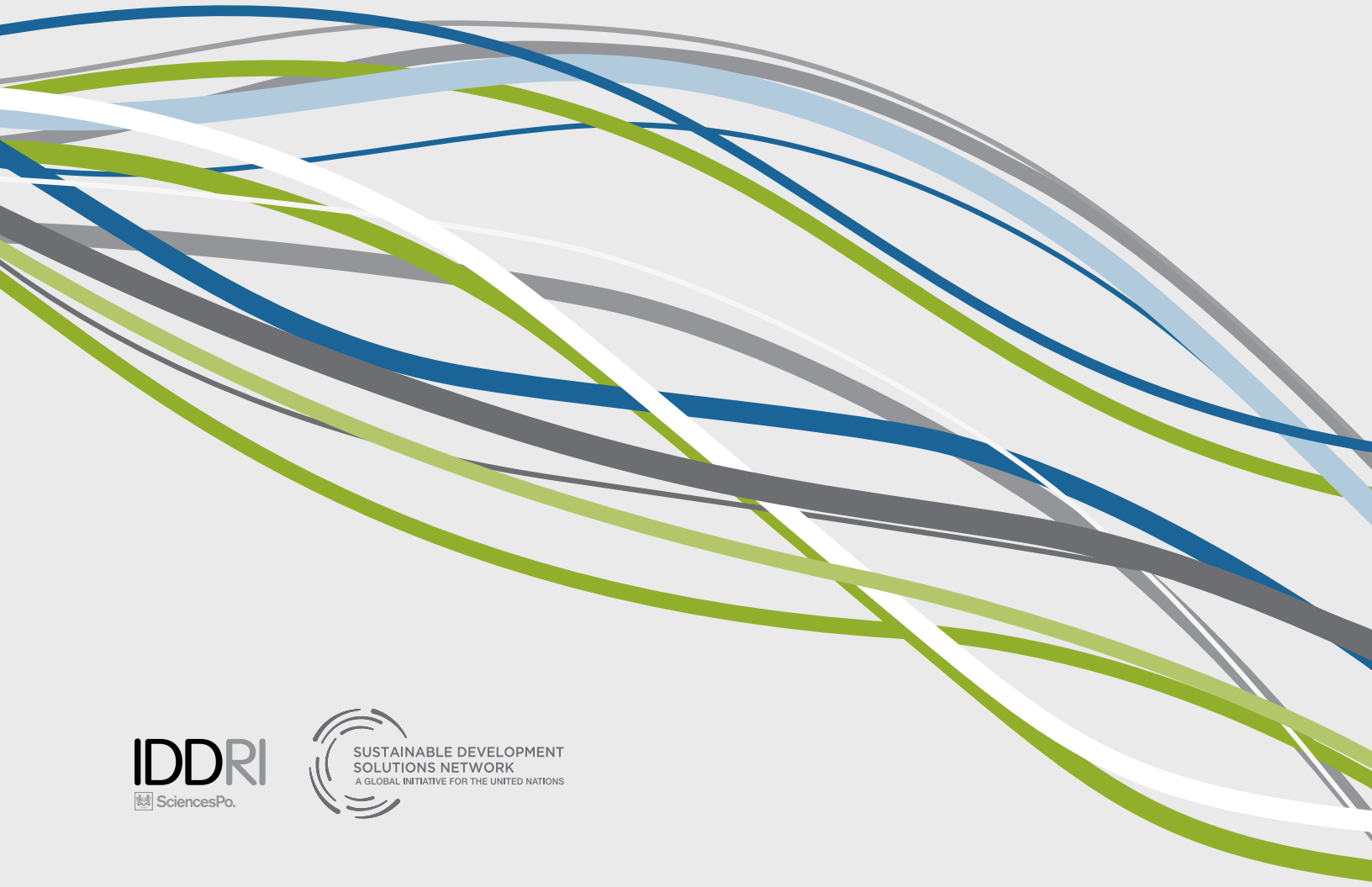
South Korea Chapter

pathways to
deep decarbonization

2014 report



IDDRI SciencesPo.

