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The Economic Opportunities and Constraints of Green Growth

The Case of South Korea

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Executive Summary

The Green Growth Policy in South Korea has symbolized a paradigm shift to cope with climate change, fossil fuel depletion, and global economic recession. The emerging paradigm stands to create new engines for economic growth through green technology and clean energy. The government recently unveiled the Roadmap of Green Energy Strategy 2011 (2011–2030) that aims to position Korea as a world leader in the green energy industry. To this end, 15 green technologies were chosen as priorities for governmental support: PV, wind, fuel cells, bio fuels, energy storage, clean fuels, CCS (carbon capture storage), IGCC (integrated gasification combined cycle), smart grid, nuclear energy, clean fossil-fuel-fired plants, energy conserving buildings, efficient lighting, heat pumps, and green vehicles. A number of green growth policies, such as the emission trading system, the Green Homes Project and the Renewable Portfolio Standard, are expected to provide a stable framework for domestic market expansion. In addition, the government R&D investment plan is expected to play an important role in filling a technological gap between South Korea and leading countries in green energy.

The nation's well-developed industrial foundation in areas such as technology and infrastructure will be an advantage that can be easily applied to the green energy industry. South Korea's world-leading shipbuilding companies are entering the wind power business, and semiconductor companies such as Samsung and LG are now developing PV cells. Furthermore, the nation's advanced IT and electronic technology firms have entered the smart-grid business.

Based on strong political support and policy measures, South Korea's green growth policy has showed noticeable progress in a short period of time. However, the biggest challenges are technological dependency and growing competition in the global market. Also, the transition from a hydrocarbon-based economy to a renewable-based one could bear a huge economic and social cost. The speed of the transition, as well as a series of external variables – such as the global economic condition – will also affect the progress of green growth in South Korea.

The green growth strategy of South Korea is a comprehensive policy package covering most major renewable energy sources and GHGs reduction measures. As the government hopes to keep up with the global market leaders, the participation of foreign enterprises are being encouraged especially, in the R&D sector. As the size of

domestic market is relatively small and endowments of renewable energy are not sufficient, the green growth strategy also targets at the global market, which will often require a coalition with major foreign energy companies. The most promising opportunities for the foreign companies could be found in the linkage of Korea's core-competitiveness in IT, electronics, steel, and construction sectors with the advanced technology in parts and design of the current market leaders.

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Introduction

To cope with the challenges of energy supply and climate change, the need for a new energy paradigm for future sustainable development is apparent. The "Green Growth Policy" initiated by the South Korean government symbolized the paradigm shift to a new energy future. This policy was initiated as President Lee Myung-Bak proclaimed "Low Carbon, Green Growth" as a national vision in his National Liberation Day anniversary speech of August 15, 2008. The green growth policy was declared as the nation's new development paradigm that will address three problems of the 21st century, namely the climate change, fossil fuel depletion, and global economic recession. It aims to explore possible solutions for these problems through green technology and clean energy.

The major objectives of South Korea's green growth policy is "creating new engines for economic growth." In particular, development of the green energy industry is a key strategy to achieve this goal. In 2011, the South Korean government unveiled the *Roadmap of Green Energy Strategy 2011 (2011–2030)* (hereafter, Roadmap), which aimed to position Korea as a world leader in the green energy industry by increasing the country's share in the global energy market from 1.2% today to 18% by 2030. To this end, 15 green technologies out of three different categories were chosen as priority technologies to be eligible for financial and technical support from the government. This study is focused on the business opportunities and constraints associated with these 15 green energy industries identified in the Roadmap.

The purpose of this study is to review various initiatives taken by South Korea's government in the context of its new green growth policy. By examining their rationale and major features, this paper aims to assess the business opportunities brought by the transition to low-carbon growth as well as the associated constraints. This study intends to answer the following questions by analyzing South Korea's green growth policy, particularly its green energy industry:

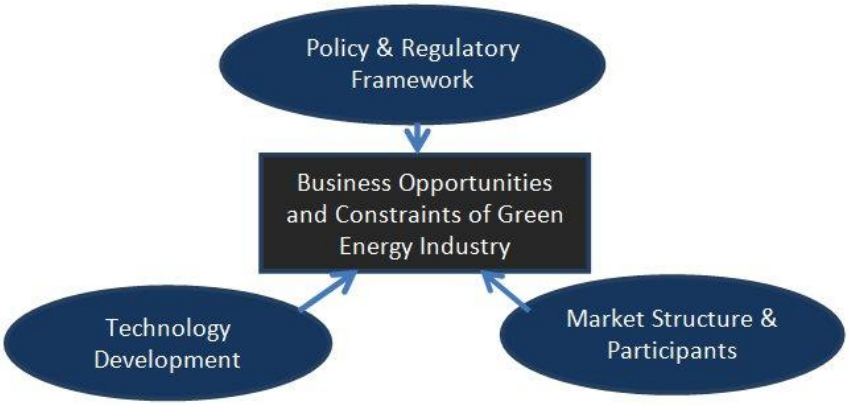
- What is the rationale of the Green Growth Initiative and the institutional foundation for this new development paradigm?
- What are the current technological status and key development strategies for the 15 green energy industries?
- What are the key business opportunities and constraints for the development of those green energy industries?

Method and Framework

The business opportunities and constraints of the green energy industry are assessed from three standpoints: 1) policy and regulatory framework; 2) market structure and participants; and 3) technology development. This is summarized in figure 1. The policy and regulatory framework includes administrative bodies established for Green Growth, as well as legal mechanisms to promote green energy technology. The market condition is an important factor in making business decisions, which include human and resource capital, educational and production infrastructure, and market participants. In terms of technology development, this study provides an overview of the current status of 15 priority green energy technologies in South Korea and analyzes the government's investment and development plan. This study adopts a comprehensive review of policies, statistics, and research from government, academia, and the business sector.

Figure 1.

Framework for Business Opportunities and Constraints of the Green Energy Industry



Plan of Study

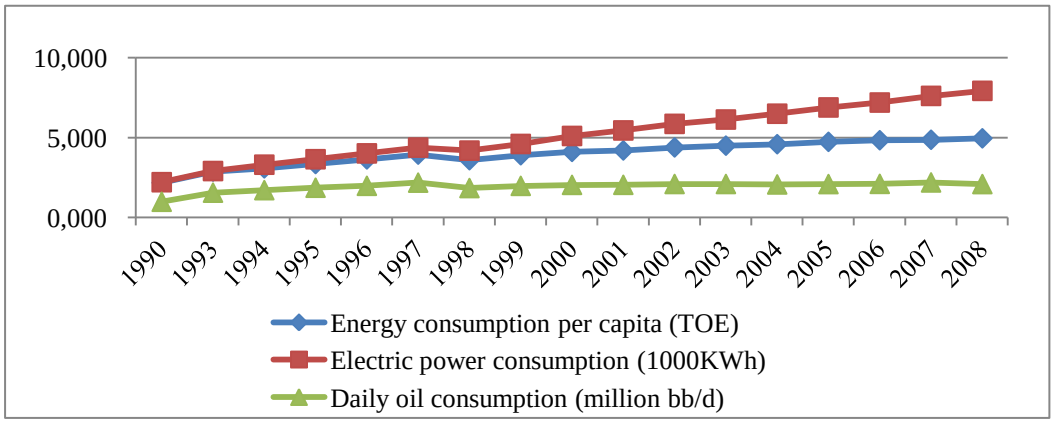
This study begins with an overview of the energy status in South Korea as well as the policy and regulatory framework for green growth. The features of key legislation and policy schemes are discussed here, particularly a GHG reduction and emission trading market, smart-grid policy, and renewable portfolio standard. The second section provides a review of the green energy market, major facilities, and infrastructure of the green industry. The third section explores key features of green technologies based on an overview of the Roadmap for 15 priority green technologies. The final section concludes by pointing out business opportunities and constraints for the green energy sectors in South Korea.

