power plants is in operation, using modulated amine blend solvent, which was first developed by the Korea Carbon Capture & Sequestration Center. The pilot plant had achieved more than 2 000 hours of continuous operation with regeneration energy at 2.2 GJ/t CO_2. An amine-based dry solid sorbent capture is undergoing long-term testing at a 0.5 MW pilot plant at the Daegu Dyeing Industrial Center. In addition, a polyimide-based hollow fiber membrane pilot plant (2 000 normal metre cubed per hour (Nm^3/h) at Halla Cement Co., Ltd. in Gangneung has completed for 2 000 hours of continuous operation and achieved 90% purity under the condition of 85% CO_2 recovery. Korea is also developing pre-combustion capture technologies linked to integrated gasification combined cycle and oxy-fuel combustion.

Korea is also undertaking CO_2 capture projects in the steel and cement industries. Specifically, the development of a single process for CO_2 capture and conversion to reduce greenhouse gases from the cement industry is ongoing for the period 2018~20. An earlier project for the development of CCU processes to produce a high-quality precipitated calcium carbonate and liquefied CO_2 in the cement industry was operating from 2015~18. A pilot project for the development of CO_2 capture and utilisation processes in the iron and steel industry was operating from 2009 to 2014.

Utilisation and conversion

Since 2012, Korea has been operating several pilot-scale projects of chemical and biological conversion and mineralisation technology.

The Korea Research Institute of Chemical Technology is undertaking a demonstration pilot project at Daejeon for the production of syngas through CO_2 conversion via catalytic reforming. The pilot project has shown a CO_2 conversion efficiency above 95% and allows for the utilisation of 20 t CO_2 annually. The development of a demonstration scale CO_2 reforming plant is ongoing, with the aim to reach an annual CO_2 utilisation of 7 000 t. Eventually, Korea aims to establish an integrated CO_2 reforming, sequential CO conversion and separation/purification system to manufacturing CO_2-based chemicals. The ultimate objective is for the syngas to replace petroleum-based chemicals.

Since late 2019, private sector Green Chemical is operating a pilot plant for the production of environmentally friendly alkylene carbonate from captured CO_2 as a reagent that does not require phosgene. The daily capacity of the pilot plant is 3 t of alkylene carbonate production.

Techwin, another private company, is implementing an electric-chemical conversion demonstration project at the site of the Hadong CO_2 capture pilot project. The captured CO_2 is converted via direct electrochemical conversion into formic acid at a rate of 500 kg/day. The design phase for a commercial size system of 10 t of formic acid per day production was completed in 2019. The plant-scale system is the world's largest operating system utilising electrochemical conversion technology of CO_2.

Finally, Korea also researches the use of biological conversion of captured CO_2 to produce high-value materials. For this, the Korea District Heating Corporation operates a demonstration project at its liquefied natural gas (LNG) power plant in Seongnam-si where captured CO_2 from the plant's flue gas is converted by enriching microalgae to produce raw material of antioxidants, so-called astaxanthin. The microalgae uses 30% of the CO_2

from LNG-fired flue gas and converts this to biomass with a yield of 2 grammes per litre. The capacity of the bioreactor is 10 t/day.

The Korean government is also actively supporting R&D investment in CO_2 utilisation technology, and basic research on chemical and biological CO_2 conversion has been conducted. Since 2017, the Next Generation Carbon Upcycling Project, supported by the Ministry of Science and Information and Communication Technology, has been underway for developing several technologies that utilise various carbon resources such as CO_2, by-product gases and organic waste to produce clean fuels and chemical products such as methanol, olefins, aromatics, organic acids and polymers (Korea's Joint Ministries, 2016).

Through the project, some innovative catalysts and chemical processes for simultaneous conversion of CO_2 and organic wastes or steel by-product gases have been developed. A highly efficient catalyst for direct hydrogenation of CO_2 to liquid hydrocarbons has also been developed and is now under development of an integrated process of "power to liquids and gas" in a pilot scale. Also, the Ministry of Science and Information and Communication Technology will launch a new CO_2 utilisation R&D projects with an investment of KRW 40 billion in the later part of 2020.

Storage

Korea has set a target to carry out multiple CCUS demonstrations for a total of up to 1 Mt CO_2 storage and establish a legal and regulatory framework for commercialisation by 2020. The key challenge in promoting CCUS in Korea remains storage and the identification of adequate exploration sites. The government has carried out its first offshore CO_2 storage demonstration project in the Pohang Basin (storage capacity is estimated to be around 270 000 t) since 2013. Experimental CO_2 injection was 100 t between 2013 and 2017. However, the Pohang earthquake in 2017 has halted its operation out of safety concerns, and in May 2019, the government announced a further delay without a clear due date. This also implies a delay of the second phase of the project, during which over 10 000 t annually were expected to be injected.

A small-scale onshore CO_2 storage situated in Janggi Basin, in the Pohang area, has also been suspended temporarily. The government is now working to increase the social acceptability of carbon storage projects among the local population. In addition, work on enhancing the safety for offshore CO_2 storage safety and site monitoring is ongoing.

Monitoring and evaluation

The government is revising the monitoring and evaluation of public RD&D projects with a view to enhance the efficiency and accountability of the evaluation. The last in-depth review in 2012 pointed to the need to streamline the RD&D evaluation process and linking the outcomes of funded projects to future RD&D planning and design. For this, the government introduced a comprehensive *ex ante* review system and strengthened the evaluation process to enhance the flexibility of project developments and to allow corrective actions to be taken early, or even to abandon projects if it is no longer likely that they will reach the desired outcome.

The government has also introduced a sunset provision for all R&D programmes which is expected to secure funding for future projects. This also allows shifting resources to new priority RD&D areas in line with the 4th ETDP.

Under the new structure, KETEP is charged with implementing the monitoring and evaluation process. The system now consists of seven phases, starting with the announcement of a call that outlines the programme timelines for which proposals will be requested. The RD&D project monitoring and evaluation cycle ends with a performance and impact evaluation undertaken by a designated external institute. The impact evaluation includes an assessment of any spill-over effects of the project's outcomes during the implementation of the project and up to a five-year period after the termination of the project. Obtaining an "excellent performance" rating is one criterion when evaluating future applications under new call for bids. The other five phases are:

1. Concept evaluation assesses the preliminary proposals and summarises the research ideas.
2. Full proposal evaluation is an in-depth review carried out by either using an online meta evaluation system or a debate-based evaluation, depending on the project type.
3. Regular monitoring of progress is conducted through oral presentations of the ongoing research and allows for a discussion of changing objectives, or even the suspension of projects. At this stage in the project, it is possible to obtain support for the purchase of external technologies through a so-called "buy-R&D programme" to enable researchers to secure time-sensitive technologies at an early project stage.
4. Phase evaluation deliberates the progress made in the project phase under evaluation and decides on whether to provide funding for the proposal for the next phase of the RD&D project.
5. Final evaluation mandates the submission of a certified test report to allow for the verification of RD&D outcomes. This phase also provides incentives for those projects that have created commercial values. Projects that are completed early are preferred when applying for new RD&D support.

The new evaluation process has two innovative elements. The first is the inclusion of an assessment of the social impacts. The applicants present the social value creation plan and expected effects related to the R&D task in their proposals, and KETEP, as the evaluation agency, summarises the value creation expected of both the social and economic effects into one of the assessment items to evaluate the applicants. The social assessment is in an initial stage, and KETEP is working on refining the procedure. The government may wish to consider publishing, in English, case studies of such social impact assessments to share with a wider audience globally as a best practice example.

The second innovative element is the development by KETEP of a unique online review tool: the "online meta evaluation" system. This tool allows evaluators, applicants and management agencies to evaluate each other and to verify how professional and fair the review was. The online evaluation process, which was earlier used only for preliminary reviews, is now being applied throughout the evaluation process. Its implementation has been timely as it allowed the evaluation to move forward during the Covid-19 situation and did not delay the decision-making process of important RD&D projects.

Industry collaborations and private RD&D

Korea has a strong track record of public-private RD&D co-operation. Exports from the private sector are involved in the development of the RD&I roadmap to ensure that industry interests and priorities are reflected in the government's policy.

Private companies are actively encouraged to participate in government-funded RD&D projects by creating consortia with universities, research centres and the public sector. The government's rationale for the creation of such consortia is to facilitate the conversion of RD&D outcomes into innovation and new business models. The majority of projects are designed to allow the private sector to take the lead in these consortia and to contribute financially.

The share of private RD&D co-funding, however, strongly declined over the period 2012-18. Co-funding fell from a peak of KRW 8.6 billion in 2014, when it accounted for 127% of public funding, to just KRW 2.7 billion in 2018, or 42% of public funding. This was the lowest share of private co-funding over the period 2012-18 (Table 6.2).

The reason for the peak of private co-funding in RD&D in 2013 and 2014 was the exceptionally high spending in the category "new and renewable energy" in those years. This was due to the substantial private contribution for the "Korea model 300 MW integrated gasification combined cycle demonstration plant" that significantly exceeded the government's contributions.

The reason for the decrease in private investment is due to changes in the mandatory co-funding ratio since 2014. The requirement of co-funding for small and medium-sized enterprises was reduced, which resulted in the desired significant increase of participating enterprises in RD&D. However, as the required co-funding share for large private companies increased, their participation and the overall volume of private funding decreased.

It is important to note that the private investment in Table 6.2 only represents the co-funding in government R&D projects by the private sector. It does not include private R&D investments independently made by the private sector in non-governmental projects.

Table 6.2 Public-private partnership energy R&D expenditures, 2012-18

(million KRW)

Area	Funding type	2012	2013	2014	2015	2016	2017	2018
Energy resource	Government investment	2 387	2 370	2 298	2 453	2 366	2 805	2 725
	Private investment	1 340	1 184	1 073	1 104	1 076	988	969
New and renewable energy	Government investment	2 503	2 487	2 291	2 176	2 183	2 038	2 079
	Private investment	2 288	5 315	5 892	2 759	933	811	831
Nuclear energy	Government investment	1 228	1 089	1 049	971	849	788	706
	Private investment	578	741	597	648	469	444	343
Electrical power industry	Government investment	674	907	921	886	857	677	751
	Private investment	835	823	931	919	858	577	497
Joint international research	Government investment	209	204	198	198	209	220	196
	Private investment	69	55	58	67	99	79	78
Total	Government investment	7 001	7 057	6 757	6 684	6 464	6 528	6 457
	Private investment	5 110	8 118	8 551	5 497	3 435	2 899	2 718

International collaboration

Korea maintains a very active portfolio of multilateral RDD&I collaboration. The country uses multilateral fora to also initiate international joint research activities and share information and best practices in research areas that support Korea's energy policy shift towards clean and sustainable energy development.

IEA technology collaboration programmes

Korea is one of the most active participants in the IEA's technology collaboration programmes (TCPs); being a member of 29 TCPs out of a total of 38; 2 more than at the time of the last in-depth review in 2012 (see Table 6.5). Korea's participation in the TCPs is particularly strong in groups relating to end-use technologies, renewables and hydrogen, in line with the country's overall RD&D strategy. Korea is also a frequent host for the Executive Committee meetings of the TCPs in which it is a member.

Table 6.3 Korean government participation in technology collaboration programmes by group, April 2020

Thematic area	Number of technology collaboration programmes
End-use technologies	13
Renewables and hydrogen	7
Fossil energy	3
Fusion power	5
Cross-cutting	1
Total	29

Engagement through other international partnerships

Korea joined Mission Innovation (MI) in 2016 and participates in six out of eight of MI's innovation challenges, reflecting the country's national RDD&I priorities, namely: smart grids; off-grid access to electricity; carbon capture; clean energy materials; affordable heating and cooling of buildings; and renewable and clean hydrogen.

Under MI, Korea is committed to double its public investment in clean energy by 2021 from a baseline of KRW 560.5 billion in 2016. As reported to MI in 2019, Korea has already made substantial progress towards this target, with almost KRW 903 billion of clean energy RDD&I investments (MI, 2020). Public investment tracked under MI mostly consists of RDD&I activities on power and storage technologies, as well as renewables, including not only spending from government ministries, but also that of public energy corporations like KEPCO and the Korea Natural Gas Corporation.

KETEP actively contributes to the activities of the MI Secretariat and is in charge of disseminating information and insights of the activities undertaken by MI members and to share, collect and manage MI member countries' data.

Korea is a founding member of the Clean Energy Ministerial, and hosted the meeting in 2013. As of May 2019, Korea participated in seven Clean Energy Ministerial initiatives and co-lead two of those, namely, the International Smart Grid Action Network Iinitiative, of which it is a founding member, and the Sustainable Cities and Eco-energy Towns initiative.

Korea joined the Carbon Sequestration Leadership Forum in 2005 and is represented by the Department of Trade, Industry and Energy of MOTIE in its policy group. MOTIE also supports the participation of CCUS experts from the public and private sectors in the Forum's technical group.

Assessment

Korea's national R&D energy budget has consistently been higher than the IEA member median: 0.34 per 1 000 units of GDP, compared to an IEA median of 0.32 in 2018. MOTIE's 2018 budget was USD 549 million, up 20% from 2008; however, this is a 15% decline from the peak spent in 2013.

These figures primarily reflect energy R&D budgets under MOTIE. Other ministries, such as the Ministry of Science and ICT, which is responsible for basic research, manage additional funding. Energy RD&D activities are co-ordinated across government by a director-level committee; as only MOTIE's budget is reported to the IEA, the totality of Korea's RD&D spending is underreported.

Co-funding from industry participating in government programmes declined from KRW 812 billion (USD 738 million) in 2013 to KRW 272 billion (USD 247 million) in 2018. This is partly due to MOTIE's decision to relax requirements for match funding. The figures do not include private sector R&D investments made independently.

The 3rd Energy Master Plan of 2019 continues Korea's commitment to RDD&I. The stated target of the R&D budget of KRW 1.12 trillion by 2021 is not directly related to the 3rd Master Plan, but reflects Korea's commitment under Mission Innovation. The 3rd Energy Master Plan indicates a shift to larger scale R&D and demonstrations projects, with priorities including energy efficiency, hydrogen and nuclear decommissioning.

This strategic shift is also reflected in the 4th Energy Technology Development Plan (2019-28) that has 16 priority areas with a strong focus on technologies that enhance the safety of energy use, especially nuclear and hydrogen, and on strengthening the technological capacity of future energy industries towards high-efficient and low energy consuming technologies. However, modelling is not necessarily undertaken on a whole-of-energy system basis, with a view on setting out decarbonisation pathways. Preparation of a supporting technology roadmap is ongoing, which sets out the milestones for each of the 16 priority areas and contains staged action plans to deliver on the objectives and strategies set out in the 4th ETDP.

In recent years, KETEP has strengthened the RD&D evaluation system towards a comprehensive process from call announcement to performance and impact evaluation. Universities, research institutes and private companies are eligible to apply for funding, with consortia encouraged. A particularly noteworthy feature of the revamped evaluation system is the inclusion of a social impact assessment of the research projects. Many governments could learn from the experiences in Korea undertaking such assessments and the IEA suggests that the government considers publishing, in English, selected case studies, ideally upon completion of the project when the actual impact can be measured against the initial assessment. Many governments globally are keen to show the broader relevance of RD&D funding and Korea could offer best practice examples here.

The second innovative feature is the implementation of an "online meta evaluation" system for the entire project evaluation process, which was particularly timely and useful during

the Covid-19 pandemic as it allowed the proposal assessment to move forward and not be delayed. Given the substantial RD&D programmes that are ongoing and the high innovation potential in the Korean economy, more proactive marketing of the achievements made in energy RD&D and the publication of regular reports on success stories in English should be considered.

Korea's commitment to investing in energy innovation is showing dividends, with a leadership position on smart grids in particular. The flagship test bed project on Jeju Island (2009-13), co-funded by the public and private sectors, has been followed first by 15 city demonstrators, and since 2019 by a new initiative of 2 "smart grid service demonstration towns". Korea is already actively exporting the smart grid technologies developed under the Jeju test bed as part of its official development assistance projects, but also through bilateral partnerships.

In 2019, the government published a Hydrogen Economy Roadmap. Hydrogen is seen as an important energy source to secure continuous industrial innovation and reduce GHG emissions while contributing to reducing Korea's dependence on imported fuels. Korea is a front-runner in RDD&I for the application of hydrogen and the role-out of relevant infrastructure and is implementing various pilot projects across the country. The roadmap sets a target for the production of hydrogen technologies, including 15 GW by 2040 for power generation, of which 8 GW will be for domestic demand including 2.1 GW for applications in homes and buildings. About 70% of the supply of 5.26 Mt of hydrogen in 2040 will be covered as by-product hydrogen, efficient electrolysis and overseas production, while 30% will be reformed hydrogen.

In recent years, Korea has been one of the leading countries supporting the development of CCUS. Two 10 MW demonstration projects have been running since 2013, and the government has set out a three-step plan towards the creation of 500 MW CO_2 capture plant and transport/storage facilities for 4 Mt CO_2/year by 2030. However, this ambitious target is unlikely to be realised, with the pilot CO_2 storage demonstration in the Pohang Basin paused in 2017 after an earthquake, which an independent report showed was unconnected, and which has not yet been relaunched. The IEA welcomes the government's efforts to engage the local population in the process to relaunch the demonstration project and to establish a legal and regulatory framework for CO_2 storage.

Korea continues to play an active role in international collaborations; however, there is potential to pursue further co-leadership roles in multilateral efforts that are strategically aligned with national priorities. Korea is one of the most active member countries in the IEA TCPs, participating in 29 out of the 38 programmes. It is a member of Mission Innovation and the Clean Energy Ministerial, and has been a member of the Carbon Sequestration Leadership Forum since 2005.

Recommendations

The government of Korea should:

- Invest in innovative clean hydrogen production methods to underpin its leadership ambitions for clean hydrogen. In collaboration with KOGAS, conduct research on the suitability of existing infrastructure for hydrogen.
- Base future R&D priorities on decarbonisation pathways and establish R&D plans for decarbonising heat supply and consider whether whole energy system modelling could contribute to priority setting and scenario planning.
- Given the importance of consumer acceptance and adoption of future technologies, ensure research on behaviour change is included in future R&D priorities.
- Ensure future IEA data returns reflect the totality of public spending in R&D.

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7. Electricity

Key data

(2018)

Electricity generation: 586.2 TWh (coal 44.1%, natural gas 26.5%, nuclear 22.8%, oil 2.2%, solar 1.6%, bioenergy and waste 1.4%, hydro 0.6%, wind 0.4%, other sources 0.4%) +32% since 2008

Installed capacity: 127.5 GW

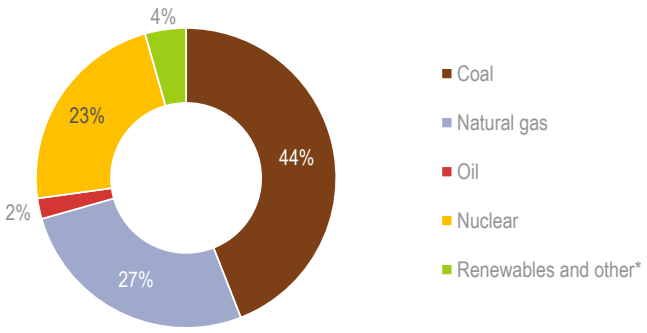
Electricity consumption: 545.5 TWh (industry 51.1%, services and other 33.4%, residential 12.4%, other energy 2.6%, transport 0.5%)

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

Electricity generation in Korea relies heavily on fossil fuels, which accounted for 73% of total electricity generation in 2018. Coal is the largest source with 44%, followed by 27% of natural gas and 23% of nuclear power (Figure 7.1). Korea has no electricity interconnections with neighbouring countries and operates an isolated system. The government is committed to strongly increase the share of energy from renewable sources in the period to 2030 and to a gradual phase-out nuclear and coal-fired power generation.

Figure 7.1 Electricity generation by source, 2018



Fossil fuels dominate electricity generation in Korea, with 73% of the total. Nuclear power is the third-largest source of electricity generation.

* Includes solar, bioenergy and waste, hydro, wind, tidal, and fuel cells.

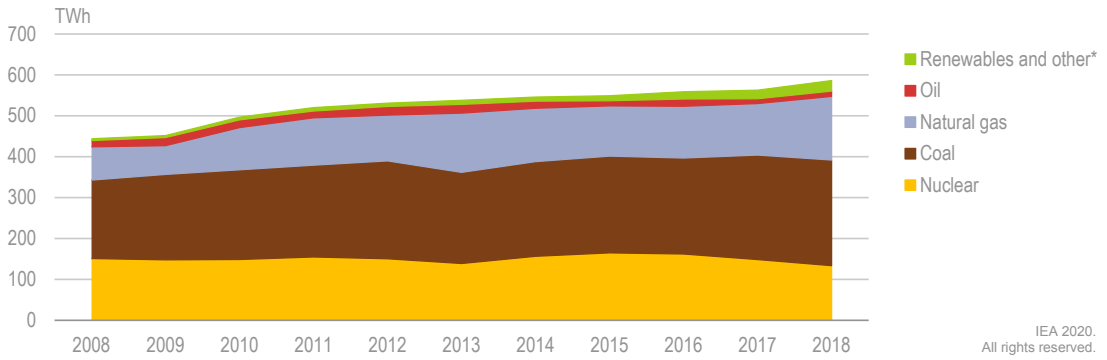
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Electricity supply and demand

Electricity generation

Korea's total electricity generation was 586 terawatt hours (TWh) in 2018, a 32% increase from 2008 (Figure 7.2). The use of coal and natural gas in electricity generation has been increasing over the last decade, while nuclear power generation has declined by 12% over the same period. However, nuclear was still the third-largest source for power generation in 2018. Renewable energies accounted for small shares – solar at 2%, hydro at 1%, and bioenergy and waste at 1% – but those shares have increased significantly since 2008.

Figure 7.2 Electricity generation by source, 2008-18



The use of coal and natural gas in electricity generation has increased over the last decade while nuclear power generation has declined during the same period.

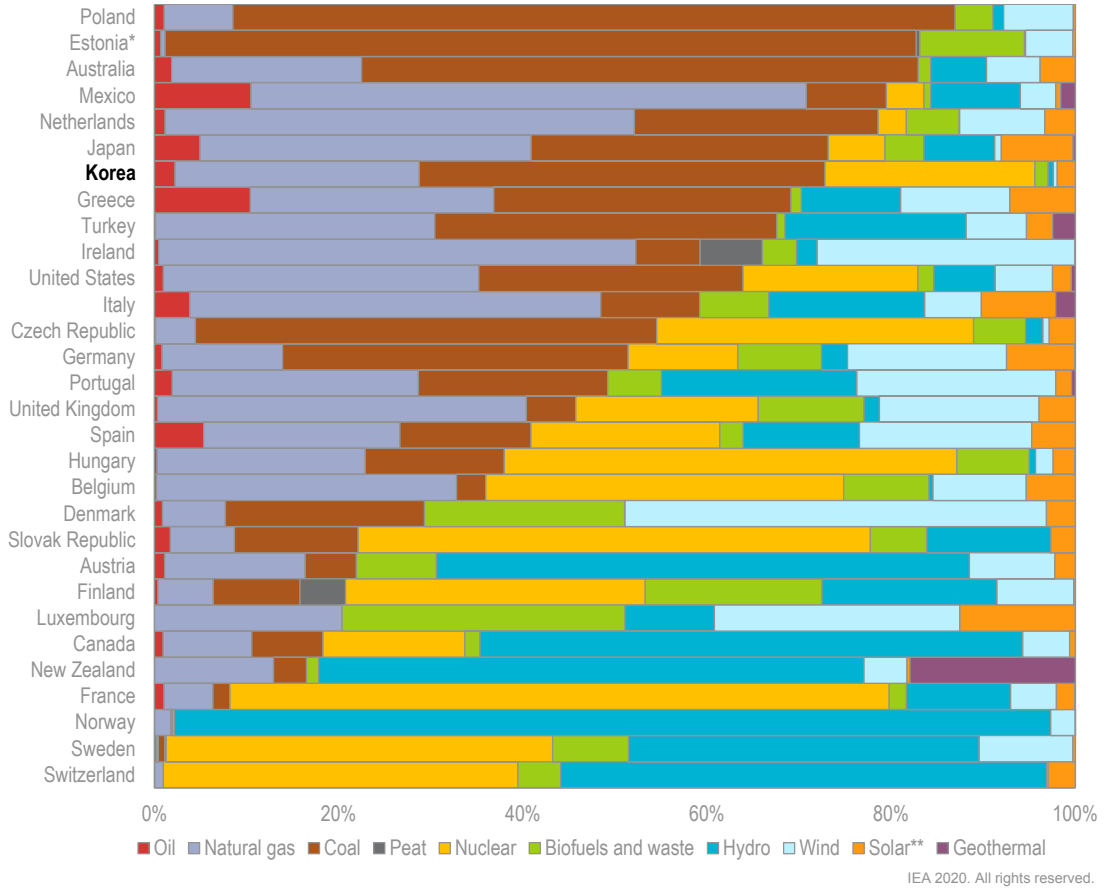
* Includes solar, bioenergy and waste, hydro, wind, tidal, and fuel cells.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

In 2018, Korea ranked seventh-highest among IEA countries in terms of the share of fossil fuels in electricity generation, and with 4% had the lowest share of electricity generation from renewables among IEA member countries[1] (Figure 7.3). Korea had the ninth-highest share of nuclear among IEA countries with nuclear in the electricity mix. Korea has no electricity interconnections with other countries and relies entirely on domestic electricity production to meet demand.

[1] Korea refers to renewable energy as "new and renewable energy". Korea defines "new energy" to include hydro, fuel cell and energy converted from fossil fuels, like integrated gasification combined cycle. Until October 2019, Korea defined "renewable energy" to include non-renewable waste energy (i.e. waste, by-product gas, etc.). As a result, there can be differences in numbers or percentages between the renewables data published by the Korean government and those published by the IEA.

Figure 7.3 Electricity generation by source in IEA member countries, 2018



Korea ranks seventh-highest among IEA member countries in terms of the share of fossil fuels in electricity generation.

Note: The countries are shown in decreasing order of share of fossil fuels in electricity generation.

* Estonia's coal represents oil shale.

** *Solar* includes solar PV, solar thermal, wave and ocean power, and other power generation (e.g. from industry waste heat and fuel cells).

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Total installed generation capacity increased by 60% between 2008 and 2018, largely due to an increase in combustible fuels and solar power capacity. Installed capacity in power plants using combustible fuels increased from 56 gigawatts (GW) in 2008 to 89 GW in 2018. Renewable capacities also experienced a significant increase during this period. Installed solar power capacity increased by more than a factor 20, from 0.4 GW in 2008 to 8.1 GW in 2018, and wind power capacity grew from 0.30 GW to 1.4 GW. Meanwhile, nuclear power generation capacity has remained relatively stable around 22 GW in recent years and hydro capacity was stable at 6.5 GW (Table 7.1). Given its isolated grid and following the power outages experienced in 2011, Korea requires generating plants to maintain an operating reserve margin of 15%.