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

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Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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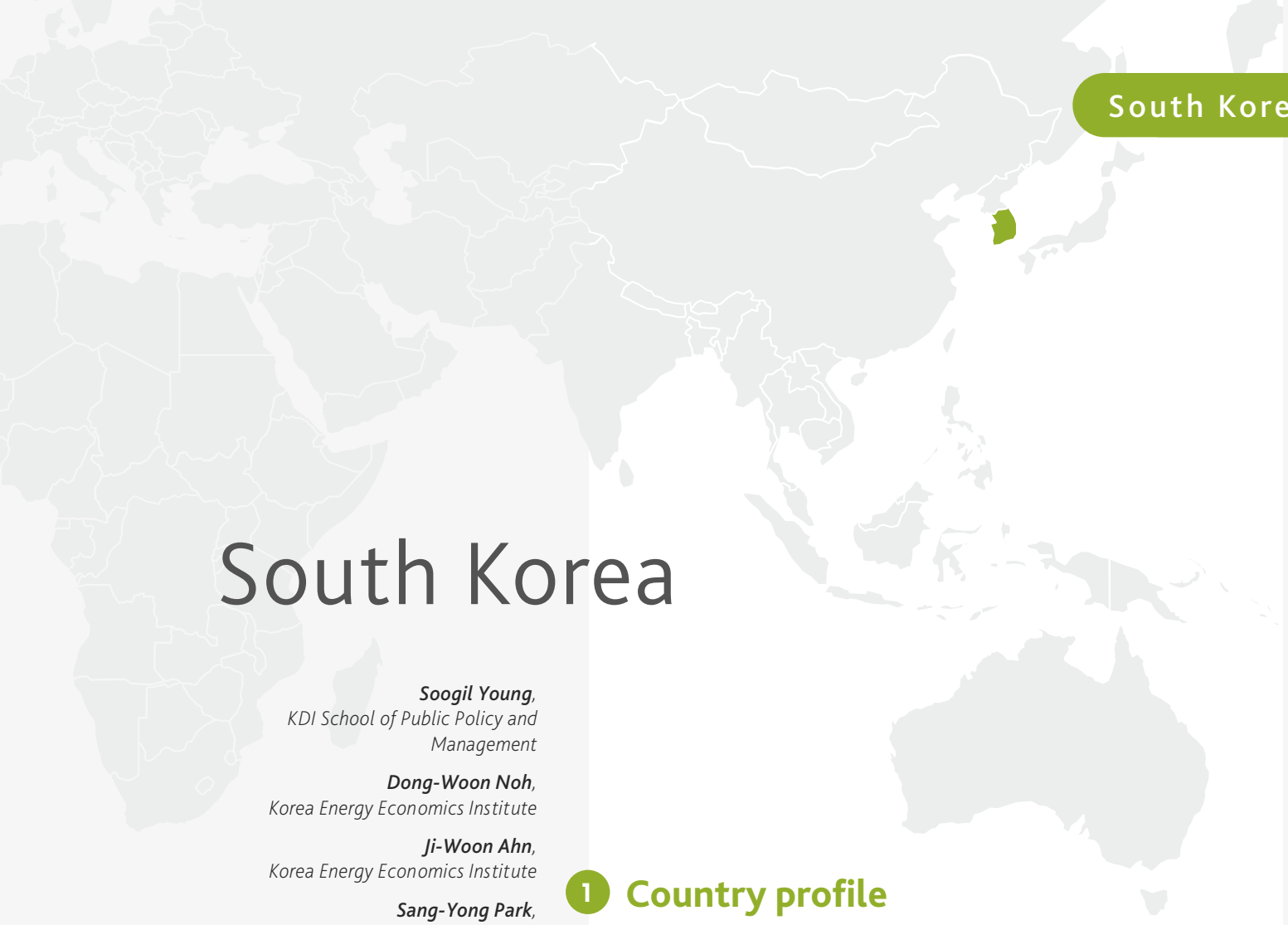

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1 Country profile

1.1 The national context for deep decarbonization and sustainable development

The Republic of Korea ('South Korea' or 'Korea', hereafter) recorded per capita GDP of 20,159 US$ in 2010. The Korean economy recorded a high growth rate of 6.9% p.a. from the 1960s until the 2000s, following the export-led industrialization strategy. As of 2010, industry was the main sector of the economy (41% of GDP), dominated by manufacturing, which alone represented 30.3%. Electricity, gas, water, and construction accounted for 8.3%, and agriculture, forestry and fishery made up the remaining 2.6%. This fast industrial development has been driven by the strong growth of exports; in 2010, they accounted for 46% of GDP. The development of industry has also encouraged rapid urbanization, with the urbanization rate reaching 83% in 2010.

Manufacturing accounted for 51.6% of Korea's final energy consumption, of which energy-intensive heavy industries constituted the dominant share of 81.0%. Korea's economy is highly dependent on fossil fuels, which represent 85% of total primary energy supply. Given its very low domestic endowment of fossil resources, 96.5% of this fossil fuel demand is met by importation, which poses the crucial question of energy security. On the other hand, renewable energy, including wastes and hydro power, accounted for only 2.8% of total primary energy supply due

