Analysis of Experiences in Sustainable Energy Development in Korea

Knowledge Sharing Forum on Development Experience: Comparative Experiences of Korea and Latin America and the Caribbean

Korea Energy Economics Institute

Knowledge and Learning Sector

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Abstract

The IDB Annual Meeting was held in Busan in March, 2015. During the event, the Knowledge Sharing Forum took place to share development experiences and potential partnerships between Korea and Latin America. The Korea Energy Economics Institute reviews and analyzes sustainable energy development in Korea including results and limitations, which was shared to promote sustainable energy development. This research covers topics such as energy efficiency, smart grid, and renewable energy policies in Korea. After the Introduction, the second chapter presents energy demand management policies in Korea and some cases that can be applied in Latin America. The third and fourth chapters provide reviews of smart grid and renewable energy policies in Korea and the last chapter draws conclusions.

Executive Summary

The paradigm shift from supply-side management to demand-side management (DSM) such as energy conservation and energy efficiency is an important issue in the energy sector across the world. The construction of new nuclear power plants are getting difficult domestically, and the reduction of greenhouse gas emission from consuming fossil fuel is required internationally. In addition, the deployment of renewable energy is limited and the increase of energy prices. Improving energy efficiency is top policy issues for both energy importing countries and energy exporting countries. In view of Korea's high dependency on energy imports (96 percent), improving energy efficiency is inevitable. There are some tasks in LAC countries for the transition to energy policies focused on demand-side management. First, adjusting or reforming energy tax rates are necessary for stable funding in energy sector. Since financing has been one of the major obstacles for energy efficiency investment in Korea. Second, it is recommended having various sectoral DSM policies such as residential or industrial sectors in LAC countries. Third, establishing a demand management system based on ICT such as Smart grids is more efficient way.

Smart grids facilitate real time, two-way communication between electricity producers and consumers and by doing so save electricity, supply renewable energy and support the electric vehicle sector. The foundation for commercialization of smart grid was laid through the establishment of a Jeju Smart Grid Test Bed. It includes the development of Advanced Metering Infrastructure (AMI), Energy Management System (EMS), Energy Storage System (ESS) and other key technologies. With the Korean experience of the Smart grids, various projects can be applicable to the LAC regions such as Smart City project. A new Smart girds business eco-systems can be created in Smart Cities. Promoting new businesses in areas such as smart grid and renewable energy will create a new growth engine for economic growth.

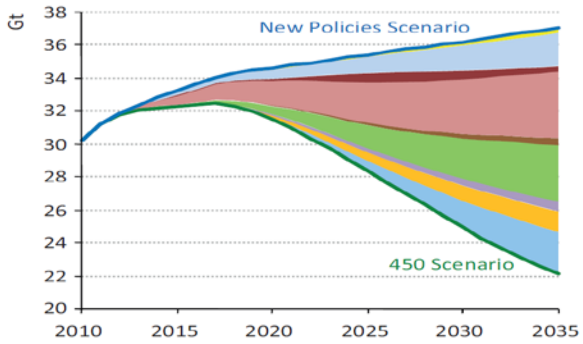
Finally, the report includes examples of success and failure in the process of renewable energy development. The experiences of Korea solving the problems in renewable energy deployment may serve useful to LAC countries. Furthermore, Korea may provide good intuition for renewable energy development system to LAC countries because Korea has a unique system focusing on R&D, commercialization, industry and infrastructure which are connected with virtuous circles.

I. Energy Demand Management Policy in Korea

A. Background of Korea's Energy Demand Management Policy and its Necessity

Energy demand management is increasingly gaining importance around the world as one of cost-effective solutions for strengthening energy security and reducing greenhouse gas emissions. The International Energy Agency (IEA) reported in 2012 that energy demand management (energy saving or energy efficiency improvement) would abate greenhouse gas emissions globally, helping reach 73 percent of the global reduction target in 2020 and 45 percent in 2035.