Table 7.1 Installed electricity generation capacity, 2008-18 (GW)

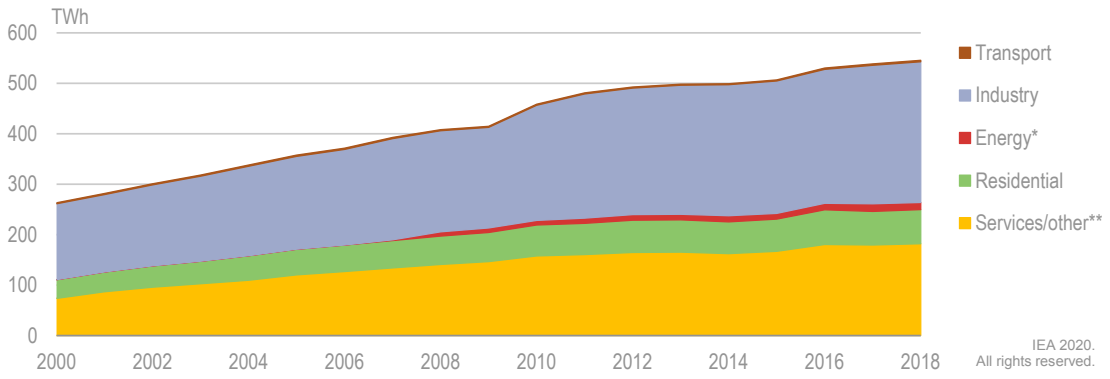
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Combustible fuels	56.0	56.5	60.4	58.3	59.1	61.8	69.1	70.1	75.6	86.4	89.0
Nuclear	17.7	17.7	17.7	18.7	20.7	20.7	20.7	21.7	23.1	22.5	21.9
Hydro	5.5	5.5	5.5	6.4	6.4	6.5	6.5	6.5	6.5	6.5	6.5
Wind	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.8	1.1	1.2	1.4
Solar	0.4	0.5	0.7	0.7	1.0	1.6	2.5	3.6	4.5	5.8	8.1
Other sources	0	0.02	0.04	0.06	0.09	0.13	0.16	0.18	0.22	0.25	0.35
Total capacity	79.9	80.6	84.7	84.6	87.8	91.5	99.8	103.2	111.2	122.9	127.5

Source: IEA (2020b), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

/Electricity consumption

Total electricity consumption in 2018 was 545 TWh, a 34% increase from a decade ago (Figure 7.4). The industry sector is the largest electricity consumer, accounting for 51% of total electricity consumption in 2018. Industrial electricity consumption has continuously increased since 2009 and reached 279 TWh in 2018. The service sector was the second-largest electricity consumer, accounting for 33% of total consumption, followed by the residential sector with 12%. The energy (2.6%) and transport (0.5%) sectors accounted for minor shares. Residential electricity consumption increased by 20% (from 56 TWh to 68 TWh), while the service sector increased by 29% (from 141 TWh to 182 TWh) compared to ten years ago. Growth in electricity consumption is not only driven by strong economic growth, but also by low electricity retail prices that do not send price signals to consumers and that do not vary in line with generation costs (see below).

Figure 7.4 Electricity consumption by sector, 2000-18



Electricity consumption has increased by 47% over the past decade in Korea, especially due to the significant increase in demand from the industry and services sectors.

* *Energy* includes petroleum refineries, coal mines, oil and gas extraction, coke ovens, and blast furnaces.

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

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Electricity outlook

Looking forward, Korea's 8th Basic Plan for Long-Term Electricity Supply and Demand (BPLE) covers the period from 2017 to 2031. A key highlight of the plan is the government's commitment to gradually reduce coal and nuclear power generation to address increasing air pollution, climate change mitigation and nuclear safety issues. Nuclear power would be phased out in the long term; the last plant would most likely close by 2083. Moreover, Korea has very limited fossil fuel resources and 78% of the fuels for electricity generation in Korea are imported, excluding nuclear feedstock. Increasing the share of renewable energies in electricity generation will therefore reduce Korea's fuel import dependence (MOTIE, 2017).

The target under the 8th BPLE is reaching a 20% renewable share of electricity generation in 2030. To achieve this target, the variable renewable capacity would need to more than quadruple from an existing capacity of 15.1 GW in 2017 to 58.5 GW in 2030 or to 63.6 GW if pumped storage facilities are taken into account (MOTIE, 2017).[2] Overall, installed generation capacity is set to reach 174 GW in 2030. Generation from renewable sources would increase from 34.4 TWh, or 6.2% of total generation in 2017, to 125.8 TWh in 2030, equivalent to 20% of total generation. Solar and wind capacity would jointly account for almost 88% of total renewable generation capacity in 2030 (MOTIE, 2017).

However, a closer look at the power generation projects under construction shows that the actual capacity of coal and nuclear plants will increase until about 2022 before eventually starting to slowly decline in the years thereafter. The share of nuclear and coal in the electricity mix will, however, start to decline earlier as the overall capacity growth to 2030 is substantial.

The share of nuclear generation would gradually decrease as of 2022, as no new construction would be permitted beyond the 7 GW capacities already under construction. In addition, there will be no more lifetime extensions of aging nuclear power plants. Nuclear capacity will therefore increase from 22.5 GW in 2017 to 27.5 GW in 2022 (if all plants under construction are commissioned according to schedule) before declining to 20.4 GW in 2030, while its share in installed capacity will fall from 19.3% in both 2017 and 2022 to 11.7% in 2030 (MOTIE, 2017).

A similar strategy applies for coal-fired power generation to address public concerns about local air pollution due to fine particles. Beyond the ongoing constructions of 7.3 GW new capacities, no additional construction permits will be granted, while uneconomical aging plants older than 30 years will either have to shut down or convert to using more environmentally friendly fuels.

Installed coal capacity will increase from 36.9 GW in 2017 to 42 GW in 2022 (if all plants under construction are commissioned according to schedule) before slightly decreasing to 39.9 GW in 2030. The share of coal in installed capacity will, however, fall from 32% in 2017 to 29.5% in 2022 and to 23% in 2030 (MOTIE, 2017).

Electricity demand is expected to continue to grow rapidly over the period covered by the 8th BPLE, with an annual growth rate of 2.1%. As a consequence, the 8th BPLE projects a reference generation scenario of 667 TWh in 2030 (compared to 575 TWh in

[2] The policies and mechanisms in place to support new and renewable electricity capacity installations are discussed in detail in Chapter 5.

2017) to meet demand. Such an increase in demand is mainly attributed to increased investments in economic infrastructure as well as production growth by iron and steel manufacturers, petrochemical businesses, and fabricated metal product businesses.

The 8th BPLE targets a reserve margin of 19% between 2018 and 2025 that will increase further to 22% during the period 2026-31. There are two components in the reserve margin: 1) a minimum reserve of 13% to address generation variabilities of wind and solar power; and 2) a 9% reserve for uncertainty to cover peak demand or mitigate risks to due to delays during installation of generation facilities (MOTIE, 2017).

Korea has witnessed a continuously growing gap between electricity consumption and peak demand in recent years and demand-side management to limit peak demand is growing in importance. Traditionally, Korea experienced peak load during summer when demand for cooling increases. However, with the spread of direct electric heating, since 2009, the peak load has shifted to the winter (MOTIE, 2017).

Korea is implementing a comprehensive demand management project that addresses both efficiency improvements and load management. The project is expected to result in a target generation for 2030 of 580 TWh, almost stable compared to the 575 TWh generated in 2017, and 13% below the reference generation scenario of the 8th BPLE (MOTIE, 2017).

The government is working on the 9th BPLE, which will be released in 2020 and that will have a special focus on safety and climate change concerns. Looking beyond 2030, the country's 3rd Energy Master Plan was released in June 2019 and sets targets for the electricity generation mix to 2040. The share of renewables in electricity generation is expected to further increase to 30-35% in 2040 (MOTIE, 2019).

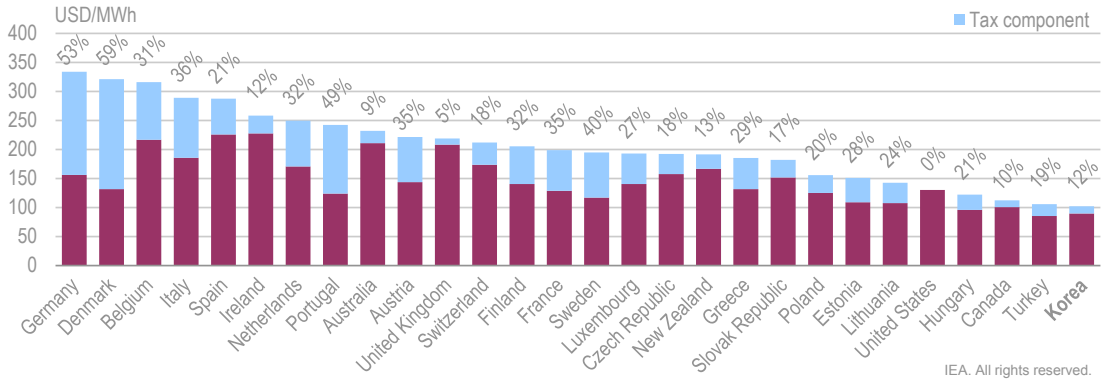
Prices and taxation

Retail electricity prices in Korea are not set by the market, but are regulated by the government through the Ministry of Trade, Industry and Energy (MOTIE).[3] The Electricity Utility Act and the Price Stabilisation Act set forth the procedures for the approval of tariffs for the retail sales of electricity. MOTIE approves all changes in end-use electricity prices, following consultation with the Ministry of Strategy and Finance and a review by the Korea Electricity Regulatory Commission (KOREC).

The tariff is composed of two parts: a demand charge and an energy charge. In 2019, Korean households paid the lowest electricity price (USD 102 per megawatt hour [USD/MWh]) in an IEA comparison, with a tax rate of 12% (Figure 7.5). Korea's electricity price for industries was lower than the IEA median at 95 USD/MWh, due to low taxes at 4% of the total price (Figure 7.6).

[3] Annex A provides more detailed information about institutions and organisations with responsibilities for the energy sector.

Figure 7.5 Electricity prices for households in IEA member countries, 2019

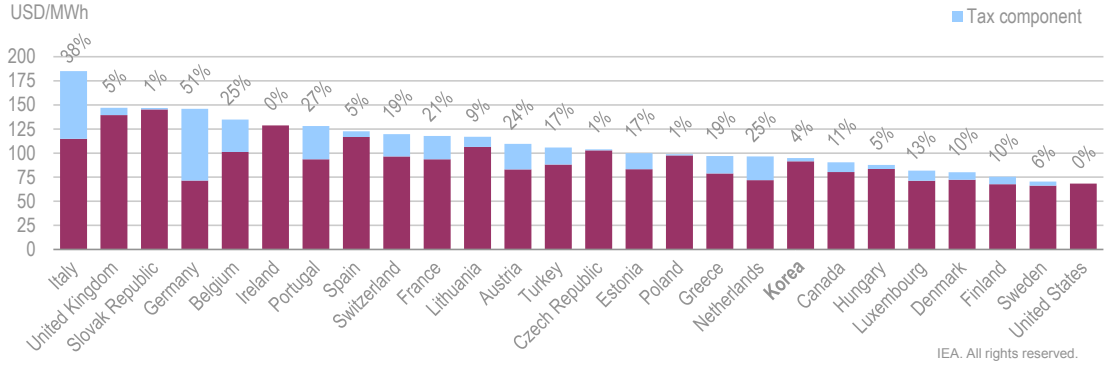


Korean households paid the lowest price for electricity among IEA countries due to a low energy price and low taxes.

Notes: The tax component includes value-added taxes and excise taxes, levies, and public charges. No tax information available for the United States. 2019 data for Japan, Mexico and Norway were not available at the time of writing.

Source: IEA (2020c), *Energy Prices and Taxes 2020* (database), www.iea.org/statistics.

Figure 7.6 Electricity prices for industries in IEA member countries, 2019



Industry electricity prices in Korea are below the median in an IEA comparison, due to low tax levels.

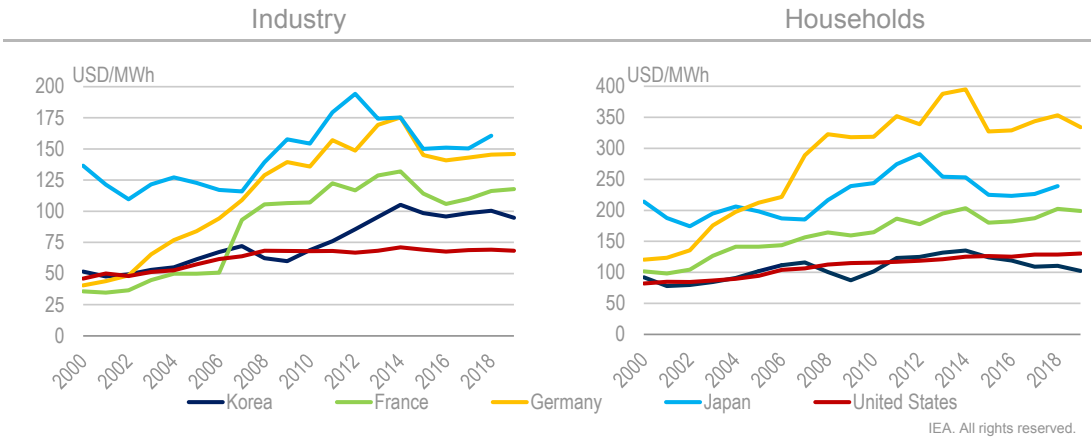
Notes: The tax component includes value-added taxes and excise taxes, levies, and public charges. 2019 data for Australia, Japan, Mexico, New Zealand and Norway were not available at the time of writing. No tax information available for the United States.

Source: IEA (2020c), *Energy Prices and Taxes 2020* (database), www.iea.org/statistics.

Electricity prices for both households and industries reached their peaks in 2014 (households at 135 USD/MWh and industries at 105 USD/MWh). After the peak, household electricity prices decreased to 102 USD/MWh in 2018 and industry prices to 102 USD/MWh. Due to low taxes and price regulation, retail consumers in Korea generally pay low prices compared to other IEA countries. Retail consumers are also not accustomed to the large and frequent tariff variations in response to global fuel price changes, as in many other large industrialised countries (Figure 7.7).

Electricity tariffs have not changed since 2013, except for the residential segment, where they decreased in 2017 and 2019 to protect low-income households. Overall, Korea's tariff system is characterised by the continued existence of cross-subsidies between the industrial and the residential segments.

Figure 7.7 Electricity prices in Korea and selected IEA countries, 2000-19



Korea has generally low prices compared to other large industrialised countries, in particular for households, with quite stable prices over the last two decades.

Note: 2018 and 2019 data are not available for Japan.

Source: IEA (2020c), *Energy Prices and Taxes 2020* USD 180/MWh (database), www.iea.org/statistics.

Korea's electricity tariff system is complex, with six categories (residential, commercial, educational, industrial, agricultural and street lighting) and with different tariffs according to use. Electricity tariffs also vary depending on the voltage, season, time of usage, rate option and other factors.

Regulatory framework and market model

Korea's electricity market is principally governed by the Electricity Utility Act. In addition, the Nuclear Safety Act and the Act on the Development, Use and Diffusion of New and Renewable Energy apply to the electricity sector.

KOREC was established in 2001 within MOTIE under the Electricity Utility Act to oversee the regulation of the newly created single-buyer market, review issues concerning the rights of electricity consumers and settle disputes related to the electricity business. The Electricity Market Surveillance Committee, an entity under KOREC, is responsible for market monitoring. While KOREC has important enforcement functions, its role is limited to an advisory one. There is no independent electricity sector regulator in Korea and MOTIE remains the key regulatory entity. MOTIE's responsibilities also include the granting of electricity business licences; the approval of market rules, transmission and distribution tariffs and retail sales prices; and the regulation of wholesale electricity prices.

The Electricity Utility Act was revised in 2018 to establish new licensing procedures for small-scale electricity brokerage businesses and electric vehicle charging businesses. Small-scale electricity brokerage businesses are authorised to collect and trade electricity that is produced from renewable sources and stored in energy storage devises, or electric vehicles and can be traded at the Korea Electric Power Exchange (KPX). Both types of businesses must register with MOTIE.

The Korea Fair Trade Commission is responsible for monitoring monopoly behaviour and unfair business practices, whereas KOREC manages technical and professional competition policy. The Fair Trade Commission and KOREC have memoranda of understanding outlining their respective roles, duties and functions in the electricity industry.

State-owned KEPCO is the dominant company in all segments of the electricity sector and used to have a monopoly over electricity generation. Since 2001, private companies are permitted to enter the Korean market. In December 2019, 20 independent fossil fuel producers and 3 442 new and renewable energy power generators, 3 297 of which are solar power producers, were operating independently of KEPCO and accounted together for 31% of total installed capacity.

Also in 2001, KEPCO's generation business was divested and divided into six wholly owned subsidiaries that control the reminder of Korea's generation market; in one of those six subsidiaries (Korea Hydro & Nuclear Power), all hydro and nuclear power plants are concentrated. KEPCO is the owner of the Korean electricity transmission and distribution systems and the only operator of the distribution system and the only electricity retailer in the country. The KPX operates the transmission system. However, the Electricity Utility Act requires the signing of an electric power transmission line utilisation agreement between KEPCO and the generation plants that wish to be connected to the transmission grid (Park and Dooley, 2019).

Korea's electricity sector is changing rapidly with the government's vision to substantially increase the share of variable renewable and decentralised generation and the expected increase in the number of community energy systems operations. These developments would suggest a rethinking of the current regulatory and ownership structure of the electricity sector to allow Korea to reap the fullest benefits from the ongoing electricity sector transition.

Wholesale electricity market

The KPX was established in 2001 as part of the electricity sector reform and is owned by the government. The wholesale electricity market operates on a cost-based mandatory pool system with prices reflecting generation costs. Electricity generators are not free to bid their prices into the mandatory pool. Instead, they are obliged to submit full details of their production costs to the KPX, which are independently checked and approved monthly by its generation cost assessment committee.

Using this information, the KPX calculates the variable costs of all generation assets and uses those variable costs to set the system marginal price (SMP) for the next day in accordance with the electricity market operation rules. The SMP of the day ahead corresponds to the variable costs of the most expensive generation plant that is needed to satisfy electricity demand on the next day (merit order system), and that plant, plus all cheaper plants, will be instructed to produce electricity the next day. In addition, generators can also earn revenues by providing ancillary services for the electricity system; the price for ancillary services is fixed by the KPX.

The Central Power Control Center of the KPX monitors the electricity generation operations. The KPX is independent from all electric utilities, including KEPCO, and operates the electricity market, the power system and the real time dispatch (KPX, 2019). It is also in charge of system operations to respond quickly to output variations. The independent power producers, such as POSCO Energy (Pohang Iron and Steel Company), SK E&S, and GS Energy, can sell electricity to the wholesale market.

The KPX is also tasked with undertaking load forecasting, covering the short to medium term. It forecasts monthly supply and demand, weekly peak load, and the expected summer peak load. The medium-term forecasts cover two to three years (KPX, 2019).

The generating assets receive a remuneration that is equal to SMP plus a reference capacity price which is determined annually based on the plant's fixed costs. Since October 2016, the reference capacity price is different for each plant so as to reflect plant-specific characteristics; for example, the year in which each unit entered commercial operations, as well as system requirements such as the 15% standard capacity reserve margin (Yi and Park, 2018). As all generation assets receive a capacity payment, also when they are producing, those assets with marginal costs that are structurally lower than the SMP may well receive higher total revenue than needed for their operation and availability.

Since 2019, the SMP also indirectly includes environmental considerations. Until then, taxes on power generation fuels such as bituminous coal and liquefied natural gas (LNG) had not properly reflected environmental costs such as fine dust. In April 2019, the Korean government adjusted the tax system by lowering the tax burden on eco-friendlier LNG, while increasing the tax burden on bituminous coal.

Korea currently only operates a day-ahead market. However, with a view to the planned sharp increase in the share of variable renewables, this is a suboptimal model. The Korean government is developing a comprehensive generation market structure by breaking down the generation planning portfolio into four phases (weekly, daily, intra-day and in real time) and intends to implement this market structure by the end of 2025.

The introduction of intra-day adjustment and real-time balancing markets will improve operational flexibility and allow the system to cope with an increasing share of variable renewable generation. This development is a positive step to increase security of supply. In addition, a better integration of variable renewable generation will also reduce the need to maintain high levels of operational reserves. Revisiting the structure of the wholesale market to include ancillary services provided by dispatchable generators (such as hydropower or gas generation) should also be considered as part of the proposed new market structure the government is developing.

As KEPCO is the country's only supplier and retailer, it is also the only wholesale buyer of electricity from the KPX. Some exceptions exist, including for community electricity business companies. In theory, large industrial energy users who require more than 30 000 kilovolt ampere (kVA) can also purchase electricity directly from the KPX market, but in practice none have. This is mainly due to the fact that direct purchasers would buy at the SMP price, which is higher than the coefficient adjusted price at which KEPCO is allowed to purchase from the KPX; this system clearly distorts competition. Moreover, direct purchasers also face an inability to hedge the financial risk arising from market volatility due to the absence of adequate financial instruments. Allowing large users to directly contract with generators, for instance through financial power purchase agreements, would improve price certainty for both generators and customers, and would encourage investment in new generation, including renewables.

Under the Electricity Utility Act and the Price Stabilisation Act, electricity tariffs are in principle established at levels that would enable KEPCO to recover its costs attributable to its basic electricity generation, transmission and distribution operations and to receive a fair investment return on capital used in those operations. However, KEPCO has been experiencing financial difficulties in recent years and ended the fiscal year 2018 with operational losses; this is likely also to be the case for fiscal year 2019 (Yoon, 2019).

Infrastructure

Korea's national power grid is an isolated system; there are no cross-border transmission lines. There is a long-term project for a cross-border power system between several North East Asian countries (see Box 7.1).

In 2019, the Korean transmission system had a line length of 34 402 kilometers (km) and 862 substations. The majority of transmission lines in the country are 154 kilovolt (kV) lines (67% of the network), but transmission voltages are also 765 kV and 154 kV or lower for local networks (Table 7.2). Since the last in-depth review, Korea has completed the second stage of the 765 kV power transmission project that serves as the backbone of the transmission system. Transmission lines connect the generation capacity that is mostly located in the north-western and south-eastern coastal regions, to the major urban and industrial demand centres in the north-west. Jeju Island in the south is connected to the transmission system via submarine high-voltage direct current cables.

Table 7.2 KEPCO transmission network, August 2019

Voltage (kV)	Length (km)	Share of total network (%)	Substation number
765	1 019	3.0	7
345	9 795	28.5	114
154	23 233	67.5	734
Others	355	1.0	7
Total	34 402	100	862

Source: Information provided by the Korean government (2019).

In addition to a well-developed transmission system, Korea has a large distribution network with a total length of 493 331 km. The network also has 2 260 transformers to convert electricity to the proper voltage for the end user (Figure 7.8).

Figure 7.8 Korea's transmission grid

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

The 8th BPLE includes several projects to ensure the reinforcement of transmission infrastructure to accommodate expected demand growth and the increased construction of decentralised variable renewable electricity generation facilities. In Korea, new renewable generation capacity mainly comes from rural and mountainous areas and requires the construction of additional lines to bring generation to load centres. From 2018 to 2031, the 8th BPLE estimates that an additional 43 substations, 89 transformers and a total of 860 km of transmission lines will need to be constructed (MOTIE, 2017).

The plan has identified a significant time gap of about four years between the installation of small-scale renewable generation facilities and the necessary transmission system reinforcement. As most IEA member countries, Korea has experienced delays in the construction of transmission lines due to opposition from the local population. To address the low public acceptance of new transmission lines and of transformation facilities, the government enacted the "Act on Transmission Facilities and Assistance to Adjacent Areas" in 2015. One objective of the act is to improve conflict resolution between the project proponents, local governments and other stakeholders. One key demand of local residents is that new transmission facilities be installed underground and the government is also committed to increase the involvement of residents early on in the site selection process (MOTIE, 2017).

KEPCO also operates and maintains the distribution network that is divided into 14 electricity supply regions and 41 distribution centres. KEPCO has two headquarters: one for transmission operation, the other for distribution control. New generation capacity is guaranteed by law to be connected to the distribution network and has to pay for the connection. However, there is an exception for new and renewable generating facilities below 1 megawatt (MW) capacity, for which KEPCO covers the connection costs.

Box 7.1 Asian super grid project

In Europe and in North America, electricity interconnectors play an important role in security of supply by allowing electricity to flow between interconnected power grids. For instance, for more than ten years, the transmission line "NorNed", a 580-kilometre submarine cable, has been connecting Norway and the Netherlands. Via this interconnection, Statnett (the Norwegian transmission system operator [TSO]) and TenneT (the Dutch TSO) transit electricity from the Netherlands to Norway and vice versa. After NorNed, numerous other seabed cables were commissioned in north-west Europe.

The Asia Super Grid (ASG) is an ambitious initiative for a grid connection plan in North East Asia. The project was initially proposed in 2011, and would connect the electricity networks of the People's Republic of China (hereafter, "China"), Japan, Korea, Mongolia and the Russian Federation (hereafter, "Russia"). It would eventually allow North East Asian countries to trade (renewable) electricity supplies produced in China and Mongolia and consumed in other countries. This would not only support the decarbonisation of the electricity supply in North East Asia, but would also bolster the region's energy security. A sub-sea interconnection with Japan could be considered eventually, as it could potentially increase the supply of renewable electricity in both countries.

In a feasibility study completed in 2018, KEPCO estimated that the part of the ASG connecting Korea with China, Japan and Russia would cost over USD 6.2 billion to build. In Korea, the ASG would help to import power supply from renewable energy, such as solar and wind power. However, details of the legal and regulatory frameworks and the comprehensive political support are yet to be decided upon to allow the design of a feasible investment model. Progress with the ASG is, moreover, also subject to geopolitical developments and there is no set timeline for the start of construction.

Sources: EIB (2007), *The European Investment Bank Finances NorNed – The Submarine Power Cable Linking the Netherlands and Norway*, https://www.eib.org/en/press/all/2007-118-the-european-investment-bank-finances-norned--the-submarine-power-cable-linking-the-netherlands-and-norway-; Renewable Energy Institute (2018), *Asia International Grid Connection Study Group Second Report*, https://www.renewable-ei.org/en/activities/reports/20180614.php; IEA (2019), *Energy Security in ASEAN+6*, https://doi.org/10.1787/6f431256-en.

Power system operation performance

Korea's total loss factor is 3.56% (1.59% for transmission and 2.01% for distribution); this percentage is substantially below the OECD's average of 6.4%. The power system performance indicators SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) both improved between 2014 and 2018, with a reduction of 12% and 22% respectively (Table 7.3).

