International Energy Agency

Energy Policies of IEA Countries

The Republic of Korea

2012 Review

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Korea, the world's thirteenth-largest economy and the seventh-largest exporter, is an energy-intensive nation. In 2008, the country adopted a long-term "green growth" strategy to foster economic development by means of low-carbon technologies and clean energy; since then, the government has implemented many policies to support these goals.

In 2012, Korea announced an emissions-trading scheme – the first of its kind in Asia – which will be implemented in 2015. This represents a major step towards achieving its target of a 30% reduction in greenhouse gas emissions by 2020. Strong energy efficiency policies have been developed to complement the emissions-reduction target. Korea has made efforts to enhance energy security by taking measures to diversify energy sources, reduce the use of fossil fuels and foster the development of renewable energy alongside the expansion of its nuclear energy programme. Government expenditure on energy-related RD&D is among the highest in the OECD.

Progress in some sectors has been slower, and the lack of a clear, long-term vision for its electricity and natural gas markets is one of the greatest energy-policy challenges facing the Korean government. Energy markets are dominated by incumbents and have been slow to open up to competition.

This review analyses the energy-policy challenges facing Korea and provides sector-based assessments and recommendations for further policy improvements. It is intended to help guide the country towards a more secure and sustainable energy future.

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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International Energy Agency

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1. EXECUTIVE SUMMARY AND KEY RECOMMENDATIONS

EXECUTIVE SUMMARY

Korea, the world's thirteenth-largest economy and the seventh-largest exporter, is an energy-intensive nation. It is the world's eleventh highest in terms of energy consumption and is the fifth-largest oil importer. Unlike many of its OECD peers, Korea emerged from the global financial crisis with its economy in robust condition and maintained growth over the past decade of more than 4% per year on average. Energy and environmental policies focus on low-carbon and green growth and on creating a momentum for economic growth by means of green technology and clean energy. In 2008, Low Carbon, Green Growth was proclaimed by President Lee Myung-bak as a national vision to guide the nation's long-term development.

MAINTAINING PROGRESS

The Korean government has developed and implemented many new policies in the energy and environment sectors since 2006 when the previous in-depth review was published. Most notably, the government has committed to reducing its greenhouse gas (GHG) emissions by 30% compared to its business as usual (BAU) case by 2020 and has integrated this commitment into its Strategy for Green Growth. This strategy has been transposed into law by the enactment of the Framework Act on Green Growth, whose implementation is coordinated by a Presidential Committee.

Korea is in the process of implementing a target management mechanism whereby major emitters agree individual emissions reduction targets. In 2012, the government announced an emissions trading scheme (ETS), the first of its kind in Asia, which will be implemented in 2015. This mechanism has the potential to provide a comprehensive and economically efficient means of reducing emissions. The government has applied a set of indicators, which were developed by the OECD, to assess progress towards green growth, to measure GHG emissions and consumption-based CO_2 production.

Energy efficiency policies have been developed to complement the 30% emissions reduction target and the government is pursuing several strategies in the transport and building sectors, for example: stricter standards on fuel efficiency; stronger building design codes; and the strengthening of existing policies in other sectors. In July 2009, Korea announced a new fuel economy standard for car manufacturers and importers of 17 kilometre (km) per litre, or CO_2 emissions of 140 gramme (g) per km by 2015, which is similar to standards prevailing in the European Union and the United States. A performance-based energy code, which limits total energy use per unit area, applied to all commercial buildings over 10 000 square metres in July 2011.

Korea has made efforts to enhance energy security by taking measures to diversify energy sources, reduce the use of fossil fuels and foster the development of renewable energy. The contribution of renewable sources to total primary energy supply (TPES) in Korea is the lowest in the OECD. To address this anomaly, the government has established an 11% target of new and renewable energy in TPES by 2030. The government also specified several key technologies (photo-voltaics, solar thermal, geothermal and bio energy) in the Third Renewable Basic Plan. In 2012, the government replaced the existing feed-in tariff mechanism with a renewable portfolio standard (RPS) applicable from 2012 for the purpose of meeting its new and renewable energy targets.

The state-owned oil company, the Korea National Oil Corporation (KNOC), has made extensive investments in overseas oil exploration and production projects. These overseas activities seek to improve energy security by giving Korea greater diversity of supply and increased access to international markets. The Korea Gas Corporation (KOGAS) is the world's largest corporate buyer of liquefied natural gas (LNG) and over the past decade, it has expanded the scope of business from import and distribution of natural gas to exploration and production by taking a participating interest in at least 20 projects throughout the world.

Korea has developed a smart grid roadmap, a long-term plan to deploy a nationwide smart grid by 2030. The first stage of this plan is the construction and operation of a smart grid test bed to pilot new technologies. A USD 65 million pilot programme consisting of a fully integrated smart grid system has been established on Jeju Island in partnership with industry.

A notable feature of Korea energy policy is the value it places on research and development. Government expenditure on energy-related research, development and deployment (RD&D) has increased significantly over the past decade and is now among the highest in the OECD. Investment in energy-related RD&D was over 600 billion Korean won (KRW) in 2010. Korea has developed and started to implement an energy RD&D strategy, the *Green Energy Strategy Roadmap*, which includes a strategic plan for market penetration of new technologies, international cooperation, human resources development and education, and collaboration with the private sector. Development of the strategy was an inclusive process with substantial involvement from the private sector. The strategy identifies 15 technology areas for focused development, and roadmaps for each area have been developed. Clear milestones for each technology area are listed, and categorised by short-, medium- and long-term objectives.

NUCLEAR ENERGY

Nuclear power is a major component of Korea’s energy policy, providing 29% of its electricity and with announced intentions to increase this percentage (five reactors are under construction and six more have been announced). This policy position stands in contrast to that of some other IEA countries, but is consistent with that of China and India. Given the demand for energy and its lack of indigenous resources, this is a logical policy. Korea has been very effective in building a strong nuclear industry, with high levels of availability and reliability, putting it as one of the leaders in efficient operation and low-cost construction. As a result, nuclear has been the main contributor to providing affordable energy, given Korea’s large dependence on imports.

Korea has been proactive in pubic engagement, which is especially important after the Fukushima Daiichi nuclear accident in 2011, and has recently set up a new safety authority, consistent with our recommendation.

Korea has been taking a more active role in international nuclear cooperation which is important in ensuring that it shares its own experiences and gains from those of other countries. It will also be helpful in moving forward with a spent fuel management policy, which is under current discussion. The nuclear power plant industry in Korea has significantly increased its domestic construction capacity and research and development capability. This was instrumental in the country making its first nuclear power plant sales to the UAE and a research reactor to Jordan.

Nonetheless, despite these progressive energy policy developments, there is some scope for strengthening the energy policy framework.

REFORMING ELECTRICITY AND NATURAL GAS MARKETS

The previous IEA in-depth review highlighted the lack of a clear, long-term vision for Korea's electricity and natural gas markets as the greatest challenge facing the government. While the government has maintained its commitment to reform, there has been limited progress and the country has faced a series of rolling electricity load-shedding events in the recent past. Secure electricity supply is one of the cornerstones of Korea's economy and electricity shortages pose a major threat to sustained economic growth.

There is a large body of evidence from elsewhere in the OECD and beyond to support the case for electricity market reform. A well thought-out reform programme can deliver better quality of service for consumers, support economic growth and welfare, strengthen government's fiscal position, and deliver more affordable and secure access to electricity for all. Reform of energy markets is a process, not an event, and the government needs to articulate a clear programme that takes into account the main drivers for reform alongside milestones and dates. The main elements of an electricity market reform programme should include: greater restructuring of the Korea Electric Power Corporation (KEPCO) and revisiting the design of the wholesale market; and strengthening the independence of the sector regulator to enable fair competition, including the removal of barriers to new entrants and third-party access to network infrastructure, and creating clear roles for publicly owned and private entities. The reform programme should draw upon best practice elsewhere, be free from interference from market participants and short-term political interests, and be fully inclusive, taking into account the needs of potential new entrants and end users throughout Korea. The programme should also take into account Korea's green growth ambitions, including its nuclear expansion programme, the targets for new and renewable energy and the new emissions trading scheme. The government should also develop targeted welfare mechanisms to ensure the interests of vulnerable customers are protected.

Reform of the electricity market should be accompanied by a complementary programme of change in the natural gas market. Korea has built significant infrastructure to support the emergence of a natural gas market. Since the last in-depth review in 2006, Korea has taken a number of steps to reform its natural gas market. An open-access policy has been put in place to give direct importers improved access to the transportation network and LNG facilities. The government has also taken steps to improve the regulatory regime although it has stopped short of establishing an independent regulator

for the sector. Korea needs to build on progress to date, and given the scale of government participation in the sector, the establishment of an independent regulatory agency, perhaps based on an expansion of the role of the Korea Electricity Commission (KOREC), should be seriously considered.

There is a broad body of evidence to support the assertion that the traditional model of centralised government control of gas utilities and direct intervention in their operations and investment decisions can often lead to price distortions, inefficient operations, and poor infrastructure. While this may not be the situation in Korea, it can certainly be argued that there is a strong business case in favour of the separation, in some form, of the various business activities of KOGAS. The trend in other markets has been to unbundle along vertical and horizontal lines and to open wholesale gas markets to new entrants. These new entrants in turn stimulate competition and the development of new markets; in gas supply, in financial products, and in pipeline capacity. Ultimately end users, both households and industry, and the Korea economy are the final beneficiaries. Under present arrangements in Korea, however, this is unlikely to happen.

KOGAS, the small number of direct importers of natural gas, the thirty city gas companies and other market participants should be encouraged to trade gas amongst themselves across the existing natural gas transmission infrastructure. All large customers should have the option of buying from a source other than KOGAS at appropriate market rates. The government should develop and implement policies to allow a wholesale gas market to emerge. Other measures which should be introduced at the same time include increased transparency regarding the utilisation of existing network and LNG facilities, improved third-party access and the introduction of more flexible supply and capacity contracts.

Consumers of energy need to develop an awareness of the market price of natural gas in order to understand its real value. The present system of regulated natural gas prices may not be appropriate for future market conditions. The government should charge the sector regulator, once established, with the task of examining the potential for introducing market-based tariffs, for large customers in the first instance.

A greater element of unbundling of storage, transmission and distribution may be required. Network operators should be incentivised to maximise the amount of services they offer through their networks, thus facilitating competition. Retail competition is an important complement to competition in generation and gas markets and consumers will respond to price signals, both by switching suppliers and by reducing their demand.

Change in both the electricity and natural gas markets will require a large amount of commitment from government supported by a strong and independent market regulator and a clear legislative framework. Accordingly, the Korean government should prepare, in consultation with all industry stakeholders and acknowledging best practice elsewhere, a detailed programme of energy market reform, including clear timescales and milestones, accompanied by the necessary legislative framework.

DESIGN OF THE EMISSIONS TRADING SCHEME

In May 2012, the Korean government announced a law establishing a cap-and-trade system for emissions to facilitate the achievement of the national objective: a 30% reduction of greenhouse gas emissions by 2020. Three initial phases have been outlined for the scheme. The first of these will run from 2015 to 2017 and the second from 2018 to 2020. The third phase, and subsequent ones if any, is expected to be a five-year term.

The government will be offering over 95% of all carbon credits for free and will auction the remainder. Some participants may be able to obtain 100% of their permits for free depending on their contribution to national trade but no specific assistance for trade-exposed industries has been provided.

Carbon pricing is a cornerstone of climate change mitigation policy, but it is not a complete solution on its own. Nonetheless, swift progress on elaborating the defining elements of the new emissions trading scheme and providing clarity on how it will work in practice can provide certainty to the electricity sector and energy-intensive industry, and allow them to make the necessary investment, such as the deployment of new technologies, needed to reduce their emissions profile. Korea needs to ensure that design of the scheme complements other policies such as the renewable energy target, nuclear energy expansion and the move towards a more competitive market-based approach in the electricity and gas sectors. Accordingly, care needs to be taken such that the package of trading scheme and supplementary policies are consistent to enable a positive permit price under varying economic conditions.

ENERGY EFFICIENCY POLICY

Korea's energy intensity, adjusted for purchasing power parity, has been declining relatively steadily since its peak in 1997, falling at an average annual rate of 0.3% between 1990 and 2010. Despite this declining trend, Korea's energy intensity is still expected to remain above that of most IEA countries in the near future.

To complement the 30% emissions reduction target, the Korean government is pursuing several aggressive policies in the field of energy efficiency and the IEA commends the progress made by Korea to date. The success of Korea's export-orientated industrial sector suggests that energy efficiency in manufacturing is high compared to other countries, nonetheless, there is scope for further improvement. For example, greater clarity on specific targets, including sector-specific targets, clear complementary plans and time schedules, and greater co-ordination and co-operation among government ministries and agencies are needed. Korea could also strengthen efforts to improve data collection and analysis in order to monitor and evaluate the results of the impact of energy efficiency policies across all sectors. Benchmarking should be used drawn upon best practices observed elsewhere. Energy-intensive industries and electricity generating plants represent significant potential for waste-heat recovery and combined heat and power operations. Korea has recently started to utilise some of this with the development of district heating systems supplying 1.8 million homes. Korea should explore further opportunities in this sector such as using the recovery of waste heat in district cooling systems to displace electricity usage during summer peaks in the electricity system.

Continuing to develop and implement effective policies to reduce energy demand, and adoption of demand restraint measures, would further enhance energy efficiency policy and help Korea achieve a higher level of energy independence, a key pillar of its Strategy for Green Growth.

KEY RECOMMENDATIONS

The government of Korea should:

- *Following extensive consultation with stakeholders, develop and implement a detailed programme of reform for the electricity and natural gas markets. The programme should include greater restructuring of Korea Electric Power Corporation (KEPCO) and the wholesale electricity market, guarantee the independence of the sector regulator, ensure fair competition including the removal of barriers to new entrants and third-party access to network infrastructure, and create clear roles for publicly owned and private entities.*
- *Elaborate on all elements of the emissions trading scheme and ensure the mechanism is compatible to the greatest extent possible with other significant policies in the energy sector and the broader economic framework. A regular review mechanism should also form part of the scheme.*
- *Develop an integrated coordinated energy efficiency strategy to improve the effectiveness of energy efficiency policies, with measurable sector targets, in particular for transport, industry and the utilities sectors.*

PART I
POLICY ANALYSIS

Figure 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.

2. GENERAL ENERGY POLICY

Key data (2011 estimated)

TPES: 258 Mtoe (oil 36%, coal 31%, natural gas 16%, nuclear 15%, renewables 2%), +37% since 2000

TPES per capita: 5.3 toe (IEA average: 4.7 toe)

TPES per GDP: 0.19 toe per 1 000 USD GDP (IEA average: 0.15 toe per 1 000 USD GDP)

Electricity generation: 516 TWh (coal 45%, nuclear 29%, natural gas 21%, oil 3%, renewables 2%), +79% since 2000

Inland energy production: 45 Mtoe, representing 18% of total primary energy supply

COUNTRY OVERVIEW

The Republic of Korea is located in the southern half of the Korean peninsula. It occupies 98 480 square kilometres – making it slightly larger than Portugal – and shares a 238 km land border with North Korea. It is a mountainous country, with lowlands accounting for only 30% of the total land area. The climate is temperate, with rainfall heavier in summer than in winter. Korea has a population of approximately 50 million, about 85% of which live in urban areas.

Korea, called Daehan Minguk in Korean, is a democratic republic with powers shared among the president, legislature and judiciary. The president is elected by direct popular vote for a single five-year term. Almost half (49.8%) of Korean people live in Seoul Metropolitan Area making it one of the world's most populated metropolitan areas. Other large centres of population include Pusan (3.6 million), Incheon (2.5 million), Daegu (2.4 million), Daejeon (1.4 million) and Gwangju (1.4 million).

In contrast to many other OECD member countries, Korea recovered faster and more vigorously from the 2008 global economic crisis and enjoys low unemployment and low government debt. Growth slowed in late 2011, reflecting the deterioration in the world economy, but is projected to reach around 3.5% in 2012, thanks in part to continued momentum in China.[1]

Korea's total primary energy supply (TPES) is relatively diverse but dominated by oil and coal and to a lesser extent by nuclear energy and natural gas. The country has limited natural resources and is highly dependent on external sources of energy while the contribution of renewable energy to TPES is among the lowest in the OECD. Korea has no oil resources, very limited reserves of natural gas and produces small amounts of indigenous anthracite. It is Asia's third-largest crude oil importer after China and Japan, and the Korea Gas Corporation (KOGAS) is the largest single buyer of LNG in the world.

1. *OECD Economic Surveys, Korea*, OECD Paris, April 2012.

SUPPLY AND DEMAND

SUPPLY

In 2011, TPES in Korea was estimated to be 258 million tonnes of oil equivalent (Mtoe). This is 3% higher than in 2010 and 37% higher than in 2000, largely reflecting economic growth over the same period. Oil and coal, 36% and 31% respectively, were the largest contributors to energy supply, followed by natural gas (16.2%) and nuclear energy (15.2%). The contribution of renewable energy to TPES is negligible and in 2011 was the lowest in the OECD. The contribution of oil to energy supply in 2011, while remaining the largest single source, has declined as a proportion of the total since 2000 when it represented 52.6% of supply. Conversely, the use of natural gas, in the form of liquefied natural gas (LNG), has increased significantly, from 17 Mtoe to 41.6 Mtoe. The supply of coal and nuclear energy has also increased: coal by 90.2% to 79.8 Mtoe and nuclear energy by 37.8% to 39.1 Mtoe.

In 2011, imports of oil largely came from Middle Eastern countries which accounted for around 87% of total crude imports with another 6.6% coming from Asia, 3.5% from the Russian Federation and 1.5% from Australia. Despite heavy reliance on imports from the Middle East, the countries of origin are relatively well diversified. Saudi Arabia (33%) was the largest single source of imports in 2011, followed by Kuwait (14%), Qatar (10%), United Arab Emirates (10%), Iraq (9%) and Iran (9%). Korea's upstream sector is very small, less than 1% of supply, although Korea National Oil Corporation (KNOC) is involved in overseas exploration and production projects in a large number of countries.

Coal is the cornerstone of the Korean power system and imports in 2011 were largely from Australia and Indonesia. The main sources of steam coal are Indonesia (43.5 million tonnes) and Australia (28.3 Mt) while Russia is another important source and to a lesser extent China and South Africa. Coking coal is imported from Australia (16.4 Mt), and to a lesser extent, Canada and the United States.

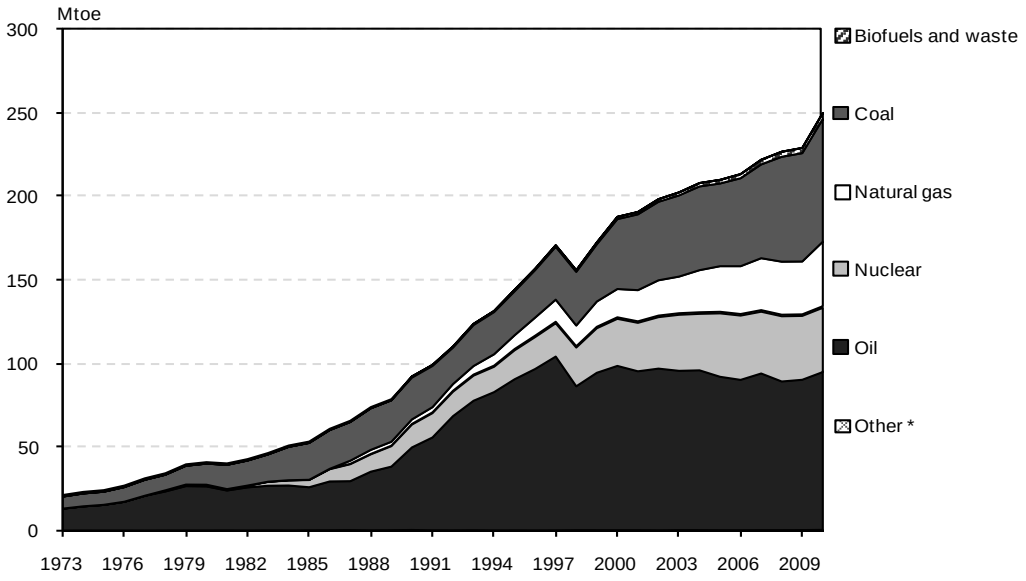
LNG imports come from a diverse range of countries with Qatar (22.5%) and Indonesia (21.3%) being the largest single sources, followed by Oman (11.6%), Malaysia (11.1%) and the Russian Federation (8.0%). Nuclear energy is provided by 23 nuclear power units in operation at present while another five are under construction.

DEMAND

Total final consumption (TFC) of energy in 2010 was 157.4 Mtoe representing an increase of 23.8%, or 30.33 Mtoe, compared to 2000, and an increase of 6.5% compared to 2009. Over the same ten-year period, real GDP grew by over 4% per year on average. Energy consumption is expected to continue increasing with a TFC of 220 Mtoe forecast by 2020.

The industry sector absorbed the largest share of TFC, accounting for around 52.3% (82.4 Mtoe) of the total in 2010. The transport sector accounted for 19.4% or 30.6 Mtoe, residential for 12.6%, and the remainder for 15.6%. This contrasts significantly with IEA averages, which in 2010 were 32% for transport, 32% for industry, 20% for residential and 16% for other sectors.

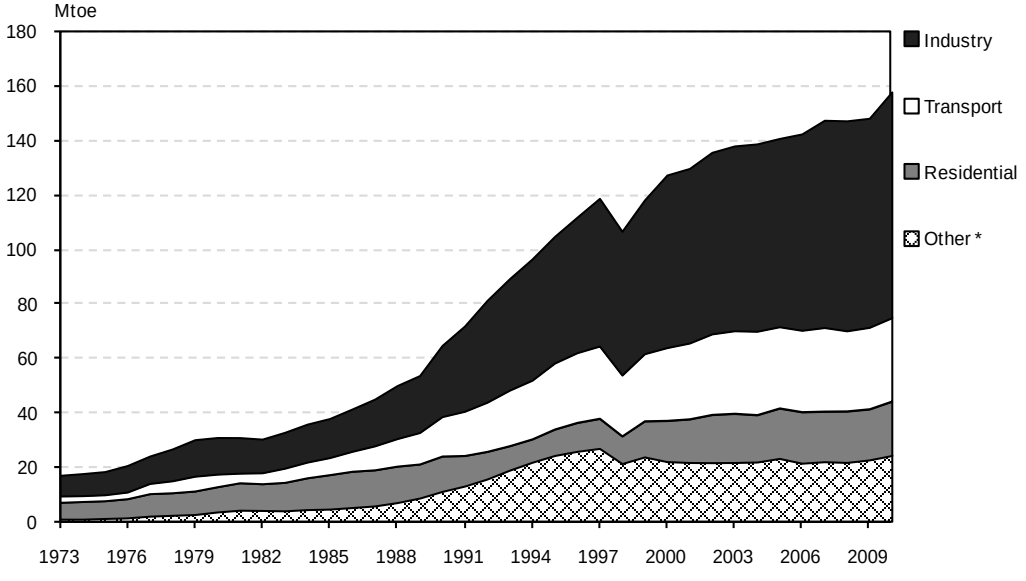
Figure 2. **Total primary energy supply, 1973-2010**



**Other* includes hydro, geothermal, solar and ambient heat production (negligible).

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012 and country submission.

Figure 3. **Total final consumption by sector, 1973-2010**



* *Other* includes hydro, geothermal, solar, and ambient heat production (negligible).

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

ENERGY ADMINISTRATION AND INSTITUTIONS

The **Ministry of Knowledge Economy** (MKE), previously known as the Ministry of Commerce, Industry and Energy (MOCIE), leads energy policy development and

implementation. It was created in 2008. The Deputy Minister within the ministry is responsible for energy and resources and the **Office of Energy and Resources** is responsible for energy policy planning, supervision of the sector, climate change policy, resource development, and energy savings and other matters relating to energy policy.

In addition, some energy-related environmental policy is overseen by the **Ministry of Environment** (MOE). The Environmental Policy Department of the ministry also develops and oversees the implementation of measures related to climate change.

The **Korea Electricity Commission** (KOREC) is the electricity supply regulator. It is responsible for implementing economic regulation and competition policy in the sector.

In addition, a number of government-affiliated companies and research institutes support energy policy development and policy implementation. Major publicly owned companies and research institutes are:

The **Korea Energy Economics Institute** (KEEI) develops energy policy, sector-specific policies for the oil, gas, electricity industries, for the new and renewable energy sector, as well as for strategies for green growth and climate change. It also provides statistics, supply and demand outlooks by sector, and develops strategies for international energy co-operation.

The **Korea Institute of Energy Research** (KIER) is in charge of technical development in the energy sector while the **Korea Energy Management Corporation** (KEMCO) elaborates research and development plans to support climate change and energy conservation measures. KEMCO also provides financial support and management for projects related to climate change and energy conservation.

The **Korea National Oil Corporation** (KNOC) is responsible for promoting stable oil supply, exploration and development, and stockpiling.

The **Korea Gas Corporation** (KOGAS) was established in August 1983 to develop a natural gas supply system. It owns three LNG regasification terminals and owns the transmission and distribution network.

The **Korea Electric Power Corporation** (KEPCO) carries out activities such as power generation, transmission and distribution, electricity-related research and technical development.

KEY ENERGY POLICIES

THE FIRST NATIONAL BASIC PLAN FOR ENERGY

In 2008, the government enacted *the Basic Energy Law* (the law), which provided for the establishment and implementation of a national basic plan for energy every five years over a period of 20 years. The law provides that the plan shall be decided after consultation has been made with the head of a relevant central administrative agency and the national energy committee has examined it.

The purpose of each plan is to suggest the direction of future-oriented energy policies and determine mid- and long-term strategies to systematically secure energy resources, expand stable infrastructure for supplying domestic energy, and rationalise the use of energy needed for the sound development of the national economy.

The plan should also include policies to minimise energy-related factors which damage the environment and also to effectively contribute to the achievement of national energy policies for expediting the development of energy related technologies.

The basic plan shall cover all fields related to energy, be systematically connected with other energy related plans and be coordinated at a high level.

The plan shall have priority over other energy-related plans and provide principles and directions for the plans in each energy source and sector.

The plan is subject to intensive consultation; the government shall collect diverse opinions from government agencies, suppliers and citizens' bodies throughout the process and aim to reach a consensus.

The First Basic Plan for Energy, established in 2008, covers the following:

- schemes to stably secure, introduce, supply and manage energy;
- schemes for the supply and use of environment-friendly energies like new and reproduced energies;
- schemes to reduce greenhouse gases emission through rationalising the use of energy;
- schemes for safe management of energy;
- developing and diffusing energy-related technologies;
- fostering energy-related professional manpower;
- promoting international harmonisation and cooperation in connection with energy policies and the related environmental policies; and
- developing and using domestic energy resources.

Since the plan is set to be published every five years, the Second Basic Plan of National Energy will be developed towards the end of 2012.

LOW-CARBON GREEN GROWTH

Korean energy and environmental strategies focus on policies to realise low-carbon and green growth and to create momentum for economic growth by means of green technology and clean energy.

In 2008, Low Carbon, Green Growth was proclaimed by President Lee Myung-bak as a national vision to lead the country's long-term economic development. In order to ensure effective implementation of this new vision, the president established the Presidential Committee on Green Growth (PCGG) in February 2009. The committee co-ordinates and evaluates the green growth policies of various ministries, and also undertakes consultation with private-sector stakeholders. It is co-chaired by the prime minister and a chairman who is appointed from the private sector. The committee consists of 50 members, 14 of them ministers and 36 appointed members who represent the private sector.

Also in 2009, the PCGG presented an ambitious draft target for reduction of national greenhouse gas emissions of 27% to 30%, which was endorsed by the Cabinet and transposed into domestic law by the enactment of the Framework Act on Low Carbon, Green Growth. Although it is the ninth-largest greenhouse gas emitter in the world, Korea is not among the 38 Annex I countries with a mandatory commitment to reduce

emissions under the Kyoto Protocol. Nonetheless, the government of Korea announced in November 2009 a national mid-term greenhouse gas (GHG) reduction goal of 30% below business-as-usual (or 4% above 2005 emissions) by 2020. This decision was complemented by the adoption in 2012 of a law establishing a cap-and-trade system for emissions. Korea also introduced a Comprehensive Action Plan for Climate Change (2008-12).

THE NATIONAL STRATEGY FOR GREEN GROWTH

In 2009, following the government's announcement of Low Carbon Green Growth as a major government policy, the Korean government implemented the Framework Act on Low Carbon, Green Growth, which addresses climate change mitigation, energy policy and sustainable development.

The purpose of the Framework Act on Low Carbon, Green Growth is to put into practice effective measures to address climate change and promote sustainable development in Korea. The Act also intended to bring together various ministries or government agencies active in the sector, or where necessary, integrate them. The National Strategy for Green Growth has three main objectives;

- to effectively deal with climate change and help attain energy independence;
- to create new engines of economic growth; and
- to improve quality of life in Korea.

In April 2010, Management of Targets for GHGs and Energy, a government policy which aims to reduce GHG emissions, was established. Implementation of this policy is divided between the directing government department, the Ministry of Environment, which handles integration guidelines and sets standards, and other responsible departments such as the Ministry of Knowledge Economy which manages compliance and evaluation work. Also established was the Low Carbon, Green Growth Enforcement Ordinance, which includes GHG reduction targets and guidelines and procedures for assisting green companies.

Commencing in 2012, a Target Management System required companies emitting more than 25 thousand tonnes (kt) of CO_2-eq per year to agree to emissions savings targets with government in 2011, those emitting more than 20 kt CO_2-eq per year in 2012 and those emitting more than 15 kt CO_2-eq per year by 2014. The Low Carbon and Green Growth Act granted the Korean government the ability to establish an emission-trading scheme and in November 2010, a separate GHG Emission Reduction Trading Act was prepared.

FIVE-YEAR PLAN FOR GREEN GROWTH

The Five-Year Plan for Green Growth (2009-13) contains about 600 projects that will cost approximately KRW 108.7 trillion, or 10% of 2009 GDP, to implement. The 25 largest programmes contained in the plan account for almost three-quarters of expenditure in the first four years of the programme and include the Four Major Rivers Restoration Project and railroad construction, which together account for almost one-third of total spending between 2009 and 2012.

NATIONAL EMISSIONS TRADING SCHEME

In May 2012, the government, the first in Asia, announced a law, the Act on the Allocation and Trading of Greenhouse Gas Emission Permits, establishing a cap-and-trade system for emissions. The National Assembly adopted a bill that aims to facilitate the achievement of the national objective: a 30% reduction of greenhouse gas emissions by 2020. Starting in 2015, the Korean ETS will cover facilities emitting more than 25 kt CO_2-eq annually, representing approximately 500 of the country's largest emitters and about 60% of national greenhouse gas emissions. The government will set emissions caps and reduction targets for each trading period.

Three initial phases have been outlined. The first of these will go from 2015 to 2017, the second from 2018 to 2020. The third phase, and subsequent ones if any, is expected to be a five-year term. The government will be offering more than 95% of all carbon credits for free in the first and second phase and the remainder will be auctioned. Some companies may be able to obtain 100% of their permits for free depending on their contribution to the country's trade and their production costs but no specific assistance for trade-exposed industries has been provided.

It is understood that the level of free allocations will decrease over time leading to full auctioning of permits. Banking and borrowing will be allowed, but the detailed mechanisms are not yet developed. Non-compliance will be penalised for each tonne of carbon over a participant's cap. The government has yet to develop any rules governing compliance, such as how many Certified Emissions Reductions issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects would be allowed in the Korean programme.

PLANNING AND FORECASTING

BASIC PLAN FOR LONG-TERM ELECTRICITY SUPPLY AND DEMAND

The Electricity Business Act requires that the MKE prepare and publish a Basic Plan for Long-term Electricity Supply and Demand (BPE) every two years. The purpose of the BPE is to set out a clear policy direction for the electricity sector, including supply and demand forecasts, a capacity plan and infrastructure needs. The fifth BPE, which contains projections for the period 2010-24, was published in December 2010 and forecasts an electricity consumption growth rate of 1.9% per year for the forecast period. Much of this increase in demand will be met by incremental growth in nuclear (48.5% in 2024), new and renewable energy capacity (8.9% in 2024) while the shares of coal (31%), natural gas (9.7%) and oil (0.5%) are expected to fall by 2024. Meeting the expected growth in generating capacity will require investments of KRW 49 trillion. The plan also contains proposals for smart grid and investment in demand-side management.

THE TENTH LONG-TERM NATURAL GAS SUPPLY AND DEMAND PLAN

Reflecting the planning process in the electricity sector, the MKE is required to prepare a natural gas supply and demand plan every two years. Accordingly, in December 2010, the MKE also published the Tenth Long-term Natural Gas Supply and Demand Plan containing a long-term demand and supply outlook alongside plans for natural gas imports and infrastructure. The plan forecasts that natural gas demand will increase at

an annual average rate of 1.8% between 2010 and 2024. This additional demand will be satisfied by more long-term LNG import contracts and investment in storage infrastructure and transmission pipelines.

ENERGY SECURITY

In order to guarantee a stable energy supply and strengthen energy security, Korea aims to achieve energy self-sufficiency through strategic overseas resource development and the concurrent expansion of domestic energy supply infrastructure. Korea is also reviewing demand-side measures with a view to establishing an effective system for reducing energy consumption and promoting more efficient energy use. These measures will be complemented by investments in new and renewable energy and research and development (R&D) in green and clean energy technologies.

In 2008, Korea altered the direction of its energy security policy from strengthening energy supply stability to expanding overseas resource development as a national priority. Since then, state-owned companies such as KNOC and KOGAS have made substantial overseas investments in the oil and natural gas supply chain. Korea also aims to revamp its resource development infrastructure, strengthen already strong international co-operation in order to prevent any setbacks for exploration of awarded blocks, and further develop domestic opportunities so as to increase self-sufficiency of oil and gas consumption from 3.2% in 2006 to 40% by 2030. The country is actively pursuing the development of unconventional energy resources such as gas hydrates in the Korean East Sea.

Table 1. **Korean energy security measures**

Energy source	Measure
Oil	Increase the share of long-term oil contracts out of total oil imports from 62% in 2007 to 85% by 2030. Strengthen co-operation with oil-producing countries. Purchase additional strategic petroleum reserves, including the establishment of a North-East Asia oil hub. Expand refinery upgrades, and promote development and diffusion of oil alternative fuels.
Natural gas	Promote mid- and long-term LNG import contracts and increase contract flexibility. Diversify LNG import sources. Build additional domestic infrastructure including the construction of a fourth LNG receiving terminal and expansion of the gas transmission grid. Increase gas storage capacity.
Electricity	Expand electricity generating capacity. Strengthen the electricity transmission system and develop a smart grid.
Coal	Supply anthracite coal for power generation to briquette production in a flexible manner. Facilitate bituminous coal development. Build a demand /supply co-operation system among bituminous coal companies.

Source: country submission.

In addition, Korea has promoted strategic resource development by establishing region-specific strategies and making full use of its diplomatic capabilities. It has strengthened infrastructure by increasing financial resources, training professionals, developing key technology and consolidating its information systems. Also, it has sought further

opportunities for domestic resource development through promoting technology development for non-conventional energy resources such as oil sand and gas hydrates.

NATURAL GAS SECTOR

Diversification of supply sources, ensuring LNG supply on the basis of long-term contracts, expansion of storage capacity and securing supply to meet high seasonal demand are the key elements of Korea's natural gas security policy. Korea does not have government gas stocks or mandatory industry stocks. KOGAS, however, maintains stocks in two forms: minimum stocks and safety stocks.

An emergency response plan is in place for the event of a gas supply disruption. Emergency response measures such as securing additional volumes of LNG on a commercial basis, use of safety stocks, fuel switching in the power sector and the reduction of gas supply to power generators and/or city gas companies are available at present.

ELECTRICITY SECTOR

Every two years, MKE develops a Basic Plan for Long-Term Electricity Supply and Demand (BPE) in order to guarantee the stable operation of its electricity system and to ensure the system is able to meet its optimum reserve margin (measured by a loss of load probability of 0.5 day per year, 15% reserve margin limit).

Despite these measures, the level of system reserve in Korea has been dangerously low over the past few years and the country has experienced a number of serious blackout incidents. In response to these events, the government has put in place a series of short-term measures including a plan to raise electricity prices during peak hours in an attempt to temper demand. The government also established a task force to revise emergency procedures if and when controlled rolling blackouts are required. Nonetheless, addressing the underlying causes of capacity shortages will require a significant programme of reform of the electricity supply market arrangements.

OIL SECTOR

Korea meets its stockholding obligation to the IEA by holding government stocks and by placing a minimum stockholding obligation on industry. Under the relevant Acts, KNOC manages the state-owned oil emergency reserves. Crude refiners and product importers are obliged to hold at least 40 and 30 days of stocks respectively, in either crude or products (excluding naphtha), corresponding to a 12-month average of the previous year's sales.

Korea's oil stocks in terms of days of net imports have consistently been above 160 days since January 2009, and government stock levels have been above the IEA 90-day commitment since December 2009. The use of emergency oil stocks is central to Korea's emergency response policy, which can be complemented by demand restraint measures. In an IEA collective action, Korea would likely respond by releasing government stocks.