Figure 1 Greenhouse Gas emission Reduction Scenarios and Forecasts



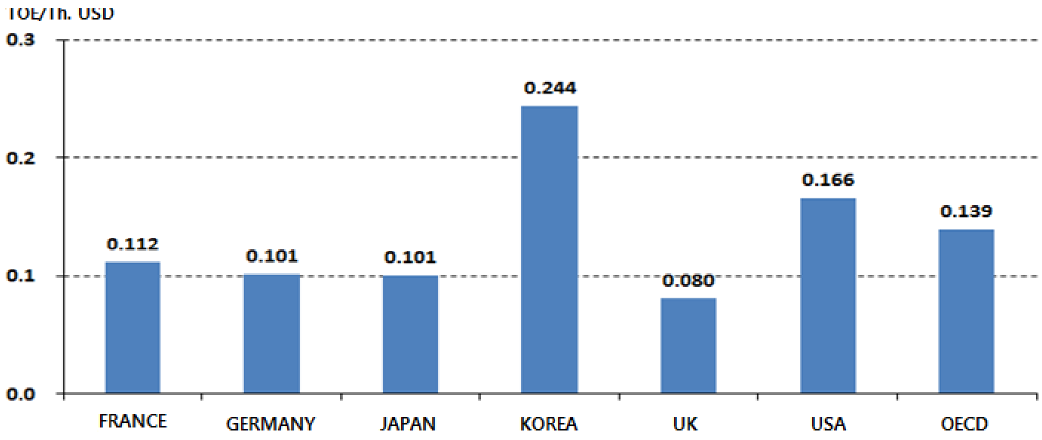
CO_2 abatement	2020	2035
Activity	2%	2%
End-use efficiency	18%	13%
Power plant efficiency	3%	2%
Electricity savings	50%	27%
Fuel and technology switching in end-uses	2%	3%
Renewables	15%	23%
Biofuels	2%	4%
Nuclear	5%	8%
CCS	4%	17%
Total (Gt CO_2)	3.1	15.0

Source: IEA (2012), WEO, p.253, Figure 8.7

Developed countries have adopted and implemented energy demand management policies to cut energy consumption and improve energy efficiency, all intended to help slash greenhouse gas emissions. Against this backdrop, energy demand management has remained at the center of government strategies in its battle against climate change, oil price hikes and energy insecurity. Accordingly, governments have put a raft of policies in place to manage energy demand. Most of all, energy demand management has been regarded as one of the most cost-effective and no-regret measures. Globally, a paradigm is shifting from supply-side management to demand-side management in tackling energy issues.

The Korean government developed and implemented four sets of energy demand management basic plans and related initiatives over the last 20 years since the introduction of the first five-year basic plan on energy saving (1993-1997). The Korean government has adopted energy policies under the banner of energy demand management. The fourth basic plan for energy use rationalization was implemented over the period 2008-2012. On the negative side, Korea's energy intensity (total energy consumption/GDP) stays relatively higher compared with developed countries' records.

Figure 2 Energy Intensity Comparison (TOE/US$1000, 2011)



Source: IEA (2012), World Energy Indicators

In addition, energy consumption grew 2.9 percent on a yearly basis through 2000-2011 based on IEA's standards; worse, energy policies in Korea failed to resolve energy issues, all calling for policy revisions. During 2000-2011, energy consumption growth varied in different countries: Korea 2.9 percent, Japan -1.13 percent, Germany -0.63 percent, and the OECD average of 0.02 percent. Korea's energy intensity improved in the 2000s, but it continued to hover higher than developed countries' figures. The main drawbacks to energy demand management and energy consumption cuts in Korea have been i) the increasing purchase of electrical appliances including air conditioners on the back of income growth, and ii) an economy that is mainly driven by energy-intensive sectors.

The paradigm should shift from supply-side management to demand-side management, taking into account current trends in the energy sector. Growing public intolerance to nuclear power following the Fukushima incident has intensified concerns over long-term energy supply and demand. On top of that, the policy environment became tougher because the government's supply-side policies met with public's resistance amid growing awareness about environmental costs and property ownership. A case in point is the fight against the construction of a power transmission tower in Miryang city, a good illustration about limitations of supply-side energy management policies. The outlook is negative for renewable energy making significant contributions to energy stability in Korea due to limited potentials in physical, technological and economic terms. At the same time, Korea's dependence on fossil fuels should be reduced given the pressure mounting on greenhouse gas emission cuts at home and abroad. Hence, energy demand management is a two-thronged approach to energy stability and climate change mitigation. It will build a buffer against economic impacts from energy price hikes, open a new frontier through convergence with knowledge-based technologies, including information communication technology, and create jobs.