Table 7.3 Duration of outages on the power system, 2018

System Average Interruption Frequency Index (SAIFI) (number/customer)		
Year	2014	2018
Total	0.086	0.076
System Average Interruption Duration Index (SAIDI) (min/customer)		
Year	2014	2018
Total	4.87	3.79

The future of the power system

Towards a more decentralised power system

The Korean government seeks to transition towards a more decentralised energy system with greater customer engagement in the market through the introduction of a smart grid across metropolitan areas by 2020 and nationwide by 2030 (see below). This will facilitate the introduction of innovative developments including virtual power plants, peer-to-peer and vehicle-to-grid trading, and enhanced demand-side management.

The Korean government is also moving to establish an integrated renewable control system to forecast renewable generation levels and monitor output in real time in order to assist the system operator (KPX) in responding quickly to output variations. In developing the control system, it will be important to ensure it can forecast and measure "behind-the-meter" renewable generation so that the KPX has a complete picture of what is occurring in real time in relation to electricity supply and demand.

Significant challenges remain to be addressed, such as ensuring that "whole-of-system costs" are minimised, and that electricity prices are cost-reflective, while incentivising efficient distributed energy investments and demand reduction, consistent with the government's objectives.

Smart grid and smart meters

The Korean Smart Grid Institute was launched in August 2009 as the secretariat of the Smart Grid Initiative and projects in Korea. The Smart Grid initiative mainly targets the modernisation of electric power systems in the country by promoting the development, demonstration and expansion of smart grid technologies. Following that, in November 2011, Korea enacted the "Act on Promoting Smart Grid Establishment and Usage" to establish the regulatory basis for building a nationwide smart grid.

It will first be developed in metropolitan areas by 2020 then extended nationwide by 2030. The national smart grid roadmap has five implementation areas: smart consumer, smart transport, smart renewables, smart power grid and smart electric services. To access real-time information and manage power flows, KEPCO is developing an advanced distribution monitoring system to prepare for generation variability and to regulate power supply with renewable energy expansion.

The Korean government is to be commended for the good progress already made in relation to smart grid development. A national rollout of smart meters is underway, with 8.48 million meters already deployed as of 2019, with the complete roll out of 22.5 million meters originally expected to be completed by 2020, although it will likely be delayed by several years depending on the project's progress. In addition, a smart grid test bed was established on Jeju Island in 2012, and demonstration projects are now being undertaken in 15 cities to promote the potential benefits of this technology.

The smart grid project on Jeju Island was the flagship project for Korea. The main goal was to set up the world's largest smart grid test bed to develop and deploy state-of-the-art technologies and apply innovative business models. This work was carried out by MOTIE, municipalities, KEPCO and other large Korean companies (such as Hyundai, SK Energy or LG). The first two phases of the project were completed from 2009 to 2013 with a budget of KRW 237.2 billion (approximately USD 200 million) to build infrastructure and test integrated operations of the smart grid for 6 000 households. This successful first large-scale project was a key milestone to make important progress in the five implementation areas defined in the national smart grid roadmap.

A new phase started in 2016, with demonstration projects in 15 cities. This phase is planned until 2025 and will include a broader scope with smart villages, vehicle-to-grid and the participation of citizens as prosumers (producers and consumers at the same time). In 2019, Korea co-leads the International Smart Grid Action Network and the Sustainable Cities and Eco-energy Towns Initiative. Both initiatives are part of the IEA's work to support co-operation and knowledge transfer to accelerate the deployment of smarter and cleaner power grids globally.

Flexibility and energy storage to integrate more renewables

The existing market structure needs to be revisited to ensure it is efficient and well adapted to a system with significant variable renewables, including ensuring flexibility through operational practices and market frameworks, which should emphasise

competition and transparency. Revisiting the structure and operation of the wholesale market should be a priority to promote more competitive outcomes and ensure that the ancillary services provided by flexible dispatchable generators are appropriately priced. The introduction of intra-day adjustment and real-time balancing markets should be pursued to improve operational flexibility, allowing for closer to delivery forecasts of renewable generation, thereby reducing the need to maintain operational reserves and allowing more frequent dispatch. The introduction of a separate ancillary services market should also be considered to efficiently procure frequency reserves, including addressing sudden variability.

To achieve the 20% renewable target as per the 8th BPLE, apart from changes to the market structure, network changes will also be necessary to deal with a higher share of variable production. Dispatchable generation and energy storage will become more important in providing security of supply. Between 2014 and 2017, KEPCO built 13 energy storage systems (ESS) using batteries to store electricity with a capacity of 346 MW. Batteries are associated with small-scale photovoltaic power generation and KEPCO regulates frequency on the network using its ESS. Since January 2017, the installation of an ESS system is mandatory for newly built public buildings. The ESS market has been growing quickly, with 1.8 GWh of ESS installed in the first half of 2018, which is exceeding the total volume of 1.1 GWh installed from 2012 to 2017.

Resilience of the power grid

Being prepared and able to respond efficiently and effectively to extreme weather events, cyberattacks, climate change or other hazards is important for maintaining energy security (Box 7.2). Korea has strong emergency response mechanisms for its national security, including energy security. The integration of a growing share of variable renewables and the move to a more decentralised system will require significant investments in the power system for the development of smart technologies and adaptation of the electricity market operation.

Resilience can be defined as the ability to withstand and recover rapidly from disruptions, including from accidents; natural disasters; and stresses, shocks and threats to economic and political systems. Energy resilience in a broader sense extends to ensuring a comprehensive risk management framework, going beyond addressing immediate supply disruptions. Rather, it emphasises prevention of and preparation for a potential crisis, flexible adaptation, and efficient recovery.

Box 7.2 Development of a national cybersecurity strategy

Due to the dominance of industrial energy use, the government is fostering a link between the energy transition and the Fourth Industrial Revolution. In that context, a successful decarbonisation of energy supplies for a cleaner and smarter industry should go hand-in-hand with the development of energy storage systems and smart grid technologies. However, more instrumentation might introduce new threats, such as vulnerability to cyberattacks.

The power system is under the rising threat of cyberattacks. There has been significant growth in instrumentation and automation at the level of the bulk power system. This allows

the electricity system to operate more efficiently and provides the system operator with much better situational awareness, which can also improve grid reliability and resilience in the face of outages; however, this added complexity can also introduce cybersecurity vulnerabilities.

The National Cybersecurity Strategy of Korea was published in April 2019 by the National Security Office. Its objectives are to: safeguard people's safety, rights and interests against cybercrime; detect and block cyber threats to guarantee that key government operations continue; and foster cybersecurity talent and continue to support the development of the cybersecurity industry. The government is preparing a National Cybersecurity Basic Plan to implement this strategy.

Source: Korea National Security Office (2019), *National Cybersecurity Strategy*.

Resilience also provides for the assessment of medium- to long-term risks, including more extreme weather events, as well as new technology threats such as cyberattacks on power grids and oil and gas facilities, thereby covering all interconnected components of the energy sector.

Weather-proofing of the power network in Korea is an important element of security of supply, given the increasing occurrence of disasters such as earthquakes or typhoons in the recent years. Extreme weather events often cause damages to transmission and distribution systems and test emergency response procedures to restore services. Several entities in Korea are working on emergency response to disasters, for instance the National Disaster Prevention and Countermeasures Headquarters and the Korea Disaster Prevention Association. Their missions focus on increasing public awareness, collecting data and developing projects related to disaster prevention.

Security of supply

Security of electricity supply is regulated by the Electricity Utility Act. In the event of an emergency, MOTIE may issue supply orders to electricity utilities to directly supply to specific consumers. The KPX will give emergency dispatch orders to KEPCO. It will determine the duration and magnitude of emergency load-shedding episodes. If the electricity system is down, the KPX will order the start-up of emergency generation plants. Korea is divided into seven regions with black start capacities and back-up transmission lines. In order to prepare for emergencies in electricity supply and demand, the KPX conducts emergency simulated drills (four times a year) with energy-related organisations and provides real-time power supply status information to the public.

According to the Korea Energy Economics Institute, the reserve margin – the difference between peak capacity and peak electricity demand – was lower than 10% on an annual basis between 2007 and 2013, and it resulted in a major blackout in 2011. These low margins were the result of delays in installed capacity additions due to low electricity prices, high peak demand due to weather, and insufficient investments in renewable energy and energy efficiency projects. Over the period 2012-16, growth in installed capacity at 5.9% was outpacing the growth of peak demand at 3.1% over the same period (MOTIE, 2017). Since 2014, the capacity margin has been at least 15% and reached 17.6% in 2017 (MOTIE, 2017). This is due to more new capacity coming online, nuclear facilities affected by safety problems in 2012 returning to service and an easing of consumption growth.

The introduction of a demand-response market in 2014 is another positive development. In December 2019, the market was comprised of nearly 4 200 participants and up to 4.3 GW of demand reduction. While arrangements continue to be refined, a responsive demand side will provide the electricity market with needed flexibility and is critical to minimising costs, particularly through shaving peak demand and reducing the need for additional generation and network investments. This is particularly important noting the spread between Korea's average and peak demand is increasing, largely due to increasing heating and cooling load. The introduction of time-of-use and seasonal pricing for industry and, to a lesser extent, residential sectors to encourage efficiency and reduce demand peaks is a positive step; however, tariffs continue to be set in an opaque manner at levels that do not directly reflect the cost of electricity.

Assessment

In 2018, fossil fuels represented 73% of total electricity generation in Korea. Among IEA member countries, this was the seventh-highest share of fossil fuels in electricity generation. Nuclear and renewables represented respectively 23% and 4% of generation.

In 2019, residential electricity tariffs were the lowest among IEA countries. Tariffs are regulated by the government. Electricity tariffs for the residential sector have not increased since 2013, and were instead reduced twice, in 2017 and 2019.

In 2017, the Korean government announced an ambitious plan to restructure its electricity system through the closure of older coal plants, a gradual reduction of the reliance on nuclear power and a substantial increase in renewable generation to 20% by 2030. This entails an increase in nominal renewable capacity from 15.1 GW in 2017 to 63.6 GW in 2030.

A more decarbonised power system will need to operate differently than the current system. It will need to combine variable renewable energy resources with dispatchable generation, energy storage, demand-side technologies and more distributed energy resources integrated into the market in an efficient manner. There is a considerable way to go. Korea commenced reforms to liberalise the electricity market in 1999, including establishing the KPX, structurally separating the state-owned KEPCO's generating arm into six separate generation companies and allowing the entry of independent power producers. While these first steps are positive, progress on market design has been limited so far.

KOREC was established in 2001 to oversee the regulation of the market. It is a subsidiary of MOTIE. KOREC does not have statutory powers to set electricity and network tariffs; these are set by MOTIE. KOREC has an advisory role. In light of the transformation of the electricity sector as envisaged in the 3rd Energy Master Plan, the government should consider transferring tariff-setting authority to KOREC. KOREC should be tasked to set tariffs through a transparent, efficient process, including consultations with consumers and industry stakeholders.

The wholesale market remains tightly regulated, with little real competition and different prices being paid to different generator types depending on adjustment factors, as well as plant-specific capacity payments – both of which are determined relatively opaquely by the Generation Cost Evaluation Committee. Given the investments needed in both renewable and flexible generation, it is critical that the market settings provide the right signals. Notably, the current day-ahead approach is not suitable for efficient market operations

following the introduction of significant renewables, whose output can vary markedly, and should be supplemented with intra-day and balancing markets. The government should undertake system modelling to allow for a holistic consideration of network costs and the location of new and renewable generation sites, to ensure investments are efficient.

In the retail sector, KEPCO remains the sole retailer and retail prices continue to be regulated by MOTIE. While the introduction of time-of-use and seasonal pricing for industry and, to a lesser extent, residential sectors to encourage efficiency and reduce demand peaks is a positive step, cross subsidies remain and prices continue to be set in an opaque manner at levels that do not directly reflect the underlying cost of electricity. Further, while large energy users can, in theory, now purchase electricity directly from the KPX market, in practice none have, as they would have to pay a higher price than the price paid by KEPCO, that purchases at a coefficient adjusted price.

The government originally expected the smart meter deployment to be completed by 2020 for all customers. However, it is now expected to be delayed by several years depending on the progress of the project. For Korea, the electricity security benefits related to smart meters include measuring voltage quality, the possibility to detect power outages through the renovating of electrical devices based on precise data, and – when short-term markets are introduced – improved investment decisions.

The completion of the smart meter roll-out offers an excellent opportunity to consider opening the retail market. Smart meters would make switching supplier much easier as physical meter reading would no longer be required to implement the switch. And once administrative price setting is abolished and consumers are exposed to cost-reflective pricing by multiple suppliers, these suppliers would be able to distinguish themselves by introducing different schemes of time-of-use pricing; this would encourage more efficient electricity use. As the market further develops, more potential benefits of the smart grid can be harvested, including the development of innovative products and services and greater consumer interaction. Therefore, the government should consider introducing retail contestability once the smart meter roll-out is completed.

Security of supply

Korea has well-established electricity security of supply procedures and institutional set-up. Those procedures are regularly tested by the KPX in close collaboration with the electricity sector actors and real-time power supply information is provided to the public as part of the exercise.

To ensure long-term security of supply, every two years MOTIE publishes a Basic Plan for Long-term Electricity Demand and Supply. Ths long-term strategy covers planning of new generation installations, major transmission lines and substation facilities. The 8th plan covers the period 2017-31, and the 9th plan will be released in 2020.

The national power grid is an isolated system; there are no cross-border transmission lines. Korea's current production capacity remains sufficient to cover domestic electricity demand. Security of supply in Korea has improved thanks to the construction of new generation capacities to increase supply and the available reserve margin. On the demand side, the KPX developed a new short-term load forecast model and operates a demand-response market of 4.3 GW compared to a total installed capacity of 122.7 GW.

Network changes will be necessary to achieve the 20% renewables generation target by 2030 in order to deal with this higher share of variable production. Dispatchable generation and energy storage will become more important in providing security of supply.

Korea's transmission and distribution loss factor is 3.56%, lower than the IEA average of 6.4%. The power system performance indicators improved between 2014 and 2018. The KPX conducts emergency simulation drills four times a year with energy-related organisations. Weather-proofing of the network in Korea is an important element of security of supply, given the increasing occurrence of typhoons.

Recommendations

The government of Korea should:

- To elevate the status of the Korean Electricity Commission as the regulator of the electric power industry, its responsibilities in areas such as tariff setting and monitoring of the market should be strengthened, and the commission's staff strength should be increased in line with the additional responsibilities.
- Carry-on modelling work to prepare decisions regarding the efficient location of new and renewable generation that will minimise overall system costs.
- Reform the wholesale market design as a matter of urgency, including freedom of financial contract, to ensure this market is efficient and well-adapted to a system with significant variable renewable generation.
- Consider opening the retail sector following the completion of the smart grid in order to allow its full benefits to be captured.
- Consider extending time-of-use tariffs to residential consumers following the completion of the smart meter roll out and retail market opening to encourage efficient energy use and demand management.

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8. Natural gas

Key data

(2018)

Domestic production: 0.29 bcm (0.26 Mtoe), +34% since 2008

Net imports: 55.4 bcm (55.4 bcm imports, 0 bcm exports)

Share of gas: 16.9% of TPES, 26.5% of electricity generation, 12.3% of TFC

Gas consumption by sector: heat and power generation 53.5%, residential 19.7%, industry 15.5%, service 8.5%, transport 2.5%, other energy 0.3%

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

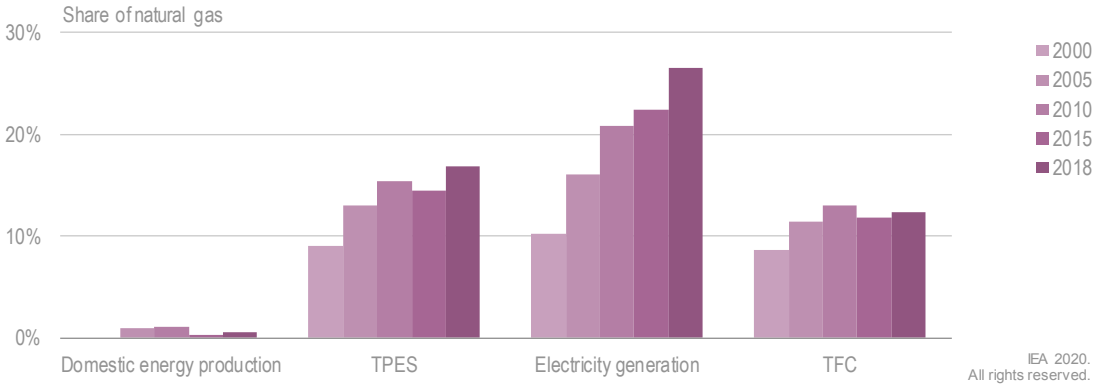
Natural gas is the third-largest energy source in Korea's total primary energy supply (TPES) after oil and coal. In 2018, it accounted for 16.9% of Korea's TPES (Figure 8.1). Korea's gas self-sufficiency is 0.6%; the rest is imported as liquefied natural gas (LNG) as the country has no cross-border pipeline connections.

Natural gas consumption has rebounded in Korea since 2017 with more stringent emission controls on coal, but is expected to decrease in 2022-23, notably in the heat and power generation sector (which is the largest consuming sector, accounting for 54% of total consumption in 2018), as new nuclear capacity is scheduled to begin operating (IEA, 2019a). Biogas represented a very small share (0.15%) of total power generation in 2018.

With a share of 12%, natural gas was the third-largest fuel in Korea's total final consumption (TFC) in 2018, after oil (52%) and electricity (25%). The share of gas in TFC has been stable over the last decade. Gas is mainly used in electricity generation and its share has increased significantly, from 18.3% in 2008 to 26.5% in 2018.

The importance of natural gas in Korea's energy supply is increasing; the challenge for the country is to ensure long-term access to a competitive gas supply from diverse sources.

Figure 8.1 Share of natural gas in different energy metrics in Korea, 2000-18



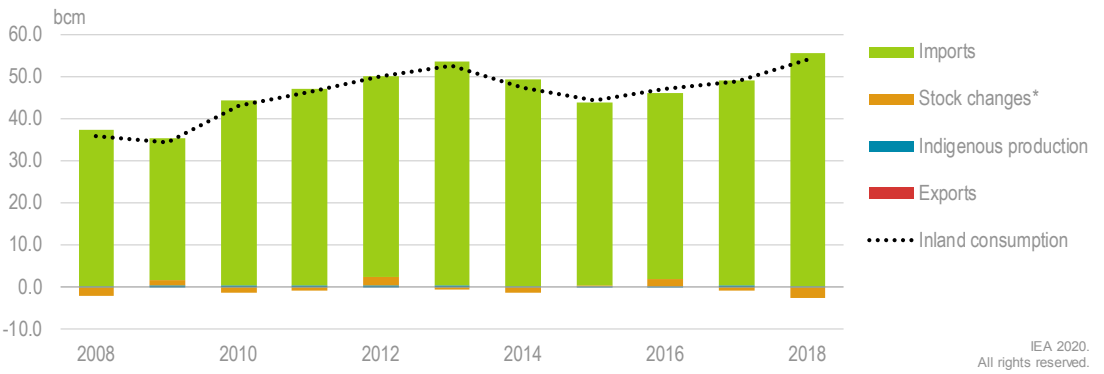
In Korea, the share of gas in electricity generation represented 26.5% in 2018.

Note: TPES = total primary energy supply. TFC = total final consumption.
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Supply and demand

With little domestic gas production and recently growing demand, Korea remains reliant on gas imports, which have increased by 49% over the last decade to reach 55 billion cubic meters (bcm) in 2018 (Figure 8.2). In that year, Korea was the third-largest importer of LNG in the world after Japan and the People's Republic of China. Korea's domestic natural gas production stood at 0.3 bcm in 2018, covering only 0.5% of total gas consumption. The production is from two offshore gas fields located off the east coast. The field operator, the Korea National Oil Corporation (KNOC)[1], plans to continue operating the fields until 2021, when the reserves will be depleted.

Figure 8.2 Overview of total supply of natural gas in Korea, 2008-18



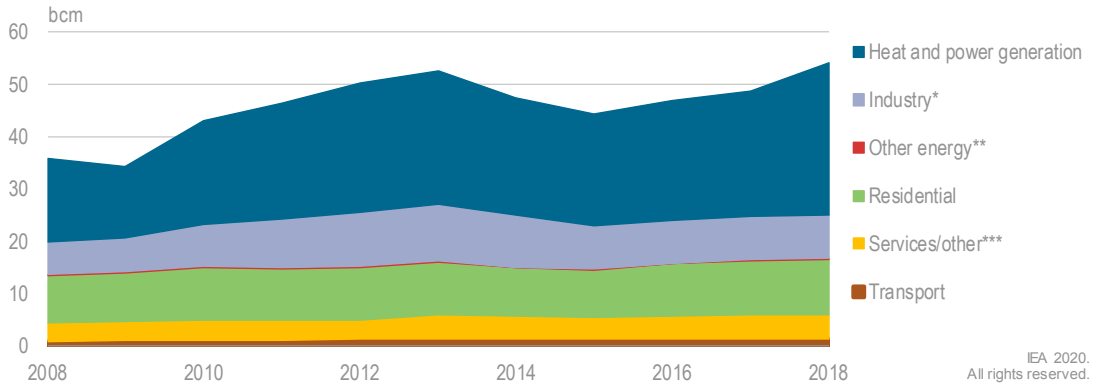
Korea has become more reliant on gas imports, which increased by 49% over the period 2008-18.

* *Stock changes* are changes in stock level of recoverable gas held on national territory; they are based on the difference between opening stock level at the first day of the year and closing stock level at the last day of the year. A stock build is shown as a negative and a stock draw as a positive number.
Source: IEA (2020b), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

[1] Annex A provides more detailed information about institutions and organisations with responsibilities for the energy sector

Demand for natural gas is largely dependent on two factors: 1) competition with coal power generation and nuclear plant availability; and 2) government policy to reduce air pollution. Since 2000, gas consumption has steadily increased. It peaked at 52.6 bcm in 2013; thereafter, consumption declined sharply (-16%) in 2014 and 2015 (Figure 8.3). Notably, gas consumption in power generation decreased in the following years, declining by 2.5% per year on average, as gas power generation was displaced by increased output from new coal-fired plants and nuclear power plants (IEA, 2019a). Nevertheless, since 2016, gas consumption in Korea has recovered and reached 54.1 bcm in 2018. This increase was mostly driven by more stringent emissions regulation for coal-fired power generation (see Chapter 10).

Figure 8.3 Natural gas consumption by sector in Korea, 2008-18



In Korea, heat and power generation accounted for 54% of total gas consumption in 2018.

* *Industry* includes non-energy consumption, such as petrochemical feedstocks.

** *Other energy* includes liquefaction (LNG) and regasification plants.

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

Source: IEA (2020b), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Heat and power generation is the largest gas-consuming sector and accounted for 54% of total consumption in 2018, followed by the residential (20%) and the industrial sectors (16%). The spike in gas demand from 2009 to 2013 was driven by higher electricity demand and economic recovery after the 2008 financial crisis. However, with global coal prices plummeting and domestic nuclear facilities coming back online after a temporary shutdown in 2012, gas demand for power generation dropped sharply from 2013 to 2015. Natural gas demand rebounded in 2016 as some nuclear plants halted operations after the Gyeongju earthquake in September 2016 (see Chapter 11). In 2018, the Ministry of Trade, Industry and Energy (MOTIE) announced that it would cap operations of seven coal-fired plants (total capacity of 820 megawatt [MW]) and five oil-fired power plants (total capacity of 280 MW) if some cities, including the capital of Seoul, were to issue an air pollution advisory (Reuters, 2018a).

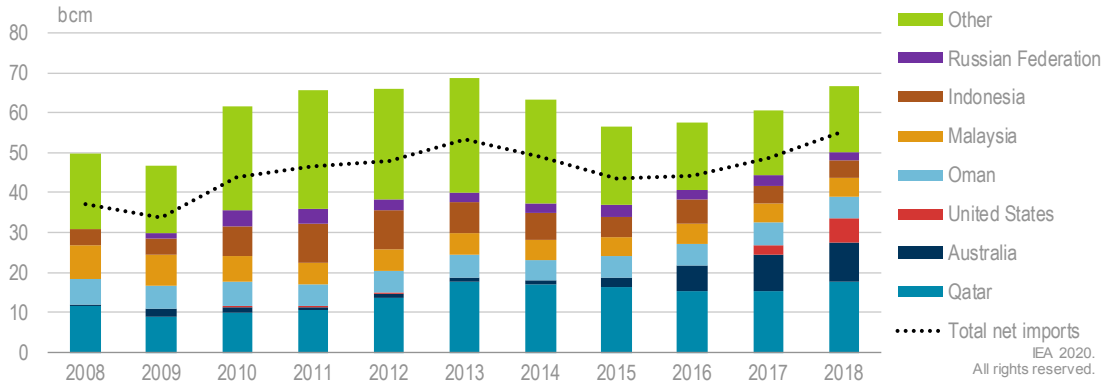
Natural gas demand in Korea has a seasonal pattern, with the highest demand occurring during the winter due to demand for heating and power generation. Winter peak demand has surpassed summer peak since 2009. Gas demand during the coldest period of the year from November to February accounts for 45% of the annual consumption. In 2018, daily gas peak demand during winter reached about 300 million cubic meters (mcm), a 36% increase compared to 2015. The total LNG storage capacity of 7.15 bcm was

theoretically able to cover approximately 24 days of winter peak gas demand in 2018.The peak output capacity (maximum rate at which gas can be withdrawn from storage) is 454 mcm/day.

Imports

The diversity of Korea's gas import sources has improved over the last decade (Figure 8.4). In 2018, Qatar remained the largest gas exporter to Korea, accounting for 32% of total imports, followed by Australia (18%), the United States (11%), Oman (10%), Malaysia (8%), Indonesia (8%) and the Russian Federation (4%). Korea does not export any natural gas. However, it is noteworthy that Korea has reloading capabilities at the privately owned Gwangyang terminal and hence in theory can re-export LNG; the first reload happened back in 2013.

Figure 8.4 Natural gas imports in Korea, 2008-18



Qatar (32%) and Australia (18%) are the main gas import sources in Korea.

Source: IEA (2020b), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Korea Gas Corporation (KOGAS), the state-owned vertically integrated gas company, purchases most of its LNG through long-term supply contracts and uses spot cargos to correct small market imbalances.

Building on the emergence of the United States as a new supply source, KOGAS has already signed memoranda of understandings (MOU) with US LNG suppliers, such as an LNG sale and purchase agreement signed in 2012 with Cheniere for a volume of 4.79 bcm per year. Korea has imported US LNG since 2016, as part of its endeavour to diversify its gas procurement sources, and became the largest importer of US LNG in 2018, followed by Mexico and Japan (US EIA, 2019).