Policy and Regulatory Framework for Green Growth

Energy Status in South Korea

As a resource-scarce country, energy security has long been a major concern of Korean governments. South Korea is currently the tenth largest country by energy consumption in the world, as well as the fifth largest net importer of oil and the second largest importer of LNG, behind Japan (IEA, 2010).[1] Without any significant domestic reserves, South Korea depends heavily on energy imports from overseas. Crude oil accounts for the largest share at 55.7% of the energy imports, followed by petroleum products (17.3%), LNG (15%), and coal (10.9%) (KEEI, 2010b). Oil imports depended largely on the Middle East, which accounted for more than 80% of South Korea's total oil imports. Korea spent as much as $121.7 billion in 2010 on energy imports, which is 28.6% of the country's total imports. This amount exceeds the country's major export products of semiconductors, cars, and mobile phones combined (KEMCO, 2011)

Figure 2. Energy Consumption in South Korea



Source: Ministry of Knowledge and Industry

[1] In 2009, total primary energy consumption of South Korea reached 243.3MTOE.

Table 1. Energy Imports in South Korea

	1990	2000	2008	2009	2010
Energy imports (billion USD)	10.9	37.8	141.5	91.2	121.7
Energy imports/ Total imports	15.6%	23.6%	32.5%	28.2%	28.6%
Dependency on foreign energy	87.9%	97.2%	96.5%	96.1%	96.2%

Source: KEMCO, 2011

In terms of primary energy consumption, oil is the largest energy source, accounting for 42%, followed by coal, LNG, nuclear, and renewable energy. In terms of end-users, industry is the largest consuming sector, accounting for 58.3% of the total final energy consumption in 2009. This is largely due to the country's energy intensive industrial structure, which includes petrochemical and steel industries. The building sector (residential and commercial) and the transportation sectors each account for 20% of total energy consumption respectively (KEEI, 2010a).

Figures 3-1 and 3-2. Breakdown of South Korean Energy Consumption (2009)

Figure 3-1. Primary Energy Consumption

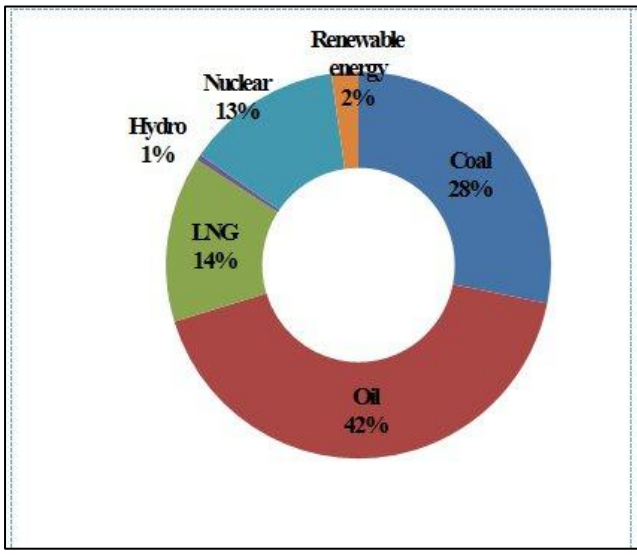
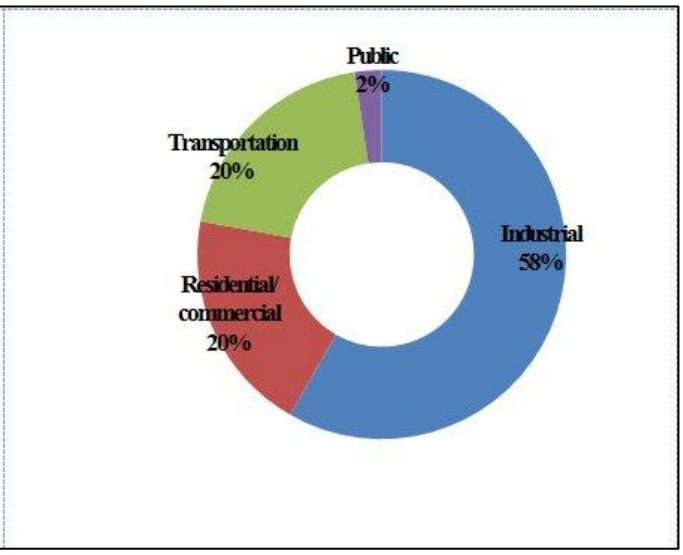
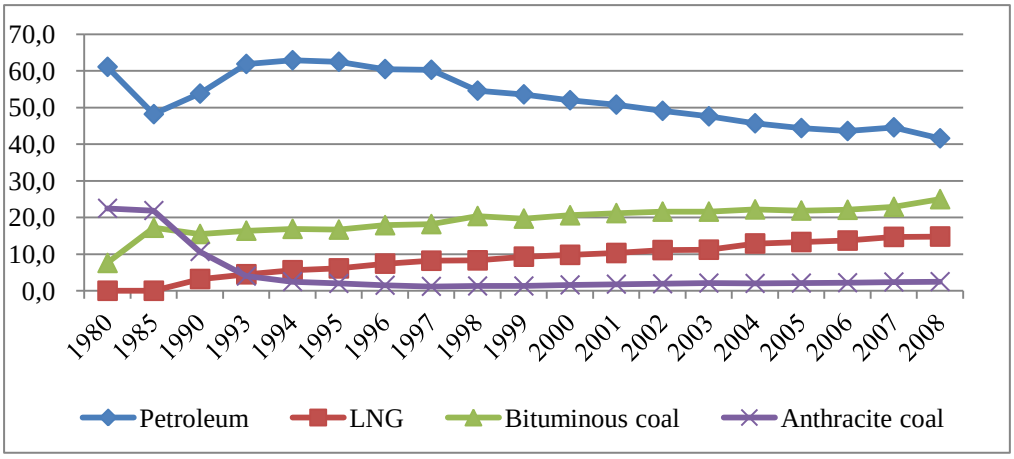


Figure 3-2. Final Energy Consumption by Sector



Source: KEEI, 2010a.

Figure 4. Energy Mix: Fossil Fuels (by sources, %)



Source: Ministry of Knowledge and Industry

Climate change is another big challenge for Korea's energy security. Korea is currently not under the Annex I of the Kyoto Protocol, but international pressures to join in the regulatory regime are growing. Greenhouse gases (GHG) emissions are still growing over 1990s levels, even though the average annual increase rate is on the decline. Energy and industry sectors are responsible for 94.7% of total emissions. The forecast of GHG emissions in the energy sector in 2030 is 818 million tons, which shows a 231% increase over emissions in the year 1990. South Korea is very vulnerable to GHG reduction because of its industrial structure, and the government is trying to find an optimal position and modality to deal with the challenges from climate change.