TAXATION

Energy taxes in Korea include various taxes such as customs duty, a consumption tax, transportation/energy/environment taxes, an education tax, a driving tax and value-

added tax (VAT). For oil, Korea levied 3% of customs duty on the oil price, 5% on the price of petroleum products, and 3% on the price of liquefied petroleum gas (LPG). Individual consumption tax is imposed on kerosene, heavy oil, and LPG while transportation/energy/environment tax is imposed on gasoline and diesel.

The driving tax, which is set at 26% of the transportation/energy/environment tax, is levied on gasoline and diesel. The government levies the 10% VAT on all products equally. Customs duty, individual consumption tax and VAT are imposed on LNG. Domestically produced coal is tax free; however, a 1% customs duty is imposed on imported coal plus VAT.

CRITIQUE

The 2006 in-depth review described Korea's progress over the last decades as "nothing short of remarkable". The energy sector has played a key role in this, developing swiftly and securely to allow Korea's rapid rate of economic growth to be maintained. This is particularly impressive given the limitations in Korea's own energy resources; its energy import dependence stands at over 96%. Energy policy has also increasingly reflected the need for economic efficiency and environmental protection. This is as true in 2012 as it was in 2006.

There have been many impressive developments in Korea's energy policy since the last review. The most significant of these was the adoption, in 2009, of an ambitious National Strategy for Green Growth, as a means of strengthening energy security, environmental sustainability and developing new engines of economic growth. A Five-Year Plan for Green Growth has been put in place; a target to reduce emissions by 30% below business-as-usual by 2020 (or a 4% cut from the 2005 level) has been adopted; a target management system is implemented; and a law to introduce an emissions trading scheme, the first in Asia, has been enacted. A cap-and-trade mechanism, which will cover 60% of Korea's emissions, will be in place by 2015 and work is underway on developing the details of the scheme.

A broad range of policy initiatives has been developed and implemented to achieve greater diversity in the energy supply mix. State-owned companies such as KNOC and KOGAS have made substantial overseas investments in the oil and natural gas supply chain, and long-term plans for the natural gas and electricity sectors have been put in place. Diversity of import sources, enhanced gas import facilities and storage infrastructure, and higher levels of oil stocks are being pursued. These measures have been complemented by a suite of supply-side measures on energy efficiency (including building codes, appliance standards and fuel efficiency) and the introduction of a renewable portfolio standard to replace the previous feed-in tariff regimes in an effort to increase the share of renewable energy in the electricity mix to 8.9% by 2024. Coal market subsidies are being phased out, and disparities in taxation of crude oil and petroleum products have been removed.

The contribution of renewable energy to TPES in Korea is among the lowest in the OECD. In an effort to correct this, the government is introducing a tradable green certificate scheme (of renewables portfolio standards, RPS) to stimulate renewable electricity deployment in a cost effective way. It will be important to design this scheme in an efficient manner, with clear transition arrangements from the current feed-in tariffs system, if the benefits are to be realised. The government is sensibly looking at

experience in other countries to help Korea to do so. Similar approaches could be used to promote renewable energy in the heating and cooling sector, in the transport sector and also for commercialising the outcomes of its R&D programme.

The government is overseeing a significant programme of investment in energy-related research, development and deployment and Korea is aiming to become a world leader in smart grid development.

Korea has developed a strong nuclear energy capability and plans are in place to expand nuclear capacity from 31.4% of the electricity generation fleet in 2010 to 48.5% by 2024. The industry has a strong efficiency and safety record and it has developed an indigenous design and construction industry that is active in overseas markets. Steps have been taken to improve inter-ministry co-ordination and introduce more checks and balances (including greater involvement of all stakeholders) building on key recommendations contained in the 2006 in-depth review.

Tentative steps have been taken to introduce liberalised natural gas and electricity markets, and more effective regulation of electricity and gas markets have been taken. In 2010, the government announced the Electric Power Industry Structuring Plan to enhance the efficiency of the electricity sector, including the promotion of competition within the sector. This is to be welcomed, as is the setting up of an energy exchange to allow generating companies to make bids, which are then assessed by the regulator and pricing applied. KEPCO, however, retains a near-monopoly position in transmission, distribution and retail, and owns the six main generating companies. At the same time, it is making losses because electricity prices are not fully reflective of market conditions.

In the gas sector, the implementation of third-party access and the introduction of competition in the import of natural gas represent progress, but KOGAS retains an almost 95% share of the import market and controls the transmission network and three of the four LNG import terminals (with another under construction), which makes it difficult for others to enter and compete in the domestic market. The government is seeking to address this problem by allowing other companies to bid for new LNG import volumes. Furthermore, KOGAS supplies almost all gas used for power generation. Accounting separation of the gas supply business from the other functions has been mandated, but the five city gas retailers are still in effect local monopolies. Full unbundling would further promote competition.

There is still some way to go towards full independence of the Korea Electricity Commission (KOREC), the regulator in the electricity market, and greater autonomy accompanied by a clearer delineation of roles between government departments, agencies and companies would be helpful. The role of the regulator could also be expanded to incorporate the regulation of the natural gas market.

Notwithstanding the many positive developments in energy policy since the previous in-depth review, the sector would benefit greatly from the development of a Second Basic Plan for Energy, which builds on the momentum of the First Basic Plan for Energy and takes into account the full range of existing policy measures and energy-related plans. Work to specify sectoral targets and implementation plans for energy efficiency and renewables can help ensure that the range of initiatives in these areas achieve the overall aims for which they are designed. It should also facilitate the development of a more streamlined and cohesive overall vision for the future of the Korean energy system, with firm milestones and implementation timetables, which will help in the important task of binding together the wide array of individual policy measures into a

coherent whole; provide benchmarks against which progress can be measured; and give greater clarity in the roles of the various ministries and agencies involved. This coherence would seem best expressed through a comprehensive energy vision, which will need to provide clarity on measurable policy goals across the many positive and substantial initiatives being taken (such as levels of emissions reductions and targets for new and renewable energies), with a variety of scenarios for how this might be achieved (*e.g.* the fuel mix) given inherent uncertainties about future developments.

Achievement of Korea's energy security, environmental and economic goals will also be made more efficient and effective if the recent steps taken towards a more competitive market-based approach are continued and accelerated.

Swift progress on these facets of Korean energy policy: development of a coherent overall energy strategy that integrates the various policy initiatives; clarity on how the ETS will work; accelerated progress to a more competitive market-based approach in the electricity and gas sectors; and development of robust market-based policy instruments can help maximise the chances of success in delivering the government's energy security, environmental sustainability and economic efficiency goals.

RECOMMENDATIONS

The government of Korea should:

- *Develop a comprehensive energy strategy that integrates the full suite of existing policy measures in a coherent manner, one which takes into account the expected impact of individual initiatives (particularly in relation to emissions reductions, energy efficiency and new and renewable energy), and the roles and responsibilities that different ministries and agencies will play.*
- *Accelerate moves to enhance a competitive, market-based approach in the electricity and natural gas sectors; further separate the different elements of the supply chain; establish a clear timetable for market-based pricing; tariff reform; and strengthen the independence and authority of the sectors' regulator.*
- *Continue to develop market-based policy mechanisms to encourage the deployment of low-carbon technologies and reduce energy demand, for example by pricing carbon, promoting new and renewable energies, and commercialising research and development results.*
- *Continue and enhance its participation in international discussions and sharing of experiences post-Fukushima, given the expected improvements of safety and regulation being considered in many countries.*

3. CLIMATE CHANGE

Key data (2010)

CO_2 emissions from fuel combustion: 563 Mt, +146% since 1990

Emissions by fuel: coal 49%, oil 33%, natural gas 16%, other 2%

Emissions by sector: electricity and heat generation 50%, manufacturing industry and construction 18%, transport 15%, households 6%, services and other 11%

OVERVIEW

Although the ninth-largest greenhouse gas emitter in the world, Korea is not among the 38 Kyoto Protocol Annex I countries with a mandatory commitment to reduce emissions.

In 2008, the President of Korea launched Low Carbon, Green Growth as the future guide for the nation's long-term economic development. Subsequently, the government developed and published a National Strategy for Green Growth and a Five-Year Plan for Green Growth. In 2009, the country pledged to reduce its emissions by 30% below business-as-usual (BAU) levels by 2020. This target was transposed into law by the Low Carbon, Green Growth Act, which was followed, in May 2012, by an announcement of a law to introduce a cap-and-trade system for emissions.

GHG EMISSIONS PROFILE

Korea's total greenhouse gas (GHG) emissions (excluding land use, land use change and forestry, LULUCF) were 647.3 Mt CO_2-eq in 2010, representing a 118.6% increase compared to 1990. The energy sector accounted for 88.7% of total emissions, followed by the industrial processes (5.0%), agriculture (3.1%), and waste sectors (1.8%).

In 2010, total GHG emissions per capita were about 13.2 tonnes (t) of CO_2-eq, an increase of 91.7% compared to 1990 levels. Korea emitted 0.43 t of CO_2 per USD 1 000 of gross domestic product (GDP) on a purchasing power parity (PPP) basis in 2010. This is 26% higher than the IEA average of 0.33 t of CO_2 per USD 1 000.

CO_2 EMISSIONS FROM FUEL COMBUSTION

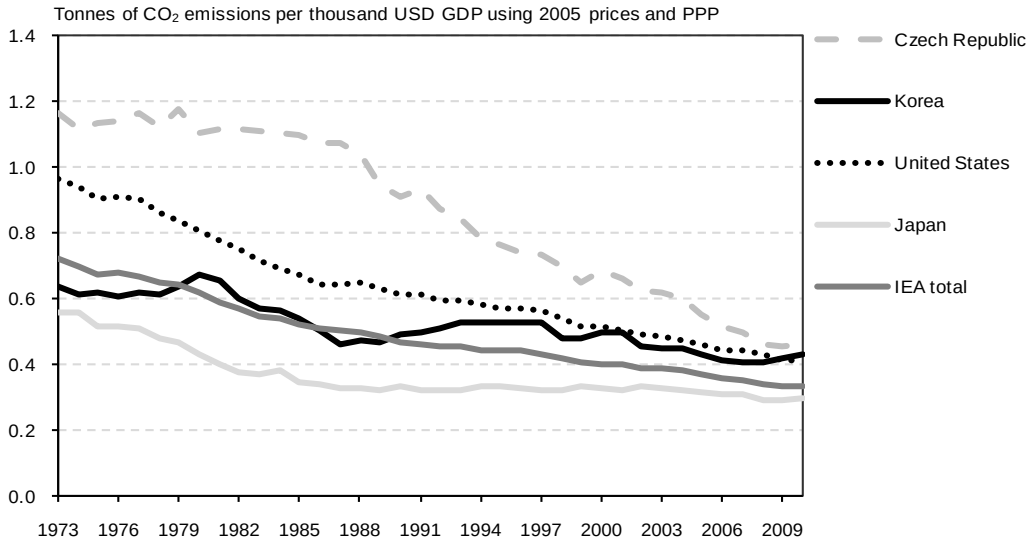
While energy-related CO_2 emissions from fuel combustion in Korea have increased significantly since 1990, there have also been large changes in the composition of the emissions mix when measured by fuel. Emissions from coal and natural gas have grown while emissions from oil have fallen.

In 1990, natural gas accounted for 2.8% (6.4 Mt CO_2) of energy-related emissions; by 2010, this had grown to 16% (90.2 Mt CO_2). Over the same period, emissions from coal increased

from 37.7% (86.3 Mt CO_2) to 49% (276.3 Mt CO_2). The share of emissions from oil combustion fell over the same period, from 59% (135.3 Mt CO_2) to 33.2% (186.6 Mt CO_2).

Similar changes to the emissions profile can be observed by sector. Emissions from the electricity sector more than doubled between 1990 and 2010, from 54.8 Mt CO_2 (23.9%) to 279.2 Mt CO_2 (49.6%). This happened as production of electricity more than quadrupled, largely driven by economic growth, and was generated by nuclear energy, coal-fired thermal capacity and to a lesser extent natural gas (as LNG). Over the same period emissions from other energy-related industries doubled, from 3.5% to 6.4%, albeit from a small base, while emissions from the industry and transport sectors as a proportion of total emissions declined. Absolute emissions from the household sector fell between 1990 and 2010, from 40.7 Mt CO_2 to 32.9 Mt CO_2, reflecting greater use of natural gas for heating at the expense of coal.

Figure 4. **Energy-related CO_2 emissions per GDP in Korea and in other selected IEA member countries, 1973-2010**

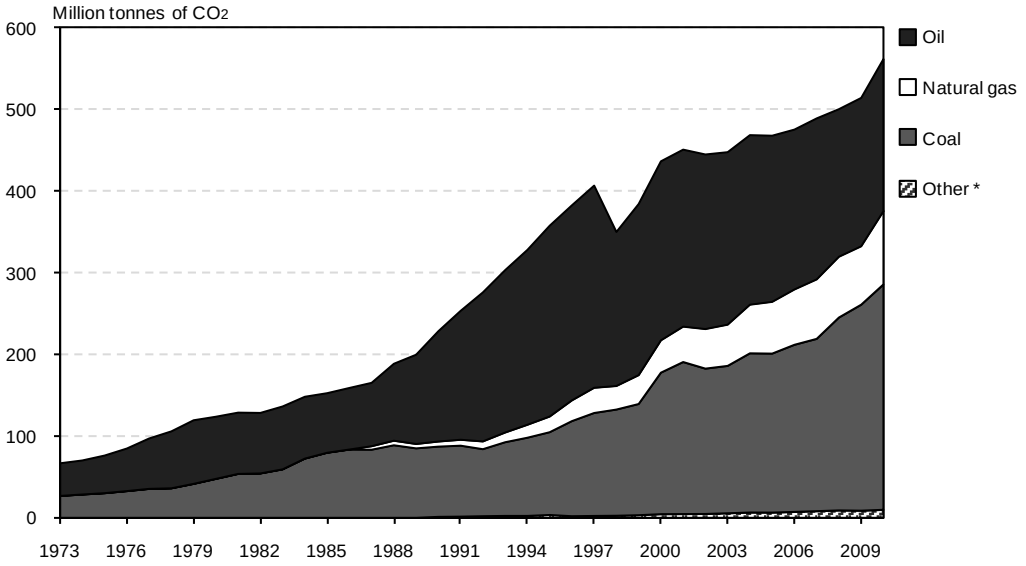


Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012, and *National Accounts of OECD Countries*, OECD Paris, 2012.

PROJECTED EMISSIONS

If the existing industry structure remains unchanged and no additional efforts are made to reduce CO_2 emissions, emissions during the forecast period to 2020 are anticipated to increase by 24.3% by 2015 and by 32% by 2020 (against 2005 levels) as the government maintains a sustainable growth rate. Emissions from the energy sector are expected to increase by 33.5% over the period but fall as a proportion of total emissions, from 82.3% in 2005 to 80.8% in 2020. Emissions from industry are projected to increase by 81.8% over the same period. Owing to improved fuel efficiency and a slow-down in car registration rates, emissions from the transport sector are expected to decrease from 17.4% to 15.7% while other sectors will experience a slight fall.

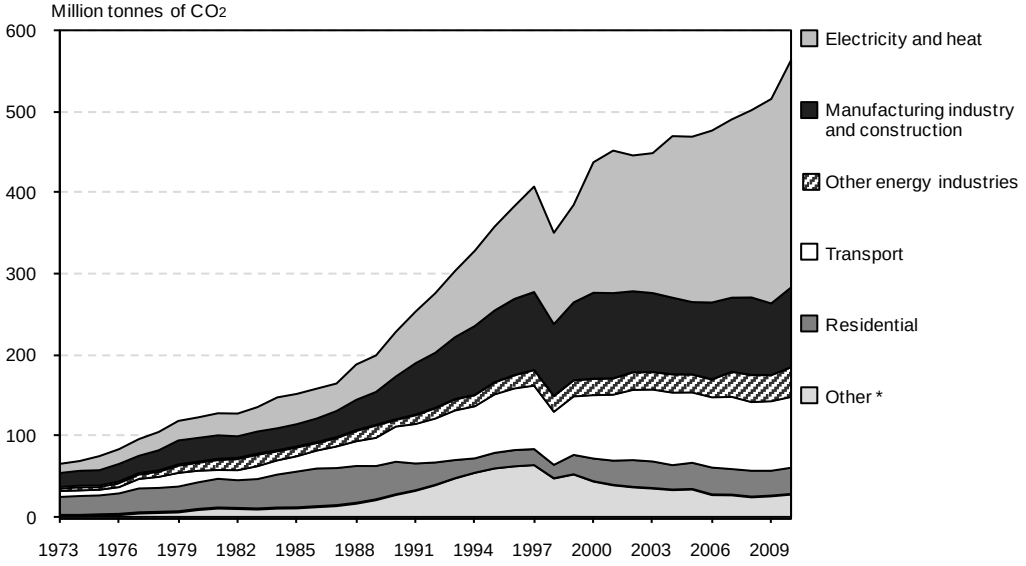
Figure 5. **CO_2 emissions by fuel, 1973-2010**



* *Other* includes industrial waste and non-renewable municipal waste (negligible).

Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2012.

Figure 6. **CO_2 emissions by sector, 1973-2010**



* Other includes emissions from commercial and public services, agriculture/forestry and fishing.

Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 2012.

INSTITUTIONS

The **Presidential Committee on Green Growth**, launched in 2009, coordinates and deliberates on policies relating to green growth including climate change. In addition, the **Ministry of Food, Agriculture, Forestry, and Fisheries**, the **Ministry of Knowledge Economy**, the **Ministry of Environment, and** the **Ministry of Land**, **Transport, and Maritime Affairs** have climate change related responsibilities for their sectors.

In accordance with the Framework Act on Low Carbon, Green Growth, the relevant ministries required to submit information on their GHG emissions are the Ministry of Food, Agriculture, Forestry and Fisheries, the Ministry of Knowledge Economy, the Ministry of Environment and the Ministry of Land, Transport, and Maritime Affairs.

Since 2010, the Ministry of Environment is responsible for the overall management of the national GHG inventory while the **National GHG Inventory Committee** is responsible for its approval. Other agencies such as the **Greenhouse Gas Inventory and Research Center**, the **National GHG Management Committee** and the **National GHG Technical Group** also contribute.

POLICIES AND MEASURES

OVERVIEW

In 2008, Low Carbon, Green Growth was proclaimed by Korea as a national vision and a Presidential Committee on Green Growth (PCGG) was established to actively promote relevant policies and measures to address climate change. Recently, Korea strengthened its policies and introduced a Comprehensive Action Plan for Climate Change (2008-12). Also, the government of Korea announced a national mid-term GHG reduction goal of 30% below the BAU level by 2020. This decision was complemented by the adoption in 2012 of a law establishing a cap-and-trade system for emissions.

THE NATIONAL STRATEGY FOR GREEN GROWTH

In 2009, following the official announcement of Low Carbon Green Growth as the major national policy, the Korean government implemented the Framework Act on Low Carbon, Green Growth, which addresses climate change mitigation, energy policy and sustainable development.

The purpose of the Framework Act on Low Carbon, Green Growth is to implement effective measures to address climate change and energy concerns and promote sustainable development in Korea. The Act also intended to bring together various ministries or government agencies active in the sector or, where necessary, integrate them.

In April 2010, a government policy, Management of Targets for GHGs and Energy, which aims to reduce GHG emissions, was established. Its implementation is divided between the directing government department, the Ministry of Environment, which sets up integration guidelines, and other responsible departments such as the Ministry for Knowledge Economy (MKE), which decides reduction targets for each company. Also established was the Low Carbon, Green Growth Enforcement Ordinance, which includes GHG reduction targets and guidelines and procedures for assisting green companies.

Commencing in 2012, a Target Management System required companies emitting more than 25 thousand tonnes (kt) CO_2-eq per year to agree emissions savings targets with government in 2011, those emitting more than 20 kt CO_2-eq per year in 2012 and those emitting more than 15 kt CO_2-eq per year by 2014.

The Low Carbon, Green Growth Act granted the Korean government the ability to establish an emissions trading scheme and in November 2010, the government notified that a separate GHG Emissions Reduction Trading Act was being prepared.

FIVE-YEAR PLAN FOR GREEN GROWTH

The Five-Year Plan for Green Growth (2009-13) contains about 600 projects that will cost approximately KRW 108.7 trillion, or 2% of 2009 GDP each year, to implement. The 25 largest programmes contained in the plan account for almost three-quarters of expenditure in the first four years of the programme and include the Four Major Rivers Restoration Project and railroad construction, which together account for almost one-third of total spending between 2009 and 2012.

Box 1. The National Strategy for Green Growth

The strategy, announced in July 2009, has **three objectives:**

1. Promote a synergistic relationship between economic growth and environmental protection.

2. Improve people's quality of life and promote a green revolution in their lifestyles.

3. Contribute to international efforts to fight climate change and other environmental threats.

Three goals:

1. Mitigating climate change and promoting energy independence.

2. Creating new engines for economic growth.

3. Improving the quality of life and enhancing Korea's international standing.

And **ten policy agendas** to achieve the three goals:

1. Effective mitigation of greenhouse gas emissions: the government will pursue mitigation strategies for buildings, transport and industry, require reporting on emissions and promote forestation.

2. Reduction in the use of fossil fuels and the enhancement of energy independence: Korea will reduce its energy intensity to the OECD average, increase the use of renewable energy and expand nuclear power capacity.

3. Strengthening the capacity to adapt to climate change: Korea will launch the Four Major Rivers Restoration Project and increase the share of environment friendly agricultural products to 18% by 2020.

4. Development of green technologies: the government will pursue the development of important green technologies, boosting its world market share in the relevant sectors to 8% within five years.

5. The "greening" of existing industries and promotion of green industries: exports of green goods in the major industries will rise from 10% in 2009 to 22% in 2020; and the government will help small and medium-sized enterprises (SMEs) to green their business.

6. Advancement of the industrial structure to increase the role of services: the government will develop health care, education, finance, contents industry, software and tourism as the core of high value-added services.

7. Engineering a structural basis for the green economy: the government will gradually introduce an emissions trading system, make the tax system greener and extend public credit guarantees to green industry.

Box 1. The National Strategy for Green Growth (continued)

8. Greening land and water and building the green transport infrastructure: the share of passenger travel by rail will rise from 18% in 2009 to 26% in 2020, and metropolitan mass transit from 50% to 65% over the same period.

9. Bringing the green revolution into Koreans' daily lives: carbon footprint labelling will be enacted; the government will increase mandatory procurement of green goods; and education on green growth will be expanded.

10. Becoming a role model for the international community as a green growth leader: Korea will actively engage in international climate change negotiations and increase the share of green official development assistance from 11% to 30% in 2020.

Source: Korea's Green Growth Strategy, Mitigating Climate Change and Developing New Growth Engines, OECD Economics Department, Working Papers No. 798.

NATIONAL EMISSIONS TRADING SCHEME

In May 2012, the government, the first in Asia, announced a law, *the Act on the Allocation and Trading of Greenhouse Gas Emission Permits*, establishing a cap-and-trade system for emissions. The National Assembly adopted a bill that aims to facilitate the achievement of the national objective: a 30% reduction of greenhouse gas emissions by 2020. The mechanism will enter in force in 2015 and will cover 60% of emissions.

Starting in 2015, the Korean ETS will cover facilities emitting 25 000 tonnes of CO_2-eq, representing approximately 500 of the country's largest emitters, about 60% of national GHG emissions. The government will set emissions caps and reduction targets for each trading period.

Three initial phases have been outlined. The first of these will go from 2015 to 2017, the second from 2018 to 2020. The third phase, and perhaps subsequent ones, is expected to be a five-year term. The government will be offering more than 95% of all carbon credits for free in the first and seconds phase and the remainder will be auctioned. Some companies may be able to obtain 100% of their permits for free, depending on their contribution to the country's trade and their production costs but no specific assistance for trade-exposed industries has been provided.

It is understood that the level of free allocations will decrease over time. Banking and borrowing will be allowed, but the details on how this will work are not yet developed. Non-compliance will be penalised for each tonne of carbon over a participant's cap. The government has yet to develop any rules governing compliance, such as how many certified emissions reductions issued by the clean development mechanism (CDM) would be allowed in the Korean programme.

OTHER POLICIES AND MEASURES

Transport sector

In 2010, emissions from the transport sector represented almost 15.4% of CO_2 emissions from fuel combustion. Accordingly, policies are being enforced to improve the public transport system, to increase the supply of alternative vehicles and to establish a low-carbon distribution system. A driving tax, which is set at 26% of the transportation/energy/

environment tax, is also levied on gasoline and diesel. In July 2009, the government revised the regulatory standards on fuel economy and CO_2 emissions for passenger cars. Fuel economy of 17 km per litre or CO_2 emissions of 140 g per km will be phased in by 2015.

Diesel is taxed more heavily in Korea than gasoline because of higher emissions of CO_2 and air pollutants. Likewise, there is a strong transfer of revenues from environmental taxes towards road building.

The government is promoting the deployment of smaller and greener motor cars by the provision of incentives such as the reduction of an acquisition and registration tax and the introduction of the Green-Car Promotion Strategy in December 2010. The government also plans to encourage the deployment of 1.3 million green cars by providing subsidies and tax reductions by investing in the installation of 1.35 million electric vehicle charging points and 168 hydrogen stations by 2020.[2]

Buildings and industry

In the buildings sector, efforts to reduce GHG emissions are being made through the reinforcement of design standards for energy saving in buildings, the expansion of the energy efficiency level certification system, and the acceleration of green building certification. The government has also initiated the One Million Green Homes project to replace the existing energy supply in selected homes with new and renewable energy sources such as photo-voltaic, solar and geothermal energy by 2020.

In the industry sector, the government has introduced a Voluntary Emissions Reduction Registration Programme since 2005, whereby emitting enterprises are rewarded for emissions reductions above 100 t CO_2-eq.

INTERNATIONAL FLEXIBLITY MECHANISMS

Since 2005, Korea has participated in the clean development mechanism (CDM) as a non-Annex I country. Specifically, 70 CDM projects (as of September 2012) were implemented in Korea. Expected average annual reductions from registered projects are 19 Mt CO_2-eq per year.

These CDM projects in Korea registered by the United Nations Framework Convention on Climate Change (UNFCCC) are categorised as: 47 new and renewable energy (including land field gas) projects, five nitrous oxide (N_2O) projects and six sulphur hexafluoride (SF_6) projects. In terms of emissions reductions, non- CO_2 accounts for over 16 Mt CO_2-eq, representing 85.2% of total reductions.

CRITIQUE

Over the past two decades, Korea's economy has become heavily industrialised and emissions of CO_2 per capita have increased by 115.4% between 1990 and 2010. Furthermore, emissions are expected to rise significantly, placing Korea among the OECD's top emitting economies. This is largely because of the importance in Korea's

2. The term green car in the Korean context includes electric vehicles (EV), plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), fuel cell electric vehicles (FCEV) and clean diesel vehicles (CDV).

economy of heavy industries such as steel, oil refineries and chemicals. Nonetheless, the Korean government is taking strong steps to reduce emissions while at the same time maintaining economic growth.

The government has committed to reducing its GHG emissions by 30% in 2020 compared to its BAU case and has integrated this commitment into its Strategy for Green Growth. This strategy has been transposed into law by the enactment of the Framework Act on Green Growth, whose implementation is co-ordinated by a Presidential Committee. Uncertainty remains, however, as to what this target means in practice, both in terms of the level of reductions (the BAU case is not firmly defined) and in how it will be achieved.

Korea has made important strides in developing policies to cap GHG emissions. It is in the process of implementing a target management approach whereby major emitters agree to individual emissions reduction targets. For the medium term, the 2012 announcement of an emissions trading scheme (ETS), which will be implemented in 2015, is another large step forward. This policy has the potential to provide a comprehensive and economically efficient means of reducing emissions. An ETS could avoid many of the difficulties under the target management approach, particularly if there is a timely move towards auctioning, which will happen at some point. We understand that the government is developing details of the scheme, including how the interaction between the ETS and the target management system will work in practice. For this, the government should clarify the sector and type of the target of the ETS.

Putting a price on greenhouse gas emissions is a cornerstone policy in climate change mitigation and there are significant design choices to be made in establishing an ETS. Korea has adopted an ambitious target but it is important that it takes advantage of experience acquired elsewhere when developing the detailed design of the ETS.

In the longer term, delivering the massive change in the investment patterns needed to deliver Korea's low-carbon future will require clear and consistent investment signals, including visibility of long-term emission prices. This can be achieved by allowing banking, signalling caps far in advance and political commitment to the scheme's long-term duration.[3]

Evidence suggests that the cost, both to the economy and to emission-intensive industries in particular, is a factor in ETS designs. As an energy-intensive and trade-exposed economy, Korea must ensure that these cost impacts are not over-estimated while taking care to ensure that the negative impacts on certain industries are minimised. Furthermore, should Korea decide to provide transitional assistance to selected industries, the cost of these measures may be significant and need to be carefully considered and weighed against other potential uses of the potential revenues.

Nonetheless, Korea is densely populated, heavily reliant on energy-intensive industries, and has limited natural resources for new and renewable energy development. The country is therefore likely to rely on fossil fuels for a substantial part of its energy demand in the foreseeable future. While the government envisages some reduction in the share of coal and gas in the overall energy mix by 2030 (from 28% to 16% for coal, and 14% to 12% for gas), in absolute terms, the use of these fuels is likely to rise. Deployment of carbon capture and storage (CCS) may therefore be necessary if increased GHG emissions are to be avoided. The IEA welcomes recent progress in this regard and encourages the government to support the further development of CCS in Korea.

3. *Reviewing Existing and Proposed Emissions Trading Systems*, OECD/IEA Paris, 2010.

The government also needs to acknowledge that emissions trading alone will not solve the climate problem and supplementary and complementary policies will be needed. In this regard, implementation of Korea's Strategy for Green Growth can make a huge contribution by supporting complementary energy efficiency policies, new and renewable energy measures and a strong research and development sector.

The transport sector remains the third-largest contributor to CO_2 emissions from fuel combustion. While existing policies contain strong measures targeted on the sector, Korea would benefit from additional policies. These could include stricter measures to reduce transport-related air pollution in urban areas, stricter emission limits for new vehicles, and a review of transport-related fiscal measures. For example, the transfer of environmental taxes, including the transport-environment-energy tax on gasoline and diesel, for road construction, should be ended. At present, 80% of the revenue is earmarked for transport infrastructure, primarily roads, thus encouraging GHG emissions.

RECOMMENDATIONS

The government of Korea should:

- *Develop an explicit and quantitative definition of the business-as-usual baseline for the 30% emissions-reduction target supported by a clear strategy and implementation plan to deliver that result.*
- *Clarify the details of the target management system and emissions trading scheme to ensure coherence and a structured and transparent transition from one to the other to ensure that implementation leads to cost-effective emissions reductions across the economy. For this to occur, clarify the sector and type of target of the ETS.*
- *Evaluate the cost-effectiveness of additional measures aimed at reducing emissions from the road transport sector and eliminate the transfer of revenue from environmental taxes towards the development of road infrastructure.*

4. ENERGY EFFICIENCY

Key data (2010)

Energy supply per capita: 5.1 toe (IEA average: 4.7), +27.8% since 2000

Energy intensity: 0.19 toe per 1 000 USD (IEA average: 0.15), -11.4% since 2000

Total final consumption: 157.4 Mtoe (oil 52%, electricity 25%, natural gas 13%, coal 6%, heat 3%, renewables 2%), +24% since 2000

Consumption by sector: industry 52%, transport 19%, services and agriculture 16%, households 13% (IEA average: industry 32%, transport 32%, households 20%, other 16%)

OVERVIEW

Korea is an energy-intensive economy, the world's eleventh-highest in terms of energy consumption and ninth in terms of oil consumption. To date, Korea's economy has relied on energy-intensive industry, such as steel, petro-chemicals and cement. As a result, energy consumption in the industrial sector is extremely high, accounting for 52% of total national consumption.

FINAL CONSUMPTION OF ENERGY

Korea's total final consumption of energy (TFC) in 2010 was 157.4 Mtoe, an increase of almost 7% from the previous year and almost 24% higher than in 2000. Over the same period, real USD GDP grew by over 4% per year on average. Energy consumption is expected to continue increasing with TFC forecast to reach 220 Mtoe by 2020.

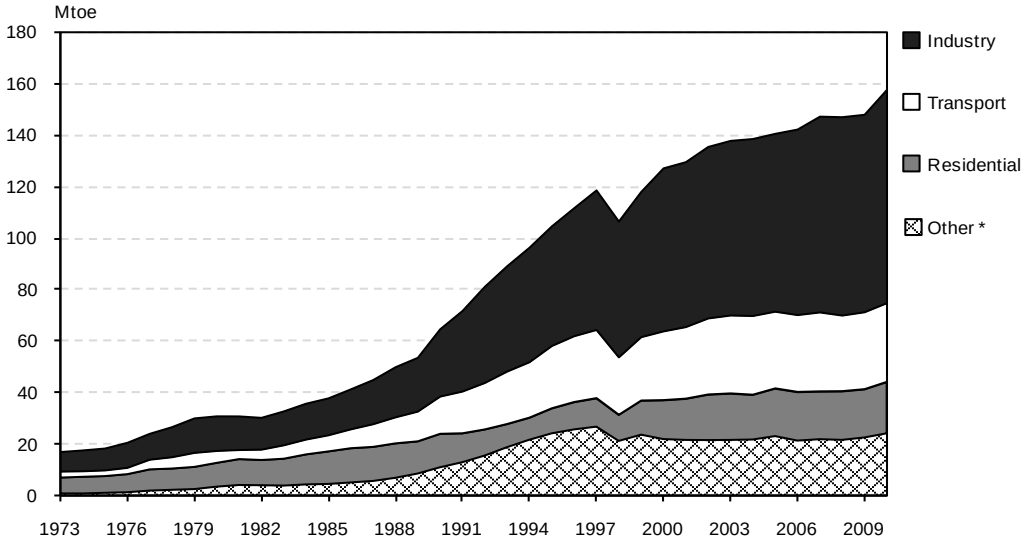
The industry sector absorbed the largest share of TFC, around 52% of the total in 2010. The transport sector accounted for 19% and other sectors, including the residential sector, for the remainder. This contrasts significantly with IEA averages, which in 2010 were 32% for transport, 20% for residential, 32% for industry, and 16% for other sectors.

Since 1990, TFC in Korea has increased in all sectors (see Figures 7 and 8), driven by strong economic growth. TFC fell, however, in 2008 reflecting the global economic downturn, but quickly recovered. The sectoral breakdown of TFC has changed in a manner untypical of other IEA economies. Industry has seen its share increase from 40% in 1990 to 52% in 2010, the transport, residential and service sectors have seen their share of the total fall while the remaining sectors have been relatively stable.

Korea relies on electricity and oil for much of its energy. In 2010, the country consumed 81.9 Mtoe of oil and 38.6 Mtoe of electricity or 52% and 24.5% of TFC respectively. Much of the remainder was supplied by natural gas, which contributed 12.9%, or 20.4 Mtoe, while coal provided 6.1% or 9.5 Mtoe. The share of renewables in TFC is among the lowest in the IEA. Nonetheless, the share of oil in TFC has remained relatively stable in volume terms in the ten years between 2000 and 2010 but has fallen by almost 10% in

terms of share of TFC. Most of the incremental growth in energy consumption has come from electricity, which increased its contribution to TFC from 22.6 Mtoe to 38.6 Mtoe, or 53% of the 30.3 Mtoe incremental growth, between 2000 and 2010. Consumption of natural gas has almost doubled in the same period, from 10.9 Mtoe in 2000 to 20.4 Mtoe in 2010.

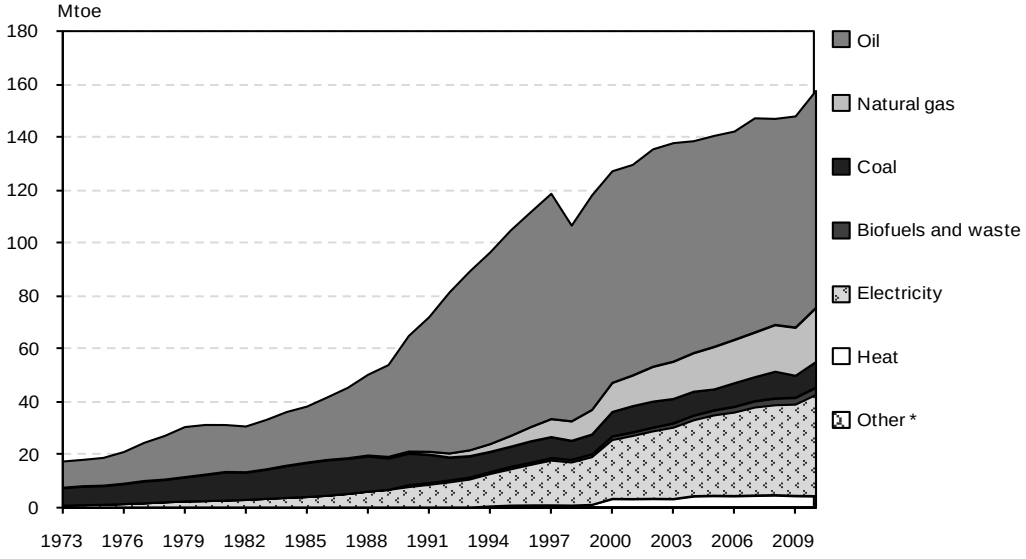
Figure 7. **Total final consumption by sector, 1973-2010**



* *Other* includes commercial, public services, agricultural, fishing and other non-specified sectors.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

Figure 8. **Total final consumption by source, 1973-2010**



* *Other* includes geothermal and solar thermal (negligible).