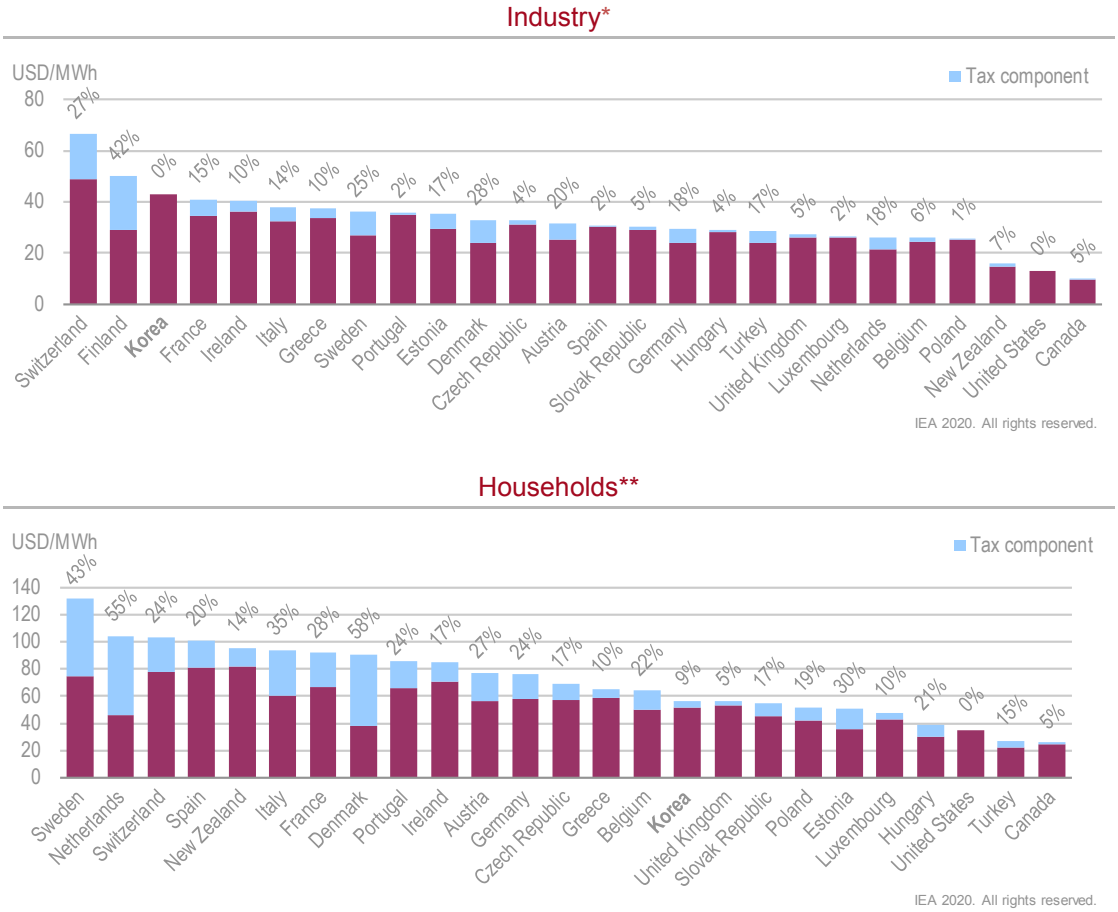
In September 2019, KOGAS also signed an agreement with BP to buy 1.58 million tonnes (mt) of US LNG for 15 years starting in 2025 (Reuters, 2019). US LNG has emerged as a flexible supply option to bolster the country's gas security. This recent development demonstrates that Korea has moved with a phased approach towards diversifying its import sources, and can continue in the future with additional LNG volumes becoming available from Australia, Qatar, the Russian Federation and the United States, amongst others.

Gas price

In 2018, Korea's gas price for industry was the third highest (43 USD/megawatt hour [MWh]) among IEA member countries (Figure 8.6). After reaching a peak at 72 USD/MWh in 2014, industrial gas prices dropped by 40% to 43 USD/MWh in 2019, in line with the drop in international gas prices.

The gas price for households is higher than that for industry in Korea. In 2019, Korean households paid 57 USD/MWh, of which 9% were taxes, which is below the median household gas price for IEA member countries. Similar to industry gas prices, residential gas prices also declined by around 33% between 2014 (86 USD/MWh) and 2018 (57 USD/MWh).

Figure 8.5 Natural gas prices in IEA member countries, 2019



Natural gas prices for industries are high compared to other IEA countries, while prices for households are below the IEA median.

* Missing data for Australia, Japan, Mexico and Norway; no data for US tax component.

** Missing data for Australia, Finland, Japan, Mexico and Norway; no data for US tax component.

Source: IEA (2020c), *Energy Prices and Taxes 2020* (database), www.iea.org/statistics.

Gas demand outlook

In the analysis of gas demand prospects in Korea, it is worth examining factors that imply an upward and downward movement; these are the potential reduction of coal consumption and the commissioning of new nuclear plants respectively.

In 2019, the Korean government announced a policy for reducing coal generation due to severe air pollution problems. One of the main policy instruments is the simultaneous increase of the coal import tax (up 28% to about USD 40/tonne) and a 75% cut in the LNG import tax (to about USD 20/tonne), enacted from 1 April 2019, alongside the setting of additional operational load limitations on coal-fired power plants. However, until 2023, seven new coal-fired power plants currently under construction (7.3 GW) will come online, while seven older plants will retire (2.8 GW) over the same period. Furthermore, early retirement of older coal-fired power plants and their conversion to natural gas will be facilitated.

On the nuclear side, the commissioning of four new nuclear reactors is scheduled from 2020 to 2023 and they are likely to reduce the share of natural gas in power generation (IEA, 2019a).

On balance, gas consumption is forecasted to decrease to approximately 50 bcm in 2022-23. However, natural gas will continue contributing to the energy transition, notably in the electricity sector, and reduce air pollution problems in large cities, with an expected rebounding of natural gas consumption in 2024 to 52 bcm.

Looking beyond gas used for power generation, the residential and commercial sectors account for roughly 30% of natural gas consumption and this level is expected to continue until 2024. The industrial sector, which accounts for 20% of natural gas consumption, is expected to maintain this share, as iron and steel and chemical/petrochemical companies continue to dominate consumption (IEA, 2019a).

Biogas and hydrogen

Biogas represented a very small share (0.15%) of total power generation in 2018. KOGAS and the Korean government have been investing in RD&D to support indigenous production of biogas as a renewable energy source. There are some demonstration projects to produce biomethane from biomass generated in cities. The production of biomethane from biomass such as organic waste, sludge, etc. was studied under the “development of biogas to biomethane and CO_2 recovery technology” RD&D project from December 2013 to May 2019. Biogas can also be used as an alternative transport fuel when compressed or liquefied; its potential should be further investigated with a dedicated cost-benefit analysis, and comprehensive risk assessments (Hengeveld et al., 2019).

Korea is one of the world leaders in hydrogen development and has ambitious targets for 2030. The country sees hydrogen as a means of managing environmental concerns from the use of diesel in the transport sector without weakening energy security (IEA, 2019b). The Hydrogen Economy Roadmap of Korea includes 2022 and 2040 targets for buses, fuel cell electric vehicles and refuelling stations, and expressed a vision to shift all commercial vehicles – including trucks and construction machinery – to run on fuel cell energy by 2035 (MOTIE, 2019). The hydrogen roadmap focuses on three key areas: 1) more hydrogen-powered vehicles on the roads; 2) more fuel cells for household and industrial use; and 3) infrastructure building for the distribution, storage and production of hydrogen (see Chapter 6).

In 2018, Korea had only 14 hydrogen fuelling stations for 2 000 hydrogen vehicles. In order to promote the development of hydrogen, the government has established a special purpose corporation called the Hydrogen Energy Network, in partnership with industrial companies such as KOGAS and Hyundai, to build 1 200 hydrogen-fuelling stations across the country.

Legal and regulatory framework of gas markets

The Korean gas market is regulated by the Urban Gas Business Act. There is no independent gas regulator in Korea. MOTIE is the central administrative body that oversees and enforces Korea's natural gas policies. It also sets wholesale prices of natural gas provided by KOGAS, as well as retail prices, and is the arbitrator for third-party access to the transmission and distribution networks (see Box 8.1 for gas sector regulations in other IEA countries). The government has gradually liberalised natural gas imports. As a result, any company that meets the requirements of the Urban Gas Business Act and the Urban Gas Business Act Presidential Decree is allowed to import natural gas for its own use.

KOGAS dominates Korea's gas sector and is also the transmission system operator (TSO). Direct importers can use the KOGAS network based on a regulated access policy, while access to the distribution pipelines is on a negotiated access basis.

Box 8.1 Gas regulatory frameworks of IEA member countries

IEA member countries have a variety of regulatory regimes for the natural gas sector.

- In Australia, the independent Australian Energy Regulator is the main regulatory body for natural gas transmission pipelines in eastern and northern Australia that are covered by regulation. It is responsible for enforcing and monitoring compliance with the National Gas Law and National Gas Rules in all jurisdictions except Western Australia, which is regulated by the state's Economic Regulation Authority.

- In the United States, where the gas industry has a high degree of private ownership with little vertical integration, the main segments of the industry are largely unbundled by Federal Energy Regulatory Commission regulations, with supply, transportation, distribution and other services provided by different companies.

- Members of the European Union are required under EU legislation to establish regulatory authorities that are fully independent from industry and the government and that can issue binding decisions and impose penalties. They must also opt for one of the following three models to separate energy supply and generation from the operation of transmission networks:

    1. **Ownership unbundling**: no supply or production company is allowed to hold a majority share or interfere in the work of a transmission system operator.

    2. **Independent transmission operator**: energy supply companies may still own and operate gas or electricity networks, but must do so through a subsidiary, and all important decisions must be taken independently of the parent company.

3. **Independent system operator**: energy supply companies may still formally own gas or electricity transmission networks, but must leave the entire operation, maintenance and investment in the grid to an independent company.

EU member states are free to opt for one of the three models. Although these models provide for different degrees of structural separation of network operation from production and supply activities, each of them is expected to be effective in removing any conflict of interest between producers, suppliers and transmission system operators. Also, it is supposed that the three models should create incentives for the necessary investments and guarantee the access of new market entrants under a transparent and efficient regulatory regime.

Other IEA member countries have not established an independent regulatory body of the gas sector. For example, in Japan, the Ministry of Economy, Trade and Industry regulates gas supply businesses and there is no independent regulator in the sector. The Gas Business Act regulates the city gas businesses, large-scale gas businesses and gas transporter-suppliers.

Sources: IEA (2019c), *Energy Policies of IEA Countries: United States 2019 Review*, https://webstore.iea.org/energy-policies-of-iea-countries-united-states-2019-review; IEA (2018), *Energy Policies of IEA Countries: Australia 2018 Review*, https://webstore.iea.org/energy-policies-of-iea-countries-australia-2018-review.

KOGAS is one of the world's largest LNG importers; it owns and operates five of Korea's seven LNG receiving terminals, which represented 91% (6.56 bcm) of the country's storage capacity (7.20 bcm in total) in 2019. Private companies, known as direct importers, own and operate the other two, smaller, LNG terminals. Local gas companies, so-called city gas companies, are responsible for the distribution of natural gas. KOGAS holds 92.7% of the gas market share for city gas and 78.7% for power generation. Direct importers have 7.3% of gas market shares for city gas and 21.3% for power generation.

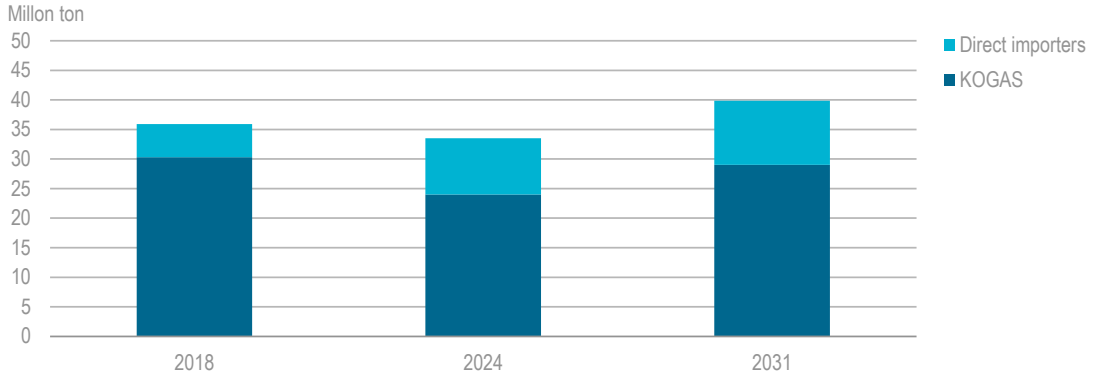
There are 11 direct importers, such as large industrial consumers or power generation companies. They can only import natural gas for their own use, for instance in their own power plants. Direct importers are not allowed to sell their gas on the domestic market, but they can re-export LNG imports by reporting it to MOTIE. Direct importers are obliged to report to MOTIE 30 days before and 30 days after the conclusion of a sale and purchase agreement. A direct importer has to secure a storage facility with a capacity equivalent to 30 days of its demand in the previous year.

As a part of the government policy to partially deregulate the country's state-controlled energy supply market, the Korean government decided that companies other than KOGAS would also be allowed to import natural gas (Shin, 2016). In 2016, MOTIE also announced that local private companies would be allowed to resell natural gas on the domestic market as of 2025, thereby bypassing state-owned KOGAS (S&P Global Platts, 2016). These initiatives are part of a major restructuring of the country's energy sector announced by the Ministry of Economy and Finance, principally targeting the move from coal to renewables, nuclear and LNG for power generation (Paik, 2018).

MOTIE publishes a Plan for Long-term Natural Gas Supply and Demand every two years. According to the 13th plan, released in April 2018 and covering the period 2018-31, the market share of direct importers is expected to increase from about 17% in 2018 to 25% in 2031 (Figure 8.6).

More recently, on 6 January 2020, MOTIE approved a new scheme for the natural gas tariffs that KOGAS charges power generators. Under the previous system, the generators all paid the same tariff, set with reference to KOGAS's average LNG import costs plus a supply margin based on operating costs. Under the new scheme, KOGAS can offer individual tariffs to power generators. This new scheme will enhance competition between KOGAS and direct importers, with unclear consequences for the market penetrations of the direct importers.

Figure 8.6 Natural gas demand outlook in Korea, 2018-31



In the long term, gas demand will increase and the share of direct importers is expected to reach 25% by 2031.

Source: Information provided by the Korean government.

Korea has 33 distribution companies and each one has monopoly control over the gas retail market in its region. Distribution pipelines are owned and operated by the city gas companies. They purchase wholesale natural gas from KOGAS at government-set prices, then sell gas to the end users at prices set by local governments, which should be approved by the mayor or governor.

Infrastructure

Pipelines

Korea has no cross-border gas pipelines. Its gas transmission network has a total length of 4 854 kilometers (km), is bidirectional and is owned and operated by KOGAS. The gas pipeline network connects the LNG receiving terminals, the storage tanks and large consuming areas. Most of the gas pipelines were constructed to form a circle-shaped network to improve security of supply (see Figure 8.7). The diameters of the gas pipelines are mostly 30 inches, 26 inches and 20 inches, and the maximum allowable pressure of the gas pipelines is 6.86 megapascal (MPa); the operation pressure is 5-6 MPa.

Expansion of the pipeline network

To supply natural gas to new power plants, KOGAS intends to expand its transmission network to 5 383 km by 2023. With 10 ongoing projects, the total length of pipeline added will be 343 km. The transmission pipelines are bidirectional, which is highly important in the event of a disruption to direct flows where they are needed.

Investments in the gas distribution network are planned to increase the interconnection between the different provinces, with the aim to add 270 km of pipeline by 2023. Five projects are ongoing to connect isolated pipelines to the main network.

Security of supply can also be improved by establishing cross-border interconnections. KOGAS and Russian Gazprom signed an MOU in 2008 to investigate the construction of a 1 200 km pipeline via the Democratic People's Republic of Korea (DPRK) to supply Russian gas to Korea. The idea of constructing this pipeline to deliver Russian gas via the DPRK had been suspended since 2013, as the international community strengthened sanctions against the DPRK, but was revived in June 2018 as geopolitical tensions decreased after the summit between the United States and the DPRK. KOGAS and Gazprom are currently conducting a joint study on the possibility of a pipeline project. However, progress for this project is subject to geopolitical developments and there is no given timeline for completion.

LNG terminals and storage

The LNG terminals are spread across the country to enhance security of supply. KOGAS operates 5 facilities (Pyongtaek, Incheon, Tongyeong, Samcheok and Jeju) with a total of 74 LNG storage tanks and a storage capacity of 6.56 bcm in 2019.

Private companies own two smaller LNG import terminals. POSCO and K-Power jointly own the Gwangyang regasification facility located on the southern coast. This was the first privately owned regasification terminal, which came online in 2005. There are four storage tanks with a total capacity of 0.30 bcm. The second privately owned regasification facility is located at Boryeong, in the north-western region, and was brought online at the beginning of 2017 by a joint venture between GS Energy and SK E&S. There are three storage tanks with a total capacity of 0.34 bcm (Table 8.1). Korea's LNG import facilities had an utilisation rate of 33% in 2018, up from 30% in 2017 (IGU, 2019).

Table 8.1 Gas storage capacity in Korea, 2019

Storage site (owner)	Storage capacity (bcm)	Number of storage tanks
Pyeongtaek (KOGAS)	1.91	23
Incheon (KOGAS)	1.63	20
Tongyeong (KOGAS)	1.49	17
Samcheock (KOGAS)	1.48	12
Jeju (KOGAS)	0.05	2
Gwangyang (POSCO Energy)	0.30	4
Boryeong (GS Energy and SK E&S)	0.34	3
Country total	7.20	81

Source: Information provided by the Korean government.

Figure 8.7 Map of natural gas infrastructure in Korea

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

The two privately owned terminals have smaller storage capacities compared to the terminals owned by KOGAS, which represent 92% of the country's storage capacity. Because of KOGAS's monopoly on gas supply and high LNG resale prices, private industries have an incentive to invest in regasification capacity and purchase LNG on the global market to lower their costs.

Expansion projects

In August 2019, KOGAS completed the construction of an LNG import terminal with two 45 000-kilolitre tanks on Jeju Island that received its first cargo at the end of September 2019. The facility was to start providing power to Jeju residents in March 2020.

There is also a new KOGAS LNG terminal under construction in Chungcheongnam (located about 100 km south of Seoul). The plan is to construct ten LNG storage tanks with a capacity of 2 bcm by 2031.

There are no underground gas storage facilities in Korea and gas storage is only in LNG tanks. The Korean government previously looked into the possibility of having an underground storage facility in a gas field off the east coast, but the project was stopped due to its low economic feasibility. Since the domestic gas fields will be depleted by 2021, there might be another opportunity to study the feasibility of underground storage. Line pack storage, which refers to gas stored in pipelines, is used in Korea as a temporary storage option, but the capacity is small compared to the LNG storage capacity.

Korea is also seeking to diversify gas supplies and have flexible LNG contracts that do not include restrictive destination clauses or take-or-pay terms to ensure gas supply security (Reuters, 2018b) (see also Box 8.2). Since gas market conditions are evolving quickly, it is also important for the government to explore strategic options for domestic gas storage and in the East Asian region, in collaboration with other regional LNG consumers. One example of such co-operation is the MOU signed in 2017 between KOGAS, Japan's JERA and the China National Offshore Oil Corp. Under the MOU, the three companies will discuss possible co-operation in joint procurement of LNG, joint participation in upstream projects and co-operation in LNG shipping and storage (S&P Global Platts, 2017).

Box 8.2 Transformation of the international LNG market and its impact on Korea

Due to a number of factors, such as geographical distance from producing countries, destination clauses (restricting the right to resell gas) and immature spot markets, gas has been more expensive in Korea and Japan than in Europe or North America (the so-called "Asia Premium"). Between 2010 and 2013, Asian LNG prices for North East Asia increased from USD 10-12 per mmbtu (million British thermal units) to USD 15-18 per mmbtu. Low Henry Hub prices,* combined with soaring LNG prices in Asia, have generated considerable interest among Asian buyers to acquire cheaper gas and explore alternatives to the current pricing structures, which is basically linked to crude oil import prices (Nakano, 2014).

In Korea, destination clauses have prevented buyers from seeking trading opportunities. However, the boost in LNG trade is also altering pricing and trade mechanisms in Asia. Changes in the international gas market, including the slump in gas prices and the growing volumes of uncontracted LNG, have shifted bargaining power to the demand side and

support the gradual liberalisation of the Korean gas market. Korean LNG importers are taking advantage of the current LNG market to conclude new LNG contracts with lower prices and more flexibility. KOGAS is pursuing more flexible destination clauses, along with a new price indexation in its LNG supply contracts. Korea's Fair Trade Commission began investigating the legality of destination clauses in LNG contracts in August 2017. Research was still ongoing at the time of writing, and no definite deadline had been announced.

* Henry Hub refers to the central delivery location located near the Louisiana's Gulf Coast, connecting several intrastate and interstate pipelines. Henry Hub has been used as a pricing reference for the future since April 1990 (CME Group, 2019).

Gas emergency response

Emergency response measures

In 2016, the Korean government promulgated the enforcement ordinance on Article 10-10 of the Urban Gas Business Act, which enforced the obligation on gas storage in practice. Outside of commercial stocks, KOGAS is required to hold two types of stocks: mandatory inventory volume and preventive reserve volume. The volumes are respectively 7 days and 3 days based on the average daily domestic sales volume of the last 24 months. If the gas stock level is forecasted to stay below the natural gas inventory for seven or more consecutive days over the next 60 days, emergency measures will be put in place to balance supply and demand. KOGAS leads the emergency assessment to determine the stage of the emergency alert system and reports to MOTIE, which is in charge of the alert announcement.

The emergency response plan envisages gradual response measures depending on the severity of the crisis. To address a light-level disruption, KOGAS can secure additional gas volume by purchasing spot cargoes, undertake cargo swaps or cargo rescheduling, although it could take several days to bring an additional cargo to the market. Demand restraint measures are part of the emergency response measures to address a severe gas supply disruption. However, there is no volumetric assessment of savings from the gas demand restraint measures available.

In January 2011, the Korean government implemented gas supply and demand stabilisation measures, as there was a shortfall in gas supply due to an extraordinarily cold winter. The government set up the Supply and Demand Task Force and implemented gas emergency response actions, such as securing additional volumes of gas and undertaking cargo rescheduling. Planning of power and city gas demand control was also in place. There has not been any other supply disruption since 2011, not even during the relatively cold winters and warm summers in 2017 and 2018.

Fuel switching and storage

As part of its 13th Plan for Long-term Natural Gas Supply and Demand published in April 2018, the Korean government has introduced fuel-switching contracts to encourage the use of alternative fuels instead of natural gas during a gas supply disruption. Currently, city gas companies are pursuing fuel-switching contracts for industries with dual boiler facilities. Despite this positive improvement, the government has not seen significant growth of fuel-switching capacity in the short term. KOGAS performs regular surveys to

check inventories of alternative fuels at power generation companies. Co-generation[2] power plants are required to include a mandatory provision to secure alternative fuels in their gas procurement contracts.

Due to the importance of storage to address supply disruptions, the Korean government established safety management measures for oil and gas storage facilities in February 2019. These measures will strengthen the management system, improve security systems, streamline onsite response systems and promote safety investment.

Network resilience

In Korea, the nationwide gas network is composed of multiple regional networks. Those gas networks have a circular shape and a high level of redundancy in the gas transmission lines to improve security of supply. This network shape is very specific and suitable for the country since there are no cross-border pipelines that might be used in case of a disruption.

The "N-1" standard relates to the ability of a country to satisfy gas demand if there is a failure of the single largest unit/piece of gas infrastructure. For Korea, the critical pieces of infrastructure are the LNG import terminals, which are the entry points for gas imports into the country.

The Incheon and the Pyoengtaek LNG terminals provide gas to the Seoul Metropolitan Area. To reduce the risk of a supply disruption, KOGAS has been working on splitting its LNG terminals into smaller plants by implementing physical separations. Adding independent compressor units is a common practice in the global gas industry to lower the risk of failure and prevent a spread effect in the event of failure. The split aims to better contain the impacts of operation failure when it takes place in facility-clustered areas. Discussions are still ongoing to implement this concept in other LNG terminals

Assessment

Korea is dependent on imports to satisfy almost all of its natural gas demand, as domestic production covers less than 1% of its total consumption. All gas is imported as LNG as Korea does not have any international gas interconnections. In the current oversupplied LNG market, suppliers are willing to contract with big economies including Korea. In the long run, however, the challenge would be to continue to ensure long-term access to competitively priced gas from a diversity of supply sources in a context of sharply rising consumption in fast-growing Asian economies. This is critical particularly from a perspective of enhancing the natural gas security of the country.

Diversification of Korea's gas import sources has accelerated over the last decade, as Korea reduced its long time dependency on gas from the Middle East. The 13th Long-term Natural Gas Supply and Demand Plan highlights the importance of further diversification of import sources and the expansion of natural gas storage. In this context, KOGAS has signed non-binding MOUs with several US LNG suppliers.

State-owned KOGAS dominates the gas sector in Korea and has quasi-monopoly power in many parts of the gas market, such as high market shares for city gas, power generation and ownership of the pipeline networks. The company also has a large control over the country's LNG market as the largest LNG importer and as the owner of two-thirds of the

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

LNG receiving terminals in the country (representing 92% of the country's import capacity in 2018). The government should deregulate the market to make the domestic gas market more competitive, flexible and transparent.

To improve market functioning, a number of political and institutional steps are required to create a competitive gas market in Korea, building upon the advantages of the significant physical infrastructure already in place. Based on the general government policy to partially deregulate the country's energy supply market, Korea has gradually expanded direct imports in recent years, but could further improve market functioning by unbundling transmission and distribution from the other elements of the gas value chain.

Direct importers have access to KOGAS's gas transmission network via regulated third-party access. A gas regulator that is independent from the central administrative body can play a critical role in objective evaluation and assessment of non-discriminatory third-party access to the gas pipeline network.

Furthermore, the distribution market could also benefit from further deregulation and restructuring. Direct importers in Korea import natural gas under strict regulations: imports can only be for their own use and domestic sales are not allowed.

The IEA welcomes the government's policy to expand the transmission network and to increase the interconnection capacity between different provinces. In addition, international interconnections could also improve the security of the gas supply. The 2008 MOU between KOGAS and Gazprom to investigate supply of Russian gas to Korea through a pipeline is an interesting initiative. However, progress under the MOU is subject to geopolitical developments.

Biogas and biomethane represented only a minuscule share of power generation in 2018. However, the government is keen to increase the share of biogas as part of its efforts to green gas. Utilisation of biomethane in the gas network requires the government to examine its feasibility, focusing on the institutional, financial and technical challenges. This should be further supported by a comprehensive risk assessment. A study to assess the feasibility of biogas and hydrogen injection into the current gas network would be a key step for scaling up development in this area. The IEA congratulates Korea for issuing the Hydrogen Economy Roadmap that sets specific targets for 2022 and 2040.