Evolution of the Green Growth Policy

In compliance with the new paradigm of green growth, the government announced on January 6, 2009 the Green New Deal, an economic stimulus package to cope with the global financial crisis by making use of green technology and investing in environmental industries. According to this policy package, 50 trillion won ($43.5 billion) would be channeled to nine core projects and 27 related projects with an aim to create 960,000 new jobs. In connection with the Green New Deal, the government unveiled a new economic growth strategy, the *Action Plan for New Growth Engine* (hereafter Action Plan), that identified 17 new growth engines in three sectors and plans to invest 24.5 trillion won ($21.3 billion) by 2013. On July 6, 2009, the *National Strategy for Green Growth*: *Five-Year Plan* was announced as a midterm plan for green growth from 2009 to 2013, which formulated three major green growth strategies and ten policy directions as shown in Table 2. In fact, the *Five-Year Plan* integrates

overlapping concepts and investments of the Green New Deal and New Growth Engine. The *Five-Year Plan* aims to inject a total of 107.4 trillion won ($93.4 billion) that corresponds to 2% of the gross domestic product into green growth projects (Presidential Committee on Green Growth, 2009).[2] The core 19 projects and the key projects – which include: Energy Goal Management; localization of nuclear technology and export overseas; the Four Major Rivers Restoration Project; R&D for green technology; expansion of zero-emission industrial complex; carbon emission trading system; expansion of green buildings and transportation; carbon labeling and carbon point system.

In coping with climate change issues, the Korea government confirmed its commitment to low-carbon green growth by announcing a midterm target of 30% reduction of GHG by 2020 (BAU) just before the Copenhagen COP (Conference of Parties) in November 2009. As an institutional foundation for its green growth policy, the *Framework Act on Low Carbon Green Growth* (hereafter Green Growth Act) was enacted and promulgated on January 13, 2010 and entered into force on April 14, 2010. This Act was designed to integrate several energy and environment-related laws, including the *Basic Energy Act*, *Framework Act on Sustainable Development,* and *Framework Act on Climate Change Response*, into one overarching legal framework. By doing so, the *Green Growth Act* embraced broad policy issues in the legal system related to economy, environment, and energy agendas.[3]

[2] UN Green Economy Initiative recommended an expenditure of 1% of GDP on green programs.

[3] The Green Growth Act was positioned higher in legal system than Framework Act on Sustainable Development that had already existed.

Table 2. Green Growth National Strategy and Five-Year Plan (2009~2013)

3 Strategies	10 Policy Directions	Budget trillion won(billion USD)
Adaptation to climate change and energy self-sufficiency	Effective mitigation of greenhouse gas emissions	5.7 (4.96)
	Reduction of the use of fossil fuels and the enhancement of energy self-sufficiency	14.9 (12.96)
	Strengthening the capacity to adapt to climate change	36.3 (31.57)
Subtotal		56.9 (49.48)
Creation of new growth engines	Development of green technology and growth engines	11.3 (9.83)
	Greening of industries and nurturing green industry	4.6 (4.0)
	Advancement of industrial structure	10.9 (9.48)
	Laying foundation for green economy	1.8 (1.57)
Subtotal		28.6 (24.87)
Improvement in lives of people and enhancement of national prestige	Creation of green homeland and transportation	25.3 (22.0)
	Green life revolution	1.9 (1.65)
	Becoming role-model for the international community as a Green Growth leader	0.7 (0.61)
Subtotal		27.9 (24.26)
Total budget for Green Growth Policy		107.4 (93.39)**

Source: Presidential Committee on Green Growth, 2009; Kim, 2010
* $1=1,150won.
** Duplicating budget is excluded in total budget.

GHG Reduction Target and Policies

A series of institutional schemes and policies have been introduced since the government announced the GHG reduction target. In June 2010, the *Greenhouse Gas Inventory and Research Center* (GIR)

was established as a national GHG inventory hub and mitigation think-tank. GIR announced its national greenhouse gas reduction target by sector in July 2011. According to this target, transportation, buildings, and power generation sectors are required to reduce 26.7–34.3% of their GHG compared to 2020 BAU levels, while the industry sector is subject to an 18.2% reduction obligation (see Table 3, below). [4]

Table 3. Sectoral GHG Reduction Target by 2020

Industry	Transportation	Power Generation	Buildings	Agriculture	Waste	Public	National
18.2%	26.7%	34.3%	26.9%	5.2%	12.3%	25%	30%

Source: Greenhouse Gas Inventory and Research Center, 2011

The *Green Growth Act* allows the government to adopt two major GHG reduction policies: the *Energy Goal Management* and the *Carbon Cap and Trade Scheme*. The Energy Goal Management, a type of command-and-control regulation, mandates the companies that emit CO_2 above 25,000t to set an emissions reduction target. Four hundred and seventy three sites -- including industrial plants, power generation, and large buildings that together account for 61% of country's total GHG -- are subject to this policy as of March 28, 2011. Companies under the obligatory requirement should set a reduction target and accomplish it at the end of every implementation period (1 year). Penalties for noncompliance are up to 10 million KRW (approximately, $10,000) and emission reduction exceeds the target cannot be credited for the next period. However, low penalties and absence of flexible mechanisms and incentives are regarded as major weakness of the Energy Goal Management. The government plans to extend the coverage of the scheme to the entities with lower annual GHG emissions gradually, as the schedules show in the Table 4.

[4] The industrial sector accounts for 31% of total GHG emission of Korea. If emissions from generation are distributed to the end use sector, its share becomes larger.

Table 4. Designation Criteria for the Energy Goal Management

	~2011.12.31		2012.1.1~		2014.1.1~	
	Basis of enterprise	**Basis of site**	**Basis of enterprise**	**Basis of site**	**Basis of enterprise**	**Basis of site**
GHG emissions (CO_2 ton)	125,000	25,000	87,500	20,000	50,000	15,000
Energy use (terajoules)	500	100	350	90	200	80

Source: Greenhouse Gas Inventory and Research Center

Overall handling of the Energy Goal Management is to be administered by the Ministry of Environment (ME), but other government agencies are also in charge of designating obligated entities, setting a target, and evaluating the implementation of the target set for the different sectors. For example, the Ministry of Knowledge and Economy (MKE) administers 378 industrial and generation plants, while the Ministry for Food, Agriculture, Forestry, and Fisheries (MFAFF), Ministry of Land, Transport and Maritime Affairs (MLTM), and Ministry of Environment administer 27 agricultural and livestock farms, 45 sites in the transport and building sector, and 23 waste-management facilities, respectively. Liable companies in the industry and generation sector administered by MKE cover the largest share of the GHG emissions and energy use -- 94% and 97%, respectively.

Table 5. The Number and Types of Enterprises in the Energy Goal Management

Government Agency	Industry Type	Number of enterprises (%)	Number of sites (%)	GHG emissions (%)	Energy use (%)
MFAFF	Agricultural and livestock farm	27 (5.7)	68 (4.3)	2,238 (0.5)	36,312 (0.8)
MKE	Industry	345 (72.9)	338 (49.9)	210,733 (54.3)	3,167,024 (56.6)
	Generation	33 (7.0)	133 (8.9)	186,372 (42.0)	2,260,012 (40.4)
ME	Waste management facility	23 (4.9)	333 (21.1)	7,578 (1.7)	24,581 (0.6)
MLTM	Building and Transportation	45 (9.5)	246 (15.7)	6,368 (1.4)	96,217 (1.7)
Total		473 (100)	1,618 (100)	442,289 (100)	5,592,591 (100)

Source: Park, 2011

South Korea's Carbon Emission Trading Scheme (ETS) is regarded as market-friendly GHG regulation. It sets the total amount of carbon emissions and allows companies or buildings under obligation to trade their allocated emission permits so that emissions can be reduced in the least-cost way, which is also called cap-and-trade scheme. The Emission Trading Scheme Act, which contains the details of the scheme design, is waiting for congressional endorsement. ETS will be phased-in in 2015, and the emission permit will be allocated by a "grandfathering" method.[5] However, an enterprise participating in ETS will not need to comply with the Energy Goal Management.