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

In 2010, Korea required 0.19 tonne of oil equivalent (toe) of primary energy for each thousand US dollars of GDP. The relatively high energy intensity of the Korean economy is explained by the predominance of large energy-intensive industries. The heating requirement is lower than in most IEA member countries. Energy intensity has improved on average by 0.3% per year from 1990 to 2010, compared with the IEA member country average of 1.3%.

INSTITUTIONS

In June 2009, in response to the Package of Measures for Energy Demand Side Management, the Ministry of Knowledge Economy (MKE) created an **Energy Efficiency Bureau** to actively promote the energy efficiency and saving. Its primary duties are to establish an energy plan and related policy, implement sectoral measures and operate greenhouse gas (GHG) and energy reduction commitments. The Energy Efficiency Bureau is comprised of three divisions; an energy efficiency policy division, an energy efficiency management division and an energy co-operation division.

The **Korea Energy Management Corporation** (KEMCO), a government-affiliated institute, is comprised of 16 divisions across four locations, one affiliated organisation, and 12 branches. KEMCO's primary duties are to improve the energy efficiency, deploy new and renewable energy technologies, and respond to climate change challenges. KEMCO is responsible for implementing sectoral (industry, buildings, transport, public) policy measures, public relations, capacity building, energy audits and energy statistics for energy efficiency. KEMCO has established an industry generation target management division, a green energy cooperation division and a financing division for energy services companies (ESCOs) to assist in the implementation of energy efficiency policy. About one-third of its 455 full-time staff is working in energy efficiency-related activities.

POLICIES AND MEASURES

In 2008, the government established the First National Energy Plan and the Fourth Energy Use Rationalization Plan to generate an improvement in energy efficiency of 46% by 2030. In the short term, Korea proposes to increase energy efficiency by 11.3% or 34.2 Mtoe by 2012 by investing KRW 18.3 trillion over the period 2008 to 2012.

VOLUNTARY AGREEMENTS

The National Energy Saving Committee, which was established by the Energy Use Rationalisation Act in 1998, introduced a voluntary agreement for energy saving and GHG reductions. Under this programme, industries have been voluntarily setting and realising energy-saving and GHG reduction goals. The government has supported these agreements by means of direct funding and fiscal measures. This mechanism initially focused on companies consuming over 5 000 toe per year but in 2004 the system expanded to include companies consuming over 2 000 toe per year. The initiative was launched in 1998 with 15 pilot projects and by 2009, about 1 300 workplaces had participated in the scheme.

ENERGY AUDIT SYSTEM

The Energy Audit System, introduced in 2007, in accordance with the Energy Use Rationalisation Act, aims to conserve energy and reduce GHG emissions in the industrial

and buildings sectors. It does this by regularly inspecting businesses that consume more than 2 000 toe per year. In businesses that consume less than 10 000 toe, the cost of audits will be partially supported by as much as 90%. Potential energy savings of approximately 148 000 toe have been identified, or 276 toe per business audited.

From 2007 to 2010, 1 497 companies in the industrial sector and 410 buildings underwent an energy audit. The audit system identified 2.2 Mtoe of potential energy savings, which has led to significant investment in energy-saving facilities and ESCO projects.

CONSULTATION ON ENERGY USE PLAN

The Consultation on Energy Use Plan is a system in which industries of a given scale are required to consult on their plans for energy supply and efficiency enhancement. Started in 1993, this system was designed to assist the public sector, but its application was extended to the private sector in 2002. At present, eight sectors, including urban development, industrial complex development, port construction, are parties to the scheme. By means of this scheme, a total of 882 prior agreements have been reached regarding the energy use plan. As a result, potential savings of 15.6 Mtoe have been identified.

INVESTMENT SUPPORT FOR ENERGY-EFFICIENT FACILITIES

The government has supported the investment in energy-efficient facilities by making long-term loans at low interest rates available to businesses that wish to replace outdated, low-efficiency equipment and to purchase new high-efficiency technology. Introduced in 2000, the scheme is regularly updated and, between 1980 and 2010, a total of KRW 8.9 trillion was made available. In 2011, approximately KRW 601.8 billion was made available under the scheme.

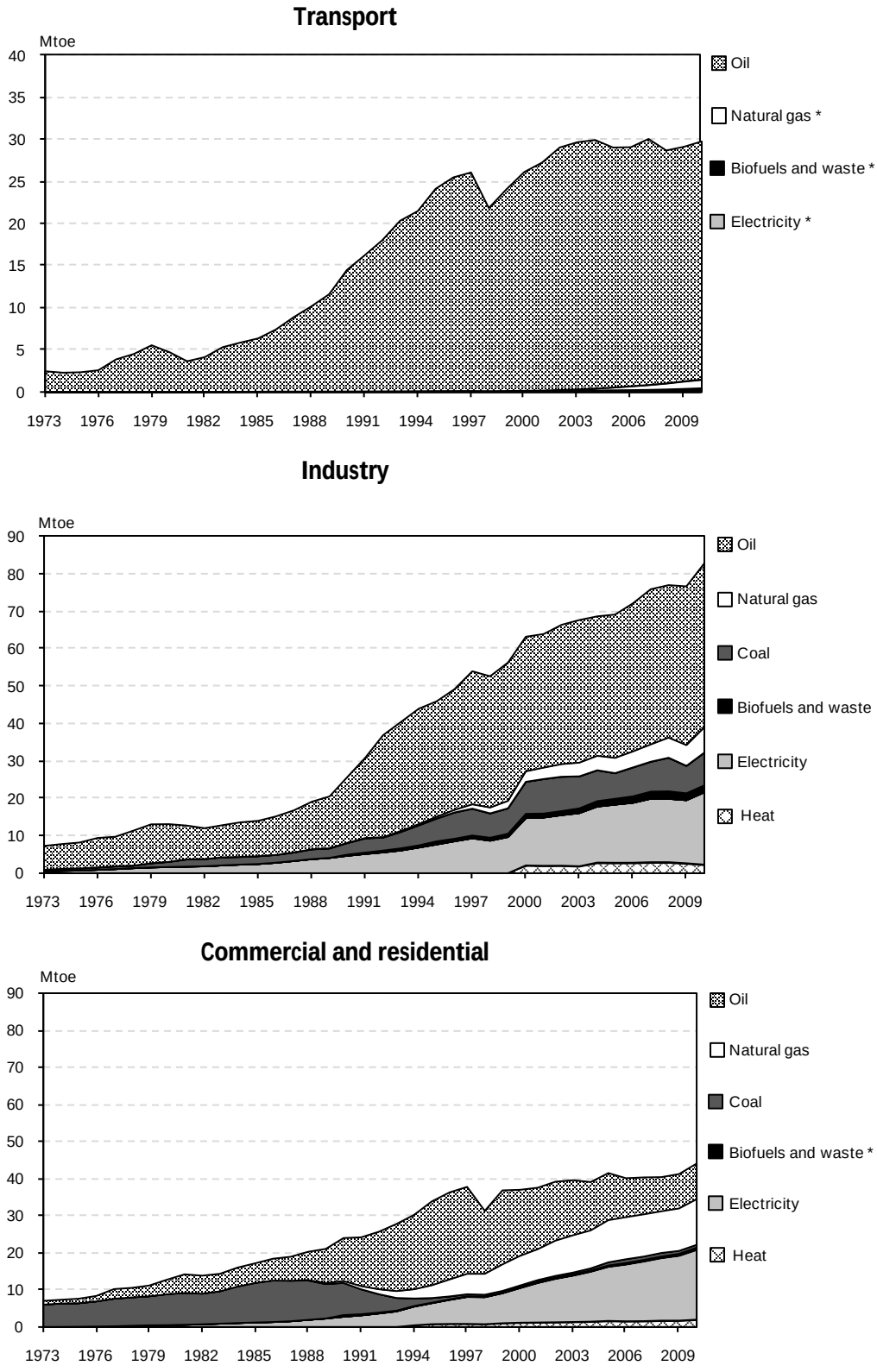
BUILDINGS

Building codes have been revised a number of times in order to strengthen energy efficiency requirements. Revisions have included the introduction of an insulation criterion for core components and the installation of stand-by cut-off outlets, light-emitting diodes (LED), and renewable equipment. According to the latest revision to the codes, a performance-based energy code, which limits total energy use per unit area, was applied to all buildings in the business sector over 10 000 square metres in July 2011. The government's aim is to gradually keep updating building codes such that by 2025 all newly constructed buildings will be zero-energy buildings.

Eco-friendly home codes were established in October 2009 to deploy low energy-consuming homes. Blocks of flats with over 20 households must be designed so as to improve energy efficiency by 20% over the existing building. The government provided KRW 14 billion for the retrofitting of homes in 2010 and compelled buildings containing over 300 households to reveal their energy consumption on an internet portal. The government plans to deploy one million eco-friendly homes, the so called "Green Home" for newly constructed and renovated buildings by 2018.

The Building Energy Certification Programme is currently applied to new apartments and commercial buildings and will gradually be extended to all types of buildings by 2013. By that date, owners of buildings will be obliged to provide prospective buyers or tenants with a certificate indicating the building's energy efficiency.

Figure 9**. Total final consumption by sector and by source, 1973-2010**



* Negligible.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

The GHG Energy Target Management System was introduced for large commercial buildings and public buildings in 2010. Under the scheme, the government imposes a greenhouse gas emission target, as well as limits to energy use, on designated entities (companies with large GHG emissions and energy consumption). The government in turn monitors the achievements of these entities. All new public buildings must meet the highest standard in the energy performance certification programme. If they exceed 10 000 square metres in area, achieve energy savings of over 5%, or are likely to recover the investment within ten years, they are required to propose an ESCO project.

APPLIANCES

The government operates three major schemes to improve energy efficiency in this sector:

- an energy-labelling programme;
- a high-efficiency equipment certification programme; and
- an energy stand-by programme.

The **Energy Labelling Programme** was introduced in 1992. Energy efficiency labels are required on all energy-consuming products. The production and sale of products rated below the lowest efficiency standards are forbidden. The programme is a mandatory scheme and all manufacturers are required to comply. Thirty-five products, including lighting devices, are contained in the programme. Furthermore, in 2012 the government will introduce the **Energy Frontier Programme**, which is similar to Japan's Top Runner programme, a system which sets an efficiency target based on the model meriting the top rating and maintaining an average efficiency over a certain period.

The **High-Efficiency Equipment Certification Programme**, which was introduced in 1996, includes 39 products, among them pumps, boilers and LED lighting. This programme issues a special certificate for products exceeding certain criteria.

The **Stand-by Programme** was introduced to deploy power-saving appliances with standby power consumption below a certain criterion in 1999. It is applied to 22 products including computer set-top boxes. A stand-by warning label must be attached on products below a certain criterion.

In addition, public institutions phased out all incandescent lamps by 2009 and are required to replace 30% of their lamps with LED technology by 2012. The government will phase out all incandescent lamps by 2013 and replace 30% of all lamps with LED lighting by means of the LED Deployment 18/30 Plan by 2020.

INDUSTRY

As Korea implemented the Emissions Reduction Target Management System, it established targets and follow-up action plans in 2011 for 366 controlled entities. By 2014, the number of designated companies will increase to 520. Furthermore, a sectoral assistance programme and a Green Credit Scheme will be introduced. Under the Green Credit Scheme, major companies that assist SMEs to reduce their GHG emissions will be credited with the emissions savings. To encourage companies to use the Energy Management System (EMS) more widely, the government has provided sectoral application software and SME support packages. An ESCO loan fund, up to KRW 390 billion, for promoting ESCOs and a KRW 150 billion ESCO fund has also been created. The government gives a preference to a guaranteed saving model and carries out a competitive process to selectively identify and support the best projects.

TRANSPORT

In July 2009, the government revised the regulatory standards on fuel economy and CO_2 emissions for passenger cars. Fuel economy of 17 km per litre, or CO_2 emissions of 140 g per km, which is similar to advanced standards elsewhere, will be phased in by 2015. The average fuel economy programme for passenger cars will be applied after 2013. Measures such as vehicle labelling will be improved in 2012, following the example of the United States' five-cycle method to reflect real fuel economy.

A tyre labelling programme will be introduced to encourage the deployment of high-efficiency tyres. This programme will be applied to passenger cars and light-duty commercial vehicles, and tyres annually, commencing in December 2012. The government is promoting the deployment of smaller and greener motor cars by providing incentives such as the reduction of acquisition and registration taxes.

The Law on the Development and Deployment of Eco-Friendly Cars was revised in May 2009 and the Green Car Promotion Strategy was published in December 2010. The government plans to support the deployment of 1.3 million green cars by providing subsidies and tax reductions and by investing in the installation of 1.35 million electric vehicle charging points and 168 hydrogen stations by 2020.[4]

A weekly No-Driving Day programme is compulsorily implemented in public institutions and voluntarily operated in the private sector. The government provides a radio-frequency identification (RFID) tag for local governments and reduced road tax (reductions of 5% to 10%) to promote the participation in the private sector. Seoul city imposes congestion fees (KRW 2 000) on car owners in major traffic congestion areas. Many local governments are installing express bus lanes and bus rapid transit (BRT) to promote greater use of public transport.

CRITIQUE

Korea is an energy-intensive economy, ranking eleventh-highest worldwide in terms of energy consumption and ninth in terms of oil consumption. Its energy intensity, adjusted for purchasing power parity, has been declining relatively steadily since its peak in 1997, falling at an average annual rate of 1.2% between 1997 and 2010. Despite this declining trend, Korea's energy intensity is still expected to remain above that of most IEA countries throughout 2012.

In 2009, the government announced a 30% GHG reduction target and enacted the Low Carbon, Green Growth Act. To meet this ambitious target, the government is pursuing several strategies in the transport the buildings sectors, for example, stricter standards on fuel efficiency, CO_2 regulation, building design, and strengthening existing policies. The IEA commends these efforts and also the progress made by Korea to date. Nonetheless, greater clarity on specific targets, including sector-specific targets, clear complementary plans and time schedules, and greater co-ordination and co-operation among government ministries and agencies are needed.

The road transport sector is a major consumer of energy, most notably oil. In July 2009, Korea announced a new fuel economy standard for car manufacturers and importers of

4. The term green car in the Korean context includes electric vehicles (EV), plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), fuel cell electric vehicles (FCEV) and clean diesel vehicles (CDV).

17 km per litre, or CO_2 emissions of 140 g per km, by 2015, which is similar to prevailing standards in the European Union and the United States. In 2012, energy labelling for passenger cars will be improved on the basis of the North American five-cycle method to reflect real fuel economy. The IEA welcomes the introduction of these measures, the planned introduction of a tyre-labelling programme and the development of an innovative eco-driving scheme. Energy labelling for heavy-duty vehicles will be introduced in 2013. Continuing to develop and implement effective policies to reduce energy demand, and the adoption of demand restraint measures, would further enhance the overall energy efficiency policy.

In the buildings sector, Korea has revised its building codes many times in order to strengthen energy efficiency requirements. A performance-based energy code, which limits total energy use per unit area, will be applied to all business buildings of over 10 000 square metres. This should be extended to smaller buildings. Further improvement could be made by implementing energy efficiency policies targeting windows and the older building stock.

Regarding appliances and equipment, progress made in energy efficiency policy measures for television products is relatively behind those of the other appliances. This is an important area for improvement given the increasing market share for these products, especially since Korean television products are relatively dominant in the world home appliances market. The IEA understands that the government will soon introduce the Energy Frontier Programme. Lighting consumes around one-fifth of national electricity; therefore, strengthening energy efficiency policies in this sector is important. Good progress has been made to date; in 2009 the public sector phased out incandescent lighting and roll out LED by 2015.

Korea should strengthen its efforts to improve data collection and analysis in order to monitor and evaluate the results of energy efficiency policies across all sectors. Benchmarking should be used drawn upon best practices in the European Union.

The recovery of waste heat results in reduced demand for primary energy. Meeting heat demand with supply from combined heat and power (CHP, or co-generation), instead of the separate generation of heat, results in significant efficiency improvements. Energy-intensive industries and power plants in Korea constitute a significant potential for waste heat recovery and combined heat and power operations.

Korea has begun harvesting this potential energy efficiency improvement with the development of district heating systems supplying 1.8 million homes. Approximately 60% of this development has been achieved through a state-owned company, Korea District Heating Corporation. Co-generation was initially selected as one of 15 key technologies in the Green Energy Technology Strategy of the Korea Institute of Energy Technology Evaluation and Planning; however, in the Green Energy Strategy Roadmap 2011, the focus was limited only to small-scale co-generation.

The use of district heating/cooling systems provides further indirect benefits to the Korean energy system; the heating services provided can replace electric heating and LNG combustion at times when these systems are operating in peak mode with high marginal costs. Likewise, recovery of waste heat as district cooling would replace electricity during summer peak load in the electricity system.

Notwithstanding Korea's recent strong progress, the government should continue efforts to fully implement the IEA recommendations, where relevant, for improving energy efficiency (Box 2).

Box 2. **IEA 25 energy efficiency recommendations**

To support governments with their implementation of energy efficiency, the IEA recommended the adoption of specific energy efficiency policy measures to the G8 summits in 2006, 2007 and 2008.

In 2011, in order to reflect emerging priorities, the IEA, in consultation with international experts and member countries, streamlined and updated the 25 recommendations. The updated 25 recommendations cover a robust portfolio of policies that member and non-member countries should consider in the context of their energy economies.

This portfolio of recommendations includes policies to cost-effectively increase energy efficiency by establishing market signals to motivate effective action, accelerate the introduction of new technologies, and strengthen and enforce minimum energy performance standards (MEPS) for appliances, lighting, equipment and building energy codes.

1. To improve *energy efficiency* across all sectors, the IEA recommends action in the following areas:

§ energy efficiency data collection and indicators;

§ strategies and action plans;

§ competitive energy markets, with appropriate regulation;

§ private investment in energy efficiency; and

§ monitoring, enforcement and evaluation of policies and measures.

2. To achieve savings in the *buildings sector*, the IEA recommends:

§ mandatory building energy codes and minimum energy performance requirements;

§ aiming for net zero energy consumption buildings;

§ improving energy efficiency of existing buildings;

§ building energy labels and certificates; and

§ energy performance of building components and systems.

3. To achieve significant energy savings in the *appliances and equipment* sector, the IEA recommends:

§ mandatory energy performance standards and labels for appliances and equipment; and

§ test standards and measurement protocols for appliances and equipment.

4. To achieve significant energy savings in the *lighting sector*, the IEA recommends:

§ phase-out of inefficient lighting products and systems; and

§ energy-efficient lighting systems.

Box 2. IEA 25 energy efficiency recommendations (continued)

5. To achieve significant energy savings in the *transport sector,* the IEA recommends:

§ mandatory vehicle fuel efficiency standards; and

§ measures to improve vehicle fuel efficiency;

§ fuel-efficient non-engine components;

§ improving operational efficiency through eco-driving and other measures;

§ improve transport system efficiency.

6. To achieve significant energy savings in the *industrial sector*, the IEA recommends:

§ energy management in industry;

§ high-efficiency industrial equipment and systems;

§ energy efficiency services for small and medium-sized enterprises; and

§ complementary policies to support industrial energy efficiency.

7. To achieve significant energy savings in *energy utilities* and *end-use energy efficiency*, the IEA recommends:

§ governments should establish regulatory and other policies to ensure that energy utilities support cost-effective, verifiable end-use energy efficiency improvements.

RECOMMENDATIONS

The government of Korea should:

- *Strengthen co-operation and coordination between different ministries for the implementation of energy efficiency policies and identify clear roles and responsibilities.*
- *Develop an integrated, more clearly coordinated, strategy to improve the effectiveness of energy-efficiency policies, with measurable sector targets, in particular for transport, industry and the utilities.*
- *Establish an effective monitoring and analysis system to ensure progress in sector-specific energy consumption and devise energy efficiency indicators drawing on best international practice.*
- *Develop and implement policies to address gaps in the existing portfolio of energy efficiency polices, particularly with respect to the buildings, transport and district heating and cooling sectors.*
- *Continue to develop and implement effective policies to reduce energy demand.*
- *Analyse the cost effectiveness and full environmental benefits from a strategy including CHP and waste heat recovery in an infrastructure for district heating and cooling.*
- *Include energy services from bioenergy, waste, geothermal energy distributed to final consumers in district heating or cooling systems as qualifying in the Green Homes scheme.*

PART II
SECTOR ANALYSIS

5. NATURAL GAS

Key data (2011 estimated)

Net imports: 46.8 bcm (Qatar 22%, Indonesia 21%, Oman 12%, Malaysia 11%, Russia 8%, others 26%)

Share of natural gas: 16.2% of TPES and 21.2% of electricity generation

Inland consumption (2010): 43.2 bcm (power generation 47%, residential 23%, industry 18%, services and other 9%, transport 3%)

OVERVIEW

Natural gas represented 16.2% of total primary energy supply (TPES) in 2011 and powered 21.2% of electricity generation. Domestic gas production is negligible and Korea depends on imported LNG for 99.7% of its demand. The sector is dominated by Korea Gas Corporation (KOGAS), the owner of three LNG import facilities and the transmission network.

SUPPLY AND DEMAND

SUPPLY

Korea started importing LNG in 1986 and is one of the world's largest LNG importers. In 2011, the country imported 46.8 billion cubic metres (bcm) of LNG, an increase of almost 7.5% compared to 2010 and more than 140% more than in 2000. Imports are well diversified with supply coming from approximately 16 producing countries. Qatar and Indonesia are the largest sources of LNG, delivering 10.5 bcm (22.5%) and 10 bcm (21.3%) in 2011. Other large suppliers include Oman (11.6%), Malaysia (11.1%) and the Russian Federation (8%). The Korea Gas Corporation (KOGAS) is the largest LNG import company in the world and it was responsible for 95% of Korea's total gas imports in 2011.

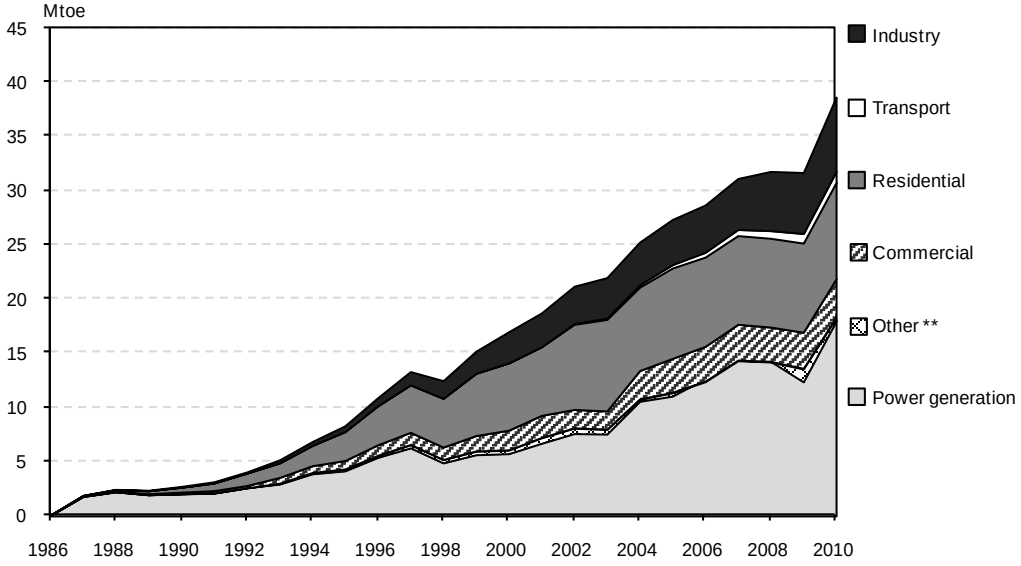
KOGAS imports approximately 80% to 90% of its LNG volumes though mid- to long-term contracts. Owing to the heavy seasonality in gas demand, some long-term contracts allocate more volumes in winter. This seasonality, complemented by other variables such as the shortage of storage facilities, requires 10% to 20% of domestic demand to be met by purchases on the spot market. Imported volumes are distributed through the nationwide pipeline network after regasification at three import terminals.

KOGAS imports its LNG either through long-term contracts at a rate indexed to the price of crude oil, or through the spot market. Contracts initially been drawn up on delivered-ex-ship (DES) basis, but KOGAS has started to renegotiate contracts on the more flexible free-on-board (FOB) basis. The link between spot gas prices and crude oil prices weakened in 2009 owing to capacity gluts at the regional level. In September 2008, KOGAS and

Gazprom, in an effort to move away from its dependence on European markets, signed a memorandum on the supply of natural gas, via pipeline through North Korea, to Korea. (North Korea has not yet given consent to the construction the pipeline and it is uncertain whether and when the planned pipeline project will materialise.)

In 2010, the parties signed a roadmap for exports to Korea. The document specifies that deliveries of 10 bcm per year will commence in 2017 and last for 25 years. In 2010, a final report, which studied options for natural gas supplies to Korea from Vladivostok, was published. In September 2011, Gazprom and KOGAS agreed a roadmap on natural gas supply, which included the key actions to be taken by both parties.

Figure 10. **Natural gas supply by sector*, 1986-2010**



* TPES by consuming sector.

** *Other* includes other transformation and energy sector consumption.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

DOMESTIC GAS SUPPLY

Korea was estimated to possess little more than 1.0 bcm of proven reserves of natural gas at the end of 2011.[5] Domestic gas production is negligible; in 2011, Korea produced 0.41 bcm of natural gas, less than 1% of total consumption. All domestic gas was produced from the offshore Donghae-1 gas field, the only domestic gas field in production. The Korea National Oil Corporation (KNOC) started commercial production from this gas field in July 2004 and production is expected to end in 2016. Gas from the field is transported via a 75 km underwater pipeline to the Onsan gas treatment plant in Ulsan from where it is processed and distributed to the Ulsan and Kyungnam areas.

There are large unexplored areas of continental shelf offshore Korea, including three sedimentary basins: the Ulleung Basin, the Yellow Sea Basin and the Jeju Basin. In 2007, KNOC successfully drilled for gas hydrates in the Ulleung Basin, which is estimated to

5. IEA Statistics, *Natural Gas Information* 2012, IEA Paris, 2012.

hold 600 Mt of gas hydrates, sufficient to meet the country's LNG needs for 30 years. At the time of the discovery, the government announced its intention to begin commercial production from the deposit by 2015.

Table 2. **Natural gas production in Korea and forecast production, 2005-15**

		2005	2008	2009	2010	2015
Production volume	(thousand tonnes)	398	181	383	415	185
	(million Nm^3)	477	217	459	495	222

Source: Ministry of Knowledge Economy.

DEMAND

Gas demand has steadily increased since the first LNG shipments arrived in 1986. Korea's gas consumption in 2011 was 45.9 bcm compared to 42.7 bcm in 2010, an increase of 7.5%. In 2010, the transformation sector, largely electricity production, was responsible for approximately 47% of gas use. Excluding transformation, final consumption of gas in 2010 was 22.8 bcm with the residential sector and industry the largest consumers, using 10 bcm and 7.7 bcm respectively. The iron and steel (1.8 bcm) and chemicals (1.7 bcm) were the largest consumers of natural gas within the industry sector.

Consumption in the electricity sector has increased significantly in recent years. In 2004 it was 8.8 bcm and by 2010 it had increased to 15 bcm. Between 2008 and 2010, demand from the combined heat and power (CHP) producers increased from 3.7 bcm to 5.0 bcm.

Gas demand tends to peak in winter when demand for space heating and cooking increases heavily. The turn-down ratio (TDR), which Korea uses to measure the seasonality of natural gas, is the maximum monthly volume divided by the minimum annualised monthly volume. The TDR was 2.58 in 2011 with consumption peaking at 6.5 bcm in January compared to 2.5 bcm in August.

LONG-TERM NATURAL GAS FORECASTS

The Ministry of Knowledge Economy (MKE) prepares a long-term natural gas supply and demand plan every two years. The plan examines LNG import facility construction and expansion projects, electricity supply and demand plans (each within the context of the Basic National Energy Plan) and the gas demand outlook by sector based on past trends.

The Tenth Long-term Natural Gas Supply and Demand Plan, which was published by MKE in December 2010, contains a detailed long-term natural gas supply and demand outlook, a gas import plan and an infrastructure investment plan for the 15 years from 2010 to 2024.[6] The Tenth Plan forecasts that natural gas demand in Korea will increase at an average rate of 1.8% per year between 2009 and 2024. Town gas (supply to urban areas) demand is forecast to increase at an average rate of 2.3% while demand in the power generation sector over the same period is anticipated to increase by 1.1%, less than other sectors owing to the greater role of nuclear energy and new and renewable energy in the future. The total length of the transmission network is forecast to expand from 2 853 km to 4 244 km.

6. Korea's Tenth Long-term Natural Gas Supply and Demand Plan, Ministry of Knowledge Economy, December 2010.

The Tenth Plan also proposes that KOGAS leverage its position as the world's largest purchaser of LNG to secure greater imports, mainly from the Asia-Pacific region, under short- to medium-term contracts until 2014. From 2015, it proposes that KOGAS secure oil-indexed long-term contracts, with improved flexibility and conditions. New long-term contractual arrangements should be augmented by greater co-operation between Korea and its LNG-importing regional neighbours such as Japan and Chinese Taipei (Taiwan). The Tenth Plan also requests that KOGAS seeks out a greater role in upstream developments in producing regions.

MARKET STRUCTURE

OVERVIEW

The Korean natural gas industry is dominated by KOGAS; it owns three of the four LNG import facilities (with another under construction), the transmission system, almost all storage capacity and is the sole wholesaler of gas. There are 30 city gas companies that are responsible for supply to industrial, residential and commercial consumers. Fourteen power companies, with the exception of POSCO (a steel producer) and SK E&S (formerly K-Power) purchase their gas from KOGAS. The largest of these is Korea Electric Power Corporation (KEPCO): in 2011, it purchased 69% of all gas consumed by the power sector.

KOREA GAS CORPORATION

The Korea Gas Corporation (KOGAS) was legally formed by the Korean government in 1983. Since then, it has grown to become the world's largest corporate buyer of LNG. It currently operates three LNG terminals and a nationwide pipeline network spanning over 3 022 km. KOGAS is listed on the Korean Stock Exchange, and its major shareholders are government entities, such as the central government (26.9%), KEPCO (24.5%), local governments (9.6%) and the Treasury (6.1%). As a public enterprise, KOGAS dominates the Korean natural gas market. Nonetheless, it has expanded the scope of business from import and distribution of natural gas, to exploration and production projects throughout the world with a participating interest in at least 20 such projects including in Canada, Qatar, Oman, Yemen, Iraq, Myanmar, Indonesia and Russia.

In October 2011, despite its relatively limited upstream experience, KOGAS signed a deal to develop the Akkas field in Iraq. In Mozambique, KOGAS holds a 10% share in the Mamba Complex, which is estimated to hold gas in place at over 1.1 trillion cubic metres (tcm) at the end of 2011. KOGAS also holds a large interest in gas plays in British Columbia, Canada.

KOGAS has extensive interests in LNG liquefaction facilities including in Indonesia's 2.7 bcm Donggi Senoro LNG, which is expected to commence operations in 2014. It is one of three major stakeholders in Australia's 4.9 bcm Prelude LNG, which is expected in 2017, and one of four major stakeholders in the Shell LNG JV in Canada where a final investment decision is expected in 2014.

KOGAS participates in the provision of technical services to a number of Asian LNG regasification terminal projects including the PTT LNG project in Rayong, Thailand, the Singapore LNG regasification terminal in Jurong Island and the Dalian LNG project in China.

MARKET DESIGN

MKE oversees the natural gas industry in Korea; it regulates the wholesale price of gas using a rate of return/cost of service regulatory mechanism. Local governments regulate local distribution companies' retail business. Since 2006, the government has made efforts to reform the national gas market. For example, an open-access policy has been put in place to give direct importers improved access to the KOGAS transmission network and LNG facilities. However, third-party access (TPA) to the transmission network, LNG storage facilities and import terminals which KOGAS owns and operates is still limited.

ACCESS

Separate open access systems (OAS) for pipeline and import facilities have been introduced since the last in-depth review. When it comes to pipeline facilities of the gas wholesaler, direct importers have a mandate to offer an open access policy within the current capacity. Through mutual agreement, direct importers are also able to have access to production facilities of the gas wholesaler and pipeline facilities of city gas companies. The OAS is intended to prohibit discrimination on direct importers and to establish a procedure for appeal and penalty is case of violation. When a conflict occurs between the direct importer and pipeline facility owners on the use of the pipeline, the Minister of Knowledge Economy will act as an arbitrator if such conflict is determined to cause a disruption in the demand and supply balance of natural gas.

City gas companies are to keep separate accounting for gas supply facilities from the rest of their business. According to the City Gas Business Act, only direct importers for captive use are allowed to have access to gas pipelines. KOGAS-owned transmission pipelines are generally offered on a regulated third-party basis while access to distribution pipelines is on a negotiated access basis.

In order for the facility user to have access to the transmission pipeline, the user must submit an application to KOGAS, prepared in accordance with the Network Access Code. The application should contain details such as the connection point (entrance and exit points), duration of usage (starting date and term), the expected volume (annual and monthly), maximum volume per hour, gas specification (heating value, pressure, etc.), at least twelve months before the expected starting date of the usage.

INFRASTRUCTURE

LNG IMPORT FACILITIES

There are four LNG terminals in operation in Korea. Three out of the four LNG terminals are owned and operated by KOGAS. The privately owned POSCO operates an LNG terminal in Gwangyang to support its power plant and also to supply a K-Power-owned plant.

The four terminals are currently able to supply the national gas transmission system with about 128 bcm of natural gas per year (351 mcm per day), which is 196% higher than the level of average annual gas demand in Korea. A fifth LNG terminal, the KOGAS-owned Samcheok facility, with a regasification capacity of 2.3 bcm of natural gas per year, is scheduled to be completed by 2015. Five more storage tanks, with a total storage capacity of 1.3 mcm of LNG (859 mcm of natural gas), will be built at this location.

Figure 11. **Natural gas infrastructure**

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

Source: Ministry of Knowledge Economy.

This new terminal will enhance the interconnectivity of Korea's gas transportation network, resulting in stronger gas supply security. While there are also plans to strengthen the storage capacity of the four existing LNG import terminals, there are few new LNG import terminals under consideration.

Currently, despite recent reform efforts, third-party access to the LNG storage facilities, transmission network and LNG terminals owned by KOGAS is relatively limited.

Table 3. **Existing LNG terminals in Korea**

Name	Owner	Regasification			Storage	
		Nominal capacity		Number of vaporisers	Capacity (mcm of LNG)	Number of tanks
		Mcm of LNG per year	Bcm per year of gas			
Gwangyang	POSCO	3.9	2.4	2	0.365	3
Incheon	KOGAS	84.5	51.8	37	2.880	20
Pyeong-Taek		83.6	51.3	34	2.960	21
Tong-Yeong		36.7	22.5	12	2.480	16
Total		**208.7**	**128.0**	**85**	**8.685**	**60**

Source: IEA.

STORAGE

There are no underground storage facilities in Korea. Almost all natural gas storage facilities are in the form of LNG tanks and their ancillary facilities. At the end of 2011, Korea had 60 tanks at four LNG terminals, with a total storage capacity of 8.7 mcm of LNG. The total storage capacity was able to meet about 42 days of average gas demand in 2010 and 22 days of peak gas demand in the same year.

KOGAS owns approximately 97% of the country's total storage capacity at its three LNG terminals in Incheon, Pyeong-Taek and Tong-Yeong, while the remainder is held by POSCO at its LNG terminal in Gwangyang. The Tenth Long-term Natural Gas Supply and Demand Plan forecasts that gas storage capacity will expand from 5.1 bcm to 9.4 bcm in 2017. Under this plan, the Donghae gas field is expected to be converted to a storage facility with a capacity of some 2.3 bcm of natural gas in 2017.

TRANSMISSION AND DISTRIBUTION

Korea does not have any cross-border gas pipelines. The nationwide transmission pipelines, totalling 3 099 km in length, are all owned and operated by KOGAS. There are plans to expand the pipeline network and the length of the network is expected to increase to 4 648 km by 2016.

SECURITY OF NATURAL GAS SUPPLY

OVERVIEW

Diversification of supply sources, ensuring LNG supply on the basis of long-term contracts, expansion of storage capacity and securing sufficient supply of gas for high seasonal demand are the key elements of Korea's gas security policy.