Under Korea's gas emergency response plan, gradual response measures are being implemented related to the severity of the crisis. While securing additional gas volumes by purchasing spot cargoes and strengthening storage obligations is a fundamental tool of the emergency response plan, demand restraint measures can help address larger gas supply shortages. The government should conduct robust studies on the tangible savings from the demand restraint measures to maximise the economic benefits of them.

Fuel switching can be an important element of emergency response measures. The contribution of fuel switching in Korea is currently limited to only 4% of total gas consumption. The government should investigate the switching potential in all gas-consuming sectors.

Recommendations

The government of Korea should:

- ☐ Promote greater competition in the domestic gas market by:
  - Establishing a roadmap, with necessary steps, to unbundle transmission from the rest of the value chain: imports, storage, and wholesale and retail.
  - Setting up an independent gas market regulator to monitor, among other activities, non-discriminatory third-party access to the gas pipeline network and LNG facilities.
  - Facilitating the emergence of a wholesale market with trading options for direct importers.
- ☐ Maintain efforts to diversify gas import sources in order to reduce dependency on LNG imports from the Middle East.
- ☐ Study with the relevant stakeholders the technical and economic feasibility to inject biomethane or hydrogen into the gas network, and the possible use of biomethane and hydrogen as a fuel for shipping.

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9. Oil

Key data (2018)

Domestic production of condensates: 0.5 kb/d

Domestic production of additives/oxygenates: 15.4 kb/d

Net imports of crude oil: 3 051 kb/d, +30% since 2008

Domestic oil products production: 3 443 kb/d

Net export of oil products: 532 kb/d, +83% since 2008

Share of oil: 39.1% of TPES and 2.2% of electricity generation

Consumption by sector: 110.4 Mtoe* (industry 50.3%, transport 30.8%, other energy 8.7%, services 4.0%, residential 3.2%, power and heat generation 3.1%)

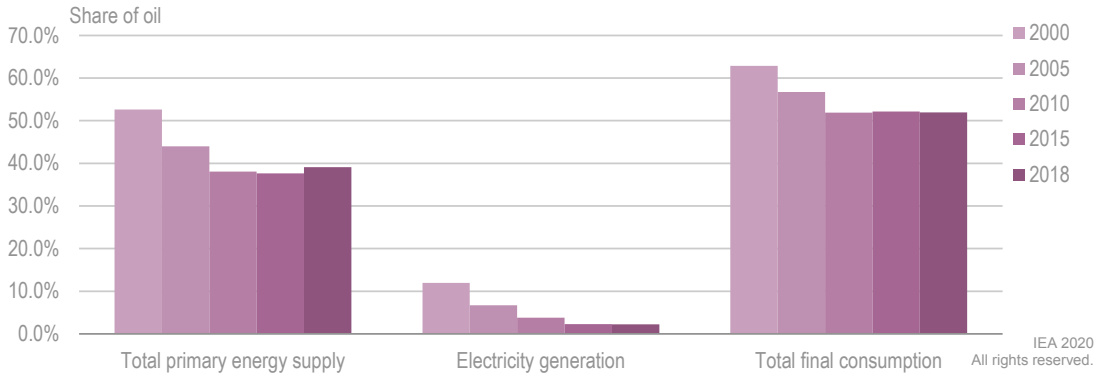
* Demand data are presented in energy units (Mtoe) for comparisons over different fuels and sectors.

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

Oil was the largest source of energy supply in Korea at 39% of total primary energy supply (TPES) in 2018. From 2008 to 2018, total oil supply increased by 23%, but its share in TPES was relatively stable due to the overall growth of TPES, from 227 million tonnes of oil equivalent (Mtoe) to 282 Mtoe over the same period. The share of oil in total final consumption (TFC) has also been stable over the last decade and was 52% in 2018. Oil use for electricity generation has been continuously declining (Figure 9.1).

Figure 9.1 Korean share of oil in different energy metrics, 2000-18



In Korea, oil in electricity generation has been phased out over the last decades.

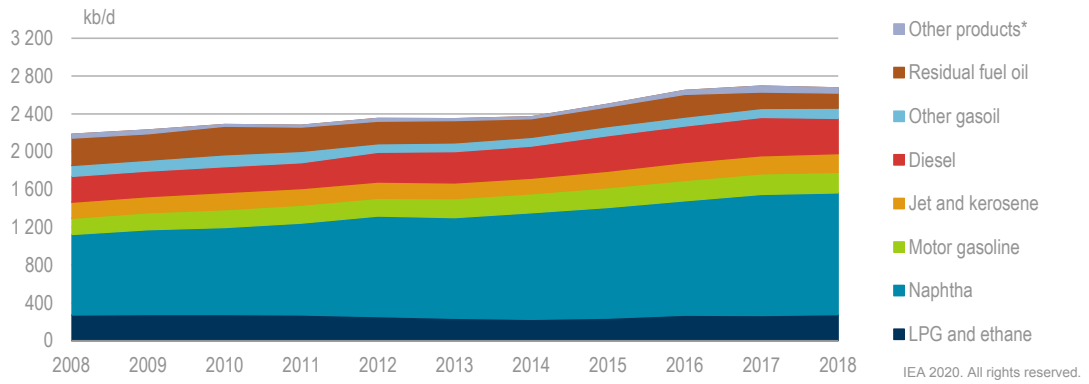
Source: IEA (2020a), *IEA World Energy Statistics and Balances*, www.iea.org/statistics/.

Supply and demand

Domestic oil production is very limited in Korea and covers less than 1% of oil demand; domestic oil production does not contribute to security of supply in the country. In 2018, Korea produced 0.5 thousand barrels per day (kb/d) of condensates and 15.4 kb/d of additives and oxygenates. Crude oil production is concentrated in two offshore fields, which started production in 2004 and 2016. Oil is produced as associated oil since those fields mainly produce gas.

Korea's oil demand stood at 2 562.1 kb/d in 2018 with a growth of 22% over the last decade (Figure 9.2). Only residual fuel oil and other gasoil consumption for heating have declined (35% and 6% respectively); consumption of other fuels has increased. Demand for naphtha has increased by 51% since 2008 and accounted for almost half of the total oil consumption at 1 287.5 kb/d in 2018. Naphtha is in high demand as the main feedstock for Korea's growing petrochemical industry. Industry is Korea's largest oil-consuming sector, accounting for half of total oil consumption in 2018, followed by transport (30.8%), minor shares of residential (3%), commercial (4%), and heat and power generation (3%). Diesel consumption (372 kb/d) is much higher than gasoline consumption (218 kb/d) and this has been a steady trend since 2000. In 2018, jet/kerosene consumption stood at 198 kb/d and residual fuel oil consumption was 215 kb/d.

Figure 9.2 Oil demand by product, 2008-18



In Korea, demand for naphtha accounted for almost half of the total oil consumption in 2018.

* Crude oil, "other" natural gas liquids, synthetic fuels, orimulsion, hydrogen, synthetic crude, refinery gas, aviation gasoline, naphtha type jet fuel, white spirit, industrial spirit, lubricants, bitumen, paraffin waxes, petroleum coke, tar, sulphur, aromatics and olefins.

Note: LPG = liquefied petroleum gas.

Source: IEA (2020b), Oil Information 2020 (database), www.iea.org/statistics.

Biofuels

Oil fuels account for 94% of transport sector demand, followed by small shares of natural gas, biofuels and electricity (natural gas 3%, biofuels 1% and electricity 1%).

Korea introduced a renewable fuel standard (RFS) on 30 July 2013, but its implementation was postponed until 31 July 2015. The RFS mandates oil refiners and oil importers to blend a certain amount of new and renewable fuels into their transportation fuels (although exporters are not mandated to blend motor diesel with biodiesel). The RFS is currently set

at a 3.0% biodiesel blending mandate into diesel. There is no blending obligation for other fuels and the government does not have plans to increase the blending mandate for diesel nor to set other blending requirements.

The biodiesel for blending is domestically produced and sizeable amounts of feed stocks are supplied by domestic producers; however, 60% of feedstocks are imported. Korea is pursuing the use of liquid biofuels such as bio-heavy oil for power generation. At present, large power generation companies have an obligation to generate a certain share of their electricity with renewable energy. In case of power generation by bio-heavy oil, renewable energy certificates will be issued (see Chapter 5).

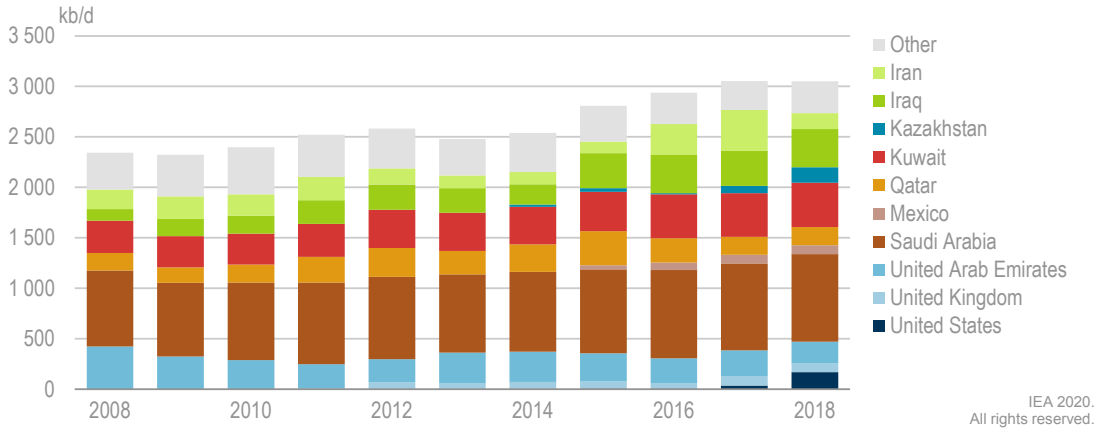
Korea is working on technology development and deployment to produce biodiesel from microalgae. In this regard, a small-scale pilot unit (2 tonnes per year) is running near the Yeongheung power plant of the Korea South-East Power Corporation. Despite ongoing efforts, the use of liquid biofuels remains marginal in the country.

Trade

Domestic oil production (condensates) covers less than 1% of total oil demand, the rest is imported. In 2018, Korea's net imports of crude oil totalled 3 051 kb/d and net exports of oil products were 532 kb/d. Over the last decade, net imports of crude have grown by 30% and net exports of oil products by 83%.

Korea has been largely dependent on crude oil imports from the Middle East, with Saudi Arabia (28%), Kuwait (14%) and Iraq (12%) being the largest import countries (Figure 9.3). By region, 70% of total crude oil imports came from Middle Eastern countries in 2018, which is the lowest percentage since 2003. The government's efforts to diversify import sources has resulted in introducing new players into Korea's oil trade in the last five years. In 2018, Kazakhstan and the United States accounted for 5% each of total crude oil imports, followed by Mexico and the United Kingdom with 3% each.

Figure 9.3 Crude oil net imports by country, 2008-18



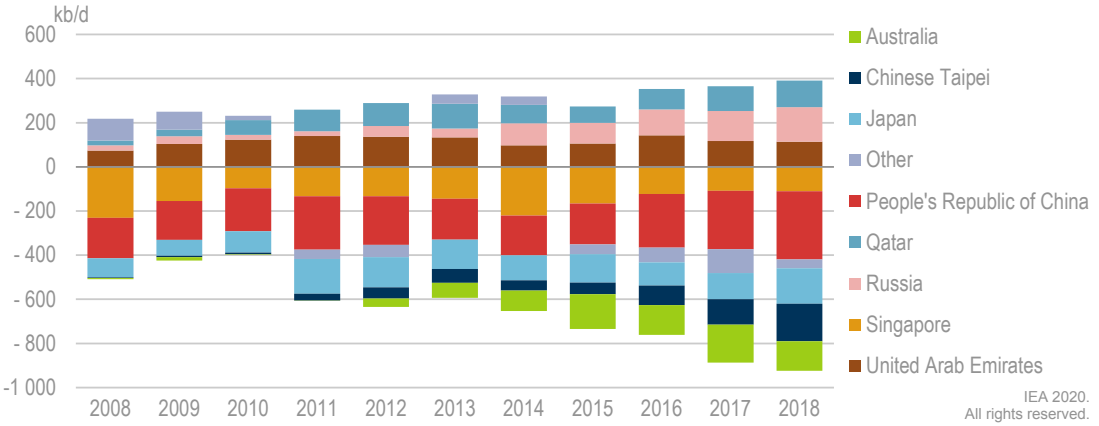
In Korea, efforts to diversify import sources resulted in introducing new trading partners such as Kazakhstan and the United States.

Source: IEA (2020b), *Oil Information 2020* (database), www.iea.org/statistics.

Korean refiners have become a large export market for US crude since 2018, despite the fact that shipping time from the US is twice as long as from the Middle East. Korean refiners have traditionally favoured Middle Eastern sources due to their relative proximity, large volumes of production and the security of long-term contracts. However, Korean buyers are becoming used to operating in a more flexible way and are capable of using different crude grades. US light crudes are expected to become a key feedstock for Korea's growing refining activity in the coming years.

As one of the major oil refiners in the world, Korea is a net exporter of oil products (Figure 9.4). The country mainly exports diesel, jet fuel and gasoline, whose domestic refinery outputs are in excess compared to domestic demands. Asian-Pacific countries, such as Australia, the People's Republic of China, Japan and Singapore are the biggest importers of Korea's oil products.

Figure 9.4 Oil products trade by country, 2008-18



Oil product exports have increased in Korea in absolute volume and diversified in destinations.

Notes: Net trade = import – export. Imports are shown as positive numbers and exports as negative numbers.
Source: IEA (2020b), *Oil Information 2020* (database), www.iea.org/statistics.

Between 2008 and 2018, oil product imports, mainly naphtha and LPG, increased to supply the growing petrochemical industry in Korea. The United States is the largest exporter of oil products to Korea, accounting for one-fifth of Korea's total oil products imports, followed by Russia (16%), and Qatar and the United Arab Emirates (each 13%). In particular, imports from the United States and Russia have grown by 2 300% and 600% respectively over the last decade.

Oil market structure

The Korea National Oil Corporation (KNOC)[1] dominates the Korean upstream oil market and is responsible for domestic and overseas exploration, and the development and production of oil and natural gas. As of the end of 2018, KNOC's domestic oil and gas reserves totalled 6.0 million barrels of oil equivalent.

[1] Annex A provides detailed information on institutions and organisations with responsibilities related to the energy sector.

KNOC is the only domestic crude oil/condensate producer in Korea and the company is currently exploring offshore oil and gas fields, located about 60 km south-east of Ulsan, with the Australian company Woodside. Through acquisitions of overseas companies and investments with major international and national oil companies, KNOC produced 126 kb/d of oil at its overseas operations in 2018. It has made extensive investments in overseas oil exploration and production projects. As of September 2019, it had 31 ongoing projects, including 22 production, 2 development and 7 exploration projects in Canada, Colombia, Iraq, Kazakhstan, the United Kingdom, the United States and the Bolivarian Republic of Venezuela.

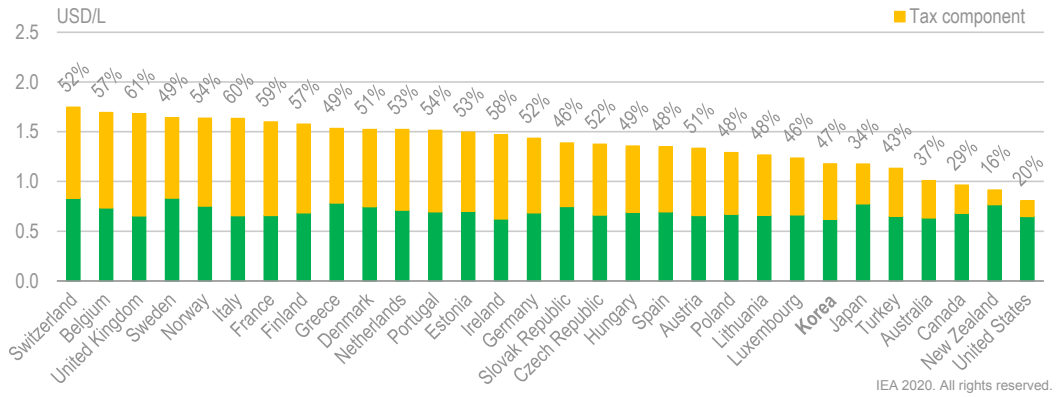
Daehan Oil Pipeline Corporation (DOPCO) is the only oil pipeline company in Korea. DOPCO is a private company jointly owned by SK Innovation, GS Caltex, S-OIL, Hyundai, Korean Air and the Korean government. It is responsible for operating the nationwide oil pipeline system consisting of six oil product pipelines connecting refineries with major cities, airports, military bases and oil stockholding facilities. Nevertheless, there are no restrictions for market players that are not DOPCO shareholders to utilise the DOPCO pipelines on a commercial basis.

Korea's domestic downstream market is dominated by four private companies: SK Innovation, GS Caltex, Hyundai Oilbank and S-OIL. Korea's oil downstream market was largely liberalised in the 1990s by removing import and export restrictions on crude and oil products. Prices have been fully liberalised since 1997. In July 2019, there were 11 507 service stations in Korea compared to 13 213 in 2011. There are technically no barriers for new competitors to enter the Korean retail market, but it remains dominated by the four domestic refiners, as 87% of the service stations carry their brand name. Since 2011, petroleum product prices are disclosed on line (www.opinet.co.kr) to improve the transparency of pricing and promote competition. The prices of petroleum products are determined in line with international oil prices.

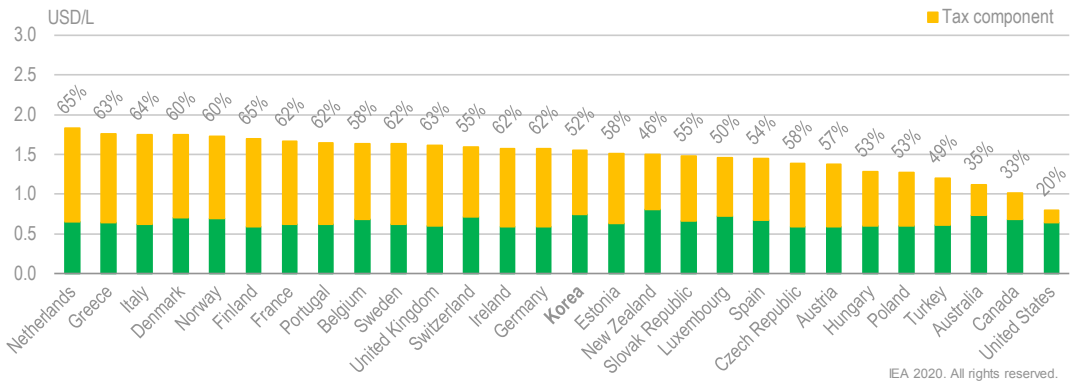
In Korea, prices for diesel, gasoline and fuel oil are relatively low in comparison to other IEA member countries (Figure 9.5). The price of automotive diesel was ranked seventh lowest, at USD 1.18 per litre (L), 47% of which was tax. The price of gasoline was ranked 14th lowest at USD 1.55/L, 52% of which was tax. For diesel and gasoline, the fuel tax consists of three different components: 71% for the transportation, energy and environment tax; 18% for the driving tax; and 11% for the education tax. Fuels sold for use in motor vehicles are also subject to a 10% value-added tax, which is levied equally on all products. The price of fuel oil was globally ranked seventh lowest at USD 0.83/L, 17% of which was tax.

Figure 9.5 Oil fuel prices in IEA member countries, Q4 2019

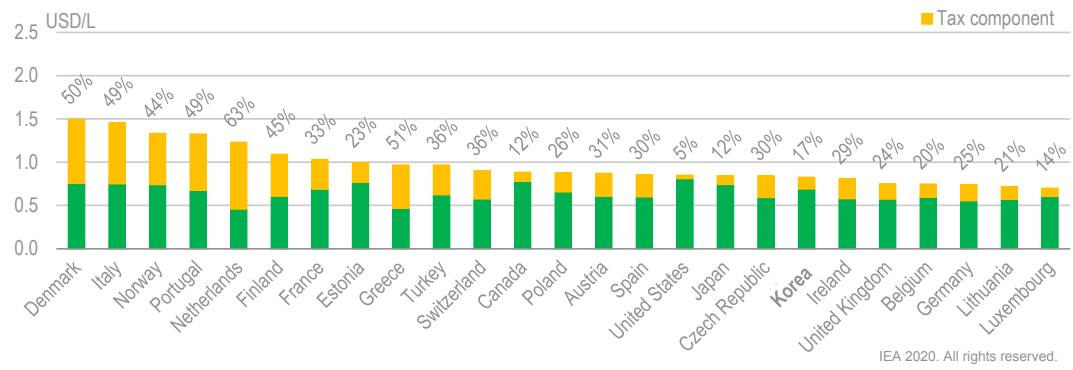
Automotive diesel fuel



Premium unleaded gasoline (95 RON)



Light fuel oil



In Korea, prices for diesel, gasoline and fuel oil are relatively low in comparison to other IEA member countries.

Note: Automobile diesel fuel data are not available for Mexico; premium unleaded gasoline for Japan and Mexico; light fuel oil for Australia, Hungary, Mexico, New Zealand, the Slovak Republic and Sweden.

Source: IEA (2020c), *Energy Prices and Taxes – Fourth Quarter 2019* (database), www.iea.org/statistics.

Infrastructure

Refineries

Domestic refineries had a combined distillation capacity of around 3.5 million barrels per day (mb/d) in 2019 and Korea was ranked as the fifth-largest country in the world for refining capacity in 2018 (BP, 2019). There are four major private sector refining companies: SK Innovation, GS Caltex, Hyundai Oilbank and S-OIL (Saudi Aramco is the controlling shareholder of S-OIL).

SK Innovation has two refineries, one in Ulsan (840 kb/d) and another in Incheon (375 kb/d). The other refineries are held by GS Caltex in Yeosu (800 kb/d), by S-OIL in Onsan (669 kb/d) and by Hyundai Oilbank in Daesan (520 kb/d). The high degree of sophistication of Korean refineries results in high capacity utilisation. In addition to those five large refineries, the refining companies operate processing units that convert condensates into products such as naphtha for petrochemical use. The most recent project is a 130 kb/d splitter, commissioned in late 2016 by Hyundai Oilbank and its joint venture partner Lotte Chemical. The total condensate splitter capacity in Korea was 519 kb/d in 2019 (Table 9.1).

Table 9.1 Crude oil and condensate refinery capacity in Korea, 2019

Refinery/ petrochemical sites	Crude distillation unit (kb/d)	Condensate processing unit (kb/d)	Total capacity (kb/d)
SK Energy Ulsan	840	–	840
SK Energy Incheon	275	100	375
GS Caltex	800	–	800
S-OIL	580	89	669
Hyundai Oilbank	520	–	520
Hyundai Chemical	–	130	130
Hanwha TOTAL	–	200	200
Total capacity in Korea (kb/d)	3 015	519	3 534

Source: Information provided by the Korean government.

In 2018, Korea's total refining outputs stood at 3 443 kb/d, higher than domestic demand at 2 562 kb/d. Korea is a net exporter of oil products, but due to a mismatch between refinery outputs and domestic demand, notably for naphtha and LPG, Korea has been relying more on imports for those products in the last decade.

Most of Korea's condensate imports were from Qatar and the Islamic Republic of Iran, before US sanctions were imposed on Iran in November 2018. Korea was granted a six-month waiver from the United States to buy oil from Iran. The waiver expired in April 2019. As of October 2019, Korea was the second-biggest purchaser of US crude.

Oil products demand growth in Asia has improved Korea's exports over the past two years. Korea is expected to remain a leading refiner in Asia, with significant exports to other Asian-Pacific countries to meet regional demand. There are six projects to increase petrochemical capacity in the country; those units will use naphtha or liquid petroleum gases as feedstocks (Table 9.2).

Table 9.2 Petrochemical capacity addition in Korea, March 2020

Company	Location	Feedstock	Capacity (kb/d)	Scheduled year
LG Chemical	Daesan	Naphtha	18	2019
Hanwha TOTAL Petrochemicals	Daesan	Propane	25	2019
Hyundai Chemical	Daesan	Naphtha/LPG	61	2022
LG Chemical	Yeosu	Naphtha	64	2021
GS Caltex	Yeosu	Naphtha/LPG	51	2021
Yeochun NCC	Yeosu	Naphtha	27	2020

Sources: IEA (2020d), *Oil 2020: Analysis and Forecast to 2025*, https://doi.org/10.1787/cf9397c0-en; data provided by the Korean government.

There are also ongoing projects to upgrade refinery outputs to respond to new demand for low-sulphur fuels for shipping; this demand is driven by the implementation of the IMO 2020 regulation, effective as of 1 January 2020 (Box 9.1).

Box 9.1 Implementation of International Maritime Organization (IMO) 2020 regulation

The main type of "bunker" oil for ships used to be heavy fuel oil, derived as a residue from crude oil distillation. Crude oil contains sulphur which, following combustion in the engine, ends up in ship emissions. Sulphur oxides (SO_x) are known to be harmful to human health, causing respiratory disease. Limiting those emissions from ships will improve air quality.

From January 2020 onwards, ships have to use marine fuels with a sulphur content below 0.5%, a significant reduction from the previous 3.5% limit. This regulation is known as IMO 2020. While the global average sulphur content in bunker fuel in 2019 was close to 2.5%, this still implies a fivefold decrease in the effective sulphur dioxide emissions ceiling applied to ships sailing in international waters.

Ship owners are free to choose how to comply with the regulation. They can continue to use high-sulphur fuel oil in conjunction with exhaust gas cleaning systems, known as scrubbers. Alternatively, they can burn oil products that contain less sulphur, e.g. marine gasoil, or a new product with a maximum sulphur level of 0.5% called very low sulphur fuel oil. Finally, they can use liquefied natural gas as a fuel, but this solution is only suitable for new vessels, since this system cannot be installed on existing vessels. Vessels sailing in the emission control areas of north-west Europe and North America will continue to be subject to a 0.1% sulphur limit.

Korea is a major exporter of oil products to Australia, China, Japan and Singapore. To produce cleaner burning fuels and respond to the implementation of the IMO 2020 regulation, there are ongoing projects to upgrade the refinery processing units in Korea.

Hyundai Oilbank has recently completed a new unit, with an 80 kb/d processing capacity, to produce feedstocks for the low sulphur fuel oil. SK Innovation will build a heavy upgrader at its Ulsan site in 2020, which will produce 34 kb/d of 0.5% sulphur fuel oil and 6 kb/d of gasoil; the project could cost USD 0.5-1 billion.