B. Story of Energy-Saving Policy in Korea

1. Overview

The Korean government introduced the first package of energy-saving policies in the 1970s and it underwent a series of modifications in the 1980s. The government launched the Energy Use Rationalization Basic Plan in 1993, aiming at a more systematic approach to energy issues. Major objectives of the Energy Use Rationalization Basic Plan are transition to a low-energy economy, energy efficiency improvement, promotion and education about energy conservation and greenhouse gas emission reduction. The priority of the first basic plan was an energy-saving framework and the second basic plan emphasized more on structural and systematic reform after the Asian financial crisis. The third basic plan (2004-2008) aimed at a paradigm shift to a low-energy economy in response to oil price hikes. The momentum behind energy saving strengthened after the Convention on Climate Change and Kyoto Protocol took effect because it became imperative to deal with oil price instability and greenhouse gas emissions. In this regard, the fourth plan targeted 11.3 percent growth in energy efficiency by 2012. It also aimed at reducing impacts from high oil prices, observing the convention on climate change and improving trade balance.

2. Energy-Saving Policy After the Oil Crisis in the 1970s and 1980s

Oil prices soared during the first oil crisis. As a follow-up measure, the Korean government came up with policies in November 1973 amid declining global crude oil supply. The government also launched a committee dedicated to energy saving and promoted energy-saving campaigns across the nation. In the early 1980s, the government revised energy-saving institutions and system and, as a result, a variety of policies were designed and implemented, making room for promotion of energy-saving policies. The one-dimensional policy with a sole focus on energy consumption cuts was relaxed or scrapped. Instead, the government designed new policy measures putting energy-saving technology development or integrated energy supply at the top of its to-do list.

3. The Five-Year Energy Saving Basic Plan since the 1990s

The main objective of the first Energy Use Rationalization Basic Plan (1993-1997) was the basic plan targeted 10.5 percent reduction in the total energy or primary energy demand. The three major policy directions were: 1) comprehensive energy saving framework for transition to a low-energy economy, 2) energy consumption growth weaker than economic growth, and 3) carbon dioxide emission reduction through energy conservation as a preemptive response to environmental regulations.

The main objective of the second Energy Use Rationalization Basic Plan (1999-2003) was to promote energy saving as one of the national strategies for economic recovery and to create a structural and systematic energy-saving scheme instead of straightforward regulatory measures in the past. The five major policy directions were: 1) structural reform of the energy sector and revision of pricing regulations, 2) transition to a low-energy economy, 3) industrialization of the energy-saving sector, 4) energy-saving and renewable energy technology development, and 5) nationwide promotion of energy-saving campaigns.

The goal of the third Energy Use Rationalization Basic Plan (2004-2008) was to transition to a low-energy economy in response to oil price hikes. This plan targeted 18.84mn TOE reduction (7 percent) in primary energy demand in 2008. The four major policy direction was: 1) Set-up of a reasonable pricing mechanism, 2) transition to a low-energy economy, 3) investment growth in energy-saving infrastructure in energy-intensive sectors, and 4) diversification of energy-saving campaigns and encouragement of public participation, and so on.