Korea does not have government gas stocks or mandatory industry stocks. However, KOGAS has internal requirements to maintain gas stocks. It holds four types of stocks: "minimum stocks", "fluctuating stock", "buffer stocks" and "safety stocks". The first is used to enable storage facilities to operate under normal conditions; the second is required to mitigate any surplus of forecasted demand; the third is needed to successfully handle discrepancy between demand and supply caused by supply delaying; and the last "safety stock" is the sum of the previous three stocks, which is the standard stock for controlling inventory level.

Currently, emergency and crisis management situations are controlled by the instruction of National Risk Management in Korea. According to the instruction of National Risk Management, government and KOGAS develop a Risk Response Manual in cope with emergency situations. KOGAS is in charge of Korea's overall domestic supply of natural gas, with the exception of those who import LNG for their own use. KOGAS, as the transmission system operator (TSO), in consultation with the gas division of MKE, plays a major role in emergency planning and managing crisis situations which affect the national natural gas system.

The Risk Response Manual has established a gas National Emergency Sharing Organisation (NESO) structure and emergency response measures and procedures. Nationwide emergency response exercises for gas supply disruptions are undertaken on a sporadic basis.

The Risk Response Manual includes measures to reduce the seasonal demand gap; there are plans to raise the differential between the seasonal gas tariffs in an effort to shift some of the demand from winter to summer. KOGAS (and the government) is investing in R&D on more efficient gas technologies and greater use of biogas.

EMERGENCY PREPAREDNESS

When an emergency situation arises, KOGAS issues alert procedures, in accordance with the Risk Response Manual, which is in place in the event of gas supply problems. The process follows the steps set out below:

Table 4. **KOGAS warning process**

Crisis alarm	Warning criteria
Blue	Below 30% of storage capacity
Yellow	Below 20% of storage capacity
Orange	Below 15% of storage capacity
Red	Below the minimum stocks

Source: Ministry of Knowledge Economy.

In the initial stage of a gas emergency, KOGAS attempts to secure additional volumes of LNG on a commercial basis, through purchases of spot cargoes, cargo swaps and cargo rescheduling. KOGAS has signed master agreements with major gas suppliers for the supply of LNG in such circumstances. KOGAS has also developed regional co-operation mechanisms as gas emergency responses with some Japanese LNG importers, through the swapping of LNG cargoes.

In the final phase of a gas emergency, the red phase, the Minister of Knowledge Economy may, in accordance with Article 24 of the City Gas Business Act, decide on the phased restriction of gas supply by priority as below:

Table 5. **Restriction of gas supply, by priority**

Order of gas supply restrictions	Restriction on gas supply
1	No supply to power plants which exceed the contracted volume of gas
2	No supply to power plants and industrial gas consumers, which have alternative fuel supply
3	No supply to power plants, which don't have alternative fuel supply
4	No city gas supply (for residential use and general use)
5	Shutdown by region

Source: Ministry of Knowledge Economy.

FUEL SWITCHING

In principle, fuel switching in the power generation sector is possible within the confines of existing regulations but the government does not have the policy tools or legal competence to promote fuel switching from natural gas to other fuels during a gas supply disruption. Furthermore, environmental restrictions in metropolitan areas, such as Seoul and the Gyeonggi province, mean that gas-fired power plants are not allowed to fuel switch should they wish to do so. Besides, gas-fired power producers are not required to maintain back-up fuel reserves. Fuel-switching capacity from gas to oil is estimated to be about 2.6 mcm per day of natural gas, which is equivalent to 2.2% of the average gas demand in 2010. In order to implement switching from gas into oil, some 14 000 barrels per day (kb/d) of fuel oil would be required.

RETAIL MARKET AND TARIFFS

In the residential sector, around 30 private gas distribution companies are granted exclusive retail rights within their respective regions, all of which are supplied by KOGAS. Twenty-eight power generating plants, owned by fourteen power producers, are also supplied gas by KOGAS. As such, there is limited direct competition between these companies, which maintain stable market shares. Korea's antitrust agency, the Fair Trade Commission, has recommended that the government slowly open up the country's gas import and distribution market, given that prices for the industrial sector in Korea tend to be higher than elsewhere in the OECD.

The wholesale tariff is composed of the material cost plus a supply margin based on the operating costs of KOGAS. The material costs include the cost of LNG, gas transportation expenses, insurance premiums and taxes, and import duties. The supply margins are made up of KOGAS's supply costs plus guaranteed returns divided by target volumes, which are decided by the Ministry of Knowledge Economy after annual consultation with KOGAS and the Ministry of Strategy and Finance (MOSF).

The tariff is subject to approval of the Minister of Knowledge Economy through its natural gas wholesale pricing committee and arrangements with MOSF. The wholesale pricing system allows KOGAS to pass its LNG costs onto consumers while the supply margin provides a guaranteed operating income to the company. The wholesale tariff is relatively risk-free in that it is insulated from global oil prices and from foreign exchange and interest rates.

The retail price of town gas varies according to the gas import price, taking into account the weighted average of mid-, long-term and spot gas costs as well as prevailing exchange rates. Town gas prices are generally adjusted every two months, but the range of adjustment must be within 3% of the previous price. The tariff is subject to approval by the mayor or the governor through the local price level consultation committee.

The final price depends on a number of factors; these include the purchase and offshore transportation costs for LNG, plus add-ons for re-gasification and transmission as well as management and maintenance costs. Various taxes, including VAT, import tariffs on the LNG import price, import surcharges on re-gasified gas, and a special excise tax on the LNG price are also taken into account.

The cost of gas used in the power industry is adjusted monthly according to gas tariff policy by adding LNG costs, import costs, and any related cost based on the planned volume of LNG procurement.

Retailers (the city gas companies) are also required to pay safety management and import charges. The Minister of Knowledge Economy has the authority to amend the cost-based city gas tariff mechanism when it is determined that public welfare is at risk because of an oil price increase or volatile exchange rates that result in the noticeable hike in the LNG import price. Any loss generated by such circumstances is the subject for compensation by the Minister of Knowledge Economy through the cost tends to be added to future tariffs.

CRITIQUE

Although not the largest source of energy, natural gas is a significant part of Korean energy supply. Natural gas, largely in the form of imported LNG, provided 16.2% of TPES in 2011, making it the third most important source of energy after coal and oil. Over half of this gas is consumed by households, commercial operations and industry by means of the city gas networks. The remainder is consumed by the electricity sector.

KOGAS imports almost all gas sold in Korea. The company is listed on the Korean Stock Exchange but the majority shareholders are government-owned: central government (26.8%), KEPCO (24.5%) and local governments (9.6%). KOGAS also operates, and is the largest user of, the gas pipeline system as well as of three LNG terminals. A fourth LNG terminal is being built by KOGAS. Small volumes of gas are imported by large users (direct importers) who import this gas for their own use, while households and other

smaller users are being supplied by the city gas companies. As a consequence, the Korean wholesale market for gas is dominated by KOGAS, whose wholesale and retail prices are determined by government policy.

Since the last IEA in-depth review in 2006, Korea has taken a number of steps to reform its natural gas market. An open-access policy has been put in place to give direct importers improved access to the transportation network and the LNG facilities. The government has also taken steps to improve the regulatory regime although it has stopped short of establishing an independent regulator for the sector. Korea needs to build on progress to date and given the scale of government participation in the sector, the establishment of an independent regulatory agency, perhaps based on an expansion of the role of the Korea Electricity Commission (KOREC), should be seriously considered.

It is widely understood that the traditional utility model of centralised government control and direct intervention in operations and investment decisions can often lead to inefficient outcomes such as price distortions, unproductive operations, and poor infrastructure development. While this may not be the situation in Korea, it can certainly be argued that the separation, in some form, of the various business activities of KOGAS could deliver better value to consumers. The trend throughout the OECD and elsewhere has been to unbundle natural gas utilities along vertical and horizontal lines and to open wholesale gas markets to new entrants. This can stimulate competition and the development of new markets: in gas supply, in financial products and in pipeline capacity to the benefit of both households and industry, and the overall economy. Under present arrangements, however, this is unlikely to happen.

KOGAS, the small number of direct importers of natural gas, the 30 city gas companies and other market participants should be encouraged to trade gas among themselves across the existing natural gas transmission infrastructure. Buyers of gas should be free to sell to all end users and all large customers should have the option of buying from a source other than KOGAS at appropriate market rates. The government should develop and implement policies to allow a wholesale gas market to emerge. Other measures which should be introduced at the same time include increased transparency regarding the utilisation of the existing network and LNG facilities, improved third-party access and the introduction of more flexible supply and capacity contracts.

Energy consumers need to develop an awareness of the market price of natural gas in order to understand its real value. The present system of regulated natural gas prices may not be appropriates to future market conditions. The government should charge the sector regulator, once established, with the task of examining the potential for introducing market-based tariffs, for large customers in the first instance.

Korea, despite its low energy resource base, has satisfied its energy demands by means of an effective imports policy. In the case of natural gas, LNG is sourced from a broad range of suppliers from both the Middle East and Asia. Since 2008, Korea has broadened its energy security policy, from relying solely on the international energy-commodities market to seeking to invest in overseas resource projects so as to secure long-term energy supplies. Korea should be commended for its proactive approach to securing adequate and diverse fuel supplies for its energy needs. Korea also recognises that overseas resource development requires significant investment of time and capital often with significant risks attached.

Transparent and open markets are vital as a first step towards ensuring energy security. Liberalising the Korean electricity and natural gas markets can result in more accurate and cost-reflective price signals at all stages of the supply chain and in more efficient resource allocation.

Nonetheless, a strong legal framework for emergency response policies and measures is required. The government should begin to develop an operational handbook that describes a gas NESO structure, emergency response measures and procedures, and continue to conduct nationwide emergency response exercises on a regular basis. There is a need to conduct a detailed survey to quantify fuel-switching capacities from gas to other fuels during a gas supply disruption. The government should consider making fuel-switching capacity during a supply emergency a permitting condition for new gas-fired power plants. This should be accompanied by a more flexible approach to the threshold of fuel switching in the metropolitan area during gas supply disruptions.

RECOMMENDATIONS

The government of Korea should:

- *Introduce greater competition in the natural gas market by:*
  - *Taking steps to unbundle the LNG, storage, transmission, distribution and sales activities of KOGAS.*
  - *Taking proactive steps to facilitate the emergence of wholesale trading of gas.*
- *Establish a well-resourced independent regulator for the sector using the existing model developed by the Korea Electricity Commission as a departure point, and empower it to oversee the transition to a transparent market-based system for gas.*
- *Continue to maintain its diverse energy import portfolio to mitigate the risks of supply disruptions of a particular fuel.*
- *Stipulate that the use of safety stocks held by KOGAS serve as an emergency response measure to be implemented in the second phase of the current gas emergency response plan.*
- *Conduct a survey to quantify fuel switching capacities from gas to other fuels during a gas supply disruption. Fuel-switching capacity should be part of the permitting conditions for gas-fired power plants to be built in the future.*
- *Take a more flexible approach to the threshold of fuel switching in metropolitan areas during gas supply disruptions.*
- *Continue to promote regional co-operation for gas emergency response, including swapping or securing of LNG cargoes.*

6. OIL

Key data (2011 estimated)

Crude oil production: 7.4 mb

Crude oil imports: 921.7 mb (Saudi Arabia 33%, Kuwait 14%, Qatar 10%, United Arab Emirates 10%, Iraq 9%, others 24%)

Oil products consumption: 688.5 mb

Oil products imports: 228.8 mb (United Arab Emirates 18%, India 17%, Qatar 13%, Saudi Arabia 10%, Kuwait 10%, others 33%)

Share of oil: 36% of TPES and 2.9% of electricity generation

OVERVIEW

Korea has limited domestic oil production and imports 99% of its crude oil requirements. Its crude oil imports stood at 921.7 million barrels (and total oil imports at 1 150.5 mb) in 2011; 87% of Korea's crude oil was sourced from the Middle East. Conversely, Korea is a net exporter of refined petroleum products, with exports reaching 386.5 mb in 2011. The country, however, imports significant amounts of some products – notably naphtha, which accounts for 23.4% of its total oil demand owing to its large petrochemical industry.

The upstream oil market is dominated by the state-owned Korea National Oil Corporation (KNOC), while the downstream market is dominated by four private-sector refining companies. Owing to its high dependence on imported oil, Korea holds significant strategic oil reserves. KNOC has completed a 30-year project to secure storage facilities with storage capacity for 146 mb of oil.

As of December 2011, KNOC held 89.6 mb of oil – equivalent to around 100.7 days of net imports. The remainder of KNOC's oil storage capacity (approximately 56.4 mb) remains either unfilled or has been leased to other oil companies including foreign companies under the International Joint Stockpile (IJS) project. A further 86.1 mb of oil is held by industry as industry stocks.

SUPPLY AND DEMAND

SUPPLY

Crude oil

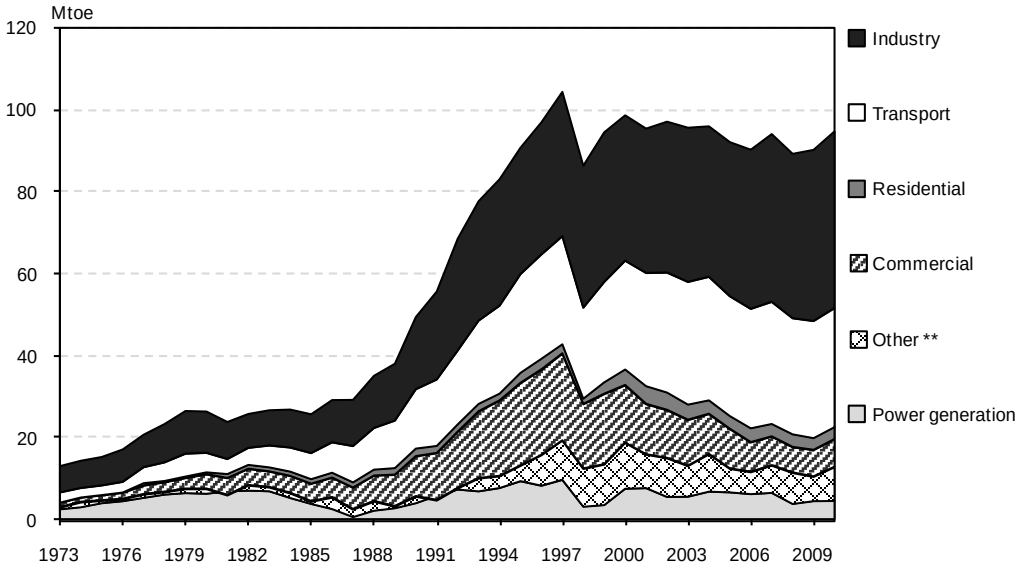
Korea's total oil imports stood at 3.3 mb per day (mb/d) (1 150.5 mb per year [mb/yr]) in 2011 – more than 99% of the country's crude oil requirements. These imports consisted of about 2.5 mb/d crude oil, and some 0.8 mb/d refined products.

With regard to crude oil import sources, Korea is highly dependent on Middle East countries which accounted for around 87.2% of total crude imports in 2011 (compared to 82% in 2010). Another 6.6% of Korea's oil imports came from Asia, 3.5% from the Russian Federation and 1.5% from Indonesia.

Despite the heavy reliance on imports from the Middle East, the countries of origin are relatively well diversified. By country, Saudi Arabia (33% of the total) was the biggest source of crude oil imports in 2011, followed by Kuwait (14%), Qatar (10%), the United Arab Emirates (10%), Iraq (9.%) and Iran (9%). Approximately 76.4% of Korea's crude oil imports are covered by long-term commercial contracts, which is beneficial in terms of security of supply.

In order to encourage the diversification of crude oil supply sources outside the Middle East, the government offers subsidies of up to 90% of the additional transport cost of importing crude oil from non-Middle East countries.

Figure 12. **Oil supply by sector*, 1973-2010**



* TPES by consuming sector. Includes non-energy use.

** *Other* includes other transformation and energy sector consumption.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

Refined products

Korea is a net exporter of refined product, with exports averaging 1 058.9 thousand barrels per day (kb/d) in 2011. Around one-third of Korea's product exports went to OECD countries – mainly Japan (15.5%) and the United States (4.0%) – while the remainder went to non-OECD countries such as China (22.7%) and Singapore (15.1%).

Korea imports significant amounts of some products – notably naphtha which, as already noted, accounted for approximately 23% of Korea's total oil demand and 71.4% of product imports in 2011. The government is content to leave the procurement of naphtha to the open market, and there are currently no plans to expand Korea's refining capacity to increase naphtha production. Roughly 54% of refined product imports in 2011 came from OPEC countries – mainly the United Arab Emirates, Saudi Arabia, Kuwait and Qatar – while some 17% of refined product imports came from India.

DEMAND

Korea's oil demand stood at about 1.9 mb/d in 2011 and has remained relatively flat during the last decade. The country uses a very large share of oil for the industry sector. It accounted for some 45.4% (dominantly naphtha) of the total oil consumption in Korea in 2010, while the transport and transformation/energy sectors represented 30.6% and 5.3% of the total, respectively.

With regard to oil demand by product, demand for diesel and motor gasoline increased by 3.5% and 15.6% respectively, between 2000 and 2011, while demand for naphtha and LPG/ethane rose by 53.7% and 17.3% during the same period. Residual fuel demand has dropped by 62%. Korea is a big consumer of naphtha, which is mainly used in the petrochemical industry. Demand for naphtha stood at 836.7 kb/d in 2011.

Crude oil (condensate) production in Korea averaged 0.7 kb/d in 2011, meeting less than 0.1% of the country's total oil demand. No further significant increase in domestic oil production is expected.

According to the New Policies Scenario of the *IEA World Energy Outlook 2011*, Korea's total oil demand is forecast to gradually decrease to 1.98 mb/d in 2015 and 1.88 mb/d in 2035.

The Korean government has a number of "green growth" and climate change policies in place which aim to lower the proportion of petroleum in the national energy mix. According to the Second National Energy Fundamental Plan, the government has a target for petroleum to make up no more than 31% of primary energy consumption by 2030.

INDUSTRY STRUCTURE

Korea's oil industry was largely liberalised in the 1990s, removing import and export restrictions on oil and oil products. Prices have been fully liberalised since 1997. The industry is now dominated by four private companies and the state-owned Korea National Oil Corporation (KNOC).

UPSTREAM MARKETS

The upstream oil market in Korea is dominated by KNOC, which is responsible for domestic and overseas exploration, development and production of oil and natural gas.

KNOC is the only domestic crude oil/condensate producer in Korea. Since the early 1980s it has drilled 43 offshore exploration wells, resulting in the discovery of a commercially viable natural gas field named Donghae-1 located about 60 km south-east of Ulsan. The Donghae-1 offshore field began commercial production of gas and condensate in 2004. However, as already noted, crude oil (condensate) production in Korea averaged 1 kb/d in 2011, meeting less than 0.1% of the country's total oil demand, and no further significant increase in domestic oil production is expected.

KNOC has also made extensive investments in overseas oil exploration and production projects. As of June 2012, KNOC was engaged in 220 oil exploration and production projects in 25 countries. These countries include Canada, China, Indonesia, Peru, Venezuela, Vietnam and the United Kingdom. As of June 2012, KNOC's overseas oil output stood at about 237 kb/d, while its overseas oil and gas reserves totalled 1.4 billion barrels of oil equivalent.

KNOC's overseas activities reflect government policy which is to seek to improve energy security of energy supply by investing in overseas oilfields. The ownership of significant overseas fields may also allow KNOC to offset higher oil prices with increased profits, and it gives the company greater access to swap deals when needed.

DOWNSTREAM MARKETS

Korea's domestic downstream market is dominated by four private sector refining companies: they are SK Innovation, GS Caltex, Hyundai Oilbank and S-Oil (Saudi Aramco is the controlling shareholder of S-Oil). There are five refineries operating in Korea (each owned by one of the four refining companies), with a combined crude distillation capacity of 2.78 mb/d.

Daehan Oil Pipeline Corporation (DOPCO) is the major oil pipeline company in Korea. It is responsible for operating the nationwide oil pipeline system consisting of six oil product pipelines which connect the refineries with major cities, airports, military bases and oil stockholding facilities. DOPCO is jointly owned by the four refining companies. The breakdown of its shareholders is: SK Innovation (41%), GS Caltex (28.62%), S-Oil (8.87%), Hyundai Heavy Industries (6.39%), Korean Air (3.10%), and the Korean government (12.02%). Although there are no restrictions to prevent new market entrants from utilising the DOPCO pipelines on a commercial basis, no companies other than DOPCO shareholders have yet done so.

The retail market in Korea is also dominated by the four domestic refiners. At the end of 2011, there were 13 213 fuel stations, about 93% of which were owned by these refiners.

There are technically no non-market barriers to entry into the Korean refining and retail markets by new competitors, or to their accessing the DOPCO pipelines on a commercial basis. The oil industry is also subject to general business regulation by the Fair Trade Commission.

STORAGE

The government started its 30-year project of securing storage facilities for petroleum in 1980, which was completed in May 2010. At the end of 2010, Korea possessed a total storage capacity of 286 mb (45.5 million cubic metres), which was composed of 146 mb of KNOC's facilities used for government stocks and international joint oil stockpiling, and 140 mb used for industry's operation and mandatory industry stocks.

KNOC has nine storage sites across the country which, as of December 2011, held 89.6 mb of public stocks. Around 86.8% of KNOC's storage capacity is for crude oil, while the remainder is for oil products. Domestic refiners and other companies may rent storage facilities from KNOC by concluding a lease agreement, the term of which is usually less than six months.

In addition to KNOC's government stockholding capacity, Korea has 145.4 mb of industry storage capacity which is used for commercial industry operations and mandatory industry stocks. The latter account for 86.1 mb of this capacity.

Roughly 44% of the total industry storage capacity was owned by SK Innovation at the end of 2010. The remainder was held by GS Caltex (30%), S-Oil (15%), Hyundai Oilbank (9%) and DOPCO (2%).

PRICES AND TAXES

The tax rates on automotive diesel from 2007 to 2011 were around 70% to 75% of those on gasoline. This kept the price of diesel 5% to 17% lower than the gasoline price. In

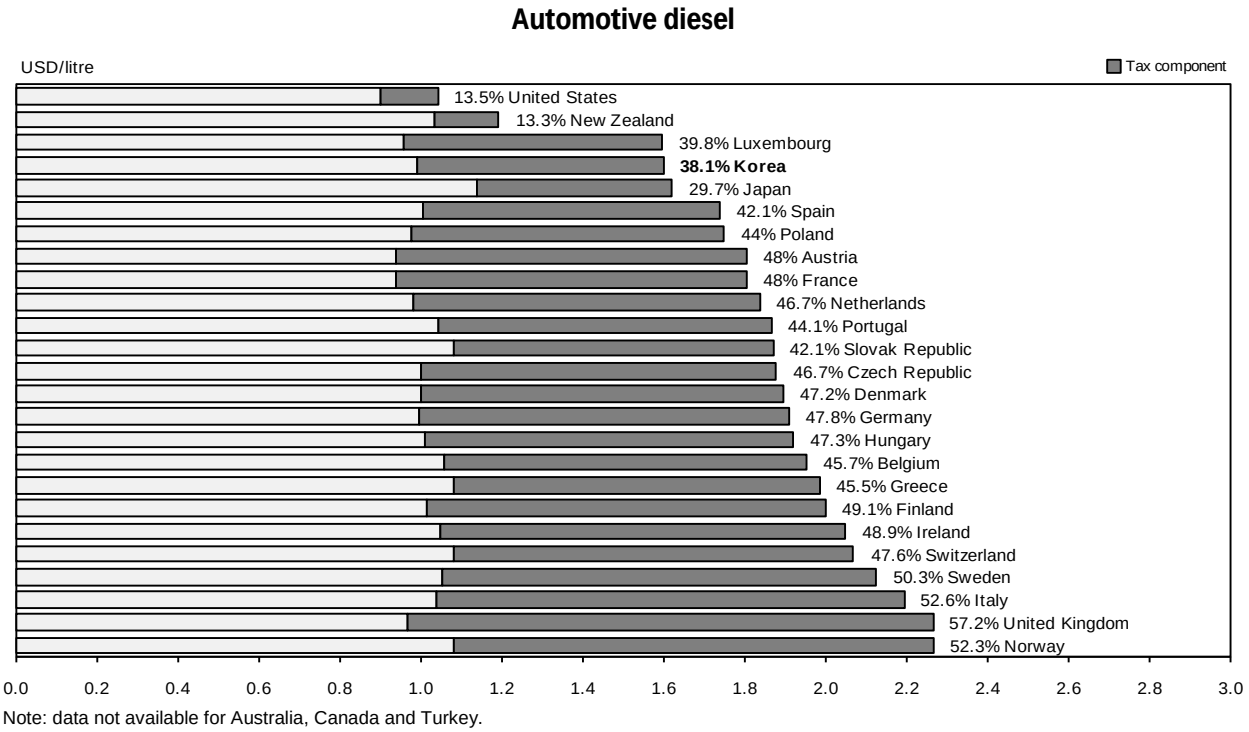
March 2012, government taxes on gasoline accounted for some 45.8% of the total price, while taxes on diesel made up about 37.6% of the total price. During the same period the tax rates on automotive liquefied petroleum gas (LPG) were roughly one-third of those on regular unleaded gasoline. Owing to the difference in tax rates between the two products, the pump price of LPG has been about 40% to 50% lower than that of gasoline.

Korea was one of the few IEA member countries that undertook downward-adjustments of excise taxes on automotive diesel and regular unleaded gasoline in the period from the fourth quarter of 2007 to the first quarter of 2009. In the first quarter of 2008, the excise taxes on diesel and gasoline were reduced by some 4.5% and 3.5% respectively. In the second quarter of 2008, when global oil prices jumped to USD 140 per barrel, the excise taxes on diesel and gasoline in Korea were further cut by some 7.3% and 7.4% respectively, from the previous quarter.

In April 2011, after consultation with the government, the four Korean refiners cut retail gasoline and diesel prices by about 5% for three months during another period of exceptionally high oil prices. Although apparently voluntary, the lowering of wholesale prices during a time of tight oil supplies and high international prices is not ideal and potentially calls into question the basis upon which prices are determined in the Korean market. Accordingly, the IEA review team concluded that more transparency in the Korean wholesale petroleum market would help to ensure that price signals are as closely linked to market supply and demand as possible.

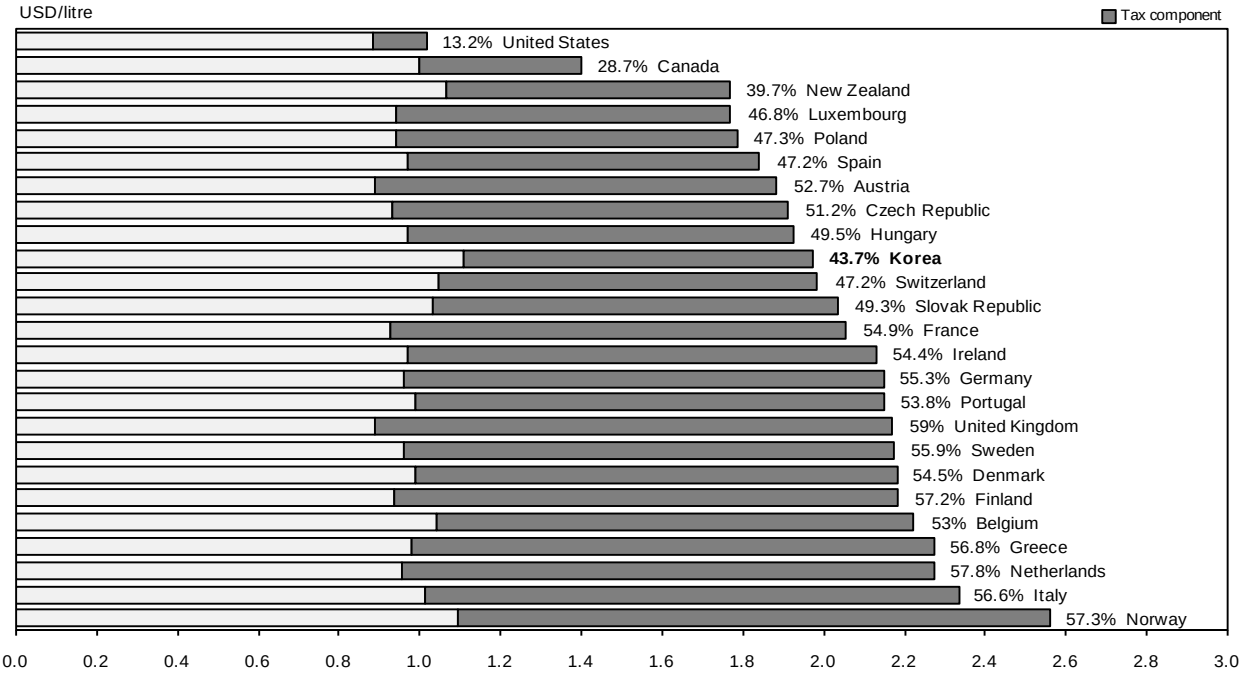
It was also reported that the government was considering cutting oil taxes at that time. However, a reduction of oil tax rates in 2011 did not occur.

Figure 13. **IEA fuel prices and taxes, second quarter 2012**



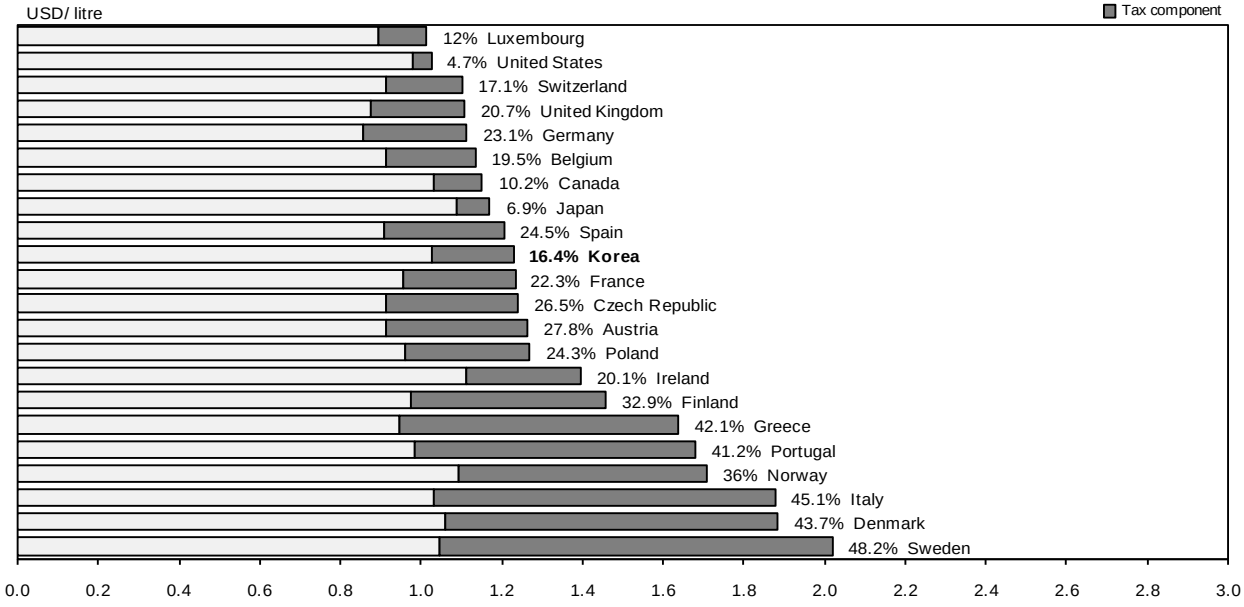
Note: data not available for Australia, Canada and Turkey.

Unleaded gasoline



Note: data not available for Australia, Japan and Turkey.

Light fuel oil



Note: data not available for Australia, Hungary, the Netherlands, New Zealand, the Slovak Republic and Turkey.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2012.

REFINING AND OIL SUPPLY INFRASTRUCTURE

REFINERY OUTPUT

There are four refineries in Korea, with a total crude distillation capacity of around 3.04 mb/d. SK Innovation has two refineries, one in Ulsan (840 kb/d) and another in Incheon (275 kb/d) with a combined capacity of 1 115 kb/d. The other refineries are held by GS Caltex in Yeosu (865 kb/d), S-Oil in Onsan (669 kb/d) and Hyundai Oilbank in Daesan (390 kb/d).

In 2011, the four refineries processed around 983.6 mb of crude oil (including natural gas liquids and feed stocks), which indicates that the overall capacity utilisation rate was about 88.7%. In the same year, the composition of production from these refineries was gas/diesel oil (31.2%), naphtha (17.9%), residual fuel oil (14.5%), aviation kerosene (11.8%), motor gasoline (11.4%), and LPG (1.8%).

Korea had a naphtha deficit of around 363.7 kb/d in 2011, and some 53% of total naphtha consumption was met by imports. The country also encountered an LPG deficit of some 123.7 kb/d in 2011, and LPG import dependence stood at about 71.7%. The government does not have a specific plan to address these product deficits, leaving their procurement to the open market.

TRANSPORT OF PETROLEUM PRODUCTS

Domestic transport of petroleum products is mainly undertaken by oil tankers, rail tank cars, tank trucks and pipelines. Among these modes of transport, tanker trucks play the most important role in transporting petroleum products from oil depots or 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.

Korea does not have any cross-border oil pipelines for exports or imports. There are six domestic oil product pipelines, with a total length of 1 104 km. These six pipelines are operated by DOPCO.

The DOPCO pipeline system connects refineries with major cities, airports, military bases and storage facilities. The recent utilisation rate of pipelines was estimated to be approximately 64% in 2010. The pipelines are reversible, and it would take about three days to change directions of pipeline delivery.

PORTS

There are eight main oil port terminals in Korea, where crude oil is imported. These oil terminals, owned by KNOC and the four big refiners, have a total crude import capacity of some 12.3 mb/d. There are seven oil port terminals which are used for imports and exports of oil products. The total importing and exporting capacity of these terminals is some 10 mb/d.

EMERGENCY RESPONSE POLICY AND ORGANISATION

The Ministry of Knowledge Economy (MKE) is the lead government body responsible for managing oil supply disruptions in Korea. Within MKE, the Energy Resource Policy

Division and the Petroleum Division have key responsibilities in this area; they also provide the core of Korea's National Emergency Sharing Organisation (NESO). The President of Korea is the head of national crisis management and is nominally responsible for responding to oil supply disruptions. However, it is the Minister of Knowledge Economy who takes the political decision whether to participate in an IEA collective action or initiate emergency response measures, including oil stock release.

The release of emergency oil stocks – which may be complemented by demand restraint measures – is central to Korea's emergency response policy. If a decision is taken to release emergency oil stocks, the first preference is to release government stocks held by KNOC as this is considered the most effective measure to address global and domestic oil supply disruptions. A secondary option following the release of government stocks is to lower the stockholding obligation on industry and/or exercise the government's first right to buy oil stocks held by foreign companies under the International Joint Stockpile Scheme.

OIL STOCKHOLDING REGIME

Korea meets its stockholding obligation to the IEA by holding government stocks and by placing a minimum stockholding obligation on industry. The Petroleum and Petroleum-Alternative Fuel Business Act and the Korea National Oil Corporation Act form the legal basis for Korea's stockholding regime. Under these Acts, KNOC manages the state-owned oil emergency reserves.

Emergency oil stocks are held entirely on the national territory, and Korea has no bilateral agreements to hold stocks on foreign territory. Korea held some 175.7 mb of emergency oil stocks at the end of December 2011, equating to 189.1 days of 2010 net imports. This was composed of 89.6 mb of government stocks (held by KNOC) and 86.1 mb of industry stocks. Some 67.4% of the total stocks were held in the form of crude oil.

Government stocks at the end of December 2011 stood at about 89.6 mb, accounting for slightly over half of the country's total stocks; 86.8% of the government stocks were held in the form of crude oil, while the remainders were LPG (4.3%) and other refined products (8.9%). The government plans to increase its own oil stock levels to 101 mb by 2013.

With regard to total industry stocks, these amounted to 86.1 mb at the end of December 2011: 47.2% was stored in crude oil and 52.8% in refined product. Obligatory industry stocks may be commingled with operational and commercial stocks. A domestic ticket market does not exist in Korea.

Crude refiners are obliged to hold at least 40 days of stocks based on a 12-month average of their previous year's sales. However, domestic refiners generally hold between 60 and 80 days of industry stocks for operational and commercial purposes, as well as for complying with the domestic stockholding requirement. The total domestic sales of the four refining companies averaged about 1 mb/d in 2011.

In addition, product importers, LPG importers and petrochemical companies are required to hold at least 30 days of stocks, on the basis of their domestic sales.

KNOC is responsible for monitoring quantities, quality and locations of industry stocks, as well as for collecting data from industry. KNOC is authorised to visit commercial storage facilities to verify physical stock levels. The government has a legal authority to penalise non-compliant companies.

International Joint Stockpile project

Since 1999, KNOC has been engaged in the International Joint Stockpile (IJS) project which allows national and international oil companies to lease storage space in KNOC's oil storage facility. Under the IJS deal, KNOC rents out storage space to foreign firms for a fee, but it also gives Korea first rights to purchase crude oil in case of an oil emergency. Stocks held under this scheme are not counted towards Korea's 90-day IEA obligation and, as of 1 April 2012, are not reported in the Monthly Oil Statistics (MOS). Nonetheless the government has agreed to start including stock data under the IJS scheme in the *MOS* as a form of total stock figure for informational purposes.