Sources: IEA (2020c), *Oil 2020: Analysis and Forecast to 2025*, https://doi.org/10.1787/cf9397c0-en; Hellenic Shipping News (2019), *Refinery News Roundup: Major Autumn Work Underway*, https://www.hellenicshippingnews.com/refinery-news-roundup-major-autumn-works-underway-in-japan; IMO (2020), *Sulphur 2020 – Cutting Sulphur Oxide Emissions*, www.imo.org/en/mediacentre/hottopics/pages/sulphur-2020.aspx.

Pipelines

Korea does not have any cross-border oil pipelines. Domestically, Korea does not have any crude oil pipeline; it relies exclusively on tanker shipments for crude oil supply.

In Korea, domestic transport of petroleum products is mainly undertaken by oil tankers, rail tank cars, tank trucks and pipelines. Among these modes of transport, tank trucks play the most important role in transporting petroleum products from oil terminals to service stations and large consumers, such as factories. Coastal oil tankers are also used, since Korea is surrounded by ocean on three sides and all the domestic oil refineries are located near the coast (Figure 9.6).

DOPCO operates six domestic oil product pipelines, with a total length of 1 105 km. DOPCO did a resilience assessment on its network, carrying out physical tests, including tests on supply and demand imbalances and restoration of flows after a power failure. The results obtained were satisfactory and this assessment concluded that the domestic oil pipeline network is resilient to disruptions.

Figure 9.6 Korea's oil infrastructure

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

Ports

The oil port infrastructure is well developed in Korea; there are 23 sea ports and 3 container terminals. Five oil port terminals are owned by KNOC and five are located at the refineries and owned by the major domestic refiners. These oil ports are used for crude oil and oil product imports and exports. For crude oil import, the total capacity is around 14.4 mb/d; for imports and exports of oil products, the total trade capacity of these terminals is close to 9 mb/d.

Oil storage

To protect against oil supply disruptions and price fluctuations, Korea holds strategic and commercial oil reserves of both crude oil and petroleum products. In 2019, Korea had a combined storage capacity of over 378.4 mb, which was composed of 135.2 mb of government facilities for government stocks and international joint oil stockpiling, and over 243.2 mb of commercial facilities for industry operation and obligated industry stocks. There are nine government storage facilities.

In terms of stock composition, the government storage capacity for crude oil is 116.7 mb and 18.5 mb for products. As set out in the government's 4th Stockpiling Plan, covering the period from 2014 to 2025, Korea is slightly increasing government storage capacity, from 146 mb in 2013 to 147 mb by 2025.

As part of Korea's efforts to become a major liquids storage and trading hub in North East Asia, KNOC, through joint ventures with other companies, has been operating commercial terminals for crude oil and petroleum products at Yeosu in the south-western region of the country. It came online in 2013, with 8.2 mb of capacity. In addition, KNOC has a plan for building commercial terminal at Ulsan, located in the south-eastern region of Korea.

Oil emergency response

Emergency response policy

Diversification of import sources of crude oil, further build-up of government stocks and expansion of storage capacity have been the main pillars in the oil security policy of Korea. The use of emergency oil stocks is central to Korea's emergency response policy. The release of government stocks held by KNOC is seen as the most effective emergency response measure against both global and domestic oil supply disruptions, which could be followed by lowering the stockholding obligation on industry.

The 2017 Petroleum and Petroleum Substitute Fuel Business Act and the 2016 Energy Act provide the legal framework for Korea's oil emergency response. The Petroleum and Petroleum Substitute Fuel Business Act has two levels of emergency, depending on the nature of the disruption. In addition to these two levels of emergencies, it also allows for specific measures at times when (potential) oil price increases threaten Korea's public order and national economy (Article 23(1)). According to Article 8(3) of the Energy Act, the Minister of Trade, Industry and Energy shall be prepared to use energy reserves at times of emergency.

Stockholding regime and emergency reserves

The 1979 Korea Petroleum Corporation Act established KNOC to manage the storage of the Korean government's emergency stocks. KNOC is also the operating agency for government and industry stocks.

Korea meets its stockholding obligation to the IEA by holding government stocks and by placing a minimum stockholding obligation on industry. By the end of 2019, Korea was well above the IEA obligation to hold at least 90 days based on net imports of oil; total oil stocks stood at 185 days.

Industry stocks

Korea obliges crude oil refiners to hold 40 days of stocks based on the average daily sales in the domestic market. Stock amounts should be equal to the monthly average of the past three months. LPG importers and by-products distributors (i.e. petrochemical companies which produce ethylene or propylene from naphtha or LPG) are required to hold respectively 15 and 30 days of stocks based on the same metric. Obligatory industry stocks may be commingled with operational and commercial stocks. In order to verify that each refiner meets its obligated target per month, KNOC checks stock levels every month. Companies have some flexibility: the actual stocks in a given month can be lower than what they are supposed to hold, but then in other months the stocks have to be higher, so that the three-month average matches the obligation.

Naphtha, a feedstock for the petrochemical industry, is the petroleum product with the highest consumption in Korea. The IEA methodology does not take into account naphtha imports to calculate the 90 days of net imports. The Korean government does not have separate naphtha stocks, but it takes into consideration high naphtha consumption when setting oil stockpiling targets. As of end-November 2019, industry stocks stood at 112 mb, or 52% of total emergency stocks in the country.

Government stocks

The Korean government holds government stocks based on days of net imports. As of end-November 2019, Korea held 96 mb of government stocks, equal to 48% of total emergency stocks in the country. All stocks (industry and government) are physical reserves stored on the national territory. There is no ticket market in Korea; the country has no bilateral agreements to hold stocks on behalf of other IEA countries. As set out in the government's 4th Stockpiling Plan, Korea is expanding the government stocks to increase stocks of refined products. The Korean government plans to increase government stocks from 96 mb to 101 mb by 2025.

To finance the government stocks, the government allocates a budget for the purchase of oil stocks and the construction and maintenance of stockholding facilities to KNOC. The Korean government does not provide financial support for building compulsory industry stocks. All refiners and importers must self-fund the operational costs of meeting emergency requirements. These costs are passed on to consumers.

International Joint Stockpile

Since 1999, KNOC has been engaged in an International Joint Stockpile programme which allows foreign oil companies to lease storage space in KNOC's oil storage facilities. There are seven companies under this programme; KNOC rents out storage space for a fee, and

the programme gives Korea priority rights to purchase those barrels in the case of an oil emergency. Stocks held under this scheme are not counted towards Korea's 90-day IEA obligation. In January 2020, there were 1.1 mb of crude oil, 0.2 mb of diesel and 1.4 mb of jet kerosene held in KNOC's storage facilities under the International Joint Stockpile programme. Releasing of stocks held under the programme is considered to be a supplementary emergency response measure.

Contributions to IEA collective actions

Korea joined the IEA as a member in 2002. It participated in the IEA collective action in 2005 after Hurricane Katrina with a stock draw of 2 916 kb. During the IEA collective action in 2011 for the Libyan crisis, Korea also met its obligation by suppling government emergency oil stocks to the four refiners, for a total amount of 3 465 kb.

There has not been any major supply disruption in Korea since the last IEA emergency response review in December 2015.

Assessment

Korea's energy system is highly dependent on imported fossil fuels, with very limited domestic oil production. Oil is the largest energy source in TPES and in TFC. Korea's oil demand has continued to grow and naphtha accounts for half of total oil demand. By region, 70% of total crude oil imports came from the Middle East in 2018. Additional countries have contributed to diversify crude oil import sources and decreased the reliance on crude imports from the Middle East. In 2018, Kazakhstan and the United States accounted for 5% each of total crude oil imports.

Oil products imports continue to increase, with recent growth driven by naphtha and light petroleum gas imports, to supply the growing petrochemical industry in Korea. The United States is the largest exporter of oil products to Korea, accounting for one-fifth of the total oil product imports of Korea, followed by Russia, Qatar and the United Arab Emirates. Korea is a net exporter of oil products, with Australia, China, Japan and Singapore being its largest markets.

Korea has four major private sector refining companies. Total combined refining capacity is around 3.5 mb/d and the refineries are spread out over the country. Due to gaps between refinery outputs and domestic demand, notably for naphtha and LPG, Korea has been relying on imports for those products.

Korea does not have any cross-border oil pipelines and relies exclusively on tanker shipments for crude oil supply. There are five oil port terminals owned by government-owned KNOC; five additional oil port terminals are located at the refineries and are owned by the domestic refiners. There is extensive storage capacity in Korea due to the fact that the country relies fully on oil imports.

Korea's oil market was largely liberalised in the 1990s when the import and export restrictions on crude and oil products were eliminated. Prices have been fully liberalised since 1997 and the Korean oil market is not subject to price regulation. There are technically no barriers for new competitors to enter the Korean retail market. Nevertheless, it remains influenced by the four domestic refiners, as 87% of the service stations carry their brand name.

The Renewable Fuel Standard mandates oil refiners and oil importers to blend 3% biodiesel into diesel. There is no increase planned in the blending target. The blending component is domestically produced; 60% of feedstocks have to be imported, as there are limited feedstocks available in Korea. There is no blending obligation for gasoline or LPG to be used in vehicles. The use of liquid biofuels remains marginal in Korea.

Korea is pursuing the use of liquid biofuels such as bio-heavy oil in the power generation sector. Large power generation companies are required to use a specified share of renewable fuel to generate electricity. Renewable energy certificates are issued for the use of bio-heavy oil for power generation.

Oil emergency response

KNOC is the operating agency for government stocks and oversees industry stockholding. The Korean government holds public stocks based on days of net imports and places an obligation on industry. Korea is compliant with the IEA 90-day stockholding obligation. As of end-November 2019, it held 185 days of net imports, equivalent to 184 mb. Fifty-two per cent of total stocks are held by industry and the remaining 48% are government stocks. All emergency reserves are stored within the national territory in nine government facilities and major commercial storage sites, spread across the country.

The Korean government plans to increase the storage capacity of KNOC and the level of government stocks from 96 mb to 101 mb by 2025 and also increase the share of refined products.

The use of emergency oil stocks is central to Korea's emergency response policy. Among emergency oil stocks in Korea, the release of government stocks held by KNOC is seen as the most effective emergency response measure for oil supply disruptions.

Recommendations

The government of Korea should:

- Maintain efforts for diversification of oil import sources in order to reduce the high dependency on imports from the Middle East.
- Conduct constructive and open dialogue with the refining industry to ensure refinery outputs meet future oil product demand and product specifications.
- In line with the policy objectives set in the 3rd Energy Master Plan of 2019, re-evaluate the tax and charge structures of each transportation fuel and explore the possibility to establish a rational relative pricing system, through social consensus, based on an objective evaluation of the external costs of each transport fuel.
- Study the possibility to expand blending of biofuels, with appropriate consideration for domestic market circumstances and stakeholders' positions.

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10. Coal

Key data
(2018)

Production: 1.1 Mt/0.5 Mtoe (100% hard coal), -59% since 2008

Net imports: 135.6 Mt/79.8 Mtoe

Share of coal: 28.5% of TPES and 44.1% of electricity generation

Consumption by sector: 80.5 Mtoe (heat and power generation 71.3%, other energy 17.5%, industry 10.7%, residential 0.6%)

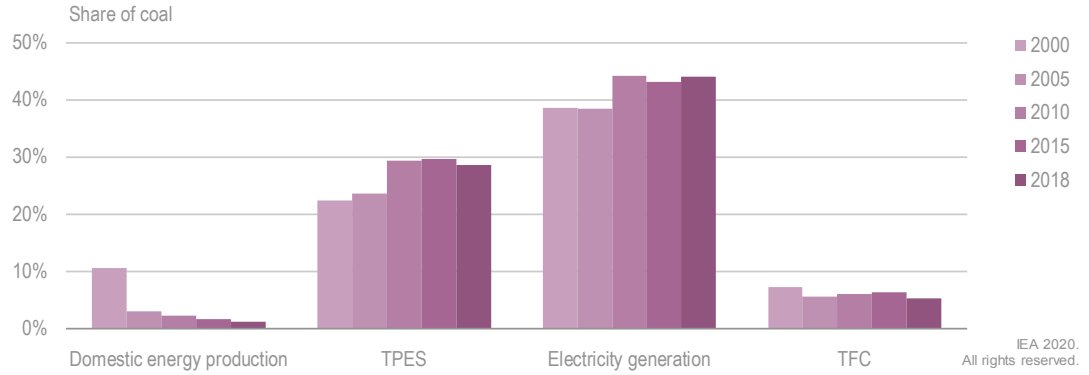
Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

Overview

Coal has kept a stable share of Korea's total primary energy supply (TPES) at around 30%. Its share of electricity generation increased to around 44% between 2008 and 2018 (Figure 10.1). Korea is the world's fourth-largest coal importer as coal demand has significantly increased over several decades, mainly to support the country's rapidly growing electricity consumption. Since 2011, coal demand has remained quite stable, but coal remains an important part of Korea's energy system. Domestic coal production has continuously declined and nearly all of Korea's coal supply is imported. The remaining domestic coal production is mostly used for heating in rural areas, and the production is subsidised by the government.

Concerns about greenhouse gas (GHG) emissions and local air pollution have led the government to plan for reducing coal in power generation, but no precise timeline for a complete coal phase-out has been set. Korea has an Emissions Trading System (ETS) in place, but has not yet provided enough incentives to cut coal power in any significant way. Stronger incentives will be needed to reduce emissions from coal-fired power generation in line with Korea's nationally determined contribution to the Paris Agreement (see Chapter 3). Another option for GHG mitigation is to use carbon capture, utilisation and storage (CCUS) technology on coal-fired power plants.

Figure 10.1 Share of coal in different energy supplies, 2000-18



Korea uses coal mainly for electricity generation, where it accounts for around 44%. The growing demand is nearly all met by imports, as domestic production is very small.

Note: TPES = total primary energy supply. TFC = total final consumption.

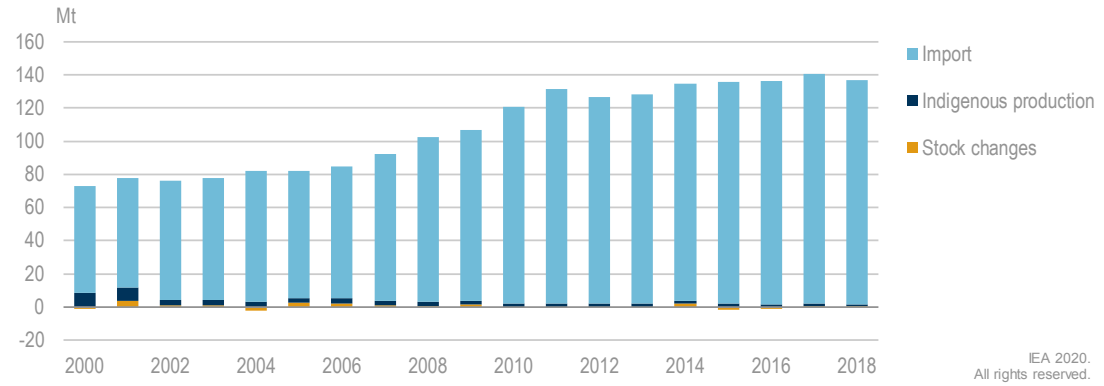
Source: IEA (2020a), "World energy balances", *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Supply and demand

Korea's coal consumption has nearly doubled since 2000, from 72 million tonnes (Mt) to 137 Mt in 2018. The most rapid increase happened during the period 2006-11, when consumption grew by 54% in five years. Since then, coal demand has increased at a slower rate, with a 5% growth from 2011 to 2018. While coal demand has increased, domestic coal production has decreased by 86% since 2000 from already low levels, leading to a substantial growth in coal imports. In 2018, domestic production covered less than 1% of total coal demand; the rest was imported (Figure 10.2).

Korea is the world's fourth-largest coal importer (IEA, 2020b). Steam coal used in power generation accounted for 71% of coal imports in 2018 and the rest was coking coal used mainly in coke ovens and blast furnaces of industries. By weight, 36% of total coal imports came from Australia in 2018, followed by 28% from Indonesia, 17% from Russia and 7% from Canada (Figure 10.3).

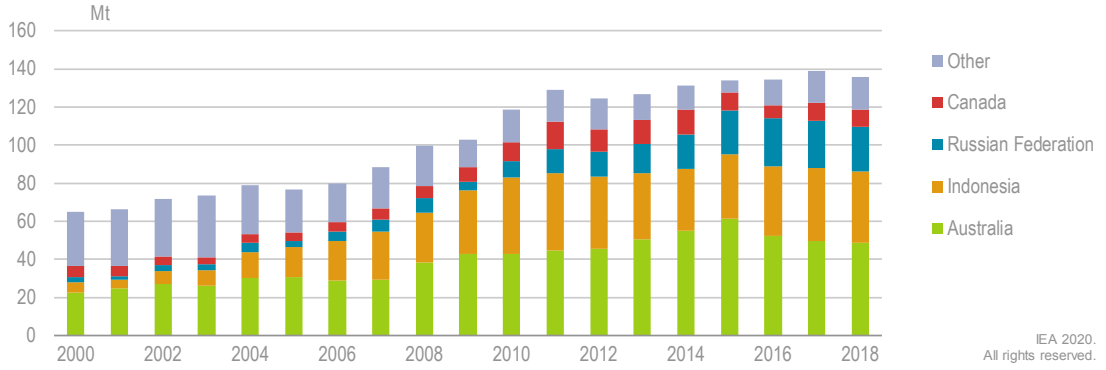
Figure 10.2 Coal supply by source, 2000-18



Korea's coal supply has increased by 33% in the last decade through increased imports, as domestic production covers less than 1% of total demand.

Source: IEA (2020b), "World energy statistics", *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Figure 10.3 Coal imports by country, 2000-18



Korea's coal imports have doubled since the early 2000s, but stabilised around 135 Mt in recent years; just four countries supplied 88% of total coal imports in 2018.

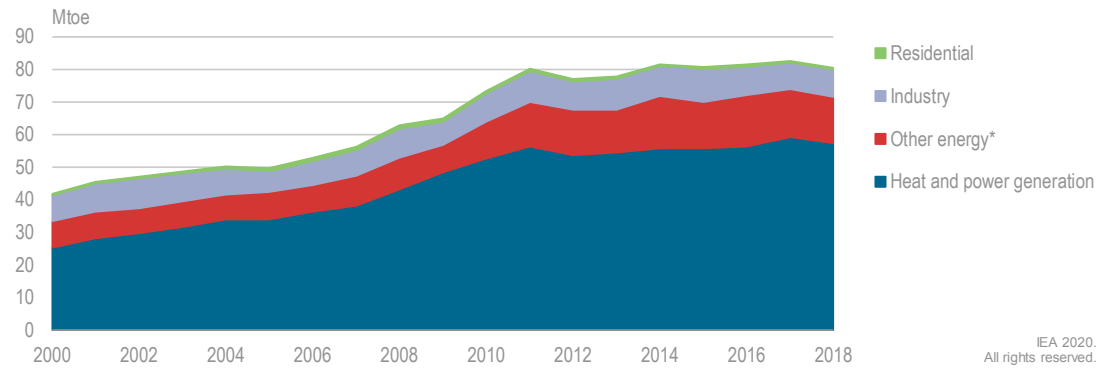
Note: Includes both hard coal and brown coal.

Source: IEA (2020b), "World energy statistics", *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Power and heat generation is the largest coal-consuming sector in Korea and has driven most of the overall increase in coal demand. In 2018, power and heat generation accounted for 71% of total coal consumption (in energy terms). Coal power is the largest source of electricity in Korea, with a 44% share of total electricity generation in 2018. Coal consumption in power generation grew noticeably during the period 2006-11, with a 55% increase in three years. Since then, coal consumption in power generation has increased slowly, with a 2% growth between 2011 and 2018.

Another 18% of coal use was in blast furnaces and coke ovens (registered in IEA data under "other energy sector"), mostly in connection to steel manufacturing. A further 11% was used directly by industry plus a small share in the residential sector (Figure 10.4).

Figure 10.4 Coal consumption by sector, 2000-18



Coal consumption has been quite stable, at around 80 Mtoe since 2011. Power and heat generation accounted for 71% of the total coal consumption in 2018.

* Other energy includes coke ovens and blast furnaces and the manufacture of patent fuels.

Source: IEA (2020a), "World energy balances", IEA World Energy Statistics and Balances (database), www.iea.org/statistics.

Industry structure/coal mining policy

In 2018, Korea had five active coal mines, which employed 3 000 people and produced 1.2 Mt per year. This compares to 347 mines and 24 Mt production in 1988. Korea Coal Cooperation,[1] the state-owned company, owns three of the five coal mines and accounted for 55% of production in 2018. The other two mines are operated by two private companies; Kyungdong Corporation produced 540 000 tonnes and Taebaek Mining Corporation produced just 10 000 tonnes in 2018. In 2016, the last year for which data are available, Korea still had just under 200 Mt of proven reserves, of which just over 50% were located in the five mines that are still operating.

All of the mined coal is anthracite, which is used to produce briquettes for heating (81%) and for power generation (19%) and is only consumed domestically. In addition to domestic coal production, Korea Coal Cooperation operates overseas mines in Australia, China, Indonesia, Mongolia and Russia.

Coal subsidies

Korea subsidises domestically produced anthracite coal and coal briquettes to support uneconomic mining. It is one of the two IEA member countries (with Mexico) left on the OECD coal subsidy list in 2018 (IEA, 2020c). Since 1989, Korea has been implementing a coal industry rationalisation policy which aims to gradually reduce coal mining and subsidies for coal mining. No final exit date has been set by the government due to the relative importance of coal mining in isolated and economically depressed rural communities that offer little alternative employment opportunities (Park, 2018). Demand for locally produced coal decreased by 73.2% from 2008 to 2018.

In 2018, total coal subsidies were USD 24 million, of which one-third was paid to the power generator for using domestic coal. In the same year, the subsidy paid for coal briquettes amounted to around 15% of the production costs, or KRW 19 100 per tonne for household consumption, for USD 16 million in total (MOTIE, 2019a).

Since 2016, Korea has been increasing the prices of domestically produced coal by 8% annually and that of coal briquettes by 19.6% annually to reduce subsidies. It is unclear whether the government will phase-out subsidies for local coal entirely as, beyond the consequences for local employment, domestically produced coal briquettes are used for heating by the poor (see section below).

The role of coal in Korea's energy transition

Korea is committed to reduce its dependence on coal in the longer term as part of the country's nationally determined contributionss under the 2015 Paris Agreement to reduce GHG by 57% in 2030 against a business as usual scenario, and in alignment with the 3rd Energy Master Plan (EMP) and the 8th Basic Plan for Long-term Electricity Supply and Demand (BPLE). Coal accounted for over 50% of Korea's energy-related carbon dioxide (CO_2) emissions in 2018 (see Chapter 3).

Local air pollution and fine dust are raising concerns in Korea and, in particular, in the greater Seoul area, which is home to 25 million people, or 48% of Korea's total population.

[1] Annex A provides detailed information on institutions and organisations with responsibilities related to the energy sector.

In 2017, Korea was exposed to the highest fine particulate matter (PM2.5) among OECD member countries, with 25.14 micrograms per cubic metre (μg/m^3) (OECD, 2020).

The number of days with a high concentration of PM2.5 increased from 92 in 2016 to 146 in 2017 before reaching 158 days in 2018 (MOTIE, 2019a). However, the number of days with a concentration above 36 μg/m^3 of PM2.5, that is considered unhealthy, decreased from 62 in 2016 to 60 in 2017 before reaching 59 days in 2018 (MOTIE, 2019b).

In September 2017, the Korean government announced a comprehensive plan to reduce domestic fine dust emissions by more than 30% and to reduce the number of days with fine dust exceeding 50 μg/m^3 by 70%, or from 258 days in 2016 to 78 days in 2022. These standards were further tightened in March 2018, reducing the daily average to 35 μg/m^3 (Yoon and Cho, 2018).

The 3rd EMP therefore targets a drastic reduction in coal power generation to tackle the problem that has quickly increased in importance on the national policy agenda. Nevertheless, the role of coal in Korea's final primary energy supply to 2040 is not expected to see any meaningful reduction and would remain at almost the same level (in Mtoe) as in 2017, after having peaked in 2030. However, the share of coal in total primary energy supply would reduce from 35% in 2017 to 30% in 2040 (MOTIE, 2019a).

Coal use in the power sector

The 8th BPLE sets out the role of coal-fired generation for the period 2017-31 (MOTIE, 2017). At the end of 2018, Korea's total coal-fired generation comprised 60 plants with a capacity of almost 37 gigawatts (GW) out of a total of 119 GW installed capacity.

The share of coal in the electricity mix was 44% in 2018, equivalent to 258 terawatt hours (TWh); a marginal decline compared to 2017, when the share was 45%, equivalent to 259 TWh. Korea commissioned over 6 GW of new coal-fired capacity from December 2016 to December 2017, while only 525 megawatts (MW) were decommissioned. The incoming capacity displaced more expensive oil-fired generation (which dropped by 10 TWh), and also compensated for a sharp reduction in nuclear output (down by 14 TWh), largely due to the decommissioning of the 587 MW Kori No. 1 reactor (see Chapter 11).

Despite a political commitment in the 3rd EMP to drastically reduce coal use in the power sector, the phase-out of coal-fired generation will only be gradual, starting with the closure of 10 plants between 2017 and 2025 that have been operating for over 30 years and that account for 3 345 MW. In addition to the three plants closed in 2017, three more with a total capacity of 1 320 MW were closed in 2019 while two plants with a total capacity of 500 MW will close in 2021 and the remaining two plants with 500 MW capacity each in 2022. Four existing and two coal-fired plants currently under construction with a combined capacity of 4 060 MW will be converted to liquefied natural gas (LNG) between 2020 and 2030.

Overall, installed capacity of coal-fired generation is expected to rise to 42 GW in 2022 before reducing slightly to 39.9 GW in 2030. However, while total installed coal-fired generation capacity is projected to be higher in 2030 than in 2017, the share of coal capacity falls from 32% in 2017 to 29.5% in 2022 and then to 22% in 2030 due to the overall strong increase in installed capacity in Korea (MOTIE, 2017).

Beyond the reduction of the share of coal-fired capacity in the overall electricity generation capacity mix, the 8th BPLE and the 3rd EMP include several other policy actions to advance the phase-out of coal-fired generation and to support a shift to cleaner fuels in the power sector.

Reducing the cost gap between coal- and LNG-fired generation

Korea's 3rd EMP stresses the importance to reflect the external environmental costs related to the use of coal and LNG for power generation and the need to regularly adjust taxes and charges on those fuels accordingly. The Korean government is employing three distinct measures to gradually reduce the cost gap between coal- and LNG-fired power generation to make coal burning financially less attractive.

First, since 2019, the external environmental cost of using LNG and coal are explicitly included when determining the dispatch priority in the electricity market. While LNG is charged at KRW 43/kilogramme (kg), the environmental charge for bituminous coal is KRW 85/kg to take into account the cost of local air pollutants.