Renewable Energy Target and Policy

The Low Carbon Green Growth Act stipulates that a Basic Plan for Response to Climate Change and a National Basic Energy Plan (NBEP) should be established and implemented. NBEP, published every five years, is the highest national strategy for energy-related government policy, which covers demand-side management as well as energy supply plans including electricity, gas, coal and renewable energy. The first NBEP, published in 2008, projected the energy demand and fuel mix by 2030 and set a renewable energy target of 11% of the primary energy consumption in 2030 -- increased from 2.14% in 2006. The NBEP identifies the renewable energy industry as the new growth engine of the future, as well as a way to reduce greenhouse gases. To this end, the government adopts a two-track strategy: (1) the establishment of mass diffusion of renewable energy in the domestic market with wind, bio, and ocean energy, which were identified as priority renewable technologies; and (2) government R&D investment to step up for four energy technologies, such as solar photovoltaic (PV) wind, fuel cell, and integrated gasification combined cycle (IGCC) that are deemed to have great market potential and spill-over effects to other industries.

As a key instrument for renewable energy development, the government will introduce a renewable portfolio standard (RPS) in 2012, replacing the existing feed-in-tariff system. The Korean RPS mandates power generators operating over 500 MW (14 generators as of September 2010) to produce a certain amount of their electricity from new and renewable sources. The RPS target is 10% by 2020, and the eligible renewable energy types include: solar, bio, wind, hydro, fuel cell, gasification or liquefaction of coal technology, ocean,

[5] The share of free allocation is up to 95% in the first implementation period, and it will be determined depending on international competitiveness after the end of the first period. The penalty for delinquency of regulations is set at as much as $1,000, and non-compliance is set to be up to three times the price of the permit.

waste, geothermal, and hydrogen energy. The key design features of the Korean RPS are as follows:

- Entities under obligation have to meet their target by surrendering the Renewable Energy Certificate (REC) that can be generated from their own renewable energy facilities; or by purchasing long-term contracts with other renewable developers; or via the REC market.
- A non-compliance fee is set at no more than 150% of the REC price.
- The Korea Energy Management Corporation (KEMCO) administers the verification of REC.
- There are solar carve-out programs, which require generators to purchase 50% of solar REC from third party solar power developers.
- The Korea RPS assigns different weight values for RECs according to the types of technologies. The purpose of the scheme is to provide more favorable financial incentives for strategic new and renewable technologies and applications. For example, the value of RECs produced from a PV system built in existing buildings or construction is 1.5 times higher than those from the system installed in non-building locations.

Table 6. Annual Target of RPS

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022 ~
Target (%)	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0

Source: Korea Energy Management Corporation (KEMCO) (2010a)

Table 7. Soar Carve-Out Program

	2012	2013	2014	2015	2016
Target (GWh)	263	552	867	1,209	1,577
Annual installation (MW)	200	220	240	260	280
Cumulative capacity (MW)	200	420	660	920	1200

Source: KEMCO (2010a)

Table 8. Weight Values for REC According to New and Renewable Technologies

	Weight	Technology and criteria		
		Installation type	Land Classification	Capacity
PV	0.7	Not using existing Buildings or construction	Five land types including farm, orchard, ranch, forest land	
	1.0		Other 23 land types	Above 30kW
	1.2			Below 30kW
	1.5	Using existing buildings or construction		
Other new and renewable energy	0.25	IGCC and byproduct gas		
	0.5	Waste and LFG(Landfill Gases)		
	1.0	Hydro, inland wind power, bioenergy, RDF (Refuse-Derived Fuel) generation, waste gas generation, tidal power with seawall		
	1.5	Wood fired generation, off shore wind power (within 5km)		
	2.0	Off shore wind power (beyond 5km), tidal power without seawall, fuel cell		

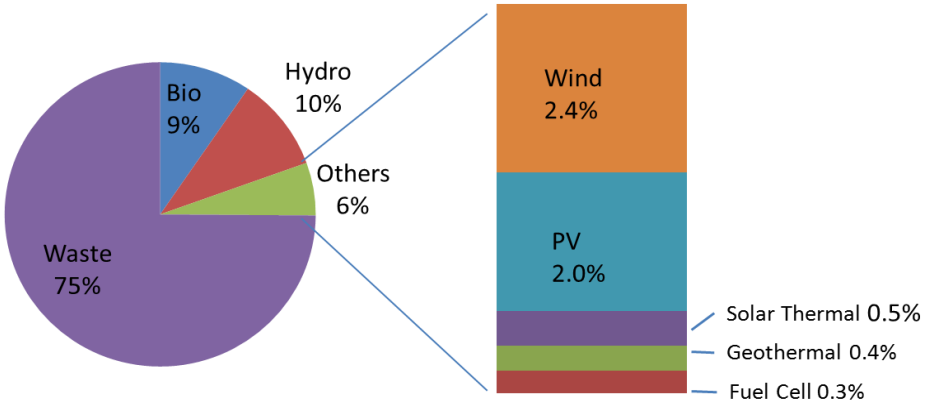
Source: KEMCO (2010a)

Green Energy Market: Structure and Participants

Market Structure

In 2009, the supply of "new and renewable energy" in Korea was 6.09 MTOE, which accounted for 2.5% of total primary energy. Waste energy takes the largest share of 75%, followed by hydro and bio energy.[6] The contribution of wind and solar energy is currently not significant, and accounts for 2.4% (wind), 2.0% (Solar PV), and 0.5% (Solar thermal) of total new and renewable energy supply (KEMCO, 2010b).

Figure 6. Energy Produced from New and Renewable Technology



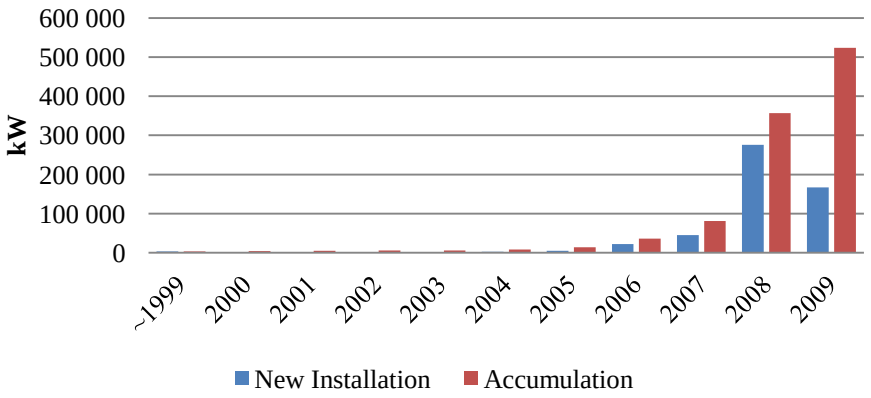
Source: KEMCO, 2010b

In the past few years, PV and wind energy development has become quite impressive in South Korea. Total PV installation has increased from 8.5 MW in 2004 to 524 MW in 2009. Wind power also increased five times during the same period, from 68 MW to 351 MW (KEMCO, 2010b). This rapid growth of the wind and PV markets is largely attributed to a favorable feed-in-tariff that was introduced in

[6] According to government's plan, however, the share of waste energy will be decreased to 33.4%, while wind and solar energy will increase to 22.4% by 2030 (MKE, 2008).