It is estimated that some 39 mb of crude oil stocks were held in KNOC's storage facilities under the stockpile project as of December 2011.

Compliance

Korea has been compliant with its 90-day obligation to the IEA since it became a member in March 2002. Korea's oil stocks in terms of days of net imports have consistently been above 160 days since January 2009, hitting the country's historical record of 201 days in September 2010. Government stock levels alone, in days of net imports, have been above the IEA 90-day commitment since December 2009.

Financing and stockholding costs

Concerning the initial set-up/capital costs of government stocks, the construction of government stockpiling facilities has been funded by the central government budget. Costs to purchase the oil for government stocks have been funded by the central government budget and KNOC's internal revenue. About 94% of Korea's government stocks have been funded by the government. Operational costs of government stocks are also financed from the central government budget or KNOC's revenue.

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.

CRITIQUE

A positive development since the previous in-depth review is the completion of the "third petroleum stockholding plan". The Korea National Oil Corporation (KNOC) completed its final oil stockholding facility at Ulsan in May 2010, bringing the 30-year project of securing storage facilities for petroleum to an end. KNOC now has 146 million barrels of oil storage capacity.

Although Korea holds substantial oil reserves that provide some security against possible of oil supply disruptions, the country has made little progress to date on efforts to reduce oil dependence and diversify oil supply sources as recommended in the previous in-depth review. Petroleum consumption was 38.7% of primary energy consumption in 2011 and dependence on Middle East oil has only decreased marginally.

More work is also needed to fully implement the second recommendation from the previous in-depth review to "continue to closely monitor the market and, if necessary,

take measures to prevent unfair practices". This issue was highlighted by reports (May 2011) that the Fair Trade Commission fined the refining companies KRW 435 billion (approximately USD 400 million) for what it says was collusion in the retail oil market to keep prices artificially inflated. This issue serves to highlight the importance of market transparency and robust enforcement of competition laws.

RECOMMENDATIONS

The government of Korea should:

- *Maintain its efforts to reduce its oil dependence and diversify import sources of crude oil and refined products.*
- *Continue to closely monitor the market and, if necessary, take measures to prevent unfair practices. This should include more transparency in the Korean wholesale petroleum market to help ensure that price signals are as closely linked to market supply and demand as possible, and making continued efforts in law to guarantee the right of new competitors to enter all elements of the refining and retail markets.*

7. COAL

Key data (2011 estimated)

Production: 2.1 Mt

Share of coal: 31% of TPES and 45% of electricity generation

Coal imports: 130.6 Mt (Australia 34.3%, Indonesia 33.3%, Russian Federation 8.2%, Canada 6.7%, China 4.3%, others 13.1%)

Inland consumption (2010): 130.3 Mt

OVERVIEW

Korea is the world's third-largest importer of hard coal behind Japan and China. Hard coal imports increased throughout the recent financial crisis and reached 118.6 Mt in 2010, an increase of 15.2% compared to 2009. In 2011, imports sharply increased by a further 12 Mt and totalled 130.6 Mt by the end of the year, a rise of 10.1%. Steam coal imports have increased by around 18 Mt since 2009 and metallurgical coal imports by about 9 Mt.

SUPPLY AND DEMAND

Coal represented 31% or 79.8 Mtoe of total primary energy supply (TPES) in 2011. Almost all of this was imported, mainly from Australia, Indonesia, the Russian Federation and Canada. Australia is the single largest supplier providing approximately 34.3% of imports. The majority (almost 80%) of coal imported is steam coal with coking coal making up the remainder. Between 2000 and 2011, coal imports increased steadily, from 6.37 million tonnes to 130.6 Mt.

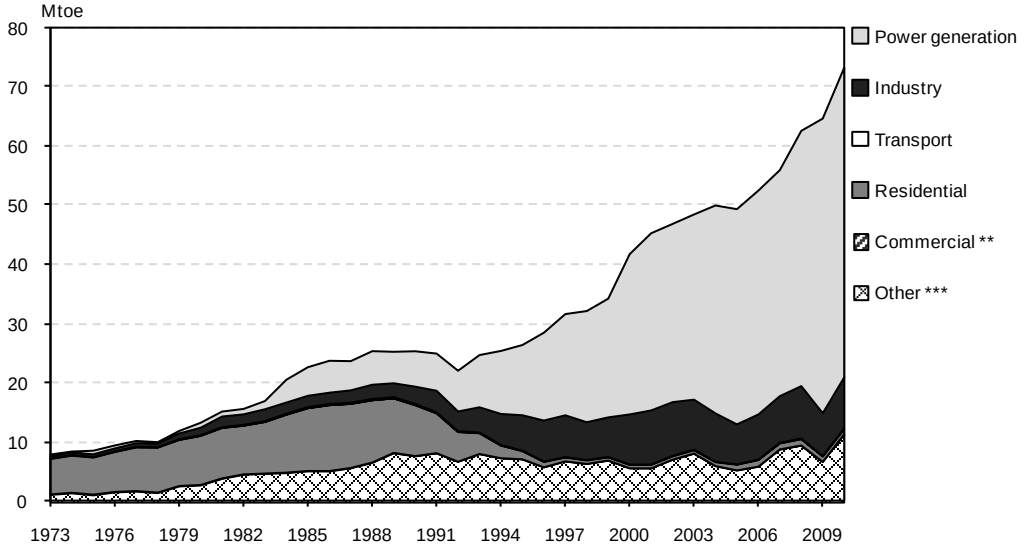
Coal imports in 2011 were made up of 100.4 Mt steam coal and 30.1 Mt of coking coal. Coking coal is largely imported from Australia, the source of approximately 16.4 Mt and to a lesser extent, Canada and the Russian Federation. The main sources of steam coal are Indonesia, which supplied 43.5 Mt, and Australia, which supplied 28.3 Mt. The Russian Federation is another important source and, to a lesser extent, Canada and China. Bituminous coal accounted for the major part of imported steam coals, but some are anthracite.

Coal is the backbone of the Korean power system. In 2011 it was the largest consumer of coal, accounting for 45.2% of electricity generation. At 22.58 gigawatts (GW) of capacity, coal represents approximately 30% of total electricity capacity. The production of heat and electricity from coal is the largest single source of CO_2 emissions in Korea, accounting for almost 30% of emissions in 2010.

Although the share of liquefied natural gas (LNG) in power generation in Korea has increased rapidly, gas is a relatively expensive energy source for power generation. LNG imports are largely indexed to oil prices. Consequently, gas prices in the Asia-Pacific region are usually higher than in Europe or the United States. This gives coal a relative

cost advantage over gas in the power generation sector. Yet, expected additions to the coal-fired power plant fleet are modest in the medium term and thus much of the growth in coal imports is expected to come from the industry sector, largely iron and steel production, which consumed 11.8% of coal in 2010.

Figure 14. **Coal demand by sector*, 1973-2010**



* TPES by consuming sector.

** Negligible.

*** *Other* includes other transformation and energy sector consumption.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

DOMESTIC PRODUCTION AND RESERVES

Korea has about 1.4 billion tonnes of coal resources, all of which are low-quality anthracite. It has five anthracite coal mines, three of which are operated by the state-owned Korea Coal Corporation (KCC). The company is also examining production opportunities abroad and developing a mine in the Uvs province of Mongolia.

Table 6. **Anthracite coal reserves in Korea (thousand tonnes)**

Ownership	Mines	Confirmed	Possible	Probable	Total
Korea Coal Corporation (recoverable reserves)	3	65 668 (29 241)	48 913 (19 022)	138 534 (8 841)	253 115 (57 104)
Private sector (recoverable reserves)	61	20 880 (14 556)	13 997 (6 022)	416 289 (35 333)	451 166 (55 911)
Mines implemented rationalisation policy (recoverable reserves)	150	122 909 (82 450)	130 989 (53 625)	401 468 (76 910)	655 366 (212 985)
Total (recoverable reserves)	**214**	**209 457 (126 247)**	**193 899 (78 669)**	**956 291 (121 084)**	**1 359 647 (326 000)**

Source: Korea Resources Corporation as of 31 December 2008.

This represents a significant decrease from the 347 mines in operation in 1988, a result of the government's policy of rationalising domestic coal production. Between 2000 and 2011, annual production fell from over 2.6 Mt to 2.1 Mt. Production of coal in Korea is subsidised by the government and the cost of production is higher than the cost of imports. Nevertheless, the government intends to stabilise supply and demand for anthracite coal, maintaining a minimum annual production volume, given that it is the nation's only natural energy resource.

SUBSIDIES

According to the government's green growth policy and the G20's initiative to abolish fossil fuel subsidies, the government has gradually reduced subsidies in the coal sector. They will come to an end in 2020. The main subsidy was for the production of coal and its use in the form of charcoal briquettes by low-income households. The subsidy covers subsidies for briquette manufacturers, industrial accident insurance premiums, and school expenses for children of mine workers. Despite the gradual decline in the subsidy, it amounted to KRW 267 billion in 2009, equivalent to around 5% of total environment-related spending by government. Previously, the IEA recommended that Korea should eliminate this subsidy in favour of more environment-friendly measures to support low-income groups.

Table 7. **Coal production and briquette price subsidy, 1988-2009**

	1988	1989	2007	2008	2009
Coal production (million tonnes)	20.8	4.2	2.8	2.9	2.5
Subsidy (KRW billion)	46	323	339	297	267

Source: Ministry of Knowledge Economy.

CARBON CAPTURE AND STORAGE

Korea's carbon capture and storage (CCS) research and development programme is conducted by three ministries: the Ministry of Knowledge Economy, the Ministry of Education, Science and Technology, and the Ministry of Land, Transport and Maritime Affairs. The Ministry of Knowledge Economy is promoting the development of core technologies for commercialisation, demonstration projects for 0.5 megawatt (MW) or more large-scale CCS research and development programme and exploration of storage sites. The Ministry of Education, Science and Technology oversees the development of small-scale projects (0.5 MW or less) and ocean-based projects are overseen by the Ministry of Land, Transport and Maritime Affairs.

Investment in R&D related to CCS has been steadily increasing, reaching approximately KRW 26.4 billion in 2009. Korea invests in the development of core technologies and in facilitating technological developments for pilot projects, and as a result, CCS research infrastructure has been established.

CCS programmes include post-combustion, pre-combustion, and oxy-fuel combustion technology development. For post-combustion, amine solvents, ammonia solvents and

dry solvents application technologies are being developed. For pre-combustion, dry CO_2 absorber and membranes are under development. Korea also invests in oxy-fuel combustion technologies.

Storage-related R&D programmes have been carried out since 2005. For ocean storage of CO_2, Korea is continuously conducting research to identify potential storage areas.

CRITIQUE

In 2011, coal-fired generation contributed 233 terawatt-hours (TWh), or 45.2%, of electricity production and represented 31% of total generating capacity. While the existing coal-fired fleet of power plants is generally regarded as efficient for its age, the government needs to examine the potential for further efficiency improvements. In 2010, coal use in the electricity sector and industry was responsible for 49% of CO_2 emissions. The relative dominance of coal in the generation portfolio coupled by the country's concentration of heavy industry, presents Korea with a significant challenge if it is to meet its 30% emissions reduction target by 2020. Over the longer term, Korea needs a clear strategy for the future of coal-fired generation, which is expected to decrease in the future, following the implementation of the emissions-trading scheme (ETS) in 2015.

The government also needs to develop a proactive policy for CCS given the potential emissions abatement opportunities that exist in the power sector and heavy industry. It is unlikely that CCS will be widely available before 2030; therefore, the government should continue to examine potential sites for large-scale CCS while at the same time assessing the compatibility of the generation fleet with likely CCS technologies.

Korea has few explicit subsidies for fossil fuels and these subsidies do not protect any important domestic industries. The main subsidy is for the production of coal and its use in the form of charcoal briquettes by low-income households. In 2008, domestic coal production amounted to only 2.8% of Korea's coal imports. Nevertheless, this subsidy distorts resource allocation and encourages excessive consumption of coal, which has more harmful emissions than other fossil fuels. Despite the gradual decline in the subsidy, it still amounted to KRW 267 billion in 2009, equivalent to around 5% of total environment-related spending by the central government. Previously, the IEA recommended that the government should eliminate this subsidy in favour of more environment-friendly measures to support low-income groups. The IEA understands that the government has commenced the phase-out of subsides and commends the government for progress in this regard.

RECOMMENDATIONS

The government of Korea should:

- *Clarify its long-term strategy for the coal-fired generation sector in light of its commitment to reduce CO_2 emissions by 30% by 2020 and the introduction of the ETS in 2015.*
- *Develop a long-term strategy for carbon capture and storage, including a legal framework for capture, transmission systems and storage sites, with criteria on safety and verification.*
- *Continue its programme to phase out inefficient subsidies for domestic coal production.*

8. ELECTRICITY

Key data (2011 estimated)

Installed capacity (2010): 79.1 GW

Total gross electricity generation: 515.5 TWh, +79% from 2000

Electricity generation mix: coal 45.2%, nuclear 29.1%, natural gas 21.2%, oil 2.9%, hydro 0.9%, biofuels and waste 0.2%, wind 0.2% and other 0.2%

Peak demand (2010): 71.3 GW

Inland consumption (2010): industry 50.8%, services and others 35.1%, residential 13.6% and transport 0.5%

OVERVIEW

Gross production of electricity in Korea was 515.5 terawatt-hours (TWh) in 2011 with coal (45.2%) and nuclear (29.1%) providing almost 75% of supply. Total capacity is 79.1 gigawatts (GW) and peak demand is approximately 71.3 GW, suggesting that margins are tight as evidenced by a series of load-shedding events in recent years. Korea's power market has expanded by around 30% over the last five years, and the government is planning further increases in nuclear and renewable generating capacity to meet future electricity demand increases.

SUPPLY AND DEMAND

SUPPLY

Gross electricity production in Korea reached 515.5 TWh in 2011, an increase of 3.8% from the previous year and 79% greater than in 2000. Almost half of electricity was generated from coal (45.2%), with most of the remainder coming from nuclear (29.1%) and natural gas (21.2%), complemented with small volumes from oil (2.9%) and from renewables (1.5%). The share of electricity from new and renewable energy sources is the lowest share among IEA member countries.

Production of nuclear electricity increased by almost 50% over the past ten years, from 109 TWh in 2000 to 150.2 TWh in 2011 while output from gas-fired plants has grown from 29.5 TWh to 109.1 TWh in the same period. Production of oil-fired electricity halved between 2000 and 2011, from 34.6 TWh to 15.2 TWh while production of electricity from coal-fired generation more than doubled, from 111.4 TWh to 233.1 TWh. The government forecasts that electricity production will increase to more than 600 TWh by 2030 with nuclear, coal and renewable energy meeting the bulk of incremental demand.

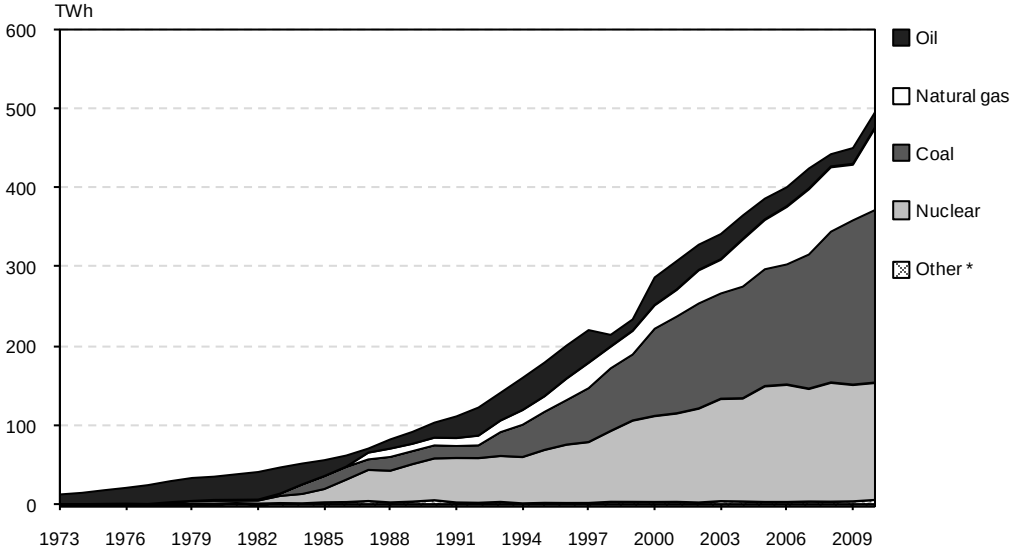
DEMAND

In 2010, total final consumption (TFC) of electricity was 458.7 TWh, half of which (50.3% or 230.5 TWh) was consumed by industry. The commercial and public services sector consumed 147.7 TWh (32.2%) and the residential sector 61.3 TWh (13.4%) with other sectors consuming the remaining volumes. Demand from all sectors has grown significantly since 2000.

TFC of electricity per unit of GDP in Korea was 35 megawatt-hours (MWh) in 2010 compared to 30 MWh in 2000, while TFC of electricity per head of population was 9.4 MWh in 2010 compared to 5.6 MWh in 2000. Owing to its energy-intensive economy, electricity consumption per capita in Korea is a little higher than other IEA member countries.

In recent years, demand has tended to peak in winter owing to growth in demand for electric heating. In 2010, monthly peak demand varied between 55 244 MW and 71 308 MW with consumption higher in winter and summer because of the demand for heating in winter and air conditioning in summer.

Figure 15. **Electricity generation by source, 1973-2010**



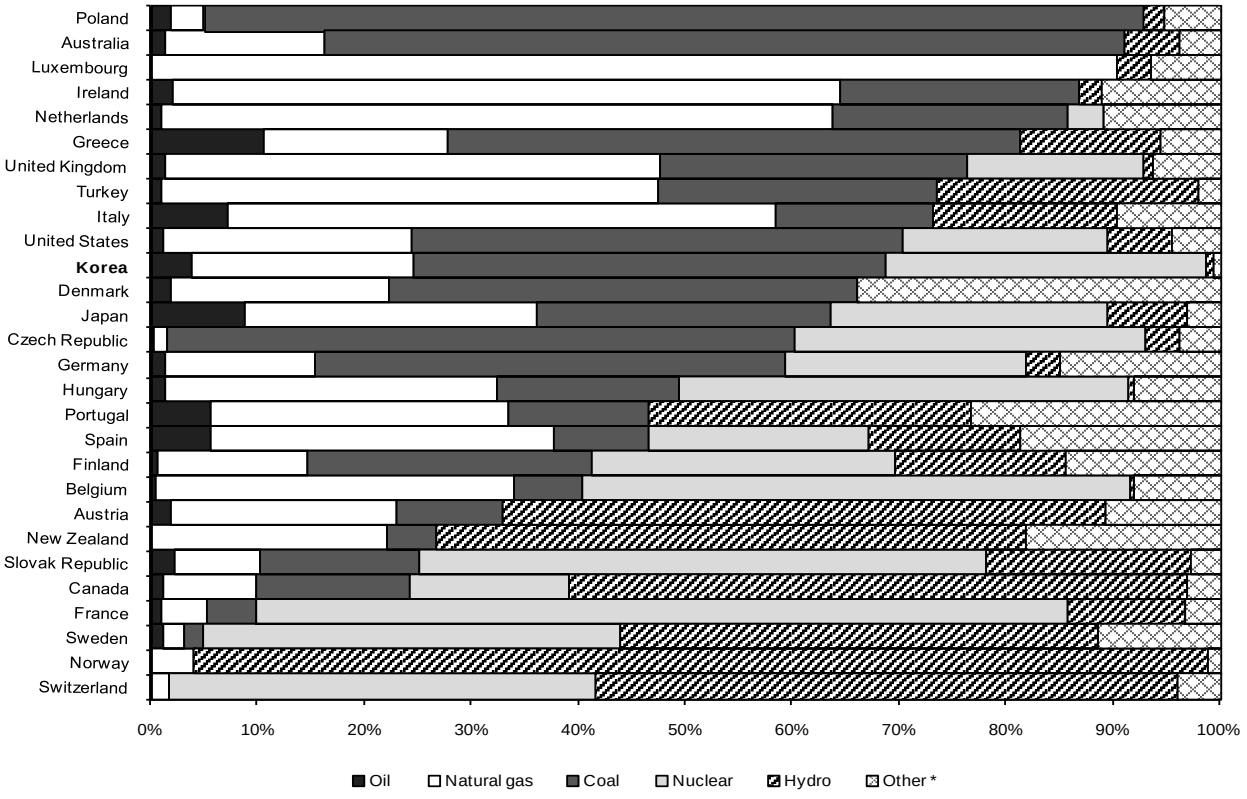
* *Other* includes hydro, solar, wind, biofuels and waste, and ambient heat production (negligible).

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

INSTITUTIONS

The **Ministry of Knowledge Economy** (MKE) is the principal agency for energy policy planning, supervision of the electricity sector, climate change mitigation measures and price controls, among others. MKE is also responsible for policies related to ensuring a secure and efficient energy mix, increasing supply capacity and effectively managing demand.

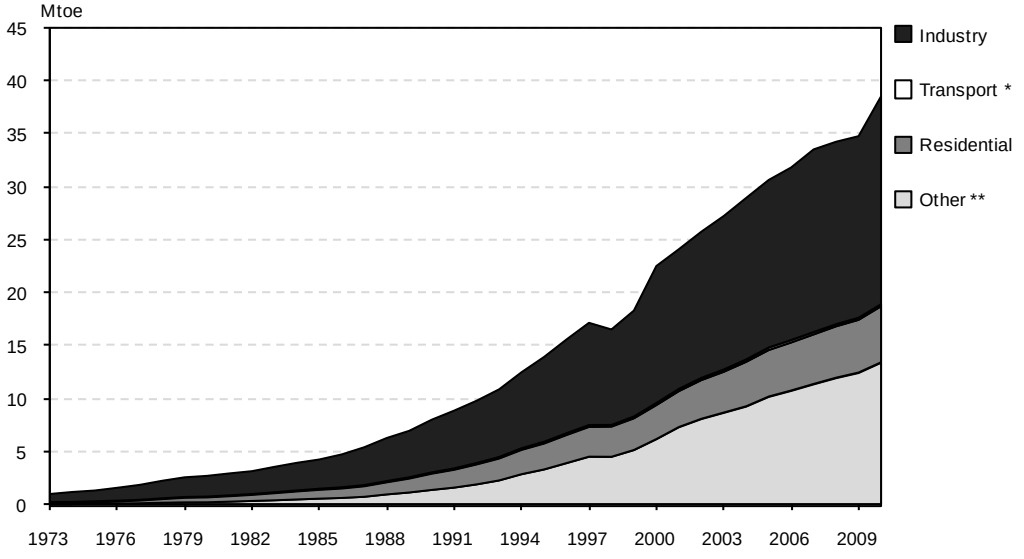
Figure 16. **Electricity generation by source in IEA member countries, 2010**



* *Other* includes geothermal, solar, wind, biofuels and waste, and ambient heat production.

Source: Energy Balances of OECD Countries, IEA/OECD Paris, 2012.

Figure 17. **Electricity consumption by sector, 1973-2010**



* Negligible.

** *Other* includes commercial, public service, agricultural, fishing and other non-specified sectors.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

The **Korea Electricity Commission** (KOREC), the sector regulator, was established in April 2001 to ensure a smooth transition to a competitive and well-functioning electricity market. It oversees matters related to licensing of market participants, power sector structuring and approving electricity tariffs. It acts as an arbitrator when necessary in disputes that involve electricity companies and consumers. The commission consists of nine or less members, who are appointed by the President of Korea, and whose status is guaranteed by law. KOREC is affiliated to the MKE and receives no funding. Its chair is recommended by the Minister of MKE and appointed by the President of Korea.

The **Fair Trade Commission** (FTC) is Korea's anti-trust agency. It is responsible for monitoring monopoly behaviour and unfair business practices, whereas KOREC manages technical and professional competition policy. It operates under the authority of the Prime Minister and also functions as a quasi-judiciary body. Since 2001, the FTC and KOREC have had memoranda of understanding outlining their respective roles, duties and functions in the electricity industry.

Korea's electricity sector is dominated by the **Korea Electric Power Corporation** (KEPCO). Originally known as the Korea Electric Company (KECO), the company was renamed KEPCO in 1982, and became a government-owned corporation encompassing generation, transmission, distribution and retail businesses. In 1989, it was listed on the Korea Stock Exchange and 21% of the company's shares were sold to the public. In 2001, it was broken up into six competing generating businesses, one of which, **Korea Hydro and Nuclear Power** (KHNP), holds all the country's nuclear and hydro assets.

The government previously planned to privatise five of the six companies (excluding KHNP) to raise money to meet Korea's obligations under the International Monetary Fund. Since then, the proposed sales have repeatedly been delayed, partly because of financial difficulties facing key prospective buyers and also because of uncertainties about the investment rate of return. In addition to privatising KEPCO's generation subsidiaries, the original liberalisation plan included implementation of open, or third-party, access to transmission lines, privatisation of the distribution network and the elimination of regional retail monopolies.

In 2003, the government established a Tripartite Commission consisting of representatives of the government, leading businesses and labour unions in Korea to deliberate on ways to introduce competition in electricity distribution, such as by forming and privatising new distribution subsidiaries. In 2004, the Tripartite Commission recommended not pursuing such privatisation initiatives but instead creating six independent business divisions within KEPCO in order to improve operational efficiency through internal competition. In 2006, following the adoption of this recommendation by the government, KEPCO created nine strategic business units each with separate management structures, financial accounting systems and performance evaluation systems, but with a common focus on maximising profitability.

On 25 August 2010, the Ministry of Knowledge Economy announced the Proposal for the Improvement in the Structure of the Electric Power Industry. The key initiatives contained in the proposal included the following:

- maintain the current structure of six generation subsidiaries;
- designate the six generation subsidiaries as "market-oriented public enterprises" under the Public Agency Management Act in order to foster competition among them and autonomous and responsible management by them;

- § create a supervisory unit to act as a "control tower" in reducing inefficiencies created by arbitrary division of labour among the six generation subsidiaries, fostering economies of scale among them; and require the presidents of the generation subsidiaries to hold regular meetings;
- § create a nuclear power export business unit to systematically enhance capabilities in order to win projects involving the construction and operation of nuclear power plants overseas;
- § further rationalise the electricity tariff by adopting a fuel cost-based tariff system in 2011 and a voltage-based tariff system in a subsequent year; and
- § create separate accounting systems for electricity generation, transmission, distribution and sales with the aim of introducing competition in electricity sales in the medium term.

OTHER STATE AGENCIES

The **Korea Energy Economics Institute** (KEEI) develops energy policies related to the production of energy statistics and demand and supply overviews, energy conservation and climate change, the petroleum industry, the gas industry, the electricity industry and the new and renewable energy industry, among others. It is financed directly by the government.

The **Korea Institute of Energy Research** (KIER), a government-funded research institution, is Korea's major energy technology research institute. It is divided into five major research departments, namely energy conservation, energy efficiency, energy environment, new and renewable energy, and technology expansion. KIER aims to develop technologies in the energy sector.

The **Korea Energy Management Corporation** (KEMCO) plays a key role in achieving Korea's research and development (R&D) policy goals for energy efficiency, energy conservation, clean energy and new and renewable energy technologies. It also manages R&D planning and financial support and management.

INDUSTRY STRUCTURE

GENERATION

Korea's installed capacity was 79.1 GW on 31 December 2010. Of this capacity, coal (24.2 GW) was the largest source, followed by natural gas (20.0 GW) and nuclear (17.7 GW). The generation fleet also contains a small amount of hydro (5.5 GW) and oil-fired capacity, (5.9 GW) and a very small amount of new and renewable energy (excluding hydro).

The Fifth Basic Plan of Long-Term Electricity Supply and Demand (BPE), published in 2010 by the MKE, provided details of generation (and transmission) capacity additions planned for the 15 years until 2024. The BPE includes plans for 50 further units, which will add 43.3 GW of capacity (excluding renewable energy facilities), 18.2 GW (14 units) of nuclear, 12.1 GW (15 units) of coal, 12.2 GW (19 units) of natural gas (mostly combined cycle gas turbine or CCGT) and 0.8 GW (two units) of hydro power (pumped storage). The government expects that the proportion of nuclear power capacity will increase significantly to 32% in 2024 (from 17.7% in 2010), whereas the shares of coal and LNG will decrease slightly.[7]

7. Korea's Third National Communication under the United Nations Framework Convention on Climate Change, Government of Korea, 2012.

TRANSMISSION AND DISTRIBUTION

KEPCO owns and operates the national power grid and all distribution networks. The transmission network is approximately 31 250 km long, including 835 km of 765 kV lines, 8 653 km of 345 kV lines and 21 530 km of 154 kV and below lines. The majority of transmission lines in the country have a capacity of 154 kV, but transmission voltages can be 154 kV or 66 kV for local networks, although many of these smaller lines are now being replaced. Transmission lines tend to run from the north-western and south-eastern coastal regions, where much of the generating capacity is located, to major urban and industrial centres in the north-west while submarine high-voltage direct current (HVDC) cables connect the island of Jeju in the south to the mainland.

The 66-kV lines are being replaced and KEPCO is carrying out the second stage of a 765 kV power transmission project that will serve as the backbone of the transmission system. Supervisory Control and Data Acquisition (SCADA) systems are used to remotely monitor and control substation operations. In addition to equipment and facility upgrading, more substations are being automated and built indoors to secure power supply reliability, and the installation of voltage stability technology to improve transmission line efficiency is being reviewed. Compared to networks in many other IEA countries, it is a young transmission network, with relatively low system losses; its transmission and distribution loss factor is less than 5%, lower than the OECD's average of 6.7%, helped by the addition in 2002 of the 765 kV transmission system.

KEPCO is planning the construction of extra-high-voltage transmission lines in parallel with the planned construction of additional nuclear power plants and thermal power capacity. KEPCO is also devising an HVDC transmission line construction plan to prepare for the construction of a large-scale offshore wind farm, to be located on the west coast, in line with the government's new and renewable energy promotion policies.

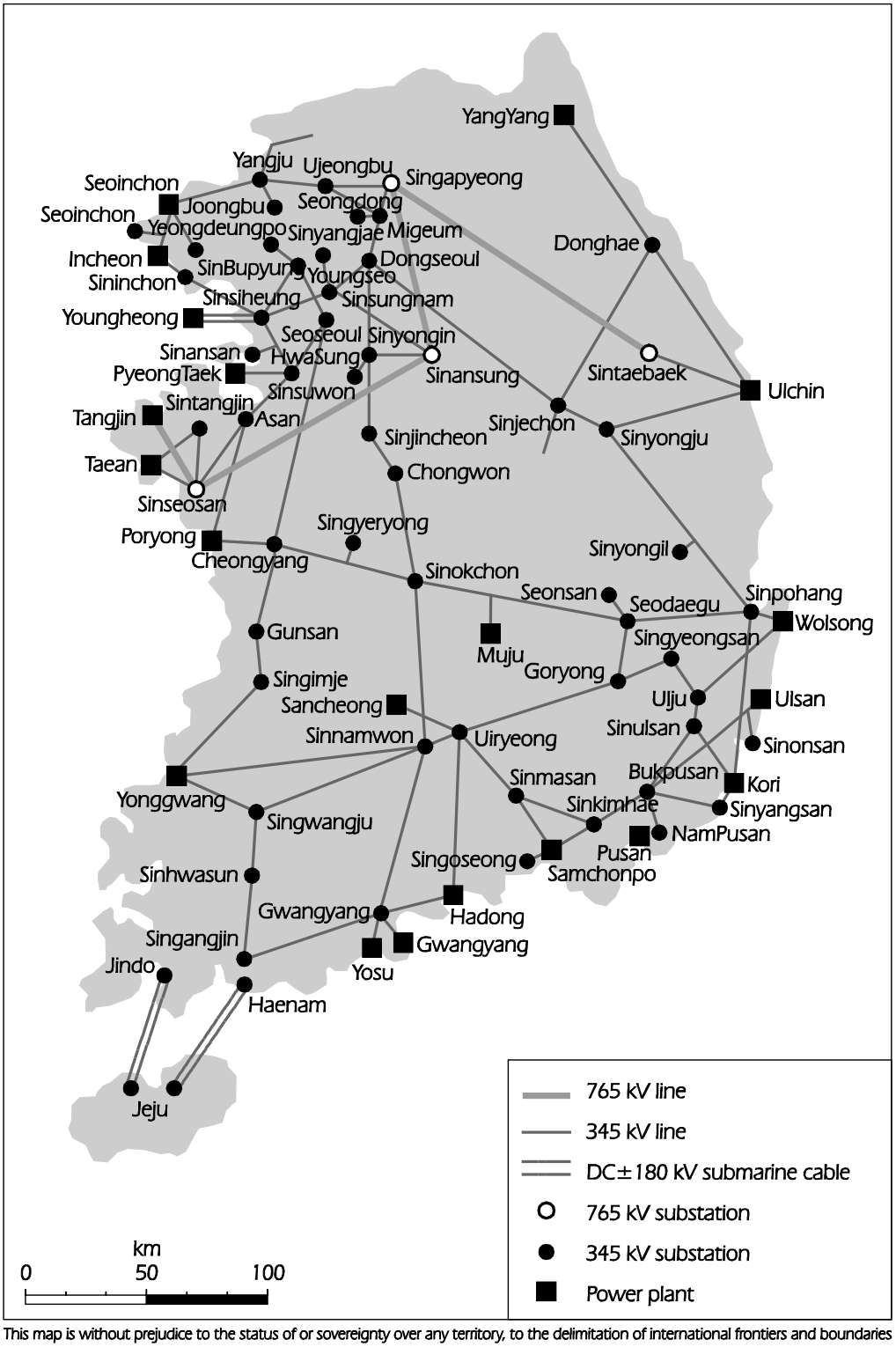
The national power grid is an isolated system; there are no cross-border transmission lines but there are a number of proposals to connect the grid with that of Russia or Japan. It is expected that the biggest obstacle for any possible interconnection with Russia will be Korea's relationship with North Korea.

Table 8. **The KEPCO transmission network at year end 2011**

Voltage	Length (km)		
	Overhead	Underground	Total
765 kV	835	0	835
345 kV	8 387	266	8 653
154 kV	18 614	2 666	21 280
66 kV	249	1	250
HDVC 180 kV	29	202	231
Total	**28 114**	**3 135**	**31 249**

Source: Korea Electric Power Corporation.

Figure 18**. Map of electricity infrastructure**



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

Source: Ministry of Knowledge Economy, KEPCO.

DISTRIBUTION AND SUPPLY

KEPCO also maintains Korea's distribution network, which is approximately 435 549 km long. It recently completed the installation of a distribution automation system at all branches of the distribution network as part of its broader maintenance and upgrade plan.

Korea is divided into 14 electricity supply zones. Community energy suppliers are responsible for the supply of electricity in certain areas. A community energy supplier is a government-licensed power producer who, for purposes of distributed power generation, possesses CCGT plants (using LNG) and distribution facilities in a certain area, generates power and heat, and supplies customers within that area.

SMART GRIDS

Smart grids are networks that monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands from end users. They are, and will continue to be, deployed at different rates in a variety of settings around the world, depending on local commercial attractiveness, compatibility with existing technologies, regulatory developments and investment frameworks.

Korea recognised the smart grid as an essential infrastructure for green growth early on and it commenced its Power IT national programme in the mid-2000s, but it was not until 2009 that a clear policy emerged under the name of Smartgrid. In 2009, Korea's Presidential Committee on Green Growth presented *Building an Advanced Green Country* as its vision, and specified the contents of the smart grid. Subsequently, the committee collected views of experts from industry, academia and research institutes to outline a national roadmap. On the basis of this roadmap, the government is developing its smart grid project in five areas:

- smart power grid;
- smart consumer response and smart home appliances;
- smart transportation;
- smart renewable; and
- smart electricity service.

The Smartgrid project will be implemented in three phases by 2030. The first stage is the construction and operation of the Smart Grid Test-Bed to test relevant technologies. In this regard, the government launched a USD 65 million government-funded pilot programme on Jeju Island in partnership with industry. The pilot consists of a fully integrated smart grid system for 6 000 households, wind farms and four distribution lines.