Second, since 2015, Korea's ETS price is already reflected in coal and LNG prices (see Chapter 3). When factoring in the ETS price, the average cost of one kilowatthour (kWh) produced from coal-fired generation increased by KRW 19.2 and by KRW 8.2 for a kWh produced from LNG (MOTIE, 2017). While CO_2 prices have risen steadily over the last few years, reaching about USD 20 per tonne, the incumbent power producers still receive 97% of their allowances for free – casting doubts about the effectiveness of the ETS system to support the shift from coal to renewable sources of energy. However, with changes planned for the third phase of the Korean ETS system in 2021, the ETS price is expected to increase further (MOTIE, 2019a).

Third are changes in the total and relative taxation of coal and LNG. The selective excise tax on bituminous coal was introduced in 2014 and has since increased annually. The last tax adjustment took place on 1 April 2018 and prices increased by KRW 6/kg. A further increase of KRW 10/kg took place in April 2019.

Moreover, in 2019, the government introduced a tax adjustment that lowered the tax burden on LNG while increasing the tax burden on bituminous coal. With effect from 1 April 2019, the coal import tax was increased by 28% to about USD 40/tonne, while the LNG import tax was cut by 75% to about USD 20/tonne.

Finally, since 2018, the government is authorised to regularly revise the levelised cost of electricity generated by each fuel type by taking into account the social and environmental impacts. This levelised cost is taken into consideration when determining the remuneration paid to the generating assets (see Chapter 7).

Temporary closure of coal-fired generation

In June 2017, the government requested eight old coal-fired plants (2.8 GW) to temporarily halt operations for one month over local air pollution concerns. Since 2018, the Clean Air Conservation Act empowers mayors and governors to authorise the (temporary) closure of coal-fired plants when air pollution and fine dust exceed the legal limits set by the government. Local governments made use of their new authority to stop

the same plants again in 2018, albeit again only for a short period of time, with a limited impact on overall coal-fired generation.

Moreover, since 2018, coal-fired power plants that are older than 30 years must stop operation between March and June of each year. While this has impacted less than 10 units so far (5 units with a total capacity of 2.5 GW in 2018 and 4 units with a total capacity of 2 GW in 2019), the number of affected plants will increase to 22 in 2030, with a capacity of 10.7 GW (MOTIE, 2017).

In November 2019, the Ministry of Trade, Industry and Energy (MOTIE) for the first time ordered the closure of at least 8 (4 GW) and up to 15 coal-fired power plants with a total capacity of 7.9 GW from 1 December 2019 to 29 February 2020 to address concerns about air pollution, despite the fact that electricity demand peaks in winter. The remaining plants were ordered to reduce their output to 80% of their capacity over the same period. Together these measures were expected to reduce fine dust from coal-fired generation by up to 44% compared to the previous winter (AFP, 2019; Regan, 2019).

As a result of the various policy measures put in place by the government, the share of coal-fired generation is expected to fall from 45% in 2017 to 36% in 2030 (MOTIE, 2017).

Despite the political commitment to the transition of the energy sector to a cleaner one, Korea has not set a specific date for the final nationwide phase-out of coal-fired generation. However, South Chungcheong Province, where over half of Korea's coal-fired generation capacity is located, joined the Powering Past Coal Alliance in October 2018, with the pledge of phasing out coal by 2050 (PPCA, 2018). South Chungcheong is responsible for about one-quarter of Korea's GHG (Chen, 2018). It is the largest coal consumer in the Powering Past Coal Alliance, larger than any of the member countries. Moreover, South Chungcheong is also the first jurisdiction in Asia to join the alliance.

The governor of the province pledged to employ all policy and regulatory instruments at the province's disposal to pursue the closure of coal-fired power generation plants. This pledge could possibly have strong implications for the future of coal in the Korean power sector, as local governments are now permitted to shut down coal-fired generation in times of extraordinary air pollution levels and may follow the example set by South Chungcheong Province. Already in 2017, South Chungcheong Province enforced the strongest air pollution standards in Korea to curb emissions from coal plants located in its jurisdiction.

Public funding for overseas coal-fired generation power plants and coal mining

Korea provided about USD 1.1 billion of public funds annually in 2016 and 2017 to finance coal-related activities in other countries (Chen and Gencsu, 2019). The funds were mainly channelled to overseas coal mining operations and construction of coal-fired generation plants by Korea Coal Corporation, the Korea Resources Cooperation and Korea Electric Power Corporation (KEPCO). In 2015, Korean companies were involved in over 50 overseas bituminous-coal projects (OECD, 2019).

Korea's international investment in coal mining and coal-fired generation is increasingly attracting the attention of international environmental groups that campaign for divestments from coal-related assets. According to press reports, some international

investors have already divested their shares in KEPCO, the publicly listed but majority government-owned Korean integrated power sector utility, while other international investors are contemplating doing the same (FT, 2020).

Moreover, the Korean Teachers Pension System and the Government Employees Pension System have committed to end or reduce their investment in companies involved in activities related to coal supply or coal-fired generation (IEA, 2019).

Coal use beyond the power sector

As in other countries, phasing-out coal use in industry is more challenging due to the lack of affordable alternative technologies. However, Korea is a world leader in innovation and sees the energy transition as key leverage for the Fourth Industrial Revolution. Korea therefore assumes that coal consumption in industry will decline by 20% in 2040 (as compared to the business as usual case) due to improved energy efficiency (MOTIE, 2019a).

Coal is still used for heating purposes in remote areas and by lower socio-economic status households. In 2018, some 110 000 households still used coal briquettes for heating, predominantly poor and old people in rural areas. The government has programmes in place to switch these households to boilers and connect them to LPG grids, and these programmes have been quite successful. However, switching the remaining group is difficult, partly due to the absence of grid connections, but also partly due to resistance of the older part of the population.

RD&D and technology development

Given the importance of coal in Korea's energy sector, Korea is active in exploring the potential for research, development and demonstration (RD&D) and innovation in carbon capture, utilisation and storage (CCUS). CCUS is included in the 3rd Five-year Plan for Green Growth (2019-23), with a key objective to promote CCUS technologies and RD&D, and also as one of the six essential climate technologies in the 2017 Climate Technology Roadmap.

Korea has a target to carry out multiple CCUS demonstration projects with a total of up to 3 Mt CO_2 storage annually and establish a legal and regulatory framework for commercialisation by 2020. Particularly with regard to demonstration, the government has set out a three-step planning for large-scale CCUS by 2030. There are currently two carbon capture pilot-scale projects underway.

The key challenge in promoting CCUS in Korea is storage. The government carried out its first offshore CO_2 storage demonstration project with a storage capacity of around 270 000 tonnes in Pohang Basin in 2013. However, the Pohang earthquake in 2017 has halted its operation out of safety concerns, and in May 2019 the government announced a further delay to reoperation without giving a clear due date. A small-scale onshore CO_2 storage situated in Janggi Basin, also in the Pohang area, has also been temporarily suspended.

Assessment

Coal is the second-largest energy source in TPES at 29%, the largest source for electricity generation at 44% and the largest source of energy-related CO_2 emissions in Korea at

over 50% in 2018. Korea's coal consumption has been relatively stable, at around 80 Mtoe in the years 2011-18 after a decade in which coal consumption nearly doubled. Power and heat generation accounted for 71% of coal consumption and the rest was consumed in the iron and steel industries, defined as other energy sectors (18%) and other industry (11%).

In 2018, Korea imported 136 Mt of coal; Australia is the largest supplier, followed by Indonesia, Russia and Canada. The only type of coal produced in Korea is anthracite (hard coal), which is predominantly turned into anthracite briquettes, mainly used by poor rural households as primary heating fuel.

Korea is one of the two IEA member countries (along with Mexico) left on the OECD coal subsidy list. Korea has continuously increased the prices of domestically produced coal and there is only about a 15% subsidy of the production cost, or USD 16 million in total, left. Given the importance of coal mining for local employment in the concerned economically depressed region and the need to provide affordable heating for the poor, it is uncertain whether the government will further reduce subsidies. Demand for domestic coal has already decreased by 73% over the last decade.

About 230 000 tonnes of domestic coal were used in a dedicated coal-fired plant in 2018. As domestic coal mining is uneconomical, the power plant received a USD 8 million subsidy in 2018 to stay competitive.

Over 6 GW of new coal-fired capacity was commissioned from December 2016 to December 2017, bringing total coal capacity to 37 GW. Coal-fired generation displaced more expensive oil-fired generation, but also compensated for a sharp reduction in nuclear output.

As part of the long-term energy transition policy, the government plans to drastically cut coal-fired power generation to reduce GHG emissions and mitigate local air pollution. However, the government should establish a precise timeline. Under the 8th Basic Plan for Long-term Electricity Supply and Demand covering the period to 2031, installed capacity of coal-fired generation is still expected to increase to 41.5 GW in 2023 before declining to 39.9 GW in 2030, in contrast with the declared long-term ambition.

Over that same period, Korea intends to close 3 345 MW capacity from coal-fired power plants older than 30 years while switching another 2 120 MW capacity to LNG. Moreover, two planned coal-fired power plants (1 940 MW) will instead be built as LNG plants. With the anticipated net decline of around 7 GW of nuclear power capacity in the coming decade, it is unsure when the actual phase-out of coal will begin.

Korea was the first Asian country to put in place an ETS for the power and industry sector in 2015. However, the increase in the use of coal for power generation casts a doubt on the effectiveness of the ETS thus far. While CO_2 prices under the ETS have risen steadily over the last few years, 97% of allowances are still distributed for free to the incumbent power producers. Without further incentives, it is unlikely that coal capacity will decline by such an extent to allow Korea to reach its GHG reduction targets.

Local air pollution has become a major social, environmental and health concern in Korea. In 2018, the government not only put more stringent regulations into place (fine particulate matter concentrations may not exceed 50 μ/m^3), but it also granted local governments the authority to curtail coal power plants when air pollution exceeds a certain threshold.

The authority granted to local governments may well become Korea's most significant measure to tackle air pollution and climate change and to reduce the country's reliance on coal. In October 2018, Korea's South Chungcheong Province became the first Asian jurisdiction to join the Powering Past Coal Alliance. The province is home to about 50% of Korea's coal-fired generation and has pledged to phase-out coal by 2050.

Another potential game changer for the use of coal could be the proposed "environmental dispatch" policy mentioned in the 8th Basic Plan for Long-term Electricity Supply and Demand. The proposed policy would require that the dispatch of power plants take into account the environmental cost of each plant's emissions. Since 2019, the external environmental costs related to the use of coal and LNG for power generation are reflected in their taxation structure. However, the impact of the 2019 tax reform on the power generation mix is still very limited, as coal is still cheaper than LNG.

Korea is exploring the potential for RD&D and innovation in CCUS. It has set a target to carry out multiple CCUS demonstrations for a total of up to 3 Mt CO_2 storage annually and to establish a legal and regulatory framework for commercialisation by 2020. Particularly with regard to demonstration, the government has set out a three-step plan for large-scale CCSU by 2030. There are currently two promising ongoing carbon capture pilot-scale projects underway.

However, the key challenge in promoting CCUS in Korea is storage. The first offshore CO_2 storage demonstration project in Pohang Basin halted its operation following the Pohang earthquake in 2017 and has not reopened since. A small-scale onshore CO_2 storage situated in Janggi Basin, also in the Pohang area, has also been temporarily suspended.

The IEA strongly encourages the Korean government to move forward swiftly with the creation of a legal and regulatory framework and to support the relaunch of pilot projects for storage. With a view to the critical role coal-fired generation is expected to play in the Korean energy sector until at least 2040, the Korean government should consider mandating that all ongoing and potential new coal generation capacity is built as CCUS-ready.

Recommendations

The government of Korea should:

- Provide enhanced incentives to power producers (strengthen carbon pricing, promoting renewables) to substantially reduce the share of coal in power generation in line with Korea's 3rd Energy Master Plan and the 8th Basic Plan for Long-Term Electricity Supply and Demand.
- Phase-out inefficient subsidies for domestic coal production, while providing support to affected mining communities and to households to switch to other fuels.
- Revitalise the CCUS programme with dedicated funding for research and deployment, while restarting the CO_2 storage demonstration projects. Mandate that new coal-fired power plants (planned and under construction) are designed as CCUS-ready.

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11. Nuclear

Key data

(2018)

Number of reactors: 24 reactors

Installed capacity: 21.9 GWe

Electricity generation: 133.5 TWh, -12% since 2008

Share of nuclear: 12% of TPES, 23% of electricity generation

Key data source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics/.

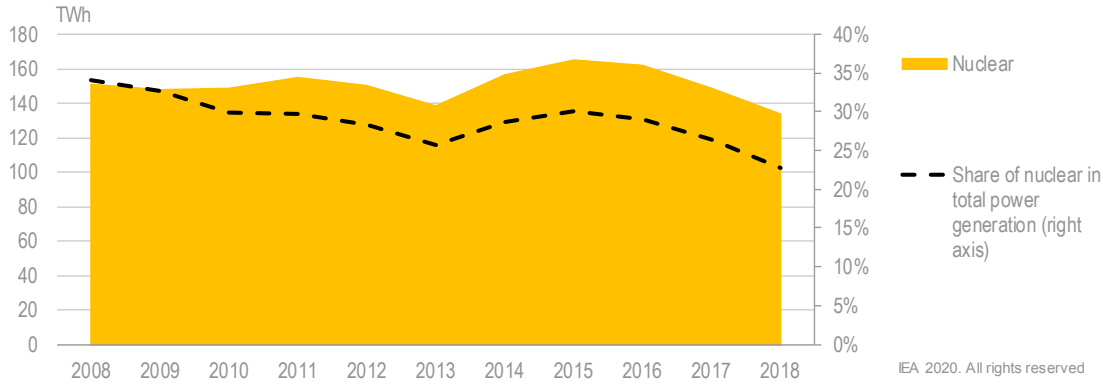
Overview

As of 2018, 24 nuclear reactors were operating in Korea, with a total installed capacity of 21.9 gigawatt electrical (GWe), generating about 133 terawatt hours (TWh) and contributing to 23% of Korea's electricity mix (Figure 11.1). In terms of installed nuclear capacity, Korea ranks as the fifth-largest country in the world, and stands as the ninth-highest country in terms of nuclear share in the electricity mix. As of 2019, 4 advanced power reactor (APR 1400) nuclear reactors were under construction.

In 2017, the Korean government decided to implement a long-term gradual reduction of nuclear reliance. Two reactors have since been permanently shut down: Kori 1 in 2017 – after 40 years of operation – and Wolsong 1 in 2019 – after 37 years of operation. Ten additional units are expected to be closed by 2030 in line with their initial design license of 30 or 40 years.

Nuclear generation rapidly increased in the early 2000s, from 52.8 TWh in 1990 to 148.5 TWh in 2010 as a result of both an increase in installed capacity (7.2 GWe to 18.6 GWe) and the average load factor (79.5% to 90.8%). Since 2010, electricity production from nuclear installations has gradually declined, and reached 133.5 TWh in 2018 as an increase in nuclear capacity has been more than compensated for by a reduction in the load factor, which dropped to 64.6%. Nuclear generation has grown at a slower rate than electricity demand over the last four decades, meaning that the share of nuclear energy has been reduced from nearly 52% in 1990 to 31% in 2010 and 23% as of 2018. Over the next five years, the completion of the four nuclear reactors under construction, and the scheduled shutdown of reactors that will reach their initial design license lifetime, implies that nuclear production is expected to increase for a few years before it continues its gradual decline.

Figure 11.1 Nuclear power generation and share in electricity generation, 2008-18



Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Nuclear energy policy in Korea

The 8th Basic Plan for Electricity Supply and Demand and the 3rd Energy Master Plan promote a long-term reduction of the reliance on nuclear power in Korea with no nuclear new build beyond the plants currently under construction (MOTIE, 2017). This means that Korea will halt electricity production from nuclear in 2083 at the latest, 60 years after the last plants will be connected to the grid.

The new nuclear energy policy is built on four measures: 1) no life extensions of existing reactors beyond their initial 40-year design lifetime; 2) no new reactors built beyond those under construction; 3) more energy efficiency; and 4) a shift towards renewables and liquefied natural gas for electricity generation.

Under this policy, the completion of the four APR-1400 reactors under construction should balance over the next decade the closures of about ten units that reach the design lifetime of either 40 years (seven pressurised water reactors with a rated capacity of 6 841 MW) or 30 years (three pressurised heavy water reactors with a rated capacity of 1 912 MW). As no new reactors beyond those under construction will be built, the initial plans for two additional APR-1400 reactors at Shin Hanul and four APR+ reactors have been respectively suspended and cancelled (Reuters, 2018).

The schedules for the grid connection of new nuclear reactors and for expected plant closures mean – on balance – that nuclear power production will slightly increase in Korea over the next five years, before it starts its long-term decline. Tables 11.1 and 11.2 present an overview of the Korean nuclear reactors in operation and under construction.

Table 11.1 Nuclear plants in operation as of January 2020

Reactor	Type	Location	Gross electrical capacity (MW)	First grid connection
HANBIT-1	Pressurised water reactor	Yeonggwang-gun	1 029	05 March 1986
HANBIT-2			1 026	11 November 1986
HANBIT-3			1 039	30 October 1994
HANBIT-4			1 022	18 July 1995
HANBIT-5			1 048	19 December 2001
HANBIT-6			1 049	16 September 2002
HANUL-1		Ulchin-gun	1 007	07 April 1988
HANUL-2			1 010	14 April 1989
HANUL-3			1 048	06 January 1998
HANUL-4			1 053	28 December 1998
HANUL-5			1 050	18 December 2003
HANUL-6			1 049	07 January 2005
KORI-2		Gijang-gun	681	22 April 1983
KORI-3			1 044	22 January 1985
KORI-4			1 044	31 December 1985
SHIN-KORI-1		Ulsan	1 044	04 August 2010
SHIN-KORI-2			1 045	28 January 2012
SHIN-KORI-3			1 485	15 January 2016
SHIN-KORI-4			1 400	22 April 2019
SHIN-WOLSONG-1		Gyeongju-si	1 048	27January 2012
SHIN-WOLSONG-2			1 050	26 February 2015
WOLSONG-2	Pressurised heavy water reactor		629	01 April 1997
WOLSONG-3			653	25 March 1998
WOLSONG-4			630	21 May 1999

Source: IAEA, *PRIS Database*, accessed February 2020 https://pris.iaea.org/PRIS/home.aspx.

Table 11.2 Nuclear plants under construction as of January 2020

Reactor	Type	Location	Gross electrical capacity (MW)	Construction start	Expected grid connection
SHIN-HANUL-1	Pressurised water reactor	Ulchin-gun	1 400	July 2012	Mid-2020
SHIN-HANUL-2			1 400	June 2013	Mid-2021
SHIN-KORI-5		Ulsan	1 400	April 2017	March 2023
SHIN-KORI-6			1 400	September 2018	June 2024

Sources: IAEA (2020), *PRIS Ddatabase*, https://pris.iaea.org/PRIS/home.aspx; WNA (2020), Nuclear Power in South Korea, https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

The energy policy outlined above comes with challenges related to reducing greenhouse gas emissions, reducing local air pollution and maintaining electricity security, which are policy goals for the Korean government as well. Nuclear power has one of the lowest levels of CO_2 emissions on a lifecycle basis, so the government is seeking to replace it with other low-carbon sources like renewables. Additionally, the dispatchability of nuclear power contributes to system reliability (MIT, 2018). Therefore, replacement of nuclear power with variable renewable electricity poses system integration and stabilisation issues that the government will need to address.

Korea is developing its own nuclear policies by considering the economic and environmental issues as well as the change in public acceptance towards nuclear energy. On balance, the 8th Basic Plan for Electricity Supply and Demand was established after considering how best to meet the national goal of reducing greenhouse gas emissions, to reduce air pollution, and to consider system stabilisation due to the expansion of renewable energy generation, while securing electricity supply at all times.

Nuclear safety regulation

Following the Fukushima nuclear accident, the Nuclear Safety and Security Commission (NSSC)[1] has been active in reviewing nuclear safety regulation in line with international best practices and peer-review exercises. This includes post-Fukushima safety measures and stress tests. In parallel, the NSSC has also addressed emerging safety cases related to the certification of specific nuclear components. In 2016, these efforts resulted in the development of an Accident Management Program for all nuclear power plants that was finalised in 2019. It is estimated that USD 0.5 billion had been spent as of early 2020 out of a USD 1 billion programme on strengthening safety since 2011, including post-Fukushima safety review, stress tests and the Accident Management Program.

[1] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

The Korea Radioactive Waste Agency was set up at the beginning of 2009 under the Radioactive Waste Management Act with the purpose to facilitate the nuclear waste management (KORAD, 2020).

Industry structure

Korea has developed its nuclear programme since the late 1970s, initially relying on technology transfers from western countries (Canada, France and the United States). From the late 1980s, Korea developed its domestic technology based on standard pressurised water reactor design. This self-reliance strategy was gradual, and initially covered local procurement of project management and civil engineering as well as manufacturing of components for the reactor turbine and the auxiliary systems. In the mid-1990s, the strategy moved to developing the optimised power reactor (OPR) 1000 reactor design based on the System 80+ design from Combustion Engineering (now Westinghouse) (Lee and Lee, 2016). In the early 2000s, the APR-1400 design was developed and – as of January 2020 – 8 units were under construction in Korea and the United Arab Emirates. The Gen III design is based on Korea's experience from the development, construction and operation of the various types of Korean reactors, including the OPR-1000 (Choi et al., 2001).

The Korea Electric Power Company (KEPCO) was Korea's sole power utility up to 2001. In 2001, KEPCO's generation capacity was divided into six entities that are still owned by KEPCO; one of them, Korea Hydro & Nuclear Power (KHNP), became responsible for the entire nuclear and (limited) hydro generation capacity in Korea. Only the KHNP is allowed to operate nuclear power plants in Korea.

The nuclear industry is structured around the KHNP and a number of KEPCO subsidiaries that work closely with several leading Korean industrial conglomerates, such as Doosan Heavy Industries and Hyundai. In addition, the Korean Atomic Energy Research Institute (KAERI) – a government-funded organisation – is in charge of nuclear R&D.

The integrated industrial model of the Korean nuclear sector has worked well over the years and is often promoted as one of the key factors of success for the rapid development of nuclear energy in the country.

Nuclear fuel cycle

Nuclear fuel cycle: Front-end

The front-end of the nuclear fuel cycle is an international competitive market. Today, Korea imports uranium concentrates from Australia, Canada, France, Germany, Japan, Kazakhstan, Niger, the Russian Federation, the United Kingdom and Uzbekistan. The conversion services are imported from Canada, the People's Republic of China, France, Germany, Japan and Russia, and enrichment services are imported from China, France, Russia and the United Kingdom.

In 2015, enrichment demand was 3.2 million separated work units (SWU). In 2007, the KHNP signed a long-term (10+ years) EUR 1 billion contract with the French company Orano for enrichment services at the new Georges Besse II plant in France. In mid-2009, it took a 2.5% equity stake in the plant. Russia's enrichment company, Tenex, has also historically been a supplier, and in 2019 its subsidiary won new tenders for fuel enrichment services (NEI, 2020a).

Regarding fuel fabrication, KEPCO NF has fabricated and supplied presurised water reactor fuel since 1990 and Canada Deuterium Uranium (CANDU) pressurised heavy water reactor fuel (unenriched) since 1987. Current production capacity covers all of the KHNP's needs.

Nuclear fuel cycle: Back-end

Spent fuel in Korea is currently stored at the reactor sites. For several years, Korea has strengthened its national framework in the area of the back-end of the fuel cycle to address both the short- and medium-term interim storage issue, and to develop long-term solutions for high-level waste management, including final disposal.

Until the creation of the Korea Radioactive Waste Agency in 2009, nuclear waste management was under the responsibility of the KHNP. Under the new organisation, activities are funded by the radioactive waste funds generated by the nuclear power plants and by specific charges on producers.

Interim storage

Interim storage of spent nuclear fuel is an ongoing issue in Korea. Spent fuel is currently stored at each reactor site. As of 2019, about 16 000 tonnes (t) of spent nuclear fuel was stored onsite, with reactor pool capacity of about 14 000 t and dry storage capacity of about 6 000 t for CANDU fuel. In addition, dry storage for CANDU fuel has been proposed for spent fuel of pressurised water reactors that will reach full capacity in the near future (the Kori and Hanul/Ulchin plants). In 2020, the NSSC approved the extension of CANDU used fuel interim storage facilities (Kim, 2020).

High-level waste management

Compared to safe management of low- and intermediate-level radioactive wastes (LILW) with the operation of a specific disposal facility, a review on national policy is currently underway in the area of high-level waste management. According to the roadmap in the "National Policy of High-Level Waste Management" in 2016, spent nuclear fuels would be stored in central interim storage in the 2030s and would permanently be disposed of in the 2050s. However, a review of the 2016 Master Plan is ongoing in order to fully achieve social consensus on high-level radioactive waste management. The Korean government will amend the 2016 Master Plan based on the resulting public consensus.

Decommissioning

The country's oldest reactor, Kori 1, was shutdown permanently in June 2017 after 40 years of service, having had a 10-year license extension. The Korean government plans to use this project to support the emergence of domestic companies in the decommissioning sector that could in the future expand to the international market. Kori 1 decommissioning is expected to start in 2022 and to last 15 years.

Wolsong 1, the country's first CANDU 6 unit, was taken offline in May 2018 and its official permanent shutdown was confirmed by the NSSC in December 2019 (Reuters, 2019). Funding for decommissioning is the responsibility of the KHNP as a licensee. The government reassesses the level of funding every two years.

Table 11.3 Korean nuclear reactors being decommissioned

Reactor	Type	Net capacity (MW_e)	Operation
Kori 1	Pressurised water reactor	576	June 1977 – June 2017
Wolsong 1	Pressurised heavy water reactor	661	December 1982 – May 2018

Source: WNA (2020), Nuclear Power in South Korea, https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

Nuclear research and competencies

In the area of nuclear R&D, the Korean government annually invests more than KRW 200 billion (EUR 150 million); in recent years funding has fluctuated between KRW 234.9 billion in 2012 and KRW 219 billion in 2018 (IEA, 2019). KAERI is the main organisation in charge of nuclear R&D activities. It was established in 1959 and has over the years played a central role in the development of the national nuclear industry, supporting in particular KEPCO/KHNP nuclear technology transfers from western companies. In addition, Korean nuclear R&D benefits from the country's participation in a number of international nuclear co-operation programmes, including the Generation IV International Forum (GIF) for nuclear fission, as well as the International Thermonuclear Experimental Reactor (ITER) for nuclear fusion.

Today, in line with the new nuclear policy, nuclear safety and high-level waste management are promoted as key areas for future R&D efforts. In recent years, KAERI has also developed several programmes on innovative nuclear technologies, including:

- **Pyroprocessing:** As a long-term option for spent fuel management, KAERI is developing a proliferation-resistant electrometallurgical "pyroprocessing" technology to recycle used nuclear fuel.