Figure 1. Decomposition of GHG and Energy CO_2 Emissions in 2010

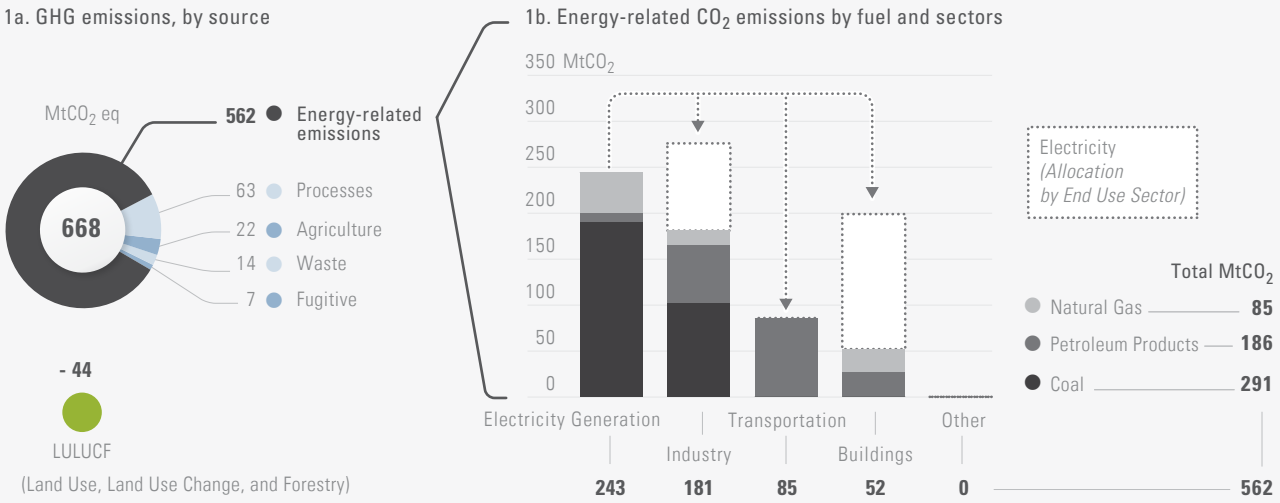
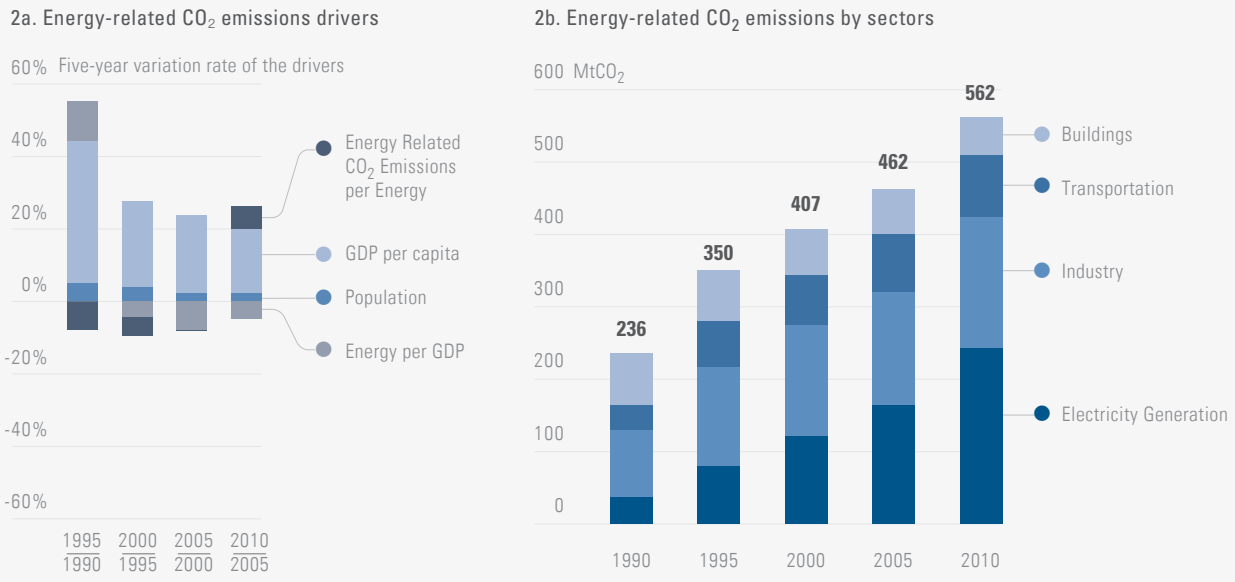


Figure 2. Decomposition of historical energy-related CO_2 Emissions, 1990 to 2010



to the limited endowment of renewable energy resources, such as solar and wind supply. Nuclear energy accounted for 12.2% of total primary energy supply in 2010.

In 2008, under President Lee Myung-bak, the Korean government launched the National Strategy for Green Growth (2009-2050), along with the first 5-Year Plan for Green Growth (2009-2013), proposing to pursue the following three objectives: (1) climate change action and energy independence, (2) the creation of new growth engines with investment in green technologies and industries, and (3) greening of the national territory, transportation, and lifestyles, while promoting a shift to high-value-added services over the period to 2050. The succeeding government of President Park Geun-hye has launched the 2nd 5-Year Plan for Green Growth (2014-2017), proposing to focus on GHG emissions reduction, a sustainable energy system, and adaptation to climate change.

1.2 GHG emissions: current levels, drivers, and past trends

Net GHG emissions including all sources and sinks were 624 $MtCO_2$-eq in 2010, about 12.63 tons per capita. Emissions from fuel combustion were 562 $MtCO_2$-eq, which corresponded to 84.1% of total emissions (668 $MtCO_2$-eq, excluding sinks) and 90.0% of net emissions (Figure 1a). Electricity generation and industry are the two main activities responsible for energy-related carbon emissions (Figure 1b).

Net GHG emissions rose during the past twenty years by 132% from 269 $MtCO_2$eq (1990) to 624 (2010), while emissions from fuel combustion increased by 139% from 235 $MtCO_2$eq to 561 $MtCO_2$eq. The key driver of the rapid increase of emissions was a rise in energy consumption due to high economic growth dependent on energy-intensive heavy industry that more than offset increases in energy efficiency. Large increases in electricity emissions reflected a massive shift in final energy demand from oil and gas to electricity due to a relatively low price of electricity made possible by increases in nuclear power supply as well as the low electricity price policy of the government. There was also an upturn of carbon intensity during the second half of the 2000s mainly due to an expansion of the coal-using iron and steel industries and coal-power plants (Figure 2).

2 National deep decarbonization pathways

2.1 Illustrative deep decarbonization pathway

2.1.1 High-level characterization

Korea's population is projected to peak in 2030 and to decline thereafter, decreasing from 50 million in 2010 to 48 million in 2050. The economy is projected to grow at the annualized rate of 2.35% on the average over this period. A major uncertainty facing Korea is when, if at all, and how, the inter-Korean unification is likely to occur. The present study ignores this contingency altogether. With the global benchmark of 1.7 tons of CO_2 emissions per person in 2050, the illustrative pathway seeks a very ambitious decarbonization path for the Korean economy and reaches an 85.4% reduction of CO_2 emissions from fuel combustion. Emissions are projected to fall from 560 $MtCO_2$ in 2010 to 82 $MtCO_2$ in 2050.