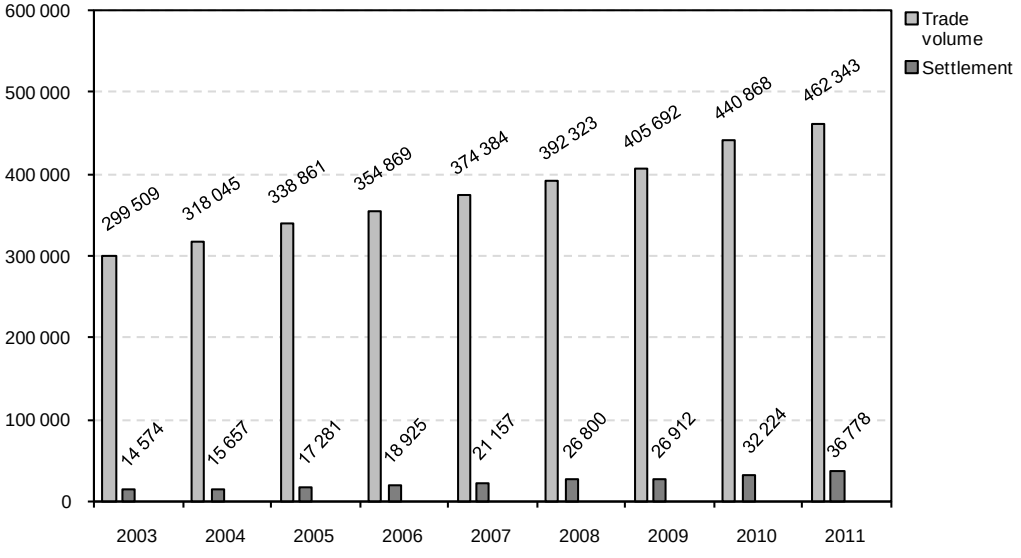
In 2013, Jeju test-bed will be completed and developed technologies and tested systems will be applied to electricity networks at city level until 2020. The third and final stage is the establishment of a nationwide smart grid.

KOREA POWER EXCHANGE (KPX)

The Korean power market consists of generation companies, a single buyer of wholesale power, large consumers and a market operator. To be able to participate in the power market, participants must meet a specific set of technical requirements, comply with the

obligations of market rules and register as KPX members. By the end of 2011, there were 418 market participants who traded 462 TWh of electricity worth KRW 36.8 trillion.

Figure 19. **Settled volumes on the Korea Power Exchange between 2003 and 2011**



Source: Korea Power Exchange.

The market is based on a cost-based pool with prices reflecting generation costs. Under the Korean pool system, all generators are obliged to submit details of their production costs, which are independently checked and approved by the Generation Cost Assessment Committee (GCAC). On the basis of this information, KPX prepares a price setting schedule (PSS) and calculates the system marginal price (SMP), the cost of the most expensive generating unit included in the PSS. In the PSS, the SMP values for each trading period (one hour) are calculated to meet demand in each hour. Congestion problems or generation constraints such as fuel limitation and district heat supply are not considered in this procedure. After real-time dispatching, settlement for the energy produced takes place according to the market price (SMP plus a capacity payment).

The capacity payment is paid to generating units that have declared their availability during the day. It is calculated yearly and is based on the unit construction cost and unit maintenance cost of a new gas turbine mentioned in the Basic Plan on Long-Term Electricity Supply and Demand.

During some hours, certain generating units are not entitled to set the market price owing to their technical characteristics such as ramping rates or minimum output level.

Traded amounts are calculated two days after trading based on the bidding data, metered data, and dispatch data. The settlement process consists of two steps, preliminary settlement and final settlement.

MARKET REFORM AND REGULATORY FRAMEWORK

Since the electricity industry restructuring plan commenced in 2001, there has been much debate over its future direction. In 2009, the Korean government decided to

review existing arrangements and in August 2010, the Ministry of Knowledge Economy announced the Electric Power Industry Structuring Plan. The purpose of the plan was to enhance efficiency by promoting competition and responsible management while balancing the need to recognise climate change concerns and pursue green growth.

The Ministry of Knowledge Economy allowed subsidiary generation companies of KEPCO to compete for dispatch and devised plans to introduce competition. Pumped-storage power plants which had been owned by the generation companies were handed to the Korea Hydro and Nuclear Power (KHNP).

Frozen electricity retail prices between January 2007 and November 2008 undermined KEPCO's viability, largely because of high commodity costs over the same period. In response, the government provided KEPCO with a compensation package in September 2008 worth KRW 668 billion to meet the forecast revenue shortfall. In return, the company was required to improve efficiency by streamlining operations and undertaking restructuring.

In June 2009, the government announced plans to introduce a new electricity pricing system that moves in line with global energy commodity prices and allows KEPCO to pass fuel costs on to consumers. Nonetheless, the new tariff system has been suspended before its application to customers. Despite increasing electricity sales, KEPCO has continued to make losses mainly owing to government policy and lower level of tariff compared to the costs of producing electricity.

SECURITY OF SUPPLY

Korea's power system is isolated; therefore, the government is pursuing policies that seek energy security, energy efficiency and environmental protection while constantly contributing to sustainable economic development. The government develops the Basic Plan of Long-Term Electricity Supply and Demand every two years in order to ensure stable operation of power systems and to cover the optimum reserve margin (loss of load probability of 0.5 day per year, 12% reserve margin limit).

Box 3. Load-shedding events in September 2011

On 15 September 2011, when many of the country's power plants, including nuclear reactors, were closed for maintenance, parts of Korea were plunged into unexpected darkness after unscheduled rolling power cuts, triggered by unusually hot weather, which led to a surge in power demand. The sudden outages affected more than 7.5 million customers in four regions over a five-hour period, with each rolling power cut lasting about 30 minutes.

The immediate response of government was to prepare a plan to raise electricity prices during peak hours in an attempt to temper demand. A task force was established to review the necessity of controlling power cuts and to prepare overall countermeasures to prevent such unfortunate events from recurring. The rolling power cuts can be attributed to a number of causes, including the mismatch between the tariff customers pay for power and the cost of production, the sudden rise in temperature, the difference between forecast demand and actual demand, and the failure to maintain an adequate reserve margin.

Box 3. Load-shedding events in September 2011 (continued)

The fifth Basic Plan for Long-term Electricity Supply set Korea's reserve margin at 15% but the actual reserve margin at the time of the rolling power cuts was 6.6%, meaning that there was inadequate reserve capacity available to meet the sudden surge in demand. Furthermore, the actual demand on the day peaked at 67.2 GW (after load shedding) while the forecast demand was 64 GW.

While the government has taken steps to strengthen short-term demand management measures and Korea Power Exchange (KPX) is improving its load forecasting; there is likely to be little change in the medium term unless strong measures are put in place to rebalance electricity tariffs. The present retail tariff mechanism reflects neither the cost of producing the power nor the profile of electricity usage in Korea providing consumers with little incentive to amend their behaviour.

In the absence of tariff restructuring, problems have continued into 2012; electricity reserves fell to dangerously low levels in early August, prompting KPX to issue a shortage warning. In an effort to reduce demand, the government approved KEPCO's request for a price increase but capped it at 4.9%. At the same time it resumed operations of the country's oldest nuclear power plant at Gori near Pusan.

PRICES AND TARIFFS

In principle, the retail price of electricity is determined at a level that compensates the overall cost required for power supply. The tariff is composed of two parts; a demand charge and an energy charge. The demand charge is calculated by multiplying the contracted demand with the demand charge unit price. The energy charge is calculated by multiplying consumption in a billing period by the energy charge unit price. For residential consumers, a progressive scheme is applied whereby the price increases with the volumes consumed in order to encourage energy conservation. In addition, a low monthly tariff is applied to residential use, streetlamps, and the midnight power service. The average market price has risen considerably since 2006 owing to rising LNG, oil and coal prices. In 2010, the average market price was KRW 86.8 per kWh and the average purchasing price was KRW 75.82 per kWh. This compares to KRW 53.16 per kWh in 2005.

Table 9. **Recovery rate of electricity price by sector in 2010**

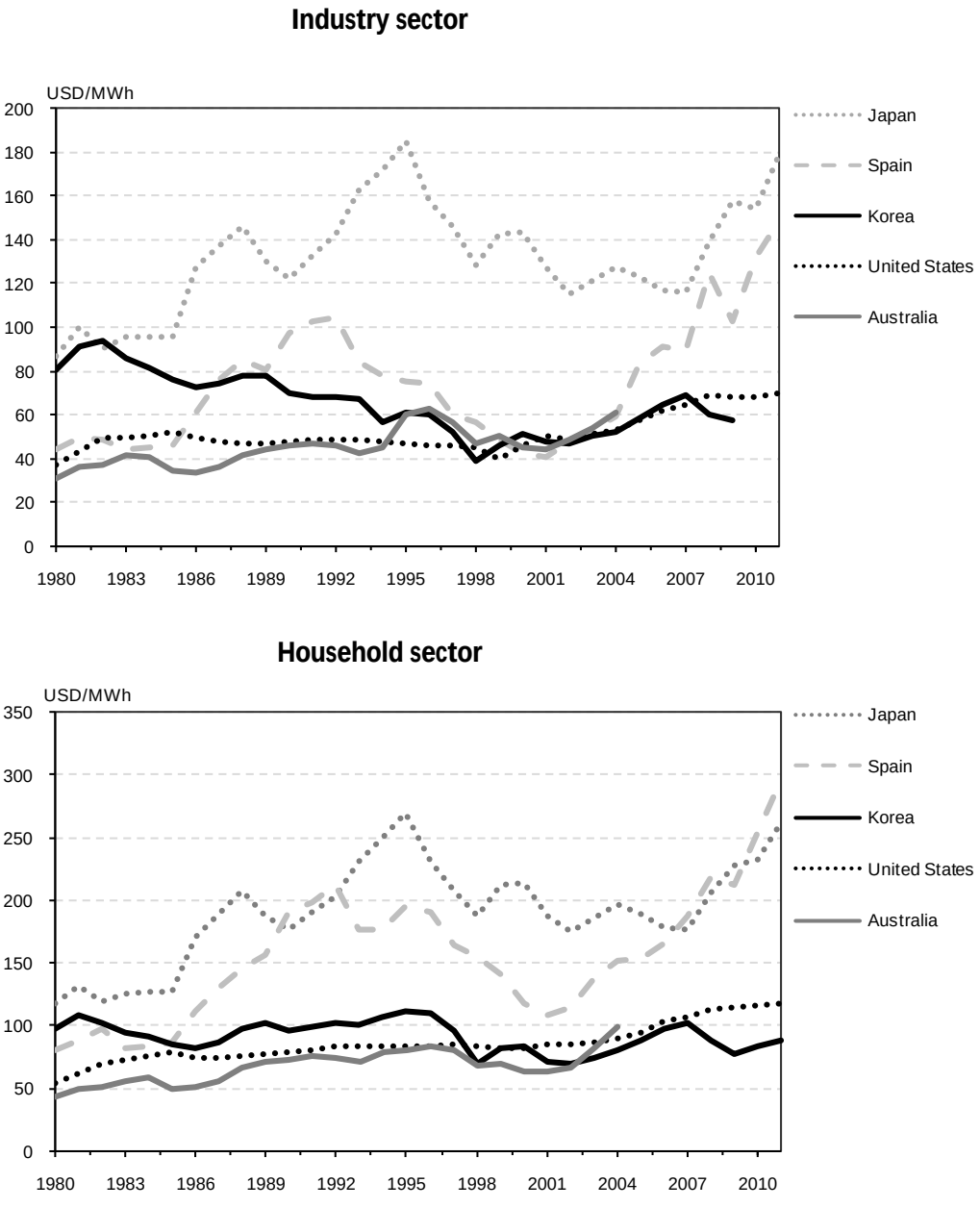
	Average	General	Residential	Industrial	Educational	Agriculture
Unit price (KRW/kWh)	86.8	98.9	119.9	76.6	87.2	42.5
Total unit cost (KRW/kWh)	96.3	102.7	127.2	85.7	103.1	116
Recovery rate in 2010 (%)	90.2	96.3	94.2	89.4	84.6	36.7
Recovery rate in 2007 (%)	93.8	108.4	99.2	90.5	88.7	39.2

Source: OECD, Ministry of Knowledge Economy.

Korea's electricity prices for industry and households are a little less than the OECD average and much lower than European countries on the basis of PPP exchange rates and one of the lowest in the OECD on the basis of market exchange rates. The overall recovery rate, the unit price as a share of the total unit cost, was 90.2% in 2010. The

price varies widely between sectors, creating significant cross-subsidies between consumers (Table 9). Although the gap between some sectors has narrowed in recent years, the overall recovery rate has fallen from 93.8% in 2007 to 90.2%, indicating that electricity prices still do not cover costs.[8]

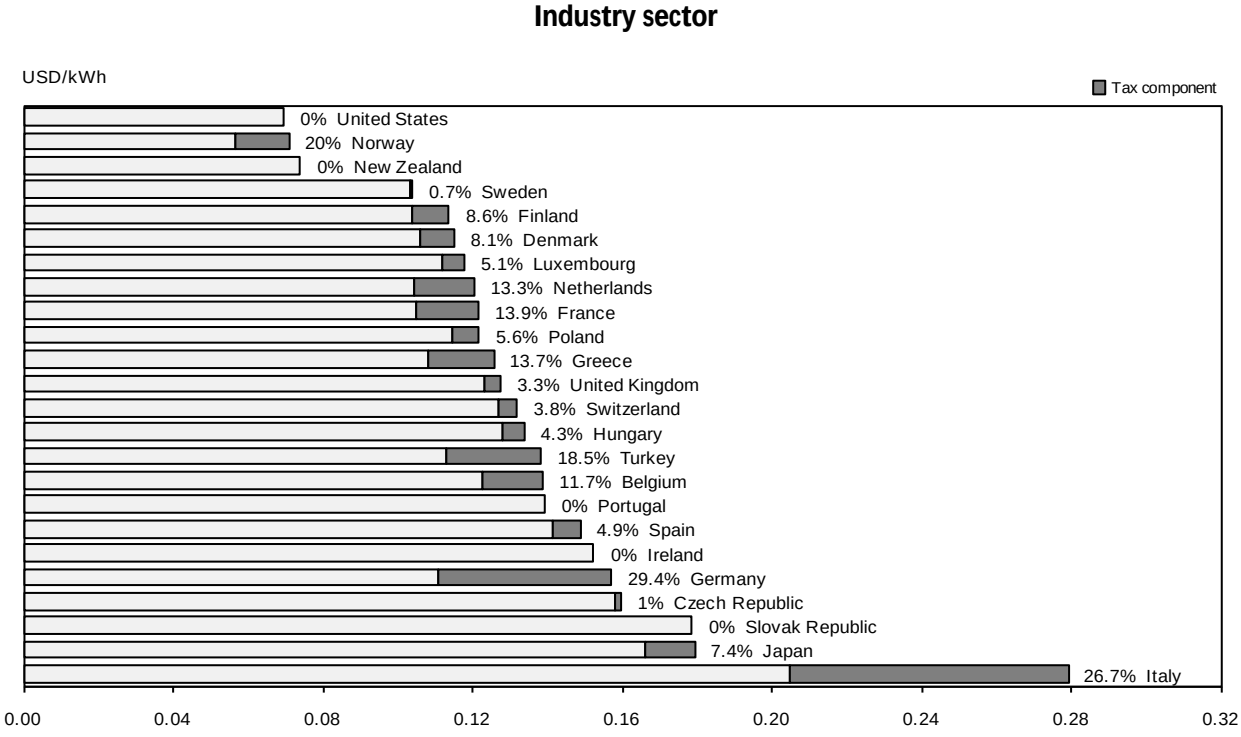
Figure 20. **Electricity prices in Korea and in other selected IEA member countries, 1980-2011**



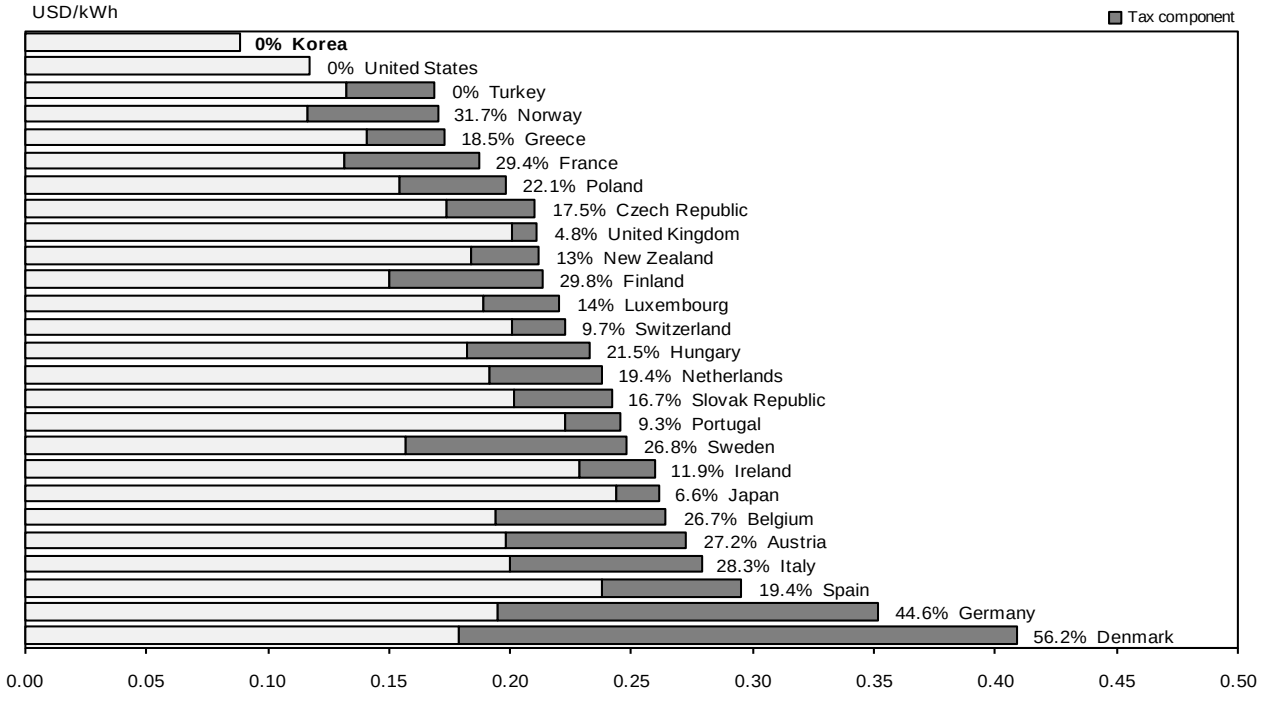
Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2012.

8. *OECD Economic Surveys; Korea*, OECD Paris, April 2012.

Figure 21. **Electricity prices in IEA member countries, 2011**



Note: tax information not available for the United States. Data not available for Australia, Austria, Canada and Korea.



Note: tax information not available for Korea and the United States. Data not available for Australia and Canada.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2012.

CRITIQUE

The electricity sector in Korea is facing a number of significant challenges as the country positions itself as a leader in the movement towards green growth. Meeting these challenges will require important changes to the traditional structure of the industry as well as large capital investments. First steps in this direction were taken in 2008 with the publication of Low Carbon, Green Growth as the vision to guide Korea's long-term development. This was followed in 2009 by the introduction of the National Strategy for Green Growth. Climate change mitigation and the promotion of energy independence formed a key pillar of the new strategy.

Korea's Green Growth Strategy requires efficient energy usage and massive investment towards a low-carbon energy sector, including large capacity additions of nuclear and new and renewable generation. If markets keep providing inefficient price signals and negative impact to cost recovery, it will pose a risk to Korea's green growth path.

Since the previous in-depth review in 2006, the government has maintained, albeit at a slow pace, its commitment to liberalise electricity markets, for example by the announcement of the Power Industry Structuring Plan, which builds on previous progress. Korea has taken some steps to diversify energy sources in terms of generation and successfully established a strong electricity system with low outage rates and transmission losses.

A significant problem is that present mechanisms for calculating wholesale and retail electricity prices do not reflect the full cost of electricity production, nor do they reflect its market value; in other words there is a direct subsidy in place in the form of the sale of electricity at prices below costs. At present the low price of electricity relative to the cost of production serves to increase energy use and greenhouse gas emissions.

The recovery rate, the unit price as a share of the total unit cost, was 90.2% in 2010, but cross-subsidies between various groups of consumers mean that the scale of the subsidy varies widely among sectors.[9] There is an urgent need to reform the present electricity pricing with a voltage-based system which would effectively reflect production costs and the time value of electricity. To do so would implement the proposal to abolish cross-sector subsidies set out in the 2008 National Energy Master Plan. Furthermore, the IEA understands that existing tariff structures facilitate cross-subsidisation between customer categories and fail to fully account for the costs of transmitting and distributing power. The absence of market-based mechanisms exacerbates an already tight position regarding the reserves margins.

Reform of electricity prices must be complemented by a series of supporting measures. The government established in 2001 a market regulator, the Korean Electricity Regulatory Commission, which among other tasks is charged with reviewing applications from KEPCO for changes to electricity tariffs. The regulator appears to have insufficient resources or independence to enable the most efficient outcome. The government should take measures to strengthen the independence of the regulator and ensure it has sufficient resources to take objective decisions related to electricity prices and network access without interference of any kind.

The present electricity market and structure also need reform. The most important step is to link the whole market price with the tariff. With a market-based price signal,

9. *OECD Economic Surveys; Korea*, OECD Paris, April 2012.

customers will decide to consume their electricity reasonably, and generation companies will make new investments positively. The present market model provides incorrect signals to generators and retail customers; for example, a fixed capacity payment does not necessarily accelerate capacity additions. Low electricity prices provide KEPCO with inadequate investment signals as evidenced by the low capacity reserve margin despite its monopoly position.

The government should extend the electricity sales market beyond KEPCO by opening the electricity market to competition for consumer welfare. A programme for restructuring the market should be developed in consultation with stakeholders and the general public. The consultation programme should include proposals for the separation of the generation, transmission, distribution and sales business of KEPCO into new entities. The IEA understands that the government has already announced plans to unbundle (through accounting separation) the KEPCO sales business from the transmission and distribution activities. The programme should also develop mechanisms that allow large users of electricity to buy power directly from the Korea Power Exchange and permit new participants enter the generation market and the sales market for the right to supply electricity to large users, and in the longer term, smaller consumers. Measures to handle stranded costs, to avoid adverse public reactions to various regional tariff systems, and possible price hikes should also be taken.

As a first step, accounting separation can allow the efficient operation, and regulation, of KEPCO´s network businesses and ensure that they are appropriately rewarded for their investments. The Korean Electricity Regulatory Commission should also be vested with authority to regulate third-party access to transmission and distribution networks.

The IEA commends Korea for its clear long-term vision to deploy a smart grid nationwide by 2030, which was announced in 2010 (Korea's smart grid Roadmap 2030). In order to achieve the Green Growth Strategy, Korea will need to invest, not only in generating capacity, but also in transmission and distribution facilities with smart grid technologies. When the smart grid is successfully deployed nationwide, all the generators and customers can be integrated into a system.

The government has established ambitious targets, including the second phase of Korea's Smart Grid Roadmap 2030, which projects deployment in major cities from 2013 to 2020. Renewable capacity is expected to more than quadruple by 2030 from the 2010 level. However, detailed implementation plans related to network investment are not necessarily reflected in the present investment plan shown in the Fifth Basic Plan for Long-Term Electricity Supply and Demand.

Network development should be synchronised with the advance of smart grid technologies and of generating capacity, taking into account the proper market signals, and vice versa.

RECOMMENDATIONS

The government of Korea should:

- *Take steps to increase competition in the electricity market by:*
  - *Separating the generation and retail activities of Korea Electric Power Corporation from its network functions.*

- *Introducing a wholesale pricing mechanism that reflects the market value of electricity after establishing a tariff system that fully meets the costs of production, transportation and supply, plus an appropriate rate of return.*
- *Eliminating inefficient retail tariffs and cross-subsidies between customer classes while considering the effects on prices and social responsibility of KEPCO as a government-owned company.*

- *Strengthen the independence and authority of the regulators (Korea Power Exchange, Korean Electricity Regulatory Commission) into overseeing the transition to a transparent market-based system.*
- *Ensure the coherent development of the electricity transmission and distribution systems by incorporating the Green Growth and Smart Grid components into the Basic Plan for Long-Term Electricity Supply and Demand, and intensifying R&D investment.*

9. NEW AND RENEWABLE ENERGY

Key data (2011 estimated)

Share of renewables: 1.6% of TPES and 1.5% of electricity generation (IEA averages: 8% and 19%)

Hydropower: 0.2% of TPES and 0.9% of electricity generation

Biofuels and waste: 1.3% of TPES and 0.2% of electricity generation

Other renewables: 0.1% of TPES and 0.4% of electricity generation

OVERVIEW

The contribution of renewable energy sources to total primary energy supply (TPES) in Korea is among the lowest in the OECD. In 2011, new and renewable energy contributed 1.6% of TPES and 1.5% of electricity supply. This compares to IEA averages of 8% and 19% respectively. Nonetheless, the country has adopted ambitious targets and plans to increase the use of new and renewable energy supply.[10] The First National Energy Basic Plan set a target of increasing the share of new and renewable sources in TPES from 2.4% (according to Korea's definition of renewables) to 6% in 2020 and 11% in 2030.

NEW AND RENEWABLE ENERGY SUPPLY

Between 1990 and 2011, TPES in Korea increased by more than 170%, from 93 Mtoe to 258 Mtoe while over the same period the contribution of renewable energy increased by over 200%, from only 1.3 Mtoe to 4.0 Mtoe. Biofuels and renewable waste are the largest contributors to new and renewable energy supply and in 2011 represented almost 66.7% of new and renewable energy production with the balance coming from hydro (21.6%) and to a lesser extent solar photovoltaic (PV) and wind.

In 2011, new and renewable energy contributed 7 849 gigawatt-hours (GWh) to electricity supply, of which 60% came from hydro. While the relative contribution of wind and solar PV is very low, both sectors have experienced significant growth in recent years.

INSTITUTIONS

The **Ministry of Knowledge Economy** (MKE) is the lead ministry for new and renewable energy policy. As part of Korea's vision of "green growth as a means of national development," MKE has developed the Green Energy Industry Development Strategy.

10. New and renewable energy is the term used by the Korean government to describe renewable energy sources and includes hydro, solar PV and thermal, wind, bioenergy (including combustible renewables and waste), geothermal, ocean energy, fuel cells, hydrogen and coal liquefaction or gasification.

The MKE is also responsible for a number of agencies active in the sector: the **Korea Energy Technology Evaluation and Planning** (KETEP) leads new and renewable energy research and development programmes and the **Korea Energy Management Corporation** (KEMCO) is responsible for industry promotion, dissemination and policy development.

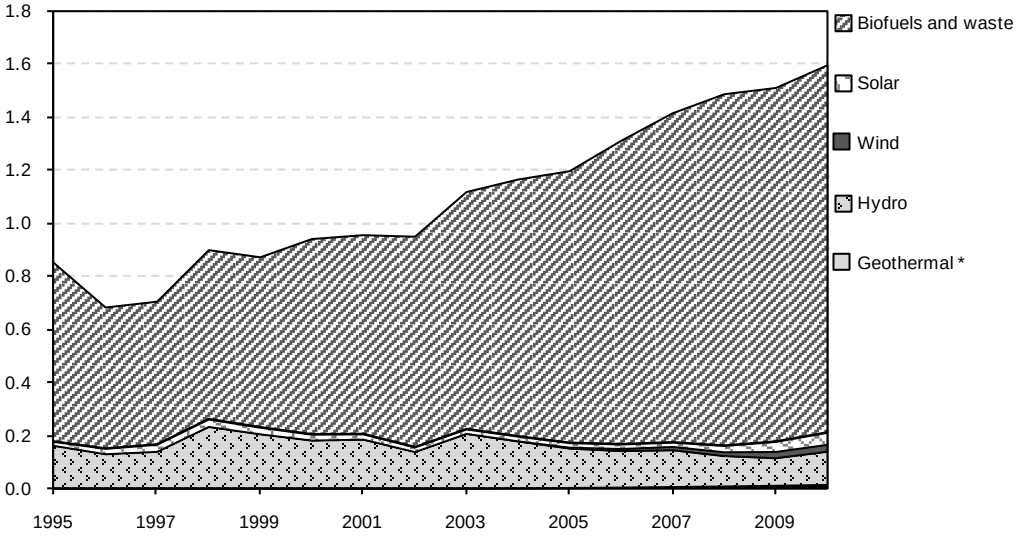
POLICIES AND MEASURES

According to the Third Basic Plan for New and Renewable Energy, Korea is aiming to increase the use of new and renewable energy to 11% by 2030. This Third Basic Plan, which was established in December 2008 following the announcement of the green growth policy, sets out medium- and long-term targets to develop and deploy new and renewable energy and provides action plans and basic strategies. These included national plans focusing on greater distribution of bioenergy, geothermal and solar thermal energy, more exports of solar PV and wind power technology, and promotion of those industries. Ultimately, the Korean government wants to make new and renewable energy a new growth engine for the economy that will transform Korea into a low energy-consuming green nation.

PROGRAMMES FOR NEW AND RENEWABLE ENERGY PROMOTION

In order to reduce Korea's dependence on fossil fuels and to foster the new and renewable energy industry, the government is promoting various policies based on the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy, which was introduced in 1997 and revised in 2004. On the basis of the Offshore Wind Power Top-Three Roadmap, for example, various policies have been implemented to develop and increase the supply of offshore wind technologies. Through these policies, KRW 9 trillion will be invested by 2019 and will be focused on the installation of new offshore wind power facilities.

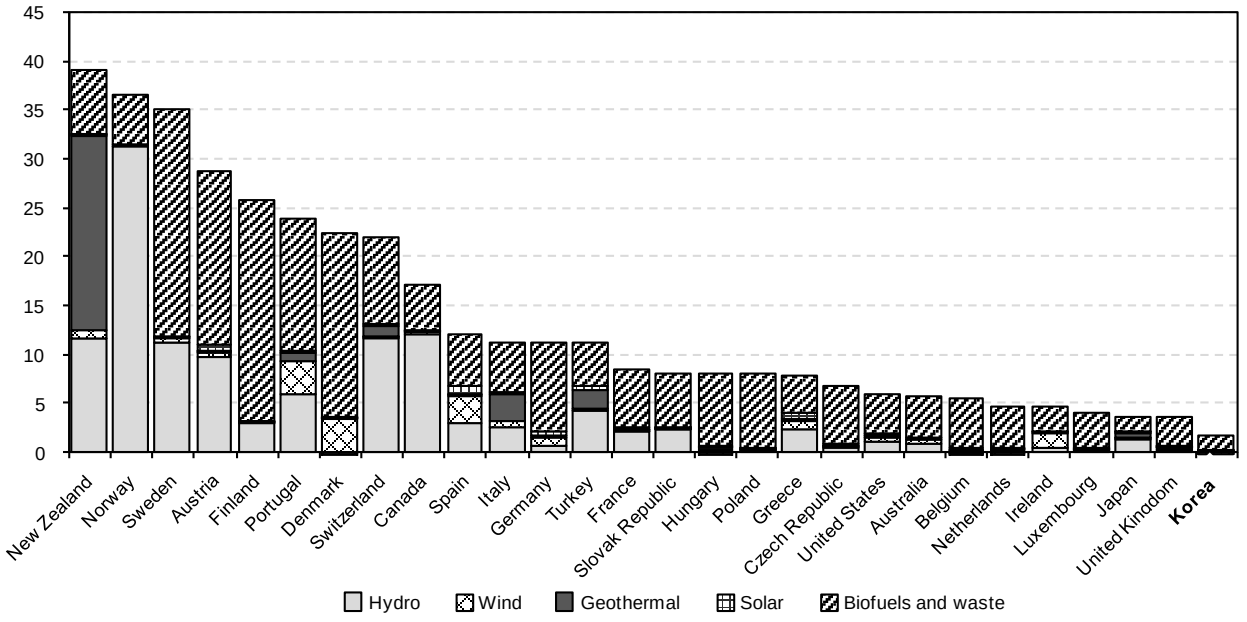
Figure 22. **Renewable energy as a percentage of total primary energy supply, 1995-2010**



* Negligible.

Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

Figure 23. **Renewable energy as a percentage of total primary energy supply in IEA member countries, 2010**



Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

PROMOTING THE USE OF WOOD BIO-ENERGY

To achieve its 11% target by 2030, supply and demand expansion policies for wood bio-energy have been implemented through a series of support programmes. Financial support is available for the development of wood pellet manufacturing facilities. As of 2010, 13 facilities have been supported by the government and five other facilities have been supported by private-sector investments. In total, 18 facilities have a production capacity of over 200 kilotonnes (kt) per year. The production of wood pellets, however, amounted to only 6 kt in 2009 and 13 kt in 2010. To increase demand for wood pellets, therefore, small wood pellet boilers have been distributed to agricultural and mountainous villages since 2009 and horticultural greenhouse heaters have also been deployed since 2010.

ONE MILLION GREEN HOMES

Launched in 2009, the One million Green Homes scheme emerged from the 100 000 Solar-Roof Programme and is a subsidy programme to facilitate the installation of new and renewable energy facilities in residential sites such as private houses, blocks of flats and public rental houses. The government offers support to a certain portion of total installation costs. While the previous 100 000 Solar-Roof Programme was to install PV systems in residential houses, the One Million Green Homes scheme focuses on a variety of resources such as PV, solar thermal, geo-thermal, fuel cells, and small wind technology.

MANDATORY USE OF RENEWABLES IN PUBLIC BUILDINGS

Since April 2011, energy supply for new buildings and recently extended or reconstructed buildings, that exceed 3 000 square metres, must include at least 10% new and renewable energy. The obligation ratio will be increased gradually from 10% in 2011 to 20% in 2020, and, since 2012, the obligation applies to buildings over 1 000 square metres.

REGIONAL DEPLOYMENT SUBSIDY PROGRAMME

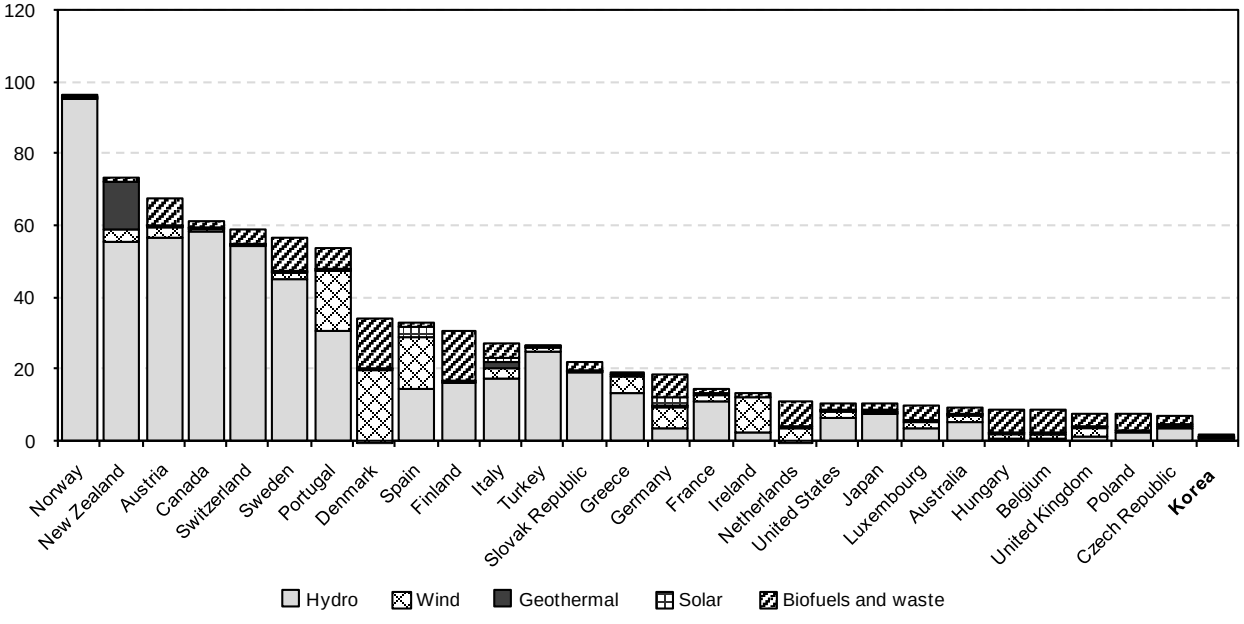
In an effort to improve the energy supply and to boost regional economies by supplying region-specific new and renewable energies, the government has been promoting a regional deployment subsidy programme designed to support various projects carried out by local governments. This programme, which started in 1996, supported both new and renewable energy and energy-saving schemes until 2005. The two areas, however, were separated in 2005 in accordance with the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy. The subsidy for installing new and renewable energy systems such as PV and wind power supports up to 50% of the investment outlay.

ELECTRICITY FROM NEW AND RENEWABLE SOURCES

With only 1.5% of electricity supply coming from new and renewable sources in 2011, Korea's market remains relatively underdeveloped. At the end of 2011, solar PV capacity stood at 0.8 gigawatt (GW) while onshore wind capacity was 0.4 GW. The 254 megawatt (MW) Sihwa Lake tidal power station, the world's largest ocean project, was commissioned in August 2011.

To reduce financial burden while inducing private investment, the Korean government replaced its feed-in tariff scheme with a renewable portfolio standard (RPS) scheme effective since 1 January 2012. The scheme requires the 13 largest public and private utilities ("the obligators") to generate or purchase (through tradable certificates) 2% of their total generation as new and renewable energy in 2012, rising to 10% by 2022.

Figure 24. **Electricity generation from renewable sources as a percentage of all generation in IEA member countries, 2010**



Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2012.

Over the medium term, Korea is expected to develop its solar and wind resources. Within the wind category, both onshore and offshore capacity is forecast to grow,

reaching 5.0 GW in cumulative capacity, by 2020. Grid access and permitting procedures are persistent constraints, though the government is seeking ways to reduce these barriers. In ocean technology, several large tidal barrages are also under consideration, but some face opposition on environmental grounds.