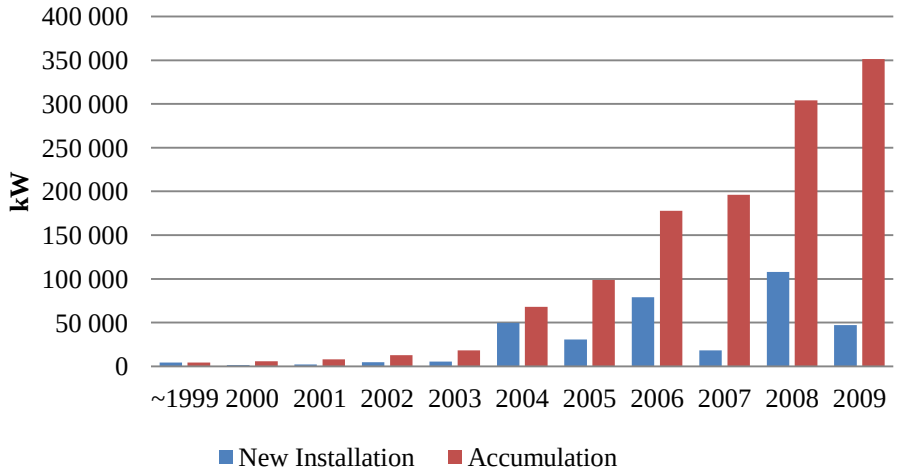
2001. PV installation exceeded wind capacity for the first time in 2008, as 236 MW of PV was added in one year.

Figure 7. Annual PV Installation and Cumulative Capacity as of 2009



Source: KEMCO, 2010

Figure 8. Annual Wind Turbine Installation and Cumulative Capacity as of 2009



Source: KEMCO, 2010b

Market Participants: Major Manufacturers of Selected Green Energy Industries

Solar PV

The PV industry in Korea has complete production chains from polysilicon, ingot, wafer, cell, module to electric equipment. While the domestic PV industry has developed especially in module and electric equipment, some core components of PV systems such as wafer and solar cells were more dependent on overseas technology. Korean companies are, however, rapidly increasing the capacity in entire PV systems based on a strong IT and electronic foundation. The major domestic PV manufactures can be found in the table below.

Table 9. Major PV Companies in South Korea

Major Manufacturer	Technology Development and Business Areas
OCI	- Polysilicon - 86,000ton/by year 2013
KCC	- Polysilicon - 24,000ton/by year 2020
Hyundai Heavy Industry	- crystalline silicon solar cell, module, and system - 600MW/year
Hanhwa Chemical	- producing 30MW/year of solar cell - Developing direct wafer technology - plans to construct integrated solar production system
KISCO	- thin-film solar cell (first in Korea) - 20MW/year
Samsung Electronics	- multi-junction PV development
LG Electronics	- silicon thin-film PV development
LG Innotek	- CIGS development

Source: Park et al., 2009; Jung et al., 2009; MKE, 2010.

Wind

In spite of the rapid growth of the wind market in Korea in the past decade, core wind technologies, such as gearboxes, blades, and generators, are mostly dependent on imports. Wind turbines installed so far in Korea are mostly imported from overseas wind manufacturing companies such as VESTAS. There is only one domestic wind turbine installed by Unison, which is the only company that has wind turbine technology in South Korea. However, a few large companies, particularly heavy industry and shipbuilding

companies such as Doosan Heavy Industry, Hyosung, Hyundai Heavy Industry, and Samsung Heavy Industry, recently began a massive investment in wind turbine development (BIR, 2011b). The landscape of the domestic wind market is expected to change significantly in the near future due to the increase of major players. The table below shows major wind energy companies in South Korea.

Table 10. Major Wind Companies in South Korea

Major Manufacturer	Technology Development and Business Areas
Unison	- production of 750-kW wind system - testing 2 MW - wind power system and parts
Hyosung	- testing 750 kW and 2 MW - wind power system, gearbox, and tower
Doosan	- developing 3 MW offshore wind power system
Hanjin	- tested 1.5-MW wind turbine
Hyundai Heavy Industry	- transformer, generator, PCS
Samsung Heavy Industry	- blade - developing 3 MW for inland, 5 MW for offshore wind turbine
Taewoong	- 15,000 ton forging press, world's largest - supply rotor shaft and tower flange for GE and VESTAS

Source: Park et al., 2009; Jung et al., 2009; MKE, 2010.

Smart Grid

With the government's strong green growth initiative, the smart-grid market is also expected to expand rapidly in the near future. In particular, South Korea aims to become a leading nation for smart-grid development and the government's favorable R&D investment and institutional support for smart-grid industry is expected to continue. In order to lay an institutional foundation for smart-grid development, the Special Law for Establishment and Support for Intelligent Grid System was passed in 2011, which includes a national plan for smart-grid development, selection of test-bed cities, and collection and protection of energy information. Based on South Korea's strong IT and electronic industrial foundation, the smart grid system is regarded as a potentially competitive arena in the global market. A number of Korean companies are actively searching for projects both within Korea and abroad. The table below shows a short list of key research institutions and companies in the smart-grid industry in South Korea.

In an initiative to reduce emissions, improve energy efficiency, and create new growth engines, the South Korean government is

developing a smart-grid system for the entire nation, beginning with the smart-grid test-bed on Jeju Island. There are 6,000 households that participate in the project using diverse smart-grid technologies, including smart meter, renewable energy, electric vehicle, power storage, and a demand response program.

Table 11. Major Smart-Grid Institutes and Companies in South Korea

Major Research Institutions/Manufacturer	Technology Development and Business Areas
Korea Electrotechnology Research Institute (KERI)	- HVDC (High-Voltage Direct Current), electric communication system, high-temperature superconductors, cable, etc. - Electric-vehicle pilot program
Korea Electric Power Research Institute (KEPRI)	- FACTS (Flexible AC Transmission System) - HVDC - Intelligent distribution system - Interconnection of distributed generation
Hyosung	- FACTS (345 kV 100 MVA) supplied to the Jeju Haengwon wind farm
Korea Electric Power Corporation (KEPCO)	- Intelligent transmission and distribution - Pilot program for real time pricing
LS Industrial Systems	- HVDC - Participating in three projects, smart place, smart transport, and smart renewable, in the Jeju smart-grid test-bed
Hyundai Heavy Industry	- Participating in smart renewable project in the Jeju test-bed

Source: Issue and Quest, 2011.

Other Renewable Energy Sources

South Korea's well-developed electronics, auto, engineering, shipbuilding and other heavy industries are expanding their business areas to the green energy industry. In addition to the PV, wind, and smart grid previously reviewed, this trend also can be found in other areas of the green energy industry, notably CCS (Carbon Capturing and Storage), energy storage, clean power plants, and fuel cells. For example, POSCO Power and Doosan Heavy Industry, with technical cooperation with overseas companies, are developing fuel-cell systems. POSCO Power and US-based FuelCell made a license agreement in 2009, which allows POSCO Power to manufacture fuel-cell stacks from the cells and module components provided by FuelCell. Hyundai and Kia groups, encouraged by recent success in the North America auto market, envision joining the ranks of the Big Four within 10 years in green-car market.

Green Technology: R&D Investment and Development Plan

Current Status of Green Technology in South Korea

According to the South Korean government's definition, the green energy industry is based on innovative technology with substantial potential for greenhouse gas reduction. As shown in Table 12, green energy industries are grouped into three categories: (1) new and renewable energy; (2) energy efficiency and carbon reducing technology; and (3) electricity and nuclear. There has been controversy over whether coal-based technology (IGCC and clean thermal power) and risk-prone nuclear energy should be regarded as green technology, but these technologies are being regarded essential in the green growth strategy because of the current energy mix in South Korea.