This is permitted by a drastic decrease of energy consumption (-37.2% in final energy consumption) due to large improvements in energy efficiency. In addition, there are important changes in the fuel mix. In particular, the importance of oil-based fuels, which represent one-half of final consumption in 2010, is significantly reduced,

and coal use is almost completely phased-out over the period (Figure 3). In parallel, electricity (and notably of renewable sources) develops with an electrification rate of final uses reaching 60.7% in 2050 (vs. less than 20% in 2010) with significant reductions of the carbon intensity of electricity production, from 531 to 41 gCO_2/kWh (Figure 4). All sectors are concerned and see their emissions decreasing radically over 2010-2050 (Figure 5).

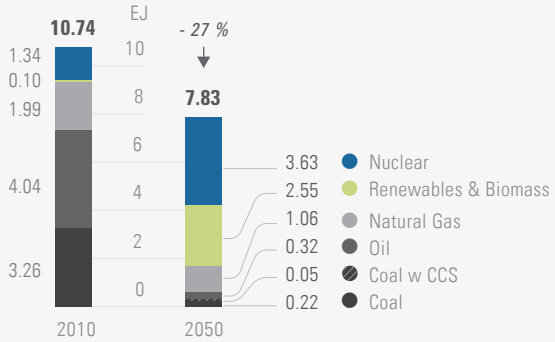
2.1.2 *Sectoral characterization*

Power

A broad set of low-carbon options for electricity generation (CCS, renewable energy such as wind and solar PV, and nuclear power) are deployed to permit the deep decarbonization of electricity supply as measured by a fall in the carbon intensity of electricity from 531 to 41 gCO_2/kWh. CCS is applied to 4% of coal power generation by 2050, and all coal without CCS and a share of gas are substituted

Figure 3. Energy Pathways, by source

3a. Primary Energy



3b. Final Energy

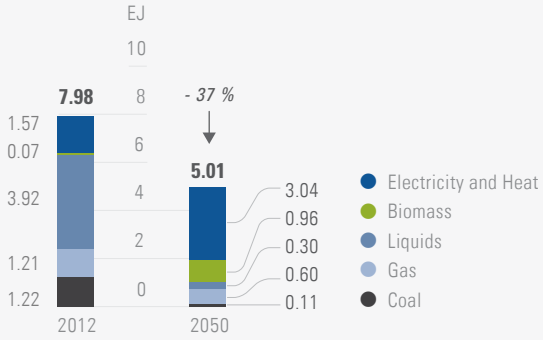
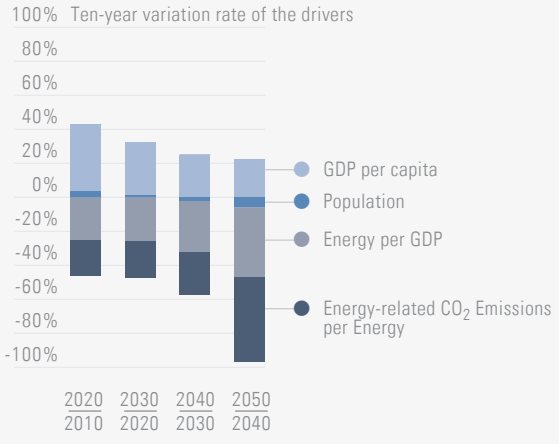
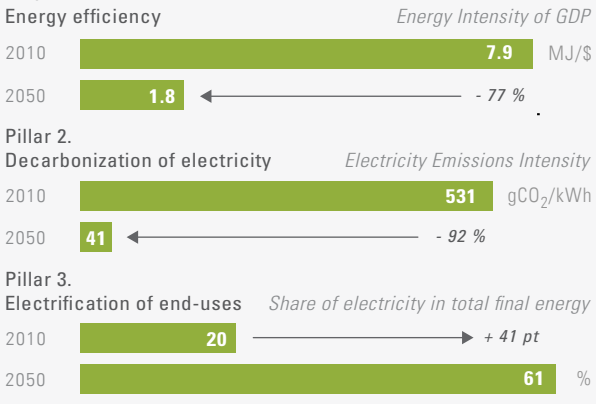


Figure 4. Energy-related CO_2 Emissions Drivers, 2010 to 2050

4a. Energy-related CO_2 emissions drivers



4b. The pillars of decarbonization



with renewables, specifically wind (14% of electricity production) and solar PV (31% of production), due to the installation of 51 GW of wind and 193 GW of solar PV. Residual fossil fuels are substituted with nuclear energy, requiring the installation of 47 GW of nuclear power. The deployment of renewable energy requires the shift to a large-scale distributed renewable electricity system. As a result, network balancing is likely to be an issue because of the intermittency of renewable energy. Additional tools such as backup facilities and energy storage should be installed to solve this problem.

Industry (manufacturing)

The manufacturing sector was the dominant source of CO_2 emissions in 2010 with 186 $MtCO_2$. It includes the energy-intensive heavy industries,[1] and the share of these industries in GDP is projected to increase from 27.2% in 2010 to 35.3% in 2050. This aggregate figure hides a structural change among industrial sub-sectors, as the share of fabricated metal industries increases while that of other heavy industries (such as cement, petrochemical, and iron and steel) decreases).[2] Manufacturing is almost decarbonized by 2050 to 16.4 $MtCO_2$ of emissions, excluding indirect emission through electricity.[3] This occurs through a combination of significant deviations from the current trajectory, notably through efficiency improvements resulting in 1) three-fold and six-fold decreases of energy intensity (with respect to the 2010 level) in light and heavy industries, respectively, 2) substitution for 20% of fossil fuels in distributed CHP in heavy industries, 3) 30% deployment of CHP to fuel light industries, and 4) an increase to 28% and 72% of the shares of electricity in light and heavy industries, respectively.