FEED-IN TARIFFS FOR NEW AND RENEWABLE ELECTRICITY

The government compensated producers for the differences between the costs of electricity generated from new and renewable sources and fossil-fuel thermal generation to promote the production and use of renewable sources. The main features of feed-in tariffs (FITs) are related to the period and volume: the FITs guaranteed 15 years of support for all new and renewable electricity facilities. Exceptionally, the total number of years that government supports PV can be either 15 or 20 years.

RENEWABLE PORTFOLIO STANDARD

A Renewable Portfolio Standard (RPS) was introduced in 2012 and replaces FITs. The RPS forces power producers to supply a certain amount of their total power generation portfolio from new and renewable sources. The standards apply to generators with more than 500 MW of capacity.

CRITIQUE

Since the last in-depth review in 2006, the share of new and renewable energy in TPES has increased by a small amount and there has been progress with strengthening the policy framework. Following the publication of the *Green Growth Policy* in 2008, the government announced the First National Energy Basic Plan and set a target of 11% new and renewable energy in TPES by 2030. The government also drew up roadmaps for all 11 new and renewable technologies in the Third Basic Plan for New and Renewable Energy.

Since 2002, Korea has supported electricity generated from new and renewable sources by means of a feed-in tariff programme. The feed-in tariff is differentiated in order to take into account the difference between power generation cost and sale prices for various types of new and renewable energy technologies. Since the last in-depth review, the level of feed-in tariffs has been regularly evaluated and adjusted to encourage continued advancements and cost reduction in new and renewable energy technologies.

In 2012, the government replaced the feed-in tariff mechanism with a renewable portfolio standard (RPS) applicable from 2012 for the purpose of meeting its 10% target of new and renewable energy in electricity supply by 2022. The IEA analysis suggests that care needs to be taken in designing green certificate schemes to ensure cost-effectiveness. By drawing from experience elsewhere, Korea should carefully design and adjust its RPS system in order to maximise its effect, taking into account natural and economic conditions in Korea.

In addition to RPS, the government plans to decrease subsidies for new and renewable energy. For example, the One Million Green Homes programme, which was expanded from the 100 000 Solar Roof programme in 2009, has been reducing its subsidies in terms of both the subsidising ratio and the standard capital costs, set by the government, for a wide range of technologies such as photovoltaics, solar thermal, fuel cells, etc. These measures represent solid progress.

The cost-effectiveness of chosen policies and measures needs to be carefully evaluated to ensure that overall new and renewable energy objectives are met without placing an excessive burden on consumers through additional taxes or higher tariffs. Particular attention should be given to the cost of each new and renewable technology. It is important that the government decreases incentives for specific technologies over time, in order to move them towards market competitiveness. On the other hand, it is also very important to provide a stable, predictable and transparent regulatory framework with a clear timeframe for the reduction and phase-out of support schemes so as to continue to attract investments in producing new technologies.

Owing to geographic and climatic conditions, the resource potential for renewable energy in Korea is relatively low when compared to other IEA member countries. This adds to the overall cost and challenges of meeting the renewable energy targets. It is important, therefore, to carefully evaluate the potential of all available technologies and ensure that the most cost-efficient projects can be developed.

Given that the goal of 11% new and renewable energy in TPES by 2030 does not make a distinction between electricity and other types of energy, Korea should investigate the cost-effective potential for new and renewable energy-based heating and cooling as well as for biofuels, and design support schemes to tap this potential.

Problems related to grid access can be a potential barrier to the future deployment of new and renewable energy technologies. It is very important to analyse the implications of the large-scale penetration of intermittent renewable energy production in the overall energy system, with regard to cost-efficiency and system reliability. Good coordination between the development of grid capacity and new and renewable energy production should be encouraged.

RECOMMENDATIONS

The government of Korea should:

- *Develop a comprehensive new and renewable energy strategy, supported by technology roadmaps containing policies and measures based on a technical and economic assessment of potential resources, for the deployment of new and renewable energy technologies, including the heating, cooling and transportation sectors.*
- *Ensure a smooth transition from the feed-in tariff system to efficient renewable portfolio standards, with the necessary flexibility to adjust its operation so as to optimise the overall effectiveness.*
- *Carefully monitor the effects of other supports for new and renewable energy technologies and, if necessary, adjust conditions over time to optimise overall cost-effectiveness.*

10. NUCLEAR ENERGY

Key data (2011 estimated)

Number of plants in operation: 23

Installed capacity: 20.7 GW

Electricity generation: 150.2 TWh (30% of total power generation)

OVERVIEW

Given Korea's strong dependence on imported energy sources, it began a process of developing and then expanding its nuclear energy programme in the 1970s. Now Korea considers nuclear power to be an indispensable part of its energy mix and each new energy plan over the last decade has strengthened the commitment to build a significant nuclear share in this overall mix.[11]

Nuclear power is considered to be Korea's most reliable energy source and its nuclear energy is largely responsible for ensuring affordable electricity. While the Korean consumer price index increased by 254% from 1982 to 2011, electricity prices increased by 29.9% in the same period.

Korea's commitment to nuclear power and its need for initial imports of nuclear technology were greatly aided by the depression of the world nuclear industry in the 1980s. This had resulted from the collapse of international oil prices in the mid-1980s; growing excess oil-generating capacity because of the delayed impact of efficiency improvements and economic restructuring prompted by the oil price hikes of the 1970s; and the negative public reaction to the Three Mile Island and Chernobyl accidents and the resulting growth of the anti-nuclear movement. These factors created a buyers' market and made it possible for Korea to conclude nuclear technology transfer agreements with foreign suppliers under favourable conditions.

Strong government commitment was essential to marshal Korea's human resources to successfully implement its national nuclear technology self-reliance programme. Korean nuclear scientists and engineers engaged in overseas nuclear power programmes were even attracted back to Korea to play key roles in the local development of nuclear power technology and enhancing direct national participation in nuclear power projects.

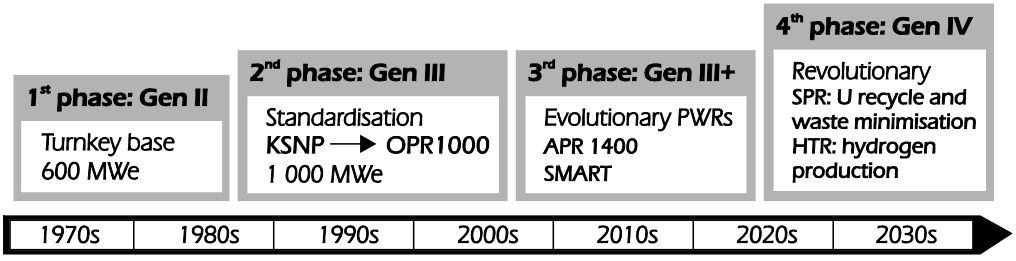
National participation in a nuclear project generally means using locally produced material and domestic manpower resources without downgrading the quality and safety aspects of the project or jeopardising the schedule of project execution. Meaningful national participation in nuclear power and plant construction requires the existence of a capable construction industry and medium and heavy manufacturing capabilities, including cement,

11. This chapter is a review based on information supplied by the various ministries and corporations during the in-depth review but has been supplemented by other information provided to the OECD Nuclear Energy Agency in the form of case studies and responses to questionnaires designed for various publications.

steel, machinery, equipment, and chemicals, as well as competence in other services such as civil engineering, quality assurance, control and testing, and specialised manpower training including managerial skills. These were all challenges that Korea accepted in developing its nuclear power programme.

The first nuclear power plant in Korea was an imported reactor with imported services and support. The early plants were mainly built through turn-key contracts, with little participation by domestic industries and limited use of local labour or construction materials (for on-site non-specialised purposes). However, in 1985, the government initiated an incremental national self-reliance policy (non-turn-key) and began allocating some responsibilities to local organisations for civil engineering and design, construction, and plant engineering; manufacture of some equipment and non-critical components for the balance of the plants; and for project management, although design and manufacture of the primary systems and turbine generators were initially contracted with foreign suppliers. This self-reliance strategy has been increasingly applied since the construction of the Yonggwang-3 and -4 nuclear power plants (NPPs) in 1989, making domestic nuclear industries the prime project contractors with only limited technological support and technology transfer from foreign subcontractors. Equally important, local manufacturers have extended their normal product lines to incorporate nuclear designs and standards, and special factories have been established locally to manufacture heavy and specialised nuclear components, sometimes under licensing arrangements with foreign suppliers. The evolution of Korea's reactors is shown in Figure 25.

Figure 25. **Evolution of Korean nuclear power plant technology**



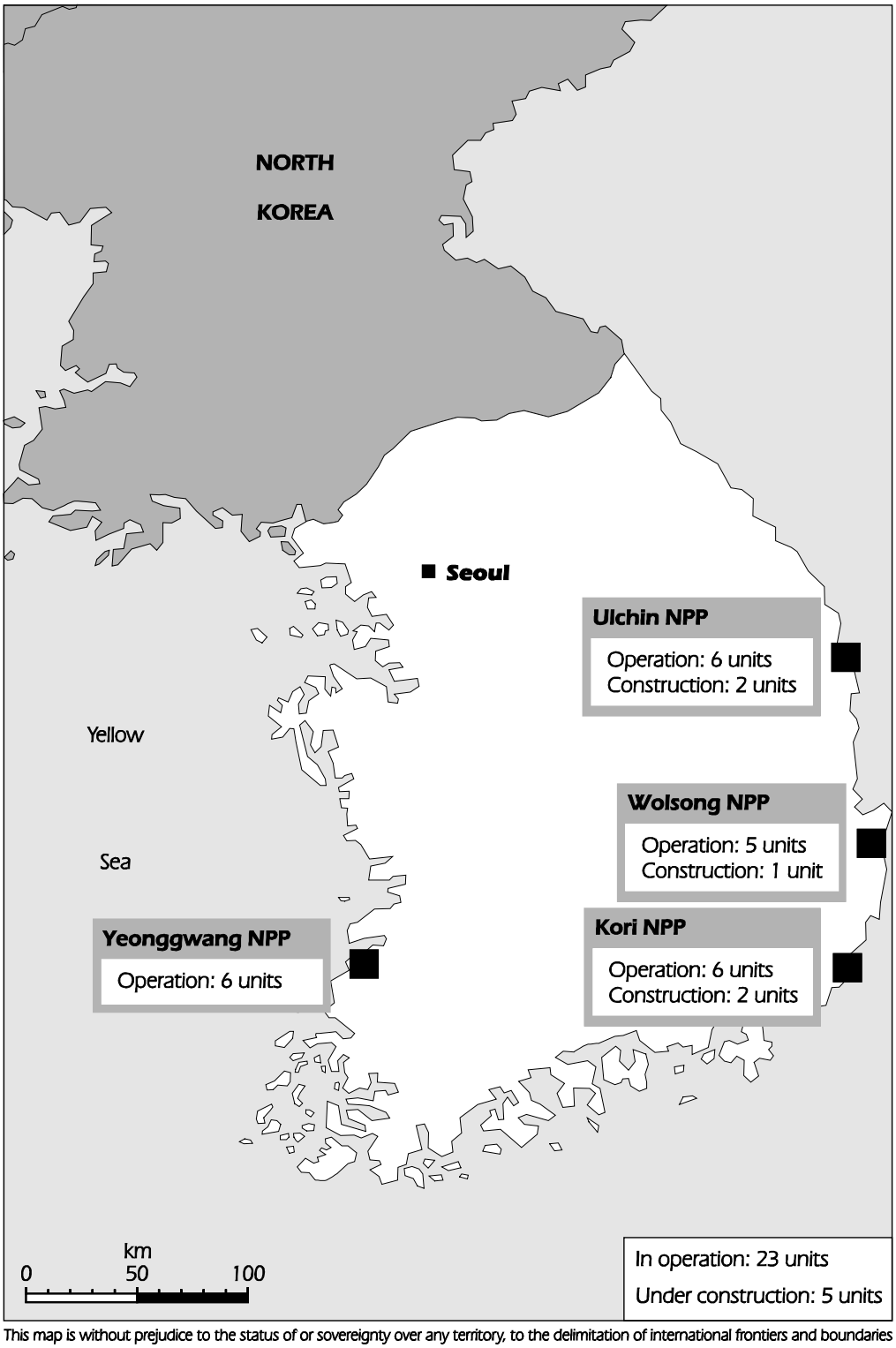
Source: Korean Case Study in: *Trends in Sustainability of the Nuclear Fuel Cycle*, OECD/NEA, Paris, 2011.

NUCLEAR POWER PLANTS

At present, there are 23 nuclear power units in operation in Korea and five more are under construction.[12] Four of these 23 are pressurised heavy water reactors (PHWRs), of the CANDU type, while the rest are pressurised-water reactors (PWRs), originally based on a Westinghouse design but now indigenously designed and manufactured. The total capacity is 20.7 gigawatts (GW) of electrical capacity. This makes Korea the fifth-largest nuclear country in the world. Four of the reactors under construction are advanced PWRs. Korea is also a leading proponent of a small modular reactor, SMART, which is at an advanced state of design. The sites for the main nuclear facilities are shown in Figure 26.

12. In February 2012, the International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS) database only gave three under construction.

Figure 26. **Location of nuclear power plants 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.

Source: IAEA PRIS database as of February 2012. This includes the two reactors connected to the grid in January 2012.

All Korean nuclear power reactors have maintained high availability factors, over 90%, making them well above the world average of around 80%. The plants are operated by Korea Hydro and Nuclear Power (KHNP), a company which is part of the state-owned electricity transmission and distribution monopoly, KEPCO. Since the last in-depth review, nuclear energy capacity has expanded to 20 716 MW of generating capacity by February 2012, which is about 33% of the total production of electricity in Korea. In fact in 2011, nuclear energy produced 150 163 gigawatt-hours (GWh), which was 29.1% of the total electricity production.

Table 10. **Nuclear reactors in Korea**

Name	Type	Status	Location	Reference unit power (MW)	Gross electrical capacity (MW)	First grid connection
Kori-1	PWR	Operational	Gijang-gun	576	603	Jun 1977
Kori-2	PWR	Operational	Gijang-gun	637	675	Apr 1983
Kori-3	PWR	Operational	Gijang-gun	1 011	1 042	Jan 1985
Kori-4	PWR	Operational	Gijang-gun	1 009	1 042	Nov 1985
Shin-Kori-1	PWR	Operational	Pusan & Ulsan	985	1 038	Aug 2010
Shin-Kori-2	PWR	Operational	Pusan & Ulsan	960	1 000	Jan 2012
Shin-Wolsong-1	PWR	Operational	Gyeongju-si	960	1 000	Jan 2012
Ulchin-1	PWR	Operational	Ulchin-gun	945	985	Apr 1988
Ulchin-2	PWR	Operational	Ulchin-gun	942	984	Apr 1989
Ulchin-3	PWR	Operational	Ulchin-gun	994	1 047	Jan 1998
Ulchin-4	PWR	Operational	Ulchin-gun	998	1 045	Dec 1998
Ulchin-5	PWR	Operational	Ulchin-gun	997	1 048	Dec 2003
Ulchin-6	PWR	Operational	Ulchin-gun	997	1 048	Jan 2005
Wolsong-1	PHWR	Operational	Gyeongju-si	660	689	Dec 1982
Wolsong-2	PHWR	Operational	Gyeongju-si	710	740	Apr 1997
Wolsong-3	PHWR	Operational	Gyeongju-si	707	729	Mar 1998
Wolsong-4	PHWR	Operational	Gyeongju-si	708	730	May 1999
Yonggwang-1	PWR	Operational	Yeonggwang-gun	953	985	Mar 1986
Yonggwang-2	PWR	Operational	Yeonggwang-gun	947	978	Nov 1986
Yonggwang-3	PWR	Operational	Yeonggwang-gun	997	1 039	Oct 1994
Yonggwang-4	PWR	Operational	Yeonggwang-gun	994	1 039	Jul 1995
Yonggwang-5	PWR	Operational	Yeonggwang-gun	988	1 046	Dec 2001
Yonggwang-6	PWR	Operational	Yeonggwang-gun	996	1 050	Sep 2002

Note: PWR = pressurised water reactor; PHWR = pressurised heavy water reactor.

Source: OECD Nuclear Energy Agency.

With regard to new construction, reactor components in Shin-Kori unit 3, the first APR1400 model to be built in Korea, were installed on 15 July 2010. Construction continues with the unit scheduled to begin commercial operation in September 2013. Shin-Kori unit 4, a twin plant to Shin-Kori unit 3, is scheduled to be completed one year later in September 2014.

In September 2010, Korea succeeded in domestically developing the Man Machine Interface System instrumentation and control system, eliminating the need to import one of the core nuclear power plant technologies. Korea is also concentrating on the development of design codes and the localisation of reactor coolant pumps, with the aim of completing these tasks by December 2012, leading to the manufacture of these components in Korea.

The oldest reactors are at Kori (June 1977, April 1983) and Wolsong (December 1982). Kori 1 obtained a life extension of ten years in 2007. However, at Wolsong-1, the first CANDU reactor in Korea, replacement of pressure tubes inside the reactor (Calandria) began in April 2009 and was completed at the end of 2010; a restart was authorised in July 2011. Korea Hydro and Nuclear Power Ltd (KHNP), the operator of Wolsong-1, submitted an application to the government in December 2009 for licence renewal.

THE FUTURE OF NUCLEAR ENERGY

According to Korea's Fifth Basic Plan of Electricity Supply and Demand (BPE), announced by the Ministry of Knowledge Economy in 2010, 13 new nuclear power units (six more in addition to the five currently under construction and two recently completed) will be constructed by 2024, increasing the total number of units to 34. Generating capacity will increase to 35.9 GW, which will account for about 49% of the country's production of electricity. Plans are being pursued to reach 59% by 2030. This will require investment of KRW 33 trillion by 2024.

REGULATION

The Atomic Energy Commission is the highest decision-making body for nuclear energy policy and is chaired by the Prime Minister. It was set up under the Atomic Energy Act. The Nuclear Safety and Security Commission (NSSC) is responsible for nuclear safety regulation, which was set up as an independent presidential commission in October 2011. The Ministry of Education, Science and Technology (MEST) was in charge of nuclear safety and nuclear safeguards before NSSC. MEST has responsibility for nuclear R&D (primary sector) at present.

The Ministry of Knowledge Economy (MKE) is responsible for energy policy, for the construction and operation of nuclear power plants, nuclear fuel supply, radioactive waste management and nuclear R&D (application and commercialisation sector).

NSSC is responsible for licences and permits. It is advised by the Nuclear Safety Commission and by the Korean Institute of Nuclear Safety (KINS), which both also carry out inspections, R&D, and safety reviews. This mechanism has been effective in regulating safety but it can appear confusing as to the various roles of the regulatory groups. Given the heightened importance of safety and effective nuclear regulation, ensuring a high profile and clear identity for the regulator is a key issue. Actions taken by the regulatory authority will be important in rebuilding public confidence and it is essential that these are consistent with international initiatives.

PROLIFERATION RESISTANCE AND PHYSICAL PROTECTION

The government has been actively taking part in the efforts of the international community to ensure the peaceful use of nuclear energy, transparency, and nuclear non-proliferation. On 18 September 2004, the Standing Committee of the National Security Council of Korea announced the Four Principles on the Peaceful Use of Nuclear Energy:

- Korea reaffirms that it does not have any intention to develop or possess nuclear weapons;
- Korea firmly maintains its principle of nuclear transparency, and will strengthen its cooperation with the international community to this end;
- Korea will faithfully abide by international agreements on nuclear non-proliferation; and
- With the confidence of the international community in hand, Korea will expand the peaceful use of nuclear energy.

These four principles recognise the concern of the international community and reconfirm the will of the government to only use nuclear energy for peaceful purposes. The government has announced that it will seek to gain the confidence of the international community and strive for higher levels of transparency. In 2005, for institutional support, the government updated the Act on Nuclear Control and instituted the Korea Institute of Non-proliferation and Control (KINAC) for technical support in domestic inspections and safeguards implementation.

In addition, Korea actively participates in international activities on safeguards, proliferation resistance and physical protection such as International Atomic Energy Agency International Project on Innovative Nuclear Reactors (IAEA INPRO) and Generation IV initiatives in these areas.

PUBLIC ACCEPTANCE

The Korean government has tried to promote public acceptance for the future development of nuclear power. There has been a general recognition that nuclear power can deliver large quantities of energy without releasing environmental pollutants and greenhouse gases. In addition, nuclear energy is seen to play a strong role in energy security, being promoted as a quasi-autonomous source, even though it requires importing uranium from abroad. Therefore, public acceptance of nuclear power and new build has been reasonably high in Korea. It is still, however, a major challenge to find a site for a waste repository.

EDUCATION AND TRAINING

Korea provides an example of firm action on education and training. Prompted by a decline in student enrolments and in the number of nuclear experts, the government sponsored a specific study on the domestic nuclear manpower status in 2002 and thereafter continued to monitor human resource development for this industry. Since the early years of the nuclear industry, when the intensive and sustained international co-operation and exchange proved vital for the development of indigenous technology, the Korean government (through MEST) adopted a very systematic approach in addressing human resources, through the Comprehensive Nuclear Energy Promotion Plan (CNEPP). The CNEPP is reviewed every five years in order to define high-level directions and objectives as well as more detailed planning for budget and investment, covering infrastructure and manpower.

In addition to the Brain Korea 21st Century (BK21) programme started in 1999 by the MEST, the Ministry of Knowledge Economy also established manpower development programmes for industries and universities related to electricity, with support extended from basic and applied science and engineering research to broader university programmes allowing diversified research, also suited for educational purposes.

MEST has provided grants to support research of undergraduate students. Under this programme, started in 2003, approximately 70 to 80 selected students are awarded annually individual research grants of about USD 7 000. The MEST has also provided nuclear education and training grants of USD 100 000 to each of the eight nuclear engineering departments in Korea.

The Korea Atomic Energy Research Institute (KAERI) provides an extensive in-house education and training programme, including fundamental and advanced courses for its own members, to industry personnel and university students. Practical and managerial courses, including research training for undergraduate students in nuclear engineering and web-based education and training programmes are delivered.

University research grants are on the increase and graduate students participate in R&D projects run by Korea Atomic Energy Research Institute (KAERI) and the Korea Institute of Nuclear Safety (KINS), fostering the development of the next generation of researchers and enhancing the co-ordination of research projects between research institutes and universities.

The Korea Nuclear Foundation holds a programme of visits to nuclear facilities for undergraduate students which counts as part of the course. About 100 students participate every year.

Longstanding internship programmes in research institutes and industrial organisations often lead to employment. Due to the limited resources, joint research initiatives among industries, universities and research organisations have been particularly beneficial in Korea, allowing the development of original and self-reliant technologies.

THE NUCLEAR FUEL CYCLE

FRONT END

Korea has not actively pursued other parts of the nuclear fuel cycle, in part because of their political sensitivity. In the front-end of the fuel cycle, Korea is fully dependent on foreign sources for supply of natural uranium, conversion and enrichment. Active efforts are being made to diversify uranium supplies. Historically, Korea has imported 100% of its uranium from Australia, Canada, and elsewhere. Since the early 1980s, KEPCO has invested in uranium exploration and development programmes in Canada and the United States, as well as in other countries. KAERI has a pilot plant for converting yellow cake to uranium dioxide (UO_2). This plant is, however, not yet in operation.

In 2006, Korea's enrichment demand was 1.8 million separative work units (SWU), supplied from overseas. Techsnabexport (Tenex), Urenco Group, and USEC, Inc. have previously supplied this, but in mid-2007 KHNP signed a long-term (10+ years) EUR 1.0 billion contract with Areva NC for enrichment services at the new Georges Besse II plant in France. In mid-2009, KHNP took a 2.5% equity stake in the plant.

The Korea Nuclear Fuel Company (KNFC) was established in 1982 and began producing nuclear fuel for PWRs on a commercial basis in 1989. It manufactures and supplies nuclear fuel to all domestic PWRs and CANDUs. To meet the increasing demand for nuclear fuel, KNFC completed construction of new fuel manufacturing facilities at the end of 1997 in addition to the previous PWR fuel manufacturing facility. The annual production capacity is 550 tonnes of uranium (metric tonnes of heavy metal, or tHM) for PWR fuel and 400 tHM for PHWR fuel. This is more than adequate for domestic demand. Hence, with this expansion of the fuel production capacity, KNFC has established a firm basis capable of exporting fuel overseas.

KNFC has developed various advanced nuclear fuels, such as the GuardianTM fuel for the optimised power reactor (OPR1000). For the three-loop Westinghouse type plants, it has provided since 2003 the Robust Fuel Assembly (RFA), which includes key mechanical enhancements to improve structural stability and vibrational characteristics. In 2002, KNFC completed the development of PLUS7TM, which is an advanced fuel for the OPR1000/APR1400. For Westinghouse type reactors in Korea, development of advanced fuel, ACE7TM, was completed in 2004.

BACK END

Spent fuel in Korea is currently stored at the reactor sites. About 12 011 metric tonnes of uranium (MtU) was stored at the end of 2011, with total on-site pool capacity being 16 927 MtU. By comparison, about 6 000 MTU was stored at the end of 2002. Dry storage is used for CANDU fuel after six years of cooling. The volume of spent fuel is expected to exceed 29 000 MtU by 2035. Full capacity of existing fuel storage is expected to be reached by 2016 and this may limit future expansion unless policy decisions are taken soon.

The Korea Radioactive Waste Management Co. Ltd. (KRMC) was set up early in 2009 as an umbrella organisation to resolve Korea's waste management issues and waste disposal, and particularly to forge a national consensus on high-level radioactive waste (HLW) management. Before 2009, KHNP was responsible for managing all its radioactive wastes. KRMC is funded by the radioactive waste funds generated by the NPPs and by charges on producers. However, considering Korea's geographic profile, securing the required number of repository sites will be challenging, and emphasises the need for longer-term strategies to ensure sustainability of nuclear energy in the country.

After a twenty-year effort to find a site for a radioactive waste facility, a suitable site for the low- and intermediate-level radioactive waste (LILW) was chosen in November 2005 in Gyeongju adjacent to the existing Wolsong nuclear power station, with overwhelming support from the local population. Construction of the LILW facility began in 2007 and was originally expected to be completed in 2010, but the construction period was extended twice by about 30 months in 2009 and 18 months in 2012, because of weak bedrock and groundwater problems found during construction. The LILW facility is currently expected to be completed in June 2014.

RESEARCH AND DEVELOPMENT (SPENT FUEL MANAGEMENT)

Korea is an active member of a number of international R&D projects, including the IAEA INPRO project and the Generation IV Forum. Within the Generation IV Forum, Korea has

signed the system arrangements for the sodium-cooled fast reactor and the very high temperature reactor. Through KAERI, it also contributes to the various project agreements related to the research on these two reactor systems.

With regard to spent fuel, even though Korea has not taken a definite decision on its management, several alternative studies on spent fuel management have been carried out over a long period. KAERI is the main body responsible for R&D, and the DUPIC programme ("direct use of used PWR fuel in CANDU reactors"), pyroprocess technology and the development of sodium fast reactors are prominent R&D activities in this area.

The DUPIC programme was initiated in the early 1990s for analysis of the technical feasibility of the DUPIC concept, which involves taking spent fuel from PWRs, crushing it, heating it in oxygen to drive off some 40% of the fission products, and re-forming it into PHWR fuel. The end product still contains all the actinides, including about 1% of plutonium. It is about 96% of uranium, including approximately 1% of U-235. Thus, its fissile content is about 1.5%, more than double that of the natural uranium usually used for today's PHWRs.

One of KAERI's research programmes on spent fuel treatment technologies aims to develop a lithium reduction process called the advanced spent fuel conditioning process (ACP), which was launched in 1997. By converting spent fuel into a single set of disposable metal forms, the process is considered to meet the criteria of proliferation resistance and physical protection that the Korean government emphasises as being critically important requirements for designing a spent fuel management strategy.

In 2006, KAERI constructed a small-scale hot cell (the advanced spent fuel conditioning process facility, ACPF) in the Irradiated Materials Examination Facility (IMEF) to demonstrate how the ACP works with US-origin PWR spent fuel. KAERI has been using only natural uranium and simulated fuel in the ACPF, and the proposal using US-origin PWR spent fuel in Korea is under review by the US government in accordance with Article 8(C) of the US-ROK nuclear co-operation agreement.

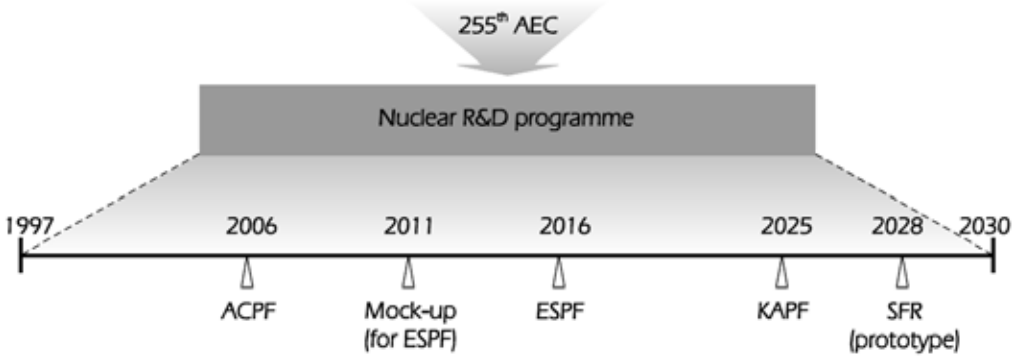
In parallel with the R&D on ACP, KAERI has also been developing technologies for electro-refining (the process for extraction of uranium) and electro-winning (the process for recovery of transuranics) to cover the full spectrum of pyroprocessing. The US government considers that the full spectrum of pyroprocessing is more sensitive than the ACP. Thus, the US government's position was that the ACP demonstration could be carried out at the ACPF, but experiments for developing electro-refining and electro-winning should be carried out on US territory. In this regard, the Cooperative Research and Development Agreement (CRADA) programme was established in 2006.

Development of these processes requires substantial United States-side nuclear co-operation. Owing to the expected renewal of the US-ROK agreement in 2014, an Engineering-scale Pyroprocessing Facility (ESPF) is planned to be built by 2016 and the Korea Advanced Pyroprocessing Facility (KAPF) will become a commercial-scale demonstration plant by 2025. Related to this, KAERI has proposed development of a sodium-cooled fast reactor (SFR). A demonstration Korean fast reactor is planned to be built by 2028.

The Korean government announced a "Long-Term Development Plan for Future Nuclear Energy System" at the 255th Atomic Energy Commission (AEC) meeting held on 22 December 2008. According to this plan, the major research initiatives by KAERI

related to spent fuel is pyro-processing and SFR technology development. Figure 27 shows the major R&D milestones associated with pyro-processing and SFR as described in the Long-Term Development Plan for Future Nuclear Energy System announcement.

Figure 27. **Long-term development plan for pyro-processing and SFR**



Note: ACPF = Advanced Spent Fuel Conditioning Process (ACP) Facility; Mock-up for ESPF (10 tHM/y) = only for natural uranium use; ESPF (10 tHM/y) = Engineering-Scale Pyro Facility; KAPF (100 tHM/y) = Korean Advanced Pyro Facility.

Source: Nuclear Energy Agency.

The major milestones in pyroprocessing development are as follows:

- development and verification of key pyroprocessing technology and construction of an engineering-scale mock-up facility (10 tHM/year) (2010-11);
- construction of an engineering-scale demonstration facility (10 tHM/yr) and technology demonstration (2012-16);
- validation of engineering-scale pyroprocessing technology (2017-20); and
- construction of the Korean Advanced Pyro Facility (KAPF) (2021-25) and operation (around 2025).

In parallel, Korea continues other R&D activities, assuming that disposal technology will be required for the country's long-term nuclear energy strategy regardless of fuel cycle options. R&D on the deep geological disposal of high-level radioactive wastes has been carried out with the co-operation of relevant organisations such as national research institutes, universities, and private companies as well as collaboration from several international participants.

In addition, active R&D on the treatment of radioactive waste from nuclear fuel cycles as well as the decontamination and the decommissioning of nuclear facilities is in progress.

INTERNATIONAL EXPORT ACTIVITIES

Korea started co-operation in nuclear activities with the United Arab Emirates (UAE) with signature of the Korea-UAE nuclear co-operation agreement in June 2009, which came into effect in January 2010. The KEPCO consortium won a tender for nuclear power plant construction in the UAE in December 2009. Subsequently, a contract to build four nuclear power plants by 2020 was signed with Emirates Nuclear Energy Corporation, marking the first export of a Korean commercial nuclear power plant.

The Jordan Research and Training Reactor (JRTR) Project was launched on August 2010 following the signing of an Engineering, Procurement and Construction contract between the Jordan Atomic Energy Commission and the Korean consortium which consists of the Korea Atomic Energy Research Institute and Daewoo Engineering and Construction. Plans call for the commissioning of the JRTR in March 2015.

CRITIQUE

Korea chose nuclear energy for security of supply, climate change and sustainability reasons in the 1970s and continues to plan for increased use of this energy source. Given its lack of other indigenous resources, the choice by Korea to pursue nuclear energy is a pragmatic and economically efficient approach.

The early nuclear power plants were built mainly through turn-key contracts, with little participation by domestic industries. However, the Korean nuclear industry is now at the point where it has full domestic capability and is actively developing an overseas nuclear power business. This is demonstrated by the signature of the first overseas contracts for four NPP units to be built in the UAE and a research reactor in Jordan.

Korea's performance in nuclear energy continues to be an excellent example for other countries and nuclear remains the cheapest of all its electricity sources. Korea has accomplished significant scientific and technological development through domestic research and international co-operation. It is now seeking a more active role in the global science and technology community to contribute to scientific advancement and also to further its knowledge for domestic social and economic development. It has many facilities and expertise that it can share with other countries, especially in the region.

This also applies to public acceptance, which has been greatly affected by the accident in one of its neighbouring countries. Public approval for nuclear dropped to its lowest level for 15 years following the accident and actions will be needed to address these concerns. While Korea has made very good progress in many areas with public awareness, the recent events at Fukushima and the need for sites for waste disposal reinforce the importance of these efforts. One of the important pieces of information for the public and others will be the costs of proceeding or not proceeding with the nuclear programme, so that the full impacts of any decision can be known.

Spent fuel generated from nuclear power plants will be stored within each plant site by expanding the storage capacity until 2016. Future national policy for spent fuel management including the construction of the interim storage facility will be decided in a timely manner through public participation, taking international trends on policy and R&D into consideration.

The regulatory process in Korea involves several agencies and is supported by the technical expertise of the Korea Institute of Nuclear Safety. However, it can be confusing as to how decisions are taken and some additional clarity on the responsibilities and processes of the nuclear regulatory authority would be useful.

RECOMMENDATIONS

The government of Korea should:

- *Work carefully towards making, and implementing, a firm policy on the final management or disposal of spent fuel, while recognising the need for a staged and transparent approach in the selection of sites.*
- *Maintain a continuous and transparent engagement with the public as a whole and with prospective host communities for nuclear facilities to share the process and consequences of any proposal for nuclear facilities and ultimately to increase public trust, especially following Fukushima.*
- *Ensure that the regulatory authority has an enhanced profile, is well resourced and fully able to take independent decisions.*
- *Continue and enhance its participation in international discussions and sharing of experiences post Fukushima, given the expected improvements of safety and regulation being considered in many countries.*

PART III
ENERGY TECHNOLOGY

11. ENERGY TECHNOLOGY RESEARCH, DEVELOPMENT AND DEPLOYMENT

Key data (2010)

Government energy RD&D spending (2010): KWR 619 billion

Share in GDP: 0.53 per 1 000 units of GDP (IEA median 0.40)

RD&D per capita: USD 11.5 (IEA median: USD 15.3)

OVERVIEW

Government expenditure on energy-related research, development and deployment (RD&D) in Korea is among the highest in the OECD. Spending has increased significantly in the past decade and in 2010, government investment in energy-related RD&D was over KRW 600 billion.

INSTITUTIONAL FRAMEWORK

The Ministry of Knowledge Economy (MKE) and the Ministry of Education, Science and Technology (MEST) share responsibility for energy-related RD&D policy in Korea. MEST manages basic science research programmes, focusing on the development of technologies for which Korean research has the greatest strategic advantage, whereas the MKE is responsible for the majority of the energy-specific R&D programmes.