Table 12. Classification of Green Energy Technology

New and Renewable Energy	Energy Efficiency/Carbon Reducing Technologies	Electricity/Nuclear
PV Wind Fuel cell IGCC Biofuel	CCS Clean Fuel Energy Storage Efficient Light Green Car Energy Efficient Building Heat Pump	Nuclear Smart Grid Clean Thermal Power

The domestic green energy market and investment have grown precipitously in recent years. The number of firms and workers and revenues of new and renewable industries have increased 2.2, 3.6, and 6.5 times for the last three years. R&D investment in clean technology also has increased by 3.5 times from 719 billion won ($625 million) to 3.558 trillion won ($3.09 billion) in the same period (MKE, 2011).

However, South Korea's green technology is still showing a certain gap with current market leaders. The technology level[7] of Korea's silicon-based PV is evaluated as reaching the 70% of top technology holders. Domestic thin-film PV technology has not yet been commercialized and stayed at the 66% level of the leading countries. In particular, the next generation PV cell is still in a development stage. Korea's wind market is mostly concentrated in the forging industry, producing main shafts and tower flanges. The technology level of the core parts of the wind system, such as blade, generator, and gear box, is assessed between 65–75% level of the leading countries.

Table 13. The Status of Technology Development for PV and Wind in South Korea

	Value chain	Technology level (Top=100%)
PV	Silicon	68%
	Wafer	75%
	Silicon-based solar cell	72%
	Thin film solar cell	66%
	Organic solar cell	40%
	Module	77%
	PCS	74%
	Production equipment	65%
Wind	Blade	75%
	Generator	75%
	Gear Box	65%

Source: Lee, C-Y & Lee, S-Y (2010)

Overview of Green Technology Roadmap

The MKE has developed detailed roadmaps for development of 15 green technologies through eight months of study conducted by 170 experts from academia, industry, and research institutes. The Roadmap is aimed to position South Korea as the leading country in the global green energy market and to raise South Korea's share in

[7] In this study, the "technology level" means a technology level index that counts the top technology as 100%, based on the study conducted by KEEI. Lee, C-Y & Lee, S-Y (2010)

the global green energy market from 1.2% at present to 18% by 2030. The main strategy for this purpose is as follows:

- Development of core parts and materials
- Promotion of small and medium-sized companies
- Enhancement of integration of related technologies
- Increase of public R&D investment
- Development of innovative technology

According to the investment plan specified in the Roadmap, the total amount for the R&D for clean energy technology by 2030 is estimated at 26 trillion won ($22.6 billion). Private and government entities will respectively be in charge of 13.65 trillion won ($11.8 billion) and 12.35 trillion won ($10.7 billion). In terms of technology, nuclear is the single largest technology on which government R&D budgets will be spent, followed by PV and clean fossil-fuel-fired plants. The Roadmap expects the following benefits from technology development:

By 2015 - Creation of 310,000 jobs, 19 trillion ($16.5 billion) of domestic market, 35 trillion won ($30.4 billion) of export

By 2030 - Creation of 1.5 million jobs, 94 trillion won ($81 billion) of domestic market, 328 trillion won ($285 billion) of export

Table14. R&D Investment Plan in the Green Energy Strategy Roadmap 2011

Technology	Funding Source	Budget (trillion KRW)	Share
PV	Government	1.41	10.4%
	Private	1.62	13.2%
	Subtotal	3.03	11.7%
Wind	Government	0.19	1.4%
	Private	0.08	0.7%
	Subtotal	0.26	1.0%
Fuel cell	Government	0.5	3.7%
	Private	1.05	8.5%
	Subtotal	1.55	6.0%
Bio fuel	Government	0.38	2.8%
	Private	0.35	2.8%
	Subtotal	0.73	2.8%
Energy storage	Government	0.72	5.3%
	Private	0.64	5.2%
	Subtotal	1.36	5.2%
Clean fuel	Government	0.80	5.9%

Technology	Funding Source	Budget (trillion KRW)	Share
	Private	0.78	6.3%
	Subtotal	1.60	6.2%
CCS	Government	1.02	7.5%
	Private	1.37	11.1%
	Subtotal	2.38	9.2%
IGCC	Government	0.62	4.6%
	Private	1.68	13.7%
	Subtotal	2.29	8.8%
Smart grid	Government	0.83	6.1%
	Private	1.28	10.4%
	Subtotal	2.11	8.1%
Nuclear	Government	4.24	31.2%
	Private	0.98	8.0%
	Subtotal	5.22	20.1%
Clean fossil fuel fired plants	Government	1.40	10.3%
	Private	1.60	13.0%
	Subtotal	3.00	11.5%
Energy conserving buildings	Government	0.12	0.9%
	Private	0.04	0.3%
	Subtotal	0.15	0.6%
Efficient lights	Government	1.09	8.0%
	Private	0.50	4.1%
	Subtotal	1.60	6.2%
Heat pump	Government	0.11	0.8%
	Private	0.24	2.0%
	Subtotal	0.35	1.3%
Green car	Government	0.22	1.6%
	Private	0.14	1.1%
	Subtotal	0.36	1.4%
Total	Government	13.6	100%
	Private	12.3	100%
	Total	26.0	100%

Source: Korea Institute of Energy Technology Evaluation and Planning (KETEP), 2011

R&D Plan by Technologies[8]

PV

PV is the fastest-growing technology in the global green energy market. The global PV market has increased 43% per year during the last five years, and its total market size is expected to be $113 billion in 2020. In terms of solar cell technology, it is expected that thin-film PV and new generation PV will dominate the global market, as modules become cheaper and diverse solar applications are found, especially in the building sector (MKE, 2011).

In the past decade, the PV industry in South Korea has also grown substantially, but there are two major problems frequently pointed out. First, South Korea's PV industry lacks the integrated structure of a supply-chain, which makes cost reduction and adjustment of supply difficult (Jung, 2009; Park et al., 2009). Second, the domestic PV industry is largely concentrated on downstream technologies, such as electric equipment and modules, which are relatively low added-value products. Thus, the core components of PV systems for domestic installation heavily depend on import, which also has left the country behind in the global market. Currently, the technology indigenization rate for silicon-based PV systems is about 70–80% and non-silicon-based PV (CIGS, dye-sensitized and organic PV) is 40–80% (BIR, 2011a).

The government revealed two-track strategies for PV development in the Roadmap. In the short run, Korea plans to expand production capacity for crystalline silicon, thin-film PV, and BIPV technologies to support the growing global PV market. In the long run, Korea plans to lead the PV market by developing and commercializing dye-sensitized and organic PV technologies (MKE, 2011). In addition, cooperation between large-, small-, and mid-sized companies in PV industries is emphasized in the government PV Roadmap. An integrated production system is also being pursued by large domestic companies, notably Hanhwa Chemical, which took over Solarfun Power Holdings, the world's fourth largest module producer, in 2010 (*Korea Times*, 2011).

Wind

Wind power is also growing fast, as the Asian market, especially China and India, has been expanding rapidly in recent years. It is expected that a 2–3-MW wind turbines for inland and a 3-MW or larger model for offshore will dominate the market in the future. In particular, as technology improves and land becomes scarce for

[8] The main contents in this part are based primarily on *the Green Energy Strategy Roadmap 2011*, published by MKE (2011). Technical terminologies are directly cited from the Roadmap and explained in more details if necessary.

inland wind power, offshore wind farm development is expected to lead the market.

The domestic wind market in South Korea has also grown quickly in the past decade. However, the core parts and materials for wind turbines largely depend on major overseas wind companies. Although the well-developed domestic forging industry currently sees business opportunities in the global wind market, but the industry's main products such as the rotor shaft and tower flange account respectively for less than 1.9% and 1.5%of the total wind system costs (BIR, 2011b). A transition to high-valued products is being discussed as a major task of the domestic wind industry.