1 Heavy industries include iron & steel, petrochemical, cement, non-metallic and fabricated metal industries. The last one here includes machinery, electronic & electric and shipbuilding sectors.

2 The share of these 3 industries in GDP is projected to decrease from 8.0% in 2010 to 4.3% in 2050.

3 Carbon intensity shown in Figure 7a also excludes indirect emission through electricity consumption.

Figure 5. Energy-related CO_2 Emissions Pathway, by Sector, 2010 to 2050

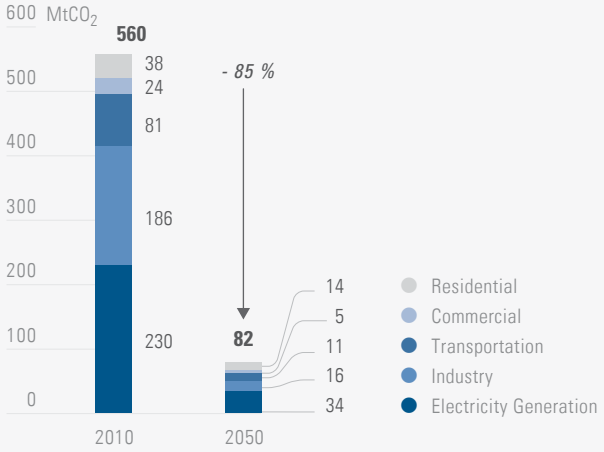
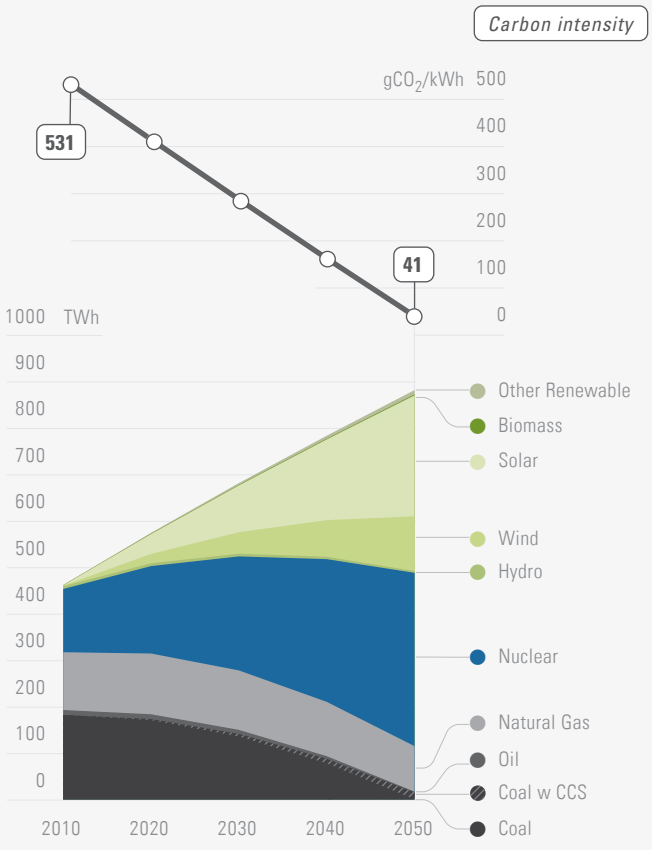