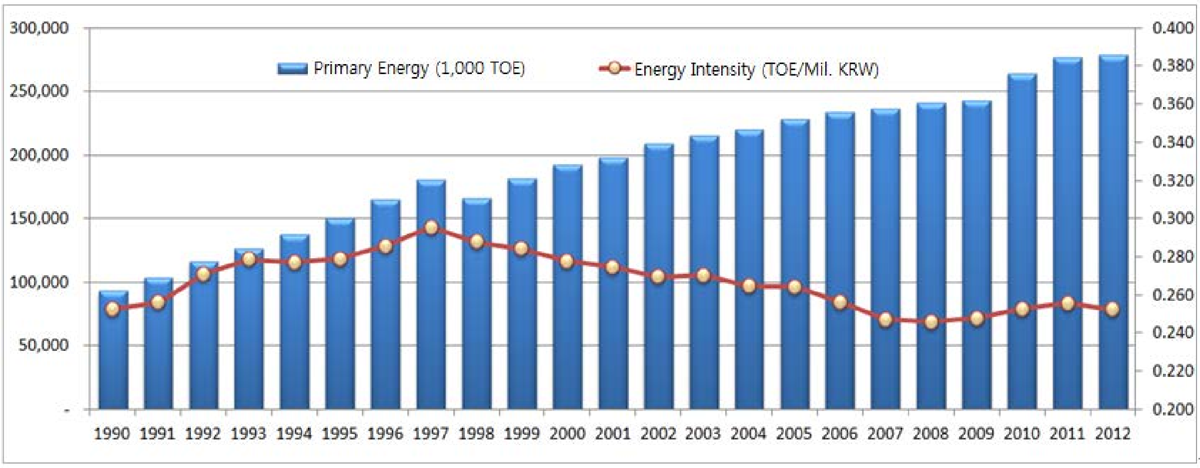
Lastly, the aim of the fourth Energy Use Rationalization Basic Plan (2008-2012) was to increase national energy efficiency by 11.3 percent in 2012 and 23.5 percent in 2017 from the level in 2007. The government rolled out incentives, including financial assistance, tax benefits, R&D spending growth and a certification system, to enhance energy efficiency, as a part of its efforts to conserve energy. It also introduced new initiatives including an energy efficiency target management system and incandescent phase out by 2013.

C. Current Status of Energy Supply and Demand in Korea

1. Major Energy Indicators and Total Energy Consumption are on the Rise

In 2000-2012, Korea's economy grew 59 percent, while the total energy consumption jumped 45 percent. Over the same period, the GDP growth surpassed the total energy consumption growth, while the energy intensity steadily improved. On the negative side, they remained relatively higher than those of advanced countries' records. Korea posted an annual growth of 7.2 percent in total energy consumption in the 1990s, but it slowed to 2.8 percent in the 2000s. By sector, on a yearly basis, energy consumption growth in the public and industrial sectors amounted to 5.1 percent and 3.6 percent, respectively, topping the ranking. On the other hand, energy consumption of households turned downward since the mid-2000s.

Figure 3 Total Energy Consumption and Energy Intensity (1990-2012)



Source: Korea Energy Economics Institute (2013), Yearbook of energy statistics

Table 1 Energy Indicators (2000-2012)

	GDP (2005, W1bn)	Total energy (1K TOE)	Final energy (1K TOE)	Total energy/GDP (TOE/W1mn)	Import dependence (percent)	Oil dependence (percent)
2000	694,628	192,887	150,274	0.278	97.2 (83.1)	43.0
2001	722,229	198,409	152,590	0.275	97.3 (83.2)	41.6
2002	773,868	208,636	160,451	0.270	97.1 (82.9)	40.5
2003	795,558	215,066	163,995	0.270	96.9 (81.8)	39.1
2004	832,305	220,238	166,009	0.265	96.7 (81.9)	37.4
2005	865,241	228,622	170,854	0.264	96.6 (80.6)	36.3
2006	910,049	233,372	173,584	0.256	96.5 (80.6)	34.9
2007	956,515	236,454	180,543	0.247	96.5 (83.6)	33.1
2008	978,499	240,752	182,578	0.246	96.4 (83.0)	31.4
2009	981,625	243,311	182,066	0.248	96.4 (83.4)	31.4
2010	1,043,666	263,805	195,587	0.253	96.5 (84.4)	29.6
2011	1,082,096	276,636	205,863	0.256	96.5 (84.4)	27.5
2012	1,104,215	278,698	208,120	0.252	96.0 (84.6)	26.2
00~12(percent)	3.9	3.1	2.8	-0.8	-0.1	-4.0

Source: Korea Energy Economics Institute (2013), Yearbook of energy statistics

Note: For imports, figures in parentheses refer to data excluding nuclear power; for oil, naphtha is excluded