According to the Roadmap, the Korea government plans to indigenize the production of key parts and materials for wind turbines and to establish an integrated structure of a supply-chain as a near-term strategy. It also includes the commercialization of 2–3-MW wind turbines for inland and 3-MW or larger models for offshore. In the long term, Korea plans to develop floating wind turbine systems utilizing the well-developed domestic shipbuilding industry.

Fuel cell

As a clean and efficient technology, the fuel-cell market is expected to take off in five to ten years (MKE, 2011). In particular, market potential of fuel-cell technology is deemed to be huge considering its diverse applications ranging from portable power and transportation to distributed generation. Currently, fuel-cell technology has not fully been commercialized in South Korea, except for some niche markets such as uninterruptible power supply (UPS) and the domestic cogeneration system.

In spite of the past investment in fuel-cell technology, South Korea's technological level is still behind compared to that of other market leaders. The technology development level of fuel cells is assessed to be 40–60% of other advanced countries. It is also pointed out that the supply-chain of the core parts and materials for fuel cells are still incomplete (MKE, 2011). Therefore, according to the Roadmap, the first priority of the fuel-cell development strategy is to gain price competitiveness by indigenizing the core technologies and introducing mass production. For this purpose, the government plans to continue support for technological development and to establish a mass-production system to create a domestic market. In the short term, technological priority is placed on the diversification of feedstock and on applications, including home, vehicle, and ships. The long-term project is focusing on the development of a fuel-cell system for a larger-scale power generation.

Bioenergy

South Korea's bio energy use, particularly of liquid fuel for transportation, is currently very limited, which largely attributed to low commercial viability and a lack of government support and

infrastructure. However, the South Korean government plans to produce 5 MTOE for transportation by adopting a Renewable Fuel Standard (RFS) in 2012. For this purpose, the government is focused on biotechnology that has relatively lower market barriers, such as biogas, biodiesel, biobutanol, and nonalcoholic hydrocarbon (MKE, 2011). In addition, strategic cooperation with tropical countries that have abundant biomass is identified as an important development strategy in the Roadmap. It is pointed out that South Korea's bio energy industry may take advantage of second generation bio energy technology using cellulose plants, because of the country's lack of available land for energy crops.

Clean fuel

Clean fuel in the government's Roadmap refers to synthetic fuel made from coal or gas. The Roadmap identifies gasification of low-quality coal, coal synthetic natural gas (SNG), and F-T (Fischer-Tropsch) composition as a short-term priority technology, while Gas-to-Liquids (GTL) and GTL-FPSO (floating production, storage and offloading) are being considered as long-term technologies. In particular, strategic cooperation with shipbuilding companies will be encouraged for an integrated design of the GTL-FPSO. Test operation of clean fuel plants will be completed by 2015, and commercialization and overseas export is expected after 2020 (MKE, 2011).

IGCC (Integrated Gasification Combined Cycle)

As a means to cope with increasing electricity demand and to reduce CO_2 emissions for climate protection, IGCC technology has drawn great attention. The global market is expected to grow to 250 GW by 2030 (MKE, 2011). In South Korea, the IGCC and coal SNG (Substitute Natural Gas) plants market is expected to grow up to 5–7 trillion won ($4-6 billion) in 2020 (increased from 2 trillion won, or $1.7 billion in 2011). The government plans to commercialize 300-MW-size IGCC plants by 2015 and to standardize 500-MW plants for exporting items to the global energy market. In particular, hybrid IGCC, such as IGCC + CCS, and SNG fuel-cell technology, is identified as a long-term priority technology in the Roadmap.

CCS (Carbon Capture and Storage)

CCS is viewed as an important technological option for Korea to achieve its CO_2 reduction target of 20% below to the BAU by 2020. It is expected that CCS will be applied to new fossil-fuel-fired plants in 2013–2017 (MKE, 2011), and the technology will be commercialized by 2020. According to the Roadmap, pilot projects of 100-MW that integrate capture-transport-storage process will be completed by 2020. At the same time, the government will continue to make an effort to reduce carbon capturing costs, which account for 80% of the total CCS cost. According to the Roadmap, the carbon capturing cost

is expected to be lowered to \$10/t CO_2 in 2030, from \$30/t CO_2 in 2012.

Clean fossil-fuel-fired plants

The South Korean government sees the growing market of clean fossil-fuel-fired power plants, such as gas and clean coal, as the country's new export items. It is estimated that the gas turbine market is reaching 16 trillion won (\$13.9 billion), and the clean coal market is 97 trillion won (\$84.3 billion) a year (MKE, 2011). In particular, the gas turbine market is dominated by major global energy companies such as GE, Siemens, Alstom, and MHI, and the market share of the four companies is 68%. As South Korea depends on import for gas turbines and some high-temperature parts, the development strategy is focused on indigenization of gas turbines and high-performance parts. Remodeling of old coal-fired power plants, automatic operation by smart-grid technology, and 700°C Class high-efficiency generation systems are also specified in the government's key development strategy (MKE, 2011).

Nuclear energy

Nuclear energy is seen by the South Korean government as a key vehicle to achieve the objectives of its green growth policy. In particular, the government has promoted the nuclear industry as a strategic export item after succeeding in winning a contract to build Korea's four APR1400 in the UAE in late 2009. In 2010, the government announced that the country would seek to become the world's third largest nuclear exporter by selling 80 nuclear reactors by 2030 (H-C Kim, 2010). The government is making efforts to bid on overseas nuclear projects, particularly those in fast-developing countries like Turkey, China and India. In July 2011, South Korea and India signed a nuclear cooperation agreement, which paved a way for local firms to participate in India's nuclear projects (Kang, 2011). As a short-term business strategy, South Korea is focused on the export of existing models of nuclear plants and technology development of the APR+ model. The long-term task is the commercialization of the APR+ and large-scale nuclear plants, as well as the development of a fourth-generation reactor (MKE, 2011).

Nuclear energy will also play an important role in the country's electricity supply in the future. According to Fifth Basic Plan for Electricity Supply published in 2010, 14 nuclear power plants will be added by 2024, which will cost about 33.2 trillion won (\$28.7 billion). If the construction goes smoothly as planned, South Korea will have 34 nuclear power plants by 2024 and the share of electricity from nuclear energy will be substantially increased from 31.4% in 2010 to 48.5% in 2024. One of the new plants in the government's nuclear plan already started commercial operation in February 2011, and seven reactors are under construction, all of which are scheduled to be completed by 2017.

After decades of deadlock, Gyungju in Gyungsang province was chosen as an intermediate- and low-level nuclear waste depository. However, the location of a permanent repository for high-level radioactive waste, such as spent fuel, has not been decided due to environmental concerns associated with radioactive materials. The high-level radioactive waste is currently stored on the plant sites, but the on-site storage will reach capacity between 2016 and 2021. Thus, dealing with high-level radioactive materials will be an important issue for the country's pursuit of its nuclear development strategy.

Smart grid

The government's near-term R&D plan is focused on an energy management system (EMS), an electric-vehicle fueling network, an advanced measurement system, an intelligent distribution/transmission (e.g., HVDC, High-Voltage, Direct Current) and equipment, the integration of distributed generation, and institutional platforms such as architecture and security. The long-term R&D technologies include a DC system, superconductors, and a city-or province-level smart-grid community.

Energy storage

As the use of renewable energy increases and intelligent grid-system develops, energy storage technology becomes more and more important for stable operation of the grid system. The South Korean government is developing a storage technology for early market adoption and promoting a consortium from energy-storage system companies to power generators for synergistic effects (MKE, 2011).