Figure 6. Energy Supply Pathway for Electricity Generation, by Source



Buildings: Residential and Commercial

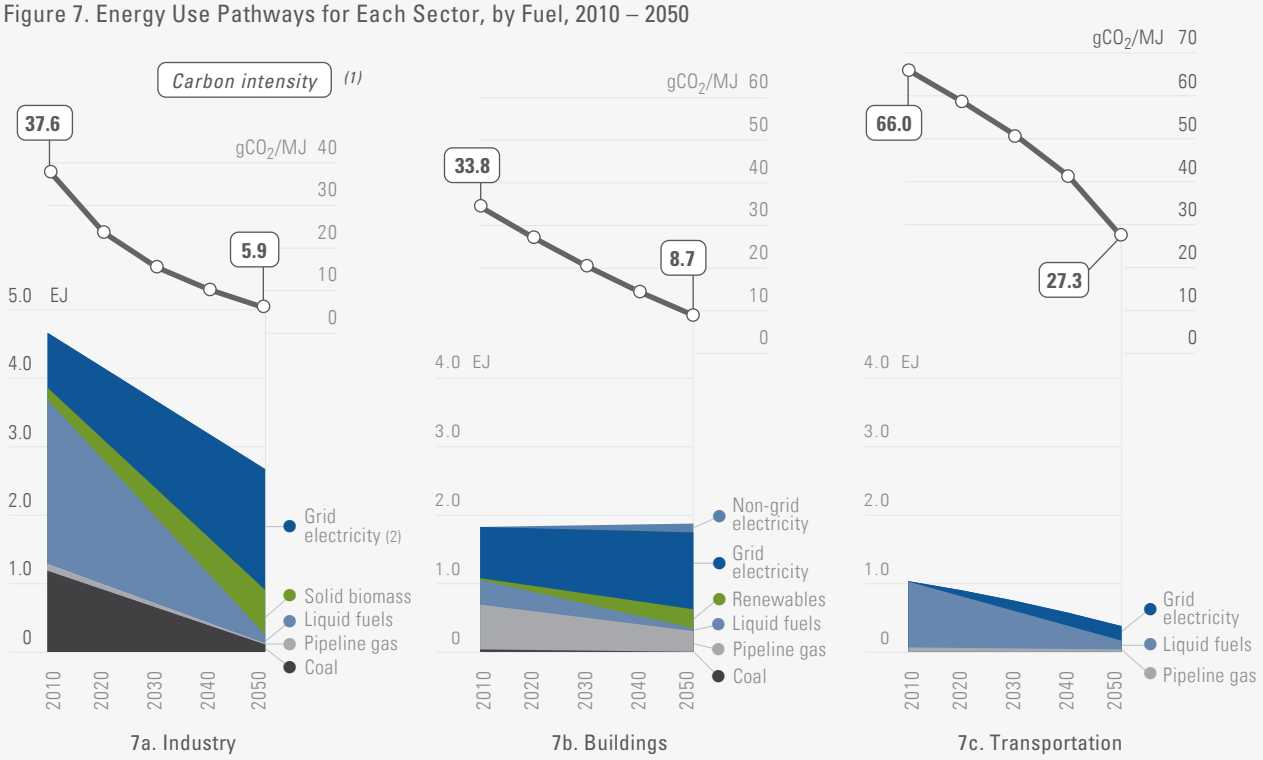
In the residential buildings sector, a 62% reduction of emissions is experienced, from 37.5 $MtCO_2$ in 2010 to 14.5 $MtCO_2$ in 2050. The floor space decreases from 24 m^2/person to 21 m^2/person. This is permitted by a combination of the following four broad groups of measures (listed in order of the ease of deployment): 1) the diffusion of LED lighting (which substitute for all exiting lighting by 2050), 2) higher efficiency of heating and cooling obtained with new technologies, 3) substituting fossil fuels in distributed Combined Heat and Power (CHP) (which substitute 17% of fossil fuels in distributed CHP in 2010 mainly with wastes and complementarily with biomass), and 4) substituting fossil fuels with renewable energy (solar-thermal and geo-thermal energy substitute 35% of the remaining fossil fuels in 2010).

The commercial buildings sector includes buildings in business, public, and agricultural sectors. In this sector, despite the continuous increase of floor space per capita (from 14 m^2/person in 2010 to 31 m^2/person in 2050), CO_2 emissions are reduced by 78% from 24.5 $MtCO_2$ in 2010 to 5.4 $MtCO_2$ in 2050. This is notably permitted by efficiency improvements in heating and cooling, waste heat and biomass in distributed CHP (substituting 11% of fossil fuels in distributed CHP in 2010 primarily with waste heat and complementarily with biomass), and the diffusion of renewable energy (substituting 35% of residual fuels in 2010 with solar-thermal and geo-thermal energy).

Transportation

The passenger kilometers per person increases from 13,400 pkm/person in 2010 to 26,300 pkm/person

Figure 7. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



(1) Excluding indirect emission –from electricity. (2) Including reused oil, wasted oil use, etc.

Note: Carbon intensity shown in Figure 7 for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity or hydrogen production.

in 2050. The transportation sector, however, experiences a drastic 87% reduction of CO_2 emissions from 81.4 $MtCO_2$ in 2010 to 11.2 $MtCO_2$ in 2050. This is permitted by a major efficiency improvement in fossil fuel vehicles (cars, trucks, and buses), biofuel deployment (biodiesel representing 20% of the diesel used in 2050), deep electrification of the car fleet (up to 80% of the stock), and the modal shift in both passenger transportation, with 70% of passenger cars in 2010 substituted with public transport such as urban buses and trains, and freight transportation, with 78% of road freight in 2010 substituted with rail freight. Such a revolutionary modal shift[4] would require a reorganization of the national transportation system as elaborated in section 2.5.

2.2 Assumptions

In the illustrative pathway discussed above, the technical options have been introduced based on a consideration of the presumed relative costs or ease of implementing the options, as determined through discussions with leading experts from both research institutes and the related business firms with expertise in the individual technology options

This has privileged particular efficiency improvements, waste energy use and fuel change, or new energy resources (e.g., renewable), while other solutions face greater technical or public opinion difficulties as detailed more precisely below:

- LED in lighting: the LED's energy saving rate is 72%.[5]
- Higher efficiency in heating and cooling in residential and commercial sectors: energy savings due to improved insulation are 58.4%.[6]
- Advancements in the efficiency of fossil fuel cars: the efficiency improvements of cars (excluding buses) and buses should be 158.5% and 45.9% respectively by 2050.[7]
- Biodiesel deployment in transport: biodiesel is to be blended into diesel for 20% of the diesel used in 2050. The existing diesel vehicles can accommodate this option.[8]
- Solar PV facilities' specification is about 0.163 GW/km^2 The total area allotted to transport roads in Korea is about 3,000 km^2, and 193 GW can be supplied from 40% of this area.
- Introduce CCS: The CCS capture efficiency will be 90%. The storage potential in Korea is estimated to not exceed 15 $MtCO_2$.[9] Accordingly, introduction of CCS for more than 5% will be limited by the storage space constraint.

2.3 Alternative pathways and pathway robustness

The illustrative pathway scenario for the power sector depends on renewable energies, mostly for emission reduction.