- **Sodium-cooled fast reactor:** Closely related to the pyroprocessing programme, KAERI has been developing the 150 MW_e Korean-prototype Generation IV sodium-cooled fast reactor, which will operate as a TRU burner (not breeder). In 2017, the programme was suspended according to the national nuclear R&D policy. Current sodium-cooled fast reactor developments focus on further improvements of strategic key technologies, the validation of the integrated safety performance of the reactors, and licensing approval of topical reports. Co-operation has been taking place with the Argonne National Laboratory in the United States as well as GIF.

- **Small modular reactor:** KAERI has been developing the SMART (System-integrated Modular Advanced Reactor) – a 365 megawatts thermal (MW_{th}) pressurised water reactor with integral steam generators and advanced passive safety features. It is designed to generate electricity (up to 110 MW_e) and/or thermal applications such as seawater desalination – up to 40 000 cubic metres (m^3)/day. This programme was licensed by the NSSC in 2012. In 2015, Korea and Saudi Arabia signed a memorandum of understanding (MOU) to jointly promote the SMART reactor in the global market. Under the MOU, the two countries have conducted a three-year pre-project engineering design project for the construction of SMART reactors in Saudi Arabia and co-operated for global promotion of SMART.

Public acceptance

Historically, public acceptance of nuclear power has been strong in Korea. Following the Fukushima nuclear accident in 2011, public acceptance has become an emerging issue in the country and a priority for the government and the industry.

In that respect, a number of initiatives have been launched over recent years to improve public confidence. In 2017, a "Citizens' Jury" voted in favour of continuing the construction of the Shin Kori 5 and 6 nuclear reactors (NEA, 2019). The panel – comprised of 471 randomly selected citizens – voted 59.5% in favour of continuing the project that had been put on hold by the new administration. At the same time, the panel voted to reduce the country's reliance on nuclear power, with a 53.2% vote in favour of this option.

On the industry side, the KHNP has developed programmes to support local communities living close to nuclear power plants, including in recent years through the creation of nuclear power plant information reliability centres.

Finally, engagement with local communities has also been promoted in the area of used fuel and high-level waste management, covering both interim storage and final disposal. In particular, the government is continuing its efforts to draw social consensus on high-level waste management. It must be noted that Korea has made significant progress in recent years in the area of low- and intermediate-level radioactive waste, for which a site was identified in 2005 and has been operational since 2015. This project was made possible thanks to the strong support of the local population.

International export activities

The success of the Korean national nuclear programme has been reinforced in recent years by the selection in 2010 of the APR-1400 for the construction of four reactors in the United Arab Emirates. Fuel loading for the first unit was completed in March 2020 (Khaleej Times, 2020).

Since 2012, Korea has continued to promote nuclear new build in several parts of the world. The KHNP and KEPCO have actively proposed the APR-1400 technology for new build projects in Europe where the design received the European Utility Requirement certification in 2017. The design received design certification in 2019 from the US Nuclear Regulatory Commission.

In addition, Korean technology has also been considered for several newcomer countries, primarily in Asia and the Middle East. In particular, in October 2015, KAERI signed an agreement with Saudi Arabia's King Abdullah City for Atomic and Renewable Energy (K.A.CARE) to perform pre-construction design for building two SMART reactors in Saudi Arabia. The SMART reactor is a 365 MW_{th} integral small modular reactor designed for electric and thermal applications, including desalination. The reactor was licensed in 2012 and in 2016 KAERI incorporated a number of post-Fukushima design modifications. In January 2020, Korea and Saudi Arabia agreed to establish a joint entity for the construction of the SMART reactor in Saudi Arabia and future global commercialisation (NEI, 2020b).

Despite the change of domestic nuclear policy, the Korean government continues to support nuclear exports. In the absence of nuclear new build contracts since 2010, the government

decided in late 2019 to shift the strategy toward full cycle of nuclear power generation, ranging from plant operation to maintenance and decommissioning (Jung, 2019).

Assessment

Korea has successfully developed a competitive nuclear sector, building on technology transfers to develop domestic industry and technologies. Historically, the Korean nuclear fleet was built on time and on budget. In 2018, nuclear energy accounted for 23% of electricity generation in Korea and 84% of its low-carbon electricity. Twenty-four nuclear power reactors were in operation and four under construction.

Recently, nuclear safety concerns following the Fukushima nuclear accident and domestic earthquakes – but also issues with nuclear-grade components certification and public acceptance for identifying high-level radioactive waste final disposal locations – resulted in a public consultation calling to reduce the country's reliance on nuclear power. In 2017, the government announced a decision to implement a long-term gradual reduction of nuclear reliance. Two nuclear reactors (Kori 1 and Wolsong 1) have been shut down, in 2017 and 2019, respectively. By 2030, 10 additional units are expected to be closed, in line with their initial design license of 30 or 40 years. Over the next five years, the completion of the nuclear reactors under construction and the scheduled shutdown of reactors mean that nuclear production will increase slightly in Korea, before it starts a long-term decline. The new policy implies that Korea would eventually halt electricity production from nuclear in 2083 at the latest; 60 years after the newest plants will come online.

This gradual reduction policy buys time to spearhead energy efficiency and to investigate alternative solutions for large-scale dispatchable generation, like hydrogen, distributed power and batteries.

Following the Fukushima accident, Korea has conducted a number of safety regulation reforms, building on international best practices and peer-review exercises. This included the implementation of nuclear stress tests using the EU methodology, and International Atomic Energy Agency Advisory Safety Service. These reviews resulted in improvements in the safety margins of existing and new nuclear power plants, in particular in terms of developing capabilities against natural hazards (seismic and tsunami risks), as well as emergency preparedness.

Engagement and open communication with the public and relevant civil society groups is critical for public acceptance of nuclear power. Public concerns over nuclear safety following the Fukushima accident, recent domestic earthquakes and issues with nuclear-grade components certification for nuclear equipment (Cho, 2013) have become an emerging energy policy issue. The government has taken measures by creating online platforms such as the NPP information reliability centre, and organising public consultation for resumption of construction of Shin-kori Units 5 and 6. The development of consent-based approaches for nuclear waste management has also been a positive step in order to reach social consensus.

Capacity constraints for interim storage of used nuclear fuel is an emerging energy policy issue for Korea. Used nuclear fuel is currently stored on each reactor site, with pool storage for pressurised water reactors and dry storage for CANDU reactors. The approval in 2020 by the NSSC of the extension of CANDU used fuel interim storage facilities will help to mitigate the eventual risk of temporary shortage of storage in the coming decade, and buys time to come up with more long-term solutions.

For high-level radioactive waste management, several public consultations have taken place over the last few years. A review committee will collect the opinions of the people and the residents near nuclear power plants that will form the framework of the used fuel management policy.

The decommissioning of nuclear power plants is a new energy policy issue in Korea, following the shutdown of the first nuclear reactors. For the Kori 1 reactor, the owner (KHNP) is to submit a decommissioning plan to the NSSC within five years from the shutdown date. The government produced a roadmap for developing decommissioning activities, including a regulatory framework, human resources and supply chain capabilities.

Support for nuclear R&D slightly declined between 2012 and 2018, but increased in 2019. Korean nuclear R&D currently focuses on decommissioning, safety and waste management activities. At the same time, efforts for developing the SMART reactor concept will continue, focusing on international market prospects. Support to ITER has remained strong.

The Korean government continues to promote exports of nuclear technology, building on the success of the United Arab Emirates project (four APR-1400 under construction at Barakah). A modified version of the APR-1400 received a design license in 2019 from the US Nuclear Regulatory Commission and nuclear new build prospects are being investigated in Europe. The Korean nuclear sector is also entering the operation and maintenance and fuel export markets.

The Korean government will need to pay attention to the attractiveness of the nuclear sector for talented young Koreans. New people will be needed over the coming decades to run the nuclear fleet and to decommission plants when they reach the end of their life time. These talents are also needed to maintain the reputable status of the Korean nuclear industry, and the ability for Korea to maintain the development of the technology and its exports.

Recommendations

The government of Korea should:

- Foster public understanding and engagement on the economic, social and environmental impacts of the use of nuclear power, especially with local communities near nuclear facilities.
- Continue to ensure that the NSSC and the Korean Institute of Nuclear Safety have sufficient resources and a shared level of technical expertise.
- Build on ongoing efforts of public engagement to reach social consensus in the near term for interim used nuclear fuel storage, and gradual progress for permanent disposal of high-level nuclear waste.
- Ensure that decommissioning plans take account of international lessons learnt and best practices for successful completion, and anticipate future needs in terms of financial provisions, human competences and industrial capabilities.

- Provide sufficient support for a broad range of nuclear R&D activities, covering emerging issues such as decommissioning, nuclear safety, long-term spent fuel management options such as recycling of spent fuel, and innovative concepts for the international market, such as small module reactors. Continue engagement and support to international endeavours such as GIF and ITER.

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ANNEX A: Institutions

Since 2013, the **Ministry of Trade, Industry and Energy (MOTIE)** deals with overall energy policy and industry development. Previously, energy was handled by the Ministry of Knowledge Economy. MOTIE is in charge of energy policy planning, supervision of the industry sector, energy innovations and efficiency policy, climate change policy, new and renewable energy development, electric power and electricity markets, smart grids and electricity transmission and distribution, among others. It is also responsible for drafting the energy master plans, the basic long-term plans for long-term electricity supply and demand, and natural gas and the basic plans for rational energy utilisation, the basic plan for new and renewable energy, the renewable energy implementation plan, and the energy efficiency innovation strategy.

MOTIE is in charge of energy-related research, development and demonstration policy and prepares the energy technology development plans. The **Ministry of Science and Information and Communication Technology** is responsible for overall basic research, including on energy, and also handles all related budget aspects.

MOTIE is the key regulatory entity in the electricity sector and its responsibilities include the granting of electricity business licences, the approval of market rules, the approval of transmission and distribution tariffs and retail sales prices, and the regulation of wholesale electricity prices. MOTIE also sets wholesale and retail prices of natural gas and is the arbitrator for third-party access to the transmission and distribution networks.

MOTIE is also in charge of decisions regarding the construction and operation of nuclear power plants, nuclear fuel supply, and the management of radioactive waste. It has oversight over the Korea Radioactive Waste Agency set up in 2009 as an umbrella organisation in charge of managing nuclear waste. Through its role in defining energy policy, MOTIE is also responsible for decisions related to the long-term operation of nuclear power plants, nuclear new build projects, as well as defining decommissioning strategies.

The **Korean Electricity Regulatory Commission (KOREC)** is established within MOTIE to oversee the regulation of the singe-buyer market, and to review issues concerning the rights of electricity consumers and to settle disputes related to the electricity business. The Electricity Market Surveillance Committee, an entity under KOREC, is responsible for market monitoring. While KOREC has important enforcement functions, its role is limited to an advisory one.

The **Korea Fair Trade Commission** is responsible for monitoring monopoly behaviour and unfair business practices, whereas KOREC manages technical and professional competition policy. The Fair Trade Commission and KOREC have memoranda of understanding outlining their respective roles, duties and functions in the electricity industry.

Environmental policy is handled by **Ministry of Environment**. The Environmental Policy Department establishes plans for atmospheric environment preservation, measures of vehicle air pollution prevention and low-emission fuel use; as well as measures to combat fine dust. It also enacts and modifies related

law, and establishes mid- and long-term measures on climate change, including the regular national climate change adaptation plans.

MOTIE and the Ministry of Environment collaborate closely to optimise the potential synergies between energy efficiency improvement and carbon emissions mitigation.

In addition, government-owned and affiliated companies and research institutes support energy policy development and policy implementation. Major public companies and research institutes include:

The **Korea National Oil Corporation (KNOC)** is a vertically integrated government-owned company in charge of exploration, development, stockpiling and logistics of oil, which is a strategic resource, promoting stable oil supply.

The **Korea Gas Corporation (KOGAS)** is a vertically integrated state-owned gas company that dominates Korea's gas sector. It owns and operates liquefied natural gas (LNG) terminals and imports the vast majority of LNG used in Korea and is also the owner and operator of the gas transmission system and the distribution network. Private LNG importers can use the KOGAS network based on a regulated access policy, while access to the distribution pipelines is on a negotiated access basis.

The **Korea Electric Power Corporation (KEPCO)** is a vertically integrated government-owned company that has a monopoly over the transmission, distribution and sales of electricity. It is the single buyer of all electricity generated with very limited exceptions, such as power generated on islands.

KEPCO's six subsidiary power generation companies dominate Korea's power generation and also play an important role in renewable power generation. KEPCO also undertakes research and development activities.

All electricity generated in Korea is dispatched to and traded through the **Korea Power Exchange (KPX)**, which operates the power system and the real time dispatch and sets the system marginal price and the price for ancillary service**.** The KPX is also in charge of load forecasting and manages the trading of renewable energy certificates. It operates the transmission system, which is owned by KEPCO, and any generator wishing to use the transmission system is required to sign an agreement with KEPCO.

The **Korea Energy Economics Institute** develops energy policy for the general energy field, oil industry, gas industry, electricity industry, renewable energy as well as strategies for green growth and responding to climate change. It also provides statistics, supply and demand outlooks by energy sector, and develops strategies for international energy co-operation.

The **Korea Energy Agency (KEA)**, known as the Korea Energy Management Corporation until 2015, play a principal role in implementing specific policy measures across all energy end-use sectors (industry, buildings and transport) and supports the energy services companies. The KEA establishes an R&D plan for greenhouse gas reductions, the low-carbon energy-based system, energy efficiency and energy savings, new and renewable energy technology development to promote rational energy use through creating an energy culture for climate change response, improving energy efficiency, developing and providing new renewable energy technology. It also provides financial support and management for those

projects. The Korea New and Renewable Energy Center under the KEA supports new and renewable energy promotion work, such as the issuance of renewable energy certificates that serve as a certified proof of renewable energy power generation

The **Korea Institute of Energy Research** supports MOTIE and the Ministry of Environment by promoting low-carbon and highly efficient energy technologies. It is in charge of technical development in the energy sector.

Non-governmental organisations such as the Korea NGO's **Energy Network** play an increasingly essential role in raising the awareness of energy efficiency by conducting a national survey on buildings' energy use as well as public campaigns.

The **Ministry of Science and Information and Communication Technology** co-ordinates overall nuclear R&D activities and assumes responsibility for nuclear international co-operation programmes. It has oversight over the Korean Atomic Energy Research Institute (KAERI), which conducts nuclear R&D.

The **Ministry of Foreign Affairs** is responsible for the nuclear diplomatic activities, including the conclusion of bilateral and multilateral nuclear agreements and treaties.

The **Nuclear Safety and Security Commission (NSSC)** has overall responsibility for ensuring nuclear safety, security and safeguards through regulatory activities. It was set up in October 2011 as an independent agency of the central government, but became part of the Prime Minister's Office in 2013. The NSSC is responsible for nuclear licenses and permits. It is advised by a technical support organisation, the Korean Institute of Nuclear Safety, which carries out safety reviews, inspections of nuclear facilities, as well as nuclear safety-related R&D.

ANNEX B: Organisations visited

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews conducted by the IEA. The Shared Goals are presented in Annex D.

Review team and preparation of the report

The in-depth review team visited Korea 14-18 October 2019. The review team met with government officials, energy suppliers, market participants, interest groups in the public and private sectors, 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 team's preliminary assessment of Korea's energy policy, the Korean 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

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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.

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The review was prepared under the guidance of Aad van Bohemen, Head of the Energy Policy and Security Division, IEA. Dagmar Graczyk managed the review and is the main author and co-ordinator of the report. Lucie Girard and Shuto Fukuoka wrote the chapters on oil, natural gas and electricity. Jihyun Selena Lee wrote the chapter on energy efficiency and renewable energy. Oskar Kvarnström, Dahyeon Lisa Yu, and Dasom Kim, prepared and drafted the sections relating to energy data contained in each chapter and, together with Alession Scanziani and Clémence Lizé ensured the preparation of the report with figures, tables and maps.

Helpful comments, chapter reviews and updates were provided by the following IEA staff: Heymi Behar, Sara Moarif, Jinsun Lim, Cycril Cassisa, Luca Lo Re, Takahiro Ori, Tiffany Vass, Simone Landolina, Samantha McCulloch, Diana Louis, Araceli Fernandez Pales, José Miguel Bermúdez Menéndez, Jean-Baptiste le Marois, Grergely Molnar, Jean-Baptiste Debreuil, Songho Jeon, Randi Kristiansen, César Aljeandro Hernandez, Peter Fraser and Carlos Fernández Alvarez.

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Organisations visited

Climate Change Center

Consumer Network for Public Interest

Consumers Korea

Electricity Market Surveillance Committee

Energy Consumer

Greenpeace

GS Caltex

Hanwha Qcells & Advanced Materials Corporation

Hyundai Motor Company

Independent Power Producer Association

Korea Association of ESCO

Korea City Gas Association

Korea Coal Corporation

Korea District Heating and Cooling Association

Korea East-West Power Corporation

Korea Electric Power Corporation (vertically integrated electricity company)

Korea Electricity Regulatory Commission

Korea Electrotechnology Research Institute

Korea Energy Agency

Korea Energy Economics Institute

Korea Gas Corporation

Korea Hydro & Nuclear Power Corporation

Korea Institute of Energy Technology Evaluation and Planning

Korea LPG Association

Korea National Oil Corporation

Korea New and Renewable Energy Association

Korea NGO's Energy Network

Korea Petrochemical Industry Association

Korea Petroleum Association

Korea Power Exchange

Korea Research Institute on Climate Change

Korea Smart Grid Association

Korea Smart Grid Institute

LG Chem

LSIS Corporation

Mine Reclamation Corporation

Ministry of Environment

Ministry of Science and Information and Communication Technology

Ministry of Trade, Industry and Energy

Nuclear Safety and Security Commission

Office for Government Policy Coordination

POSCO Energy

Samsung SDI

SK Energy

The Seoul Institute

ANNEX C: Energy balances and key statistical data

Korea

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018**
ELECTRICITY GENERATION[7]							
Input (Mtoe)	3.47	26.85	69.72	115.61	126.92	126.47	127.84
Output (Mtoe)	1.27	9.06	24.81	42.72	48.06	48.39	50.41
Output (TWh)	14.83	105.37	288.53	496.72	558.82	562.69	586.20
Output shares (%)							
Coal	*9.0*	*16.8*	*38.6*	*44.1*	*42.0*	*45.4*	*44.1*
Peat	-	-	-	-	-	-	-
Oil	*82.3*	*17.9*	*12.0*	*3.8*	*3.2*	*2.1*	*2.2*
Natural gas	-	*9.1*	*10.2*	*20.8*	*22.6*	*22.4*	*26.5*
Biofuels and waste[1]	-	-	-	*0.2*	*1.1*	*1.2*	*1.4*
Nuclear	-	*50.2*	*37.8*	*29.9*	*29.0*	*26.4*	*22.8*
Hydro	*8.7*	*6.0*	*1.4*	*0.7*	*0.5*	*0.5*	*0.6*
Wind	-	-	-	*0.2*	*0.3*	*0.4*	*0.4*
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	-	-	*0.2*	*1.2*	*1.6*	*2.0*
TOTAL LOSSES	**3.91**	**28.09**	**59.95**	**90.89**	**106.41**	**103.97**	**100.52**
of which:							
Electricity and heat generation[8]	2.20	17.79	41.56	68.45	73.66	72.44	71.48
Other transformation	0.67	6.19	8.71	10.00	17.18	17.00	14.99
Own use and transmission/distribution losses	1.04	4.11	9.68	12.44	15.57	14.54	14.05
Statistical differences	**0.17**	**-0.09**	**1.10**	**1.45**	**-2.71**	**-4.87**	**-0.47**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018**
GDP (billion 2015 USD)	89.47	408.24	798.78	1261.20	1508.97	1556.65	1598.13
Population (millions)	34.10	42.87	47.01	49.55	51.22	51.36	51.61
TPES/GDP (toe/1000 USD)[9]	0.24	0.23	0.24	0.20	0.19	0.18	0.18
Energy production/TPES	0.31	0.24	0.18	0.18	0.18	0.17	0.16
Per capita TPES (toe/capita)	0.63	2.17	4.00	5.05	5.51	5.50	5.47
Oil supply/GDP (toe/1000 USD)[9]	0.15	0.12	0.12	0.08	0.07	0.07	0.07
TFC/GDP (toe/1000 USD)[9]	0.20	0.16	0.16	0.13	0.12	0.12	0.11
Per capita TFC (toe/capita)	0.51	1.51	2.70	3.18	3.49	3.57	3.53
CO_2 emissions from fuel combustion ($MtCO_2$)[10]	68.2	231.8	431.9	550.9	589.2	600.0	-
CO_2 emissions from bunkers ($MtCO_2$)[10]	2.2	6.2	32.5	41.1	48.8	48.0	-
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-15**	**15-16**	**16-17**	**17-18**
TPES	9.0	7.3	2.9	1.7	3.6	-0.1	0.0
Coal	6.9	5.2	5.8	1.9	0.8	1.4	-2.5
Peat	-	-	-	-	-	-	-
Oil	8.1	7.1	-0.4	1.5	6.9	-0.6	1.2
Natural gas	-	20.1	8.5	0.4	5.0	4.6	10.4
Biofuels and waste[1]	-	6.6	9.7	11.0	9.1	12.1	-1.9
Nuclear	-	7.5	3.2	2.1	-1.7	-8.4	-10.1
Hydro	9.9	-4.5	-0.8	-10.2	32.4	-0.8	18.9
Wind	-	-	42.7	10.4	26.1	29.0	13.4
Geothermal	-	-	-	32.5	20.0	13.6	13.6
Solar/other[2]	-	15.4	17.1	22.9	15.9	31.0	24.8
TFC	8.0	7.0	2.2	1.9	3.2	2.5	-0.5
Electricity consumption	12.5	10.8	5.5	2.0	4.4	1.2	1.6
Energy production	7.4	4.3	2.7	2.7	0.1	-4.5	-7.9
Net oil imports	8.4	7.2	-0.4	1.5	6.7	-1.1	-0.6
GDP	9.3	6.9	4.7	3.1	2.9	3.2	2.7
TPES/GDP	-0.3	0.3	-1.7	-1.3	0.6	-3.2	-2.6
TFC/GDP	-1.2	0.0	-2.4	-1.1	0.2	-0.6	-3.1

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to 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] *Other* includes tide, wave and ambient heat used in heat pumps.

[3] In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.

[4] Excludes international marine bunkers and international aviation bunkers.

[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, co-generation and heat plants. Output refers only to electricity generation.

[8] Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear and 100% for hydro, wind and solar photovoltaic.

[9] Toe per thousand US dollars at 2015 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.

ANNEX D: 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, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, The Netherlands ,Turkey, the United Kingdom and the United States.

ANNEX E: 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

AFE	Average Fuel Economy
APR	advanced power reactor
ASG	Asia Super Grid
BAU	business as usual
BEMS	building energy management system
BPLE	Basic Plan for Long-term Electricity Supply and Demand
C-ITS	Cooperative-Intelligent Transport System
CANDU	Canada Deuterium Uranium
CCUS	carbon capture, utilisation and storage
CO_2	carbon dioxide
DOPCO	Daehan Oil Pipeline Corporation
DPRK	Democratic People's Republic of Korea
EEIS	Energy Efficiency Innovation Strategy
EERS	energy efficiency resource standard
EMP	Energy Master Plan
EMS	energy management system
ESCO	energy service company
ESS	energy storage system
ETDP	Energy Technology Development Plan
ETS	Emissions Trading System
EV	electric vehicle
FEMS	factory energy management system
GDP	gross domestic product
GDP PPP	gross domestic product with purchasing power parity
GHG	greenhouse gas
ICT	information and communications technology
IEA	International Energy Agency
ITER	International Thermonuclear Experimental Reactor
KAERI	Korean Atomic Energy Research Institute
KDHC	Korea Distric Heating Corporation
KEA	Korea Energy Agency
KEPCO	Korea Electric Power Corporation
KETEP	Korea Institute of Energy Technology Evaluation and Planning

KHNP	Korea Hydro & Nuclear Power
KNOC	Korea National Oil Corporation
KOGAS	Korea Gas Corporation
KOREC	Korea Electricity Regulatory Commission
KPX	Korea Power Exchange
KRW	Korean won
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
MaaS	Mobility as a service
MI	Mission Innovation
MOTIE	Ministry of Trade, Industry and Energy
MOU	memorandum of understanding
NSSC	Nuclear Safety and Security Commission
OECD	Organisation for Economic Co-operation and Development
PM	particulate matter
PPP	purchasing power parity
PV	photovoltaic
R&D	research and development
RD&D	research development and demonstration
RDD&I	research, development, demonstration and innovation
REC	renewable energy certificate
REP	renewable energy point
RFS	renewable fuel standard
RPS	renewable portfolio standard
SMART	System-integrated Modular Advanced Reactor
SME	small and medium-sized enterprise
SMP	system marginal price
TCP	technology collaboration programme
TFC	total final consumption
TMS	target management system
TPES	total primary energy supply
TSO	transmission system operator
USD	United States dollar
ZEB	zero-energy building

Units of measure

bcm	billion cubic metres
CO_2-eq	carbon dioxide-equivalent

GJ	gigajoule
GW	gigawatt
GW_e	gigawatt electrical
GWh	gigawatt hour
kb/d	thousand barrels per day
kg	kilogramme
km	kilometre
km^2	square kilometre
ktoe	kilotonne of oil equivalent
kV	kilovolt
kVA	kilotvolt ampere
kW	kilowatt
kWh	kilowatt hour
m^3	cubic metre
mb/d	million barrels per day
mBtu	million British thermal units
mcm	million cubic metres
MPa	megapascal
Mt	million tonnes
Mt CO_2	million tonnes carbon dioxide
Mt CO_2-eq	million tonnes carbon dioxide-equivalent
Mtoe	million tonnes of oil-equivalent
MW	megawatt
MWe	megawatt electrical
MWh	megawatt hour
T	tonne
TJ	terajoule
toe/cap	tonne of oil equivalent per capita
TWh	terawatt hour
$\mu g/m^3$	microgramme per cubic metre

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Korea 2020

Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices.

The Korean government is committed to substantially increasing the share of renewable energy sources in the electricity supply, gradually phasing out coal and nuclear power from the energy mix, significantly improving energy efficiency, and fostering the country's nascent hydrogen industry. Many of these measures will help Korea advance its energy transition and improve its energy security, a high priority given the country's limited domestic energy production. The government's pledge of a Green New Deal as part of its Covid-19 economic recovery package in July 2020 is a significant step towards accelerating Korea's energy transition. Achieving the ambitions of the Green New Deal will require addressing regulatory and institutional barriers, introducing more flexible energy markets, and making use of the country's expertise in advanced technologies and innovative capacity.

In this report, the IEA provides recommendations for further improving Korea's policies to help the country guide the transformation of its energy sector towards a secure and sustainable future.