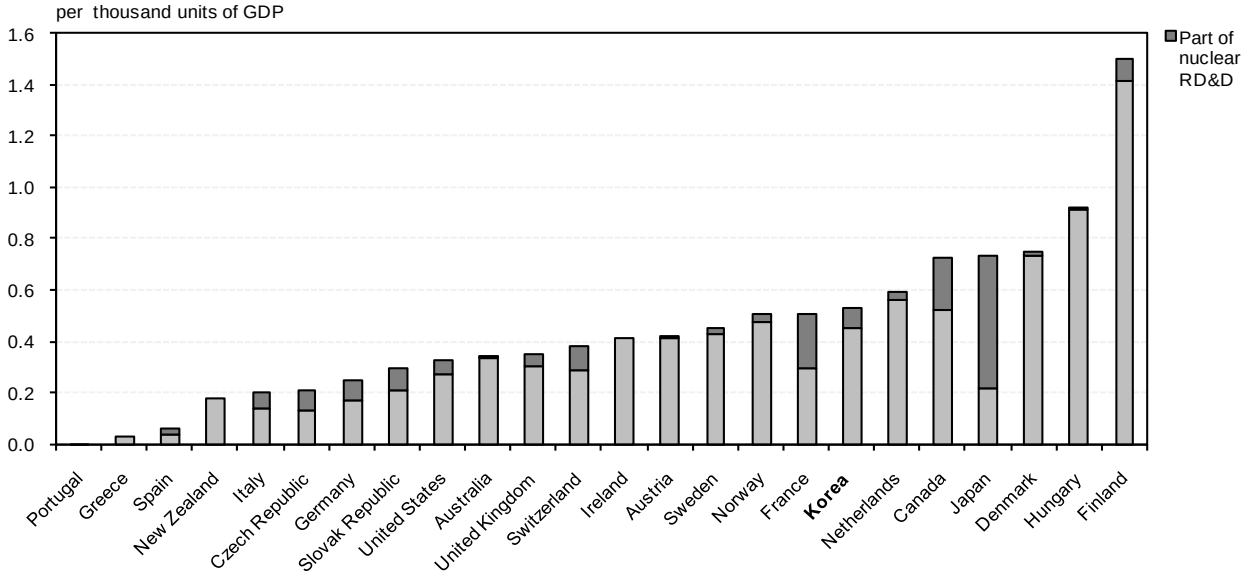
In the past, national energy-related RD&D programmes were planned and managed by four different organisations. Planning responsibility rested with the Korea Institute of Energy and Resources Technology Evaluation and Planning. Programme management was in the hands of three different organisations; energy efficiency and resource-based programmes were managed by the Korea Energy Management Corporation (KEMCO). Power generation and nuclear power programmes were managed by the Korea Electric Power Corporation (KEPCO); and new and renewable energy programmes were managed by the New and Renewable Energy Center in KEMCO.

In 2009, the Korean government decided to integrate these previously scattered responsibilities into a single agency. Accordingly, the Korea Institute of Energy Technology Evaluation and Planning (KETEP) was established in May 2009 under the Energy Act to underpin the development of innovative energy technologies through the implementation of effective planning, evaluation, and management of national R&D programmes for energy. KETEP is a government agency under the authority of the Ministry of Knowledge Economy and it is responsible for strategic planning of energy technology RD&D programmes and systematic evaluation and management of those programmes. In 2010, KETEP had a budget of USD 800 million and employed 130 staff.

POLICIES AND PROGRAMMES

Government RD&D spending is guided by the Green Energy Technology Roadmap, an action plan, published by the government in May 2009. The objective of the roadmap is to keep Korea on track to meet its Low Carbon, Green Growth policy objectives.

Figure 28. **Government energy-related RD&D budgets in IEA member countries, 2010**



Note: data are not available for Belgium, Luxemburg, Poland and Turkey.

Sources: *OECD Economic Outlook, OECD Paris*, 2012 and country submissions.

KETEP was charged with establishing a strategic R&D investment plan based on Low Carbon, Green Growth policy objectives. Key elements of the new strategy were to be the dispersion of investment risk, government support and measures to address market failure. In response, KETEP formulated the Green Energy Strategy Roadmap, which is an RD&D action plan linked directly to energy policy. The roadmap contained technology-specific action plans and a systematic division of roles in R&D investment between the government and industry.

To develop the plan, 15 technology areas were selected after technical and market evaluation by experts from the government, universities, research institutes, and the private sector. The following two criteria were utilised for selecting the 15 technologies:

§ *market attractiveness*: market potential, contribution to the environment (CO_2 reduction), competitiveness in the global market; and

§ *technical importance*: technical innovation, technology development capacity, need for government support.

A large number of experts (226) from the government, research institutes, universities and the public sector participated in formulating roadmaps and more than half (54%) of the participants were from the private sector. The roadmap focused on public-private partnership and included industry strategy as well as R&D strategy so that the R&D results could be transferred to outputs. The roadmap also included potential for short- and

long-term CO_2 reduction, job creation and export targets for the 15 technologies. On the basis of this roadmap, strategic R&D programmes are drawn up each year including plans for large-scale R&D projects.

The selected technologies were divided into two broad categories:

- **early development**: photovoltaics (PV), wind power, fuel cells, LED lighting, smart grids, integrated gasification combined-cycle (IGCC) technology, energy storage, clean fuels and CCS; and
- **next-generation development**: nuclear power, green cars, heat pumps, energy-efficient buildings, combined heat and power (CHP) and superconductivity.

The strategy also developed four guiding principles for development:

- **principle one**: expansion of strategic items, which will focus on components, materials, business models and fundamental technology;
- **principle two**: strengthening coordination with government policy, which will focus on plans for carbon capture and storage (CCS) and offshore wind power;
- **principle three**: promotion of small- and medium-sized enterprises, which will focus on analysis of business types, advantages through research on supply chains of domestic industry; and
- **principle four**: strategic items to lead global markets, including technologies such as coal gasification, concentrated PV systems, small- and medium-sized nuclear reactors, etc.

The 2011 roadmap includes 88 strategic items and 288 key technologies which Korea should focus on in order to develop the 15 green energy sectors. In addition, the roadmap also contains R&D schedules by year, commercialisation strategies and capital requirements. Korea has set itself a target of achieving 18% of the global green energy market share in 2030 compared to its present market share of 1.2%.

SMART GRID PROJECT

Korea unveiled ambitious plans to be the first country to convert its electricity networks into a smart grid system. In 2009, KEPCO launched the country's first smart grid test bed on Jeju Island off the south coast of Korea. Basic project infrastructure for the 6 000-household village was scheduled to be built by the end of 2011 and a full range of systems and services are expected to be operational no later than the end of 2013. The government will provide USD 50 million out of an estimated total cost of USD 200 million for the test bed.

FUNDING AND EVALUATION

FUNDING

Government expenditure on energy-related RD&D is among the highest in the OECD and spending has increased significantly in the past decade. Spending on energy-related RD&D was over KRW 600 billion in 2010 compared to KRW 53 billion in 2000. Renewable energy and nuclear energy combined received almost half of available funds in 2010. In the Five-Year Green Growth Plan, the government plans to expand its R&D investment in

green technologies from KRW 2 trillion in 2009 to KRW 3.5 trillion by 2013, making a cumulative amount of KRW 13 trillion. This would boost green growth-related R&D from 16% of the government's total R&D spending in 2009 to 20% by 2013. In addition to public R&D, the Five-Year Plan includes fiscal support for green R&D by SMEs.

Both public and private energy R&D budgets have seen a steady rise every year in the past and this trend is expected to continue in the future. As the public budget in energy R&D increases, the government is placing a strong emphasis on optimal allocation of the budget with the application of various quantitative and qualitative methods. Recently, Korea has carried out several research projects related to formulating an energy R&D portfolio including R&D priority setting. Energy R&D related to basic science is managed by the Ministry of Education, Science and Technology while most of the energy R&D programmes, including application and commercialisation, are managed at the Ministry of Knowledge Economy. The budget allocation between the two ministries is managed by the Ministry of Strategy and Finance.

Table 11**. Status of RD&D budgets in Korea**

	R&D objectives	Funding area	2011 budget
Energy and natural resources	Energy security Climate change	Energy efficiency Greenhouse gas reductions Natural resources	USD 448.5 million
New and renewable energy	To ensure effective accomplishment of the objectives of the government's Framework Plan for the Promotion of the Development, Use, and Deployment of New and Renewable Energy Technologies Deployment of new and renewable energy Green growth	Renewable energy includes solar thermal and photovoltaics, wind power, bioenergy, waste energy, geothermal energy, small hydropower, and ocean energy. Hydrogen, fuel cells, and coal gasification and liquefaction are defined as new energy technology areas	USD 265.4 million
Electric and nuclear power	To promote electric power technology development to address the interconnected economic, environmental, and energy security concerns and goals in a balanced and sustainable manner	Smart grid technology Development of hydro and thermal power generation Nuclear power Transmission and distribution Electricity infrastructure	USD 290.6 million
Radioactive waste management	To promote safety control technologies for the management of spent nuclear fuel and the low- and intermediate-level waste disposal facilities	Low- and intermediate-level waste management Management of spent fuel	USD 11.8 million
Total			**USD 1.163 billion**

Source: Korea Institute of Energy Technology Evaluation and Planning.

EVALUATION

In order to conduct its R&D programmes efficiently and effectively, Korea recently restructured its RD&D evaluation system. For *ex-ante* evaluation that is required for selecting R&D programmes, Korea emphasises links with national energy policy and provides greater responsibility to evaluators. The economic evaluation mechanism has been broadened significantly by the inclusion of energy economists in the evaluation group and more economic criteria in the evaluation.

After programmes are selected, KETEP can evaluate each R&D project to see whether the project is being carried out according to its objectives and target. A technical evaluation, as well as the economic validity evaluation, may be performed. Once R&D programmes have come to an end, *ex-post* evaluations are performed to determine the success or failure of the programme. KETEP can perform the evaluation on the applications and usage of the R&D outcomes for five years after the completion of the projects.

INTERNATIONAL COLLABORATION

The purpose of Korea's international co-operation in energy-related RD&D is to support international joint research programmes, in order to react to changes in the energy environment and to support green growth by enhancing international co-operation.

In addition to international joint research programmes, Korea tends to focus on energy efficiency, climate change and resource technology co-operation projects. It actively seeks out opportunities for international joint research programmes and co-operation projects in photovoltaics, wind, hydrogen fuel cells, bioenergy, geothermal and solar thermal energy as a priority. Joint development and overseas demonstration projects with foreign R&D centres on smart grid technologies, co-operation with overseas leading research institutes, or businesses, on the development of key technologies related to the nuclear power sector have also been identified as priorities.

Korea recognises the importance of international collaboration for successful innovative energy technology development. It puts much effort into bilateral collaboration and exchange of information through memorandums of understanding and joint workshops (with Japan, the United States, Germany, China, Mongolia, Malaysia, the United Arab Emirates, and Canada, among others). In addition, the Korean government has created a separate funding programme for the international R&D collaboration projects with an annual budget of USD 19.6 million.

Korea actively participates in various multilateral and bilateral international collaborations. Examples include bilateral co-operation with the United States as a result of which Korea has hosted energy-technology joint workshops in August 2008, July 2009 and August 2010, jointly with the Korean Scientists and Engineers Association (KSEA) in North America, as well as with the Energy Leaders Forum. The collaboration has also led to the establishment of an official network with Korean scientists in the United States and preparation of a foundation for bilateral joint research projects.

Korea actively participates in Asia Regional Co-operation Projects such as those between Korea, Japan and China; examples of this programme of co-operation are the China-Japan-Korea low-carbon symposium, and consultations with Japan for clean coal technology co-operation.

Korea is also one of the seven contracting parties to the international thermonuclear experimental reactor (ITER) under construction in Cadarache, France. Korea participates in the Carbon Sequestration Leadership Forum, the Expert Group on Clean Fossil Energy, and the Asia-Pacific Partnership on Clean Development and Climate.

Since the last in-depth review, Korea's participation in IEA Implementing Agreements (IA), more than doubled, from 13 to 27. In terms of participation, Korea currently ranks fourth among IEA member countries, behind the United States, Canada and Japan, contributing to 27 of the 40 IEA Implementing Agreements. Korea's participation is well distributed among each of the areas, but more prominent in renewable energy and end-

use technologies, in particular in the buildings sector. Korea holds the position of chair in one fusion IA, is vice chair to one IA (demand-side management), and vice chair and operating agent to the IA focusing on smart grids.

PUBLIC-PRIVATE PARTICIPATION

The effort that the Korean government has put to transfer and deliver the R&D outcomes is reflected by the participation of the private sector in formulating the National Energy Technology Roadmap. In addition, most of the strategic R&D programmes, which are usually large-scale projects, require the private sector to be the principal instigator.

CRITIQUE

Government expenditure on energy-related RD&D has increased significantly over the past decade and is now among the highest in the OECD. Investment in energy-related RD&D was over KRW 600 billion in 2010. Korea has developed and started to implement an energy RD&D strategy, the Green Energy Strategy Roadmap, which includes a strategic plan for market penetration, international cooperation, human resources development and education, and collaboration with the private sector. Development of the strategy was an inclusive process with substantial involvement from the private sector.

The strategy identifies 15 technology areas for focused development, and roadmaps for each area have been drawn. Clear milestones for each technology area are listed, and categorised by short-, medium- and long-term objectives. However, these 15 energy technology areas do not have a clear correlation with the 27 core green technologies that were announced in the Presidential Committee on Green Growth in 2009, as new growth engines for Korea. Such conflicting signals should be avoided, and more focused co-ordination should be pursued in order to align Korea's Green Growth Strategy with the country's energy R&D strategy.

It is notable that the Korean government has been collaborating substantially with the private sector in the development of its energy R&D strategy. The industry has provided input into the Green Energy Strategy Roadmap, and helped define which areas of energy R&D should be developed by the government and those which should be left to industry. In addition, the private sector is required to contribute 50% of R&D costs, and to be the principal instigator of large-scale projects. Such a burden-sharing approach may carry the risk of directing government-sponsored R&D towards technologies approaching commercialisation, which are of most interest to industry.

There needs to be greater clarity on the separation of public-sector investment from that of the private sector. The government should focus on the upstream areas of applied R&D (in addition to basic science), which are often highly risky phases of technology development, while industry can be expected to make research investments without public R&D support in areas covering later stages of R&D. A balanced R&D portfolio should include both high- and low-risk projects.

The establishment of KETEP in 2009 as a means of centralising previously scattered energy R&D functions is a major contributor to Korean progress and reflects the findings of the previous in-depth review. KETEP has put in place a clear priority-setting process, and has introduced a culture of *ex-ante*, interim and *ex-post* evaluation. The IEA also welcomes the development of a number of strategies, plans, programmes, roadmaps

and other initiatives in response to the previous in-depth review as measures to ensure that R&D priorities and investment levels continue to reflect energy policy objectives. The propensity of Korea to place increased emphasis on technology development policies and measures, however, calls for careful assessment and expanded policy research on the effectiveness of such policies and measures. Priority setting is an ongoing process, constantly evolving, and evaluations should take place in order to determine the worth or value of a policy, programme or project, and feed information into the decision-making process. It is important, therefore, that the government streamlines the process from priority setting to evaluation in a transparent way.

The IEA commends Korea for the manner in which it has increased the energy R&D budget steadily since the last in-depth review, and understands that this trend is expected to continue in the future. In addition, Korea's overall performance in terms of energy R&D expenditure as a percentage of GDP is above the IEA average. The Korean government is investing in robust and comprehensive energy technology areas, which were selected on the basis of their technical importance and market attractiveness, with a focus on those with a high market potential, and which offer export opportunities in other markets. Considering that the ratio of new and renewable energy in the final energy consumption in Korea is the lowest of IEA member countries, and that the government is planning to increase the ratio significantly, it may be necessary to further sharpen priorities to maximise the cost-effectiveness of government energy R&D programmes. New and renewable energy such as geothermal energy, solar thermal, and bioenergy should be priorities given the domestic resource potential for these technologies.

In addition to R&D investments, other policy instruments could be introduced in order to directly mobilise public funds to support immature pre-deployment, low-carbon technologies. For instance, public green loans, public-private equity partnerships, and subsidies in the form of prizes, tax credits and grants, have been implemented in several IEA countries with success, when tailored to the size of the financial gap and the maturity of the targeted technology. Korea is applying subsidies programmes, loans and tax incentive programmes for the deployment of new and renewable energy. Nonetheless, it should consider introducing some of the above-mentioned policy instruments in order to encourage further investment in R&D by private firms.

Korea actively participates in various multilateral and bilateral international collaborations and created a separate R&D programme for international projects in 2011 with an annual budget of USD 19.6 million. Korea has also increased its participation in IEA Implementing Agreements over the period since the last in-depth review. To augment the present rate of progress, the government should develop a strategy for international R&D collaboration, selecting topics and technologies that are more relevant, and developing procedures for prioritising international R&D collaboration as part of their national R&D priority-setting process.

RECOMMENDATIONS

The government of Korea should:

- *Continue to strengthen co-operation and co-ordination between different ministries with regard to energy R&D, identify clear roles and centralise responsibilities to avoid compartmentalisation in different ministries and proliferation of duplicates or disconnected initiatives.*

- *Ensure coherence between the energy R&D strategy and the Strategy on Green Growth in order to identify clear national priorities and maximise the cost-effectiveness of government energy R&D programmes, by increasing investment in energy technologies with significant energy resource potential.*
- *Encourage further investment in R&D by the private sector by designing policy instruments to support both existing and emerging low-carbon technologies while maintaining accountability and transparency of the role of the private sector in public R&D.*
- *Streamline the process from priority setting to evaluation, and ensure that the results of evaluations are used by R&D planners when designing programmes or investing in technologies, and by policy makers when setting targets.*
- *Develop a comprehensive strategy for international energy R&D collaboration and link this strongly to domestic energy strategy.*

PART IV
ANNEXES

ANNEX A: ORGANISATION OF THE REVIEW

REVIEW CRITERIA

The Shared Goals, which were adopted by the IEA Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews conducted by the IEA. The Shared Goals are presented in Annex C.

REVIEW PROCESS

The in-depth review team visited Seoul from 29 May 2011 to 3 June 2011. During the week-long visit, the review team met with government officials, representatives from ministries and government agencies, energy producers and suppliers, interest groups and various other organisations and stakeholders. This report was drafted on the basis of these meetings and the government response to the IEA energy policy questionnaire and other information. The team is grateful for the co-operation and hospitality of the many people it met during the visit. Thanks to their openness and candour, the review visit was highly productive.

In particular, the team wishes to express its gratitude to Minister for Knowledge Economy, Mr. Sukwoo Hong and the Vice Minister for Knowledge Economy, Mr. Seok Cho. The review team is also grateful to Mr. Yangho Chung, Director General for Energy Policy, Ministry of Knowledge Economy and Mr. Jin-Woo Kim, President of Korea Energy Economics Institute and their staff for providing detailed briefing on energy policy in Korea. Their willingness to share information and gracious hospitality contributed in no small way to a successful and productive visit. The author is particularly thankful to Ms Yangji Kim, Ms Suhee Kim and Ms Jade Ock, Energy and Resources Policy Division, Ministry of Knowledge Economy and Dr. Yongduk Pak, Senior Research Fellow, Korea Energy Economics Institute for co-ordinating the team visit and for their ongoing support throughout the drafting process.

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Kieran McNamara managed the review and is the author of the report with the exception of Chapter 6 on Oil, which was drafted by Andrew Robertson and Chapter 10 on Nuclear Energy, which was drafted by Ron Cameron. Yuichiro Nishida and Akihiro Tonai both contributed to the drafting the Chapter 5 on Natural Gas and Chapter 6 on Oil while Akira Yabumoto provided input to the Electricity chapter. Ulrich Benterbusch, Rebecca Gaghen, Kijune Kim, Cecilia Tam, Carrie Pottinger, Anne-Sophie Corbeau and Sang-il Kim contributed helpful comments throughout.

Sonja Lekovic, Yuichiro Tanaka and Bertrand Sadin prepared the figures. Karen Treanton provided support on statistics. Muriel Custodio, Astrid Dumond, Jane Barbière and Angela Gosmann managed the production process. Viviane Consoli provided editorial assistance and Catherine Smith helped in the final stages of preparation.

ORGANISATIONS VISITED

Climate Action Partnership (Ecomom Korea)

ESCO Association

GS-Caltex

Korea City Gas Association

Korea Coal Corporation

Korea Electric Power Corporation

Korea Electricity Regulatory Commission

Korea Energy Economics Institute (KEEI)

Korea Energy Management Corporation (KEMCO)

Korea Gas Corporation (KOGAS)

Korea Hydro and Power Corporation

Korea Institute of Energy Technology

Korea LPG Association

Korea National Oil Corporation (KNOC)

Korea Power Exchange

Korea Smart Grid Institute

Ministry of Education, Science and Technology

Ministry of Environment

Ministry of Knowledge Economy

Ministry of Land, Transport and Maritime Affairs

POSCO

Renewable Energy Associations

ANNEX B:
ENERGY BALANCES
AND KEY STATISTICAL DATA

Unit: Mtoe

SUPPLY		1973	2000	2009	2010	2011e	2020	2030
TOTAL PRODUCTION		**6.8**	**34.4**	**44.3**	**44.9**	**45.4**	**70.0**	**86.0**
Coal		6.7	3.6	1.2	1.0	1.0	-	-
Peat		-	-	-	-	-	-	-
Oil		-	0.7	0.7	0.7	0.7	-	-
Natural Gas		-	-	0.4	0.5	0.4	-	-
Biofuels & Waste[1]		-	1.4	3.0	3.4	3.5	12.3	18.6
Nuclear		-	28.4	38.5	38.7	39.1	57.2	66.8
Hydro		0.1	0.3	0.2	0.3	0.4	0.5	0.5
Wind		-	0.0	0.1	0.1	0.1	-	-
Geothermal, solar and heat		-	0.0	0.2	0.2	0.3	-	-
TOTAL NET IMPORTS[2]		**-37.5**	**100.6**	**142.8**	**168.7**	**226.9**	**..**	**..**
Coal	Exports	0.1	-	-	-	-	-	-
	Imports	0.5	39.1	62.9	72.9	79.5	79.5	84.6
	Net Imports	0.3	39.1	62.9	72.9	79.5	79.5	84.6
Oil	Exports	1.0	40.9	44.3	45.8	54.8	..	..
	Imports	14.2	150.4	149.3	154.6	160.2	121.1	123.2
	Int'l Marine and Aviation Bunkers	-51.1	-48.1	-25.1	-13.0	-13.0	-11.5	-13.2
	Net Imports	-37.8	61.4	79.8	95.8	92.4	..	..
Natural Gas	Exports	-	-	-	-	-	-	-
	Imports	-	17.1	30.2	39.3	42.0	46.1	54.0
	Net Imports	-	17.1	30.2	39.3	42.0	46.1	54.0
Electricity	Exports	-	-	-	-	-	-	-
	Imports	-	-	-	-	-	-	-
	Net Imports	-	-	-	-		-	-
TOTAL STOCK CHANGES		**1.9**	**-1.9**	**-1.1**	**-2.9**	**-4.1**	**..**	**..**
TOTAL SUPPLY (TPES)[3]		**21.5**	**188.2**	**229.2**	**250.0**	**257.6**	**305.3**	**334.5**
Coal		8.1	42.0	64.8	73.4	79.8	79.5	84.6
Peat		-	-	-	-	-	-	-
Oil		13.3	99.0	90.6	95.1	92.8	109.6	110.0
Natural Gas		-	17.0	31.7	38.7	41.6	46.1	54.0
Biofuels & Waste[1]		-	1.4	3.0	3.4	3.5	12.3	18.6
Nuclear		-	28.4	38.5	38.7	39.1	57.2	66.8
Hydro		0.1	0.3	0.2	0.3	0.4	0.5	0.5
Wind		-	0.0	0.1	0.1	0.1	-	-
Geothermal		-	-	0.0	0.0	0.0	-	-
Solar		-	0.0	0.1	0.1	0.1	-	-
Heat		-	-	0.1	0.1	0.1	-	-
Electricity Trade[4]		-	-	-	-	-	-	-
Shares (%)								
Coal		*37.7*	*22.3*	*28.3*	*29.4*	*31.0*	*26.1*	*25.3*
Peat		-	-	-	-	-	-	-
Oil		*61.8*	*52.6*	*39.5*	*38.0*	*36.0*	*35.9*	*32.9*
Natural Gas		-	*9.0*	*13.8*	*15.5*	*16.2*	*15.1*	*16.1*
Biofuels & Waste		-	*0.7*	*1.3*	*1.4*	*1.3*	*4.0*	*5.6*
Nuclear		-	*15.1*	*16.8*	*15.5*	*15.2*	*18.7*	*20.0*
Hydro		*0.5*	*0.2*	*0.1*	*0.1*	*0.2*	*0.1*	*0.2*
Wind		-	*0.0*	*0.0*	*0.0*	*0.0*	-	-
Geothermal		-	-	*0.0*	*0.0*	*0.0*	-	-
Solar		-	*0.0*	*0.0*	*0.0*	*0.0*	-	-
Heat		-	-	*0.0*	*0.0*	*0.1*	-	-
Electricity Trade		-	-	-	-	-	-	-

0 is negligible, - is nil, .. is not available

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**2000**	**2009**	**2010**	**2011e**	**2020**	**2030**
TOTAL FINAL CONSUMPTION (TFC)	**17.5**	**127.1**	**147.8**	**157.4**	**..**	**219.9**	**237.9**
Coal	6.5	9.1	8.2	9.5	..	27.2	27.6
Peat	-	-	-	-	..	-	-
Oil	9.9	79.9	79.7	81.9	..	106.9	107.5
Natural Gas	-	10.9	18.1	20.4	..	29.2	33.9
Biofuels & Waste[1]	-	1.3	2.4	2.6	..	9.8	14.6
Geothermal	-	-	0.0	0.0	..	-	-
Solar	-	0.0	0.0	0.0	..	-	-
Electricity	1.1	22.6	34.9	38.6	..	43.9	50.3
Heat	-	3.3	4.4	4.3	..	2.9	3.9
Shares (%)							
Coal	*37.1*	*7.1*	*5.5*	*6.1*	..	*12.4*	*11.6*
Peat	-	-	-	-	..	-	-
Oil	*56.6*	*62.8*	*53.9*	*52.0*	..	*48.6*	*45.2*
Natural Gas	-	*8.6*	*12.3*	*12.9*	..	*13.3*	*14.3*
Biofuels & Waste	-	*1.0*	*1.7*	*1.7*	..	*4.5*	*6.1*
Geothermal	-	-	*0.0*	*0.0*	..	-	-
Solar	-	*0.0*	*0.0*	*0.0*	..	-	-
Electricity	*6.3*	*17.8*	*23.6*	*24.5*	..	*20.0*	*21.2*
Heat	-	*2.6*	*3.0*	*2.8*	..	*1.3*	*1.6*
TOTAL INDUSTRY[5]	**7.5**	**63.0**	**76.3**	**82.4**	**..**	**71.8**	**77.8**
Coal	0.4	8.5	7.3	8.7	..	26.5	27.3
Peat	-	-	-	-	..	-	-
Oil	6.4	35.5	41.8	43.2	..	10.8	11.4
Natural Gas	-	2.9	5.6	6.9	..	6.5	6.4
Biofuels & Waste[1]	-	1.1	1.7	1.7	..	7.1	10.2
Geothermal	-	-	0.0	0.0	..	-	-
Solar	-	-	-	-	..	-	-
Electricity	0.8	12.9	17.1	19.6	..	21.0	22.5
Heat	-	2.1	2.7	2.3	..	-	-
Shares (%)							
Coal	*5.2*	*13.5*	*9.6*	*10.5*	..	*36.9*	*35.1*
Peat	-	-	-	-	..	-	-
Oil	*84.8*	*56.3*	*54.8*	*52.4*	..	*15.1*	*14.6*
Natural Gas	-	*4.6*	*7.4*	*8.3*	..	*9.0*	*8.2*
Biofuels & Waste	-	*1.7*	*2.3*	*2.1*	..	*9.9*	*13.2*
Geothermal	-	-	*0.0*	*0.0*	..	-	-
Solar	-	-	-	-	..	-	-
Electricity	*10.1*	*20.5*	*22.5*	*23.8*	..	*29.2*	*28.9*
Heat	-	*3.4*	*3.5*	*2.8*	..	-	-
TRANSPORT[3]	**2.5**	**26.7**	**29.9**	**30.6**	**..**	**38.6**	**38.7**
OTHER[5,6]	**7.4**	**37.4**	**41.6**	**44.4**	**..**	**56.1**	**65.1**
Coal	6.1	0.6	0.9	0.9	..	0.8	0.3
Peat	-	-	-	-	..	-	-
Oil	1.0	17.8	9.3	9.6	..	6.6	5.1
Natural Gas	-	8.0	11.6	12.5	..	21.6	26.3
Biofuels & Waste[1]	-	0.2	0.5	0.6	..	1.5	2.1
Geothermal	-	-	0.0	0.0	..	-	-
Solar	-	0.0	0.0	0.0	..	-	-
Electricity	0.3	9.5	17.6	18.8	..	22.6	27.5
Heat	-	1.2	1.7	2.0	..	2.9	3.9
Shares (%)							
Coal	*81.8*	*1.5*	*2.1*	*1.9*	..	*1.4*	*0.4*
Peat	-	-	-	-	..	-	-
Oil	*13.7*	*47.7*	*22.3*	*21.7*	..	*11.8*	*7.8*
Natural Gas	-	*21.5*	*27.9*	*28.1*	..	*38.6*	*40.4*
Biofuels & Waste	-	*0.6*	*1.2*	*1.3*	..	*2.7*	*3.2*
Geothermal	-	-	*0.1*	*0.1*	..	-	-
Solar	-	*0.1*	*0.1*	*0.1*	..	-	-
Electricity	*4.5*	*25.5*	*42.2*	*42.4*	..	*40.3*	*42.2*
Heat	-	*3.1*	*4.2*	*4.5*	..	*5.2*	*6.0*

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**2000**	**2009**	**2010**	**2011e**	**2020**	**2030**
ELECTRICITY GENERATION[7]							
INPUT (Mtoe)	**3.5**	**69.7**	**106.6**	**115.3**	**..**	**132.1**	**150.9**
OUTPUT (Mtoe)	**1.1**	**22.6**	**34.9**	**38.6**	**41.0**	**43.9**	**50.3**
(TWh gross)	14.8	288.5	451.7	496.7	515.5	552.0	632.4
Output Shares (%)							
Coal	*9.0*	*38.6*	*46.2*	*44.1*	*45.2*	*39.4*	*37.1*
Peat	-	-	-	-	-		
Oil	*82.3*	*12.0*	*4.4*	*3.8*	*2.9*	*4.7*	*3.9*
Natural Gas	-	*10.2*	*15.6*	*20.8*	*21.2*	*25.0*	*27.3*
Biofuels & Waste	-	*0.0*	*0.2*	*0.2*	*0.2*	*1.5*	*2.1*
Nuclear	-	*37.8*	*32.7*	*29.9*	*29.1*	*33.9*	*33.6*
Hydro	*8.7*	*1.4*	*0.6*	*0.7*	*0.9*	*0.8*	*0.8*
Wind	-	*0.0*	*0.2*	*0.2*	*0.2*	-	-
Geothermal	-	-	-	-	-	-	-
Solar	-	*0.0*	*0.1*	*0.2*	*0.2*	-	-
TOTAL LOSSES	**3.9**	**59.9**	**83.6**	**90.7**	**..**	**..**	**..**
of which:							
Electricity and Heat Generation[8]	2.2	41.5	63.3	68.2	..	85.3	96.7
Other Transformation	0.7	8.7	8.7	10.0	..	..	..
Own Use and Losses[9]	1.0	9.7	11.6	12.4	..	..	..
Statistical Differences	**0.2**	**1.1**	**-2.3**	**1.9**	**..**	**..**	**..**
INDICATORS	**1973**	**2000**	**2009**	**2010**	**2011e**	**2020**	**2030**
GDP (billion 2005 USD)	81.55	678.27	958.51	1 017.57	1 054.55	..	..
Population (millions)	34.10	47.01	48.75	48.88	48.92	49.33	48.64
TPES/GDP[10]	0.26	0.28	0.24	0.25	0.24	..	..
Energy Production/TPES	0.31	0.18	0.19	0.18	0.18	0.23	0.26
Per Capita TPES[11]	0.63	4.00	4.70	5.12	5.27	6.19	6.88
Oil Supply/GDP[10]	0.16	0.15	0.09	0.09	0.09	..	..
TFC/GDP[10]	0.21	0.19	0.15	0.15	..	..	..
Per Capita TFC[11]	0.51	2.70	3.03	3.22	..	4.46	4.89
Energy-related CO_2 Emissions (Mt CO_2)[12]	67.3	437.7	515.5	563.1	..	606.6	644.4
CO_2 Emissions from Bunkers (Mt CO_2)	2.2	32.2	37.7	40.6	..	35.5	40.5
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-09**	**09-10**	**10-11**	**11-20**	**20-30**
TPES	9.1	7.3	2.2	9.1	3.0	18.5	9.6
Coal	7.7	5.1	5.0	13.2	8.7	-0.0	6.4
Peat	-	-	-	-	-	-	-
Oil	9.4	7.1	-1.0	5.0	-2.5	1.7	0.3
Natural Gas	-	20.1	7.2	22.0	7.6	1.0	17.1
Biofuels & Waste	-	6.6	9.2	13.3	0.6	13.5	51.2
Nuclear	31.3	7.5	3.4	0.6	1.1	3.9	16.8
Hydro	10.0	-4.5	-3.9	31.0	28.1	1.2	16.8
Wind	-	-	57.3	18.6	5.7	-	-
Geothermal	-	-	-	50.0	39.4	-	-
Solar	-	15.4	8.4	29.9	5.3	-	-
Heat	-	-	-	29.2	56.5	-	-
TFC	8.1	7.0	1.7	6.5	..	..	0.8
Electricity Consumption	12.7	10.8	4.9	10.8	..	..	1.4
Energy Production	7.0	4.3	2.8	1.4	1.2	4.4	2.1
Net Oil Imports	-3.0	43.1	3.0	20.0	-3.5	..	..
GDP	9.0	6.5	3.9	6.2	3.6	..	..
Growth in the TPES/GDP Ratio	0.1	0.7	-1.6	2.8	-0.6	..	..
Growth in the TFC/GDP Ratio	-0.8	0.4	-2.1	0.3	..	..	..

Please note: Rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.
3. Excludes international marine bunkers and international aviation bunkers.
4. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
5. Includes non-energy use.
6. Other includes residential, commercial, public services, agriculture, forestry, fishing and other non-specified.
7. Inputs to electricity generation include inputs to electricity, CHP 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 photovoltaic.
9. Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
10. Toe per thousand US dollars at 2005 prices and exchange rates.
11. Toe per person.
12. "Energy-related CO_2 emissions" have been estimated using the IPCC Tier I Sectoral Approach from the *Revised 1996 IPCC Guidelines*. In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 2009 and applying this factor to forecast energy supply. Future coal emissions are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

ANNEX C: INTERNATIONAL ENERGY AGENCY "SHARED GOALS"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

*Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: GLOSSARY, LIST OF ABBREVIATIONS AND CURRENCY CONVERSION

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 many of the abbreviations used.

AEC	Atomic Energy Commission
b/d	barrels per day
bcm	billion cubic metres
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CDM	clean development mechanism (under the Kyoto Protocol)
CHP	combined heat and power production
DSO	distribution system operator
ESCO	energy services company
ETS	emissions trading scheme
IA	implementing agreement
IAEA	International Atomic Energy Agency
FTC	Fair Trade Commission
GHG	greenhouse gas
GW	gigawatt, or 1 watt x 10^9
KAERI	Korea Atomic Energy Research Institute
KCC	Korea Coal Corporation
KDHC	Korea District Heating Corporation
KEEI	Korea Energy Economics Institute
KEMCO	Korea Energy Management Corporation
KEPCO	Korea Electric Power Corporation
KHNP	Korea Hydro and Nuclear Power
KIER	Korea Institute of Energy Research
KNOC	Korea National Oil Corporation
KOGAS	Korea Gas Corporation

KOREC	Korea Electricity Commission
KPX	Korea Power Exchange
KRW	Korean won; KRW 1 000 = USD 1.16
kt	thousand tonnes
kW	kilowatt, or 1 watt x 10^3
kWh	kilowatt-hour, or 1 kilowatt x 1 hour
LNG	liquefied natural gas
LPG	liquefied petroleum gas
mb	million barrels
mcm	million cubic metres
MEST	Ministry of Education, Science and Technology
MKE	Ministry of Knowledge Economy
MOE	Ministry of Environment
MOST	Ministry of Science and Technology
Mt	million tonnes
Mtoe	million tonnes of oil equivalent
MW	megawatt, or 1 watt x 10^6
PHWR	pressurised heavy water reactor
PPP	purchasing power parity; the rate of currency conversion that equalises the purchasing power of different currencies, i.e. estimates the differences in price levels between different countries
PV	photovoltaic
PWR	pressurised water reactor
R&D	research and development, especially in energy technology; may include the demonstration and dissemination phases as well
RPS	renewable portfolio standard
SMEs	small and medium-sized enterprises
SFR	sodium-cooled fast reactor
TFC	total final consumption of energy
toe	tonne of oil equivalent, defined as 107 kcal
TPES	total primary energy supply
TSO	transmission system operator
TWh	terawatt-hour, or 1 terawatt x 1 hour
UNFCCC	United Nations Framework Convention on Climate Change

Korean won to USD exchange rate

Year	USD (KWN 1 000)
2000	1.131
2001	1.290
2002	1.251
2003	1.191
2004	1.145
2005	1.024
2006	0.955
2007	0.929
2008	1.101
2009	1.275
2010	1.155
2011	1.107

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