An alternative scenario depends mainly on CCS:

1. Introduce CCS for 76% of coal power generation by 2050.
2. Substitute 20% of gas with renewable energies, such as wind and solar PV. 51 GW of wind and 69 GW of solar PV should be installed.
3. Substitute all residual coal without CCS with nuclear energy. 44 GW of nuclear power should be installed.

In this scenario, CO_2 emission reductions from CCS add up to 300 $MtCO_2$ or 92.8% of total reduction in the power sector. However, this

4 Being studied by the Korea Transport Institute.

5 Average saving rate compared to incandescent & fluorescent lighting (Source: Technology DB provided by Korea Institute of Energy Research)

6 Korean technology DB, Korea Energy Management Corporation (KEMCO)

7 Ibid.

8 A more extensive deployment of this option in Korea is expected to be difficult because of the insufficient resource potential for biodiesel.

9 According to assessment by relevant Korean experts.

amounts to twenty times the domestic storage potential. This scenario assumes the availability of foreign storage spaces, an assumption that must be examined and confirmed.

Korea could consider another pathway that depends mainly on nuclear power:

4. Introduce CCS for 5% of coal generation by 2050.
5. Substitute fossil fuels with renewable energy by installing 29 GW of wind power and 14 GW of solar PV.
6. Substitute all coal without CCS and gas with nuclear energy. 84 GW of nuclear power should be installed.

In this scenario, CO_2 emissions reductions from nuclear adds up to 296 $MtCO_2$ or 91.1% of total reductions in the power sector. This scenario assumes that the problem of public acceptance associated with nuclear energy, which is currently very serious in Korea, will be addressed as discussed in the next section.

2.4 Additional measures and deeper pathways

Korea has one of the highest energy intensities in the OECD largely because of its industrial sector, which is dominated by energy-intensive heavy industries. Korea's green growth strategy proposes to promote a shift of the economic structure toward high value-added services. The present analysis has not allowed for such policy-induced structural changes of the economy.

High levels of emissions are associated with some production processes, notably, those of the steel industry. POSCO, the leading steel producer, is responsible for about 10% of Korea's GHG emission. They have developed and begun to deploy a new technology called FINEX, which reduces emissions by 40%.[10] New and replacement installations of plants over time will allow for the increased deployment of FINEX, leading to even greater reductions in CO_2 emissions by 2050.

There is significant unexplored potential for energy savings and efficiency improvements in all sectors from a reform of the electricity pricing system. Currently, Korea's power system operates on an antiquated pricing system, which distinguishes several customer groups (residential, industrial, commercial, agricultural, educational, and public) and charges different prices set by the government according to economic, industrial, and social considerations. The prices are occasionally adjusted, with a major systemic impact on the energy system. The current system is biased toward underpricing below the cost of generation and encourages the wasteful consumption of electricity, not only by underpricing per se but by more critically by preventing demand response and cost-based optimization of electricity consumption by customers. More broadly, it discourages investment in energy efficiency and renewable energy.

Shifting to a market-based pricing system would dramatically transform the energy system by broadening the choice space and deployment potential for various options. Exploration of these possibilities requires rather extensive study.

Further along this line of analysis, over the long-term to 2050, there is an explosive potential for deep decarbonization from the disruptive convergence of renewable energy, energy storage, advanced materials (such as graphene and carbon nanotubes), and Internet of Things, involving transformation toward a distributed power generation system.[11]

The Asian Super Grid proposed by the Softbank Group of Japan should be seriously explored.[12] The core idea is to harness Mongol's enormous endowment of wind and solar energy resources. When fully deployed, these resources are projected to supply 70% of the global power demand, including demand from Japan, Korea, China, and others, and even replace all current nuclear power plants.[13] The Asian Super Grid would connect national transmission lines through the existing internet cables and link all major Asian cities from the renewable energy power stations in the Gobi Desert to Beijing, Seoul, Tokyo, Shanghai, Hong

Kong, Bangkok, even to Delhi and Mumbai, and eventually to the European Desertec Super Grid.

2.5 Challenges, opportunities, and enabling conditions

- Under the Illustrative Deep Decarbonization scenario presented in this study, CO_2 emissions from fuel combustion in 2050 are reduced by about 85% relative to 2010. Key challenges for this scenario are summarized as follows:
- Considering Korea's low energy efficiency relative to value-added in energy-intensive industries (such as steel, petrochemicals, and cement[14]), improvement of the efficiency in these industries would depend largely on process innovation and dematerialization of production; a modernization of the electricity pricing system would also be necessary to provide the correct price incentives for energy efficiency improvements.
- Substituting 80% of fossil fuel cars with electric vehicles by 2050 requires cutting the cost of batteries (which essentially depends on international technology actions) and building a nationwide charging infrastructure;
- Decarbonizing the power sector requires the shift to a large-scale distributed renewable electricity system as well as installation of backup facilities (gas-fired combined-cycle, etc.), large energy storages (pumping power, batteries, etc.) and the deployment of a smart grid to solve the intermittency problem of renewable energy;
- The large modal shift in both passenger and freight transportation to public and rail transportation projected in this study would require a revolutionary reorganization of the national transportation system. Key to reorganization should be an extensive national high-speed rail network with urban and regional rapid mass transportation systems built around high-speed-rail stations, supplemented with innovative systems like conveyor-belt type rail freight services,[15] double-deck freight trains, expressway reservation systems (to maximize road capacity without new investment), bike rapid transit (or bike highway), cloud transport system to share and connect transport resources and technology-driven eco-driving;
- Continued deployment of nuclear power requires a fundamental solution to the widespread concern over its safety and especially over disposal of the spent fuel. Deployment of the SMART[16] model, which allows passive cooling, would considerably allay the maintenance safety concern by preventing a Fukushima-type meltdown of the reactor. Development of small modular reactor is also required to prepare for the deployment of distributed electricity generation system. Development and deployment of the pyro-processing technology for transmutation of high-level waste to mid-level waste would fundamentally allay the concern over the spent-fuel disposal problem by recycling the fuel. But it would take one to two decades of international R&D cooperation to develop the necessary technology;

10 While direct emission is reduced by 40%, it indirectly increases emission by 30% by using more electricity under the current carbon intensity of electricity.