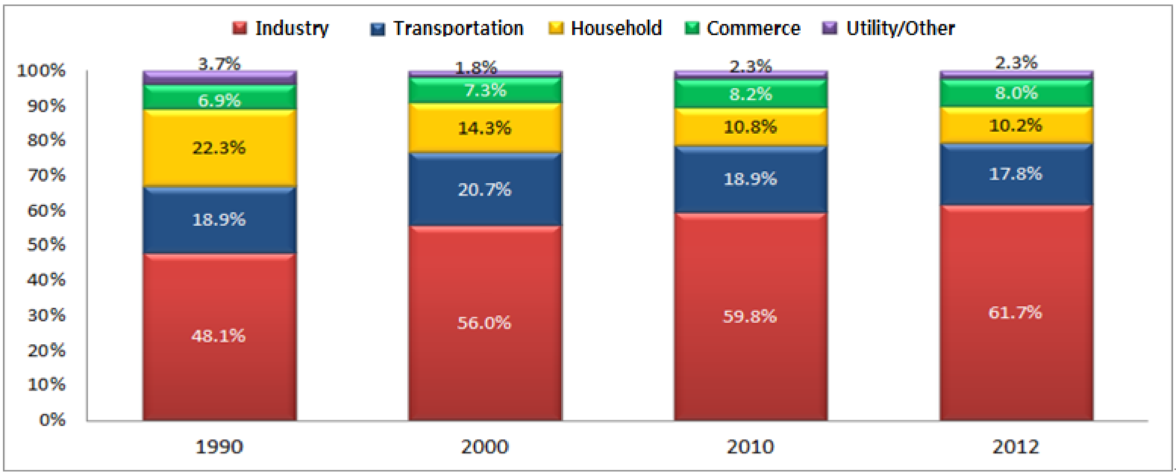
Table 2 Final Energy Consumption Growth by Sector (2000-2012)

	2000	2005	2010	2012	Yearly growth (percent)
Final energy (1K TOE)	149,852	170,854	195,587	208,120	2.8 percent
Industry	83,912	94,366	116,910	128,324	3.6 percent
Transportation	30,945	35,559	36,938	37,143	1.5 percent
Household	21,401	22,500	21,185	21,318	0.0 percent
Commerce	10,969	14,361	16,070	16,567	3.5 percent
Utility/ others	2,625	4,068	4,483	4,769	5.1 percent

.*Source*: Korea Energy Economics Institute (2013), Yearbook of energy statistics

Electricity demand is rising faster than demand for other final energy sources due to affordable prices, strong production at electricity-intensive sectors, increased penetration of electrical appliances and convenience. Electricity consumption increased 9.8 percent annually in the 1990s and registered highest growth among final energy sources in the 2000s.

Figure 4 Final Energy Consumption Breakdown by Sector (1990-2012)



Source: Korea Energy Economics Institute (2013), Yearbook of energy statistics

D. Korea's Energy Demand Management Policy

Energy demand management refers to the growth in plant utilization rate through energy demand reduction and load levelling and the efficient distribution of energy sources with an aim to boost economy. In this regard, the government developed a series of measures, including an energy demand management system for oil price hikes (June 2009), an energy-saving scheme (March 2010), energy efficiency improvement plans (June 2011) and the fifth energy use rationalization basic plan (November 2014). The government designed sector-tailored energy demand management policies (industry, transportation, buildings and home appliances) and created a stronger framework for energy demand management, including a pricing mechanism and R&D investment assistance.

Table 3 Energy Demand Management Policy by Sector

Sector	Major policies
Industry	Greenhouse gas and energy target management scheme, Energy management system (EnMS), Green credit, Energy service company (ESCO) and Energy audit program
Building	Energy efficiency labeling program for buildings, Building energy code, Building energy simulation, Performance evaluation for eco-friendly homes, Building greenhouse gas and energy target management scheme and Rational energy use in public Institutions
Transportation	Average fuel consumption, Fuel efficiency and labeling program, Tire energy efficiency standards, Transport partnership, Greenhouse gas and energy target management and public transportation promotion
Electrical device & home appliances	Energy efficiency labeling and standard, High efficiency energy infrastructure, e-Standby program, Financial incentives for energy-efficient equipment (LED lighting promotion) and energy frontier
Low-energy economy	Energy utility demand side management, Consultation about energy use plan, Energy use reporting and Financial assistance for energy efficiency investments & tax incentives
Education & campaign	Early childhood education about energy saving, energy saving campaign, media and online promotion and incentives (carbon cashback)
Pricing mechanism and technology development	New pricing mechanisms for electricity and city gas, Energy efficiency technology 20 (EETech 20), Technology for seven most energy-intensive appliances

Source: Korea Energy Management Corporation Homepage (2011)

1. Greenhouse Gas and Energy Target Management Scheme