Green vehicles

The South Korean government aims to produce 1 million electric cars in 2020, 70% of which will be for export (MKE, 2011). The short-term target is to develop core technology for electricity-driven cars and hydrogen or electric fueling stations. For this purpose, the government promotes sharing the EV platform and high-efficient parts, such as motors, inverters, and H/C (heating and cooling) systems. In the long-term, an innovative energy-storage system and the commercialization of fuel-cell cars will be developed (MKE, 2011).

In recent years, the government implemented diverse policies for electric-vehicle development. For example, in 2009, the South Korean government announced "Measures for the Promotion of Electric-Vehicle Industry," which supports a test program for electric vehicles in metropolitan areas. In 2010, EVs and Neighborhood Electric Vehicles (NEVs)[9] are allowed to drive on the road. The development of green cars (electric, hybrid, plug-in hybrid) requires

[9] A type of electric vehicle designed for lower-speed driving by reducing weight and size.

total changes of vehicle components, including electronic devices, motor and transmission systems, and electricity generation and storage systems. However, because of the short history of green car development, the domestic technology remains at the 60–80% level of leading countries.

Efficient lighting

Light Emitting Diode (LED) technology is seen as an important end-use technology in the green growth policy for diverse applications in TVs, computer monitors, illumination, traffic signals, and as a potential means for saving electricity. The global LED market from 2003 to 2008 grew at 14% per year and is expected to see a higher growth rate from 2008 to 2013 (Park et al., 2009). The domestic LED industry lags behind leading companies in the United States, Japan, and Germany, which account for 65-70% of the global market share. In particular, domestic LED companies lack patents for primary technology and the technological gap in LED chip technology is still wide vis-à-vis market leaders (Park et al., 2009). However, the LED market is expected to grow rapidly with the continuous increase of demand for LED electronic appliances and the accumulation of technology by domestic companies. It is expected that South Korea's LED market will grow 30.4% per year by 2015 (Park et al., 2009). According to the Roadmap, the ceramic discharge metal-halide (CDM) lamp, high-intensity discharge (HID) lamp, intelligent light system connected to a smart-grid, and high-efficiency LED are identified as priority technologies.

Energy-efficient buildings

It is expected that the global market for green building technology will increase from $175 billion in 2007 to $7.1 trillion in 2030, as many industrial countries promote zero-energy buildings (MKE, 2011). Recently, the South Korean government also initiated a series of green building policies to realize green growth goals. One of these initiatives is the "2 million green homes" project, which aims to build 200 energy-efficient homes (mostly apartments) by 2020. The government's green home plans also include remodeling of existing buildings and maximum energy conservation for large buildings. In terms of government R&D investment, efficient construction technologies including efficient curtain wall, windows, building shell insulation, and development of an energy audit/management system are to be promoted (MKE, 2011).

Heat pump

In 2010, the global heat-pump market is $72.4 billion and expected to increase steadily. The South Korean heat-pump market is also expected to grow fast as cooling and heating systems for large buildings in urban areas increase rapidly (MKE, 2011). During the period of 2005 through 2008, the domestic heat-pump market increased from 580 billion won ($504 million) to 1.3 trillion won ($1.13

billion). Samsung and LG electronics led the market, together accounting for 95% of the domestic market share (BIR, 2011c). The Roadmap is focused on packaged heat pumps for refrigeration and HVAC (heating, ventilation, and air conditioning) systems and mid-size efficient ATW (Air to Water) heat pumps for a short-term development strategy. The latent heat pump is identified as a long-term priority technology.

Opportunities and Constraints of the Green Energy Industry

Opportunities of the Green Energy Industry

The South Korean government's green growth initiative laid down an institutional foundation for green energy development. A number of green growth policies, such as the emission trading system, Green Homes Project and RPS, are expected to provide a stable framework for the domestic expansion of the green energy market. In addition, the government R&D investment plan is expected to play an important role in filling a technological gap between South Korea and other advanced countries. It is pointed out that previous green energy policies have been largely focused on the diffusion of new and renewable energy, which made the domestic industry more dependent on imports for core parts and materials. In response to this criticism, the green growth policy stresses the competitiveness of green energy industries as well as domestic market expansion. Once these two aims of green energy policy -- the diffusion of green energy in the domestic market and competitiveness of green energy technology -- are properly achieved, greater business opportunities can be expected.

One of the advantages that South Korea can make use of is the nation's well-developed industrial foundation, technologies, and infrastructure and these can be easily applied to the green energy industry. For example, South Korea's world-leading shipbuilding companies are entering the wind power business, and semiconductor companies, such as Samsung and LG, are now developing PV cells. Another example is that the nation's advanced IT and electronic technology has penetrated the smart-grid business. Once appropriate R&D investment is provided and industrial streams are connected properly, it will not take long for the nation's green energy industry to catch up with the world-leading countries.

Market demand can be pulled and pushed by technological development and government policy. As discussed earlier, South Korea already established a solid institutional foundation for the green energy market, and green technology is expected to be more affordable in the future. Growing market demands will also induce technological innovation and further policy implementation. When green technology provides an improved convenience and safety in daily life, it will boost market demand. As fossil fuels become more

expensive and government subsidies for conventional energy are forced to be cut, South Korea's green energy industry will have greater market opportunities.

Constraints and Challenges

The biggest domestic challenges facing the green growth policy are technological dependency and increasing competition in the global market. Although the South Korean government plans to invest a huge amount of capital in green energy R&D research, there are many issues that should be taken into consideration, such as differentiated strategies for each technology, infrastructural and institutional establishment, marketization, technology and business cooperation with major companies and other countries, and a concrete plan to enhance cooperative relations between large conglomerates and small- and mid-sized companies. In addition to the challenges of South Korea's green energy industry, there are also many problems of the green growth policy that need to be overcome in the future. Among these:

- The government green energy plan is largely focused on supply options. Less consideration has been paid for the improvement of end-use efficiency.

- The government's commitment to nuclear expansion has been strong but the government is facing increasing challenges of nuclear safety, economic feasibility, environmental sustainability, and social equity after the Fukushima nuclear accident.

- The Four River Restoration Project, to which the largest budget share of the green growth plan has been allocated, has often been criticized by opposition parties and environmental NGOs for its adverse effects on the environment.

- There are concerns about the effectiveness of an emission trading system (ETS) and the renewable portfolio system (RPS). The rules of the South Korean ETS currently pending at the National Assembly have become relaxed at the strong request of the industrial sector, including the start date, penalties, and the method of allowances allocation. The transition from feed-in-tariff to RPS also raised concerns that the RPS may no longer provide decentralized energy options.

- The government plan to introduce competition in the electricity retail market for the better use of a smart-grid system is confronted by labor union and environmental groups.

Concluding Remarks

Based on strong political support and legislative framework, South Korea's green growth policy has shown noticeable progress in a relatively short period of time. However, the real challenges lie in the management of the transition from a hydrocarbon-based energy structure to a greener one and the implementation of actual policies that often bear a huge economic and social cost. The speed of the transition, as well as a series of external variables such as the global economic condition, will also affect the progress of green growth in South Korea.

The green growth strategy of South Korea is a very comprehensive policy package covering most major renewable energy sources and GHG reduction measures. As the government hopes to keep up with the global market leaders in the fast-track, the participation of foreign enterprises is being encouraged, especially in the R&D sector. The green growth strategy also targets the global market, as the size of domestic market is relatively small and endowments of renewable energy are not sufficient. To a large degree, the green growth policy is also an export-oriented strategy. For an effective launching of new business abroad, a number of Korean companies seek partnerships with major foreign energy companies. The most promising opportunities with foreign companies could be found in the linkage of Korea's core-competitiveness in IT, electronics, steel, and construction with the advanced technology in parts and design coming from the current market leaders.

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