11 'The 21st Century Energy System: Transformation of Energy System through Convergence', A power point presentation by Namsung Ahn, Korea Institute Energy Technology Evaluation and Planning (KETEP), June 10, 2014.

12 Proposed by Masayoshi Sohn, Chairman of the Softbank Group on September 13, 2012, as he launched the Japan Renewable Energy Foundation, as a solution to replace the nuclear power system in Japan as well as in the rest of Asia.

13 According to the Japan Renewable Energy Foundation, wind power generation in the Gobi Desert will amount to 8,100TWh and solar power generation in Gobi to 4,800TWh annually.

14 Korea is among the countries which boast the highest energy efficiency in these industries when the efficiency is measured against output.

15 This technology is being developed by the Korea Transport Institute.

16 SMART stands for 'System-integrated Modular Advanced ReacTor'. SMART was developed by Korea in 2012, is one tenth (100MW) the size of the existing model (1000MW) and would fit distributed power system.

- Shift to a distributed power generation system will be necessary in order to overcome the Not-in-My-Back-Yard (NIMBY) problem obstructing the installation of various facilities including the transmission lines.

2.6 Near-term priorities

To be realistic, nuclear power and fossil-fuel power generation with CCS each offer the largest scope for decarbonization of the energy system to 2050. But the problem of disposal of the spent fuel from nuclear power presents one of the most serious obstacles to deploying nuclear power. The pyro-processing technology, if and when it becomes available, will essentially solve this problem. Accordingly, Korea should urgently enter a joint international research program on the technology with the United States, in which Korea has a binding agreement on disposal of its spent fuel. In the case of CCS, the seemingly limited availability of storage space in Korea's coastal seas is the main obstacle. Korea should urgently explore the possibility of entering agreements with suppliers of coal and natural gas, such as Australia, which could allow Korea to lease storage spaces.

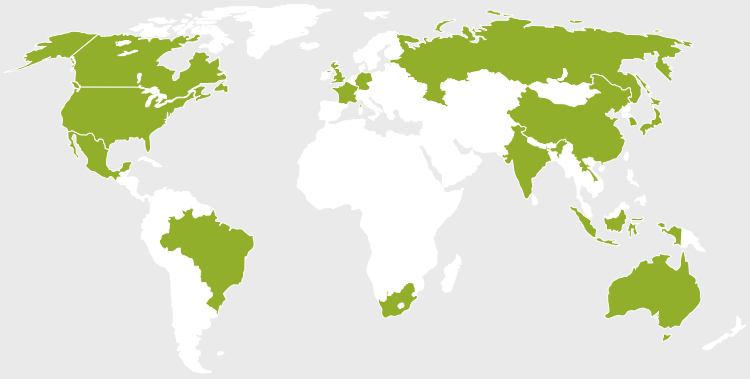
Improving the energy efficiency, in buildings, transport, and industry offers the largest scope for decarbonization in the near-term. This requires, among other things, increases in energy prices, including that of electricity, carbon pricing of energy in general, and market-based pricing of electricity. Correct pricing is necessary and urgent, accompanied by strengthening of the appropriate energy efficiency and emission standards. The same set of measures would also facilitate development and deployment of renewable energy.

In Korea, in particular, there seems to be a serious limit to deployment of solar panels because of the large space requirement. An alternative should be the installation of BIPV on the walls of buildings. Accordingly, development and deployment of BIPV should be a high priority. As to wind power, the objections from local residents or national park authorities to installation of the wind turbines is a serious obstacle to its deployment on land. The promising alternative is the offshore wind turbine. The development and deployment of this technology as well as the construction of offshore wind parks are a high priority. In addition to individual renewable energy resources, hybrid systems combining two or more energy resources including renewable energies should also be developed and deployed.

Another high-priority plan is the replacement of the current centralized electricity generation system with a distributed electricity generation system, including extensive deployment of the smart grid. This calls for a systemic reorganization of the national power system, a major reform to be carried over a decade or longer.

The most urgent priority, however, is to develop and build a national consensus on the long-term target for deep decarbonization of the Korean economy. This would in turn require widespread understanding of the objective conditions for Korea's positioning on how to apportion the collective responsibility for global decarbonization among the leading emitters today, of the range of the plausible technological pathways as well as their implications for the requisite energy system transformation. Furthermore, such consensus-building should be informed by understanding of what the pathways would entail in terms of benefits and costs to the economy and society.

The present deep decarbonization study conducted as part of an international collaborative project involving 15 main emitters provides an ideal science-based platform on which to build such understanding and the needed consensus. And Korea's green growth strategy provides an ideal organizing framework for studies and debates toward those understanding. Within the framework of the green growth strategy, Korea should seriously explore the long-term decarbonization potential to build a national consensus on the best pathway as well as the requisite action agenda for green growth during next few years. Such exploration should be based on a concrete roadmap for development and deployment of the necessary technologies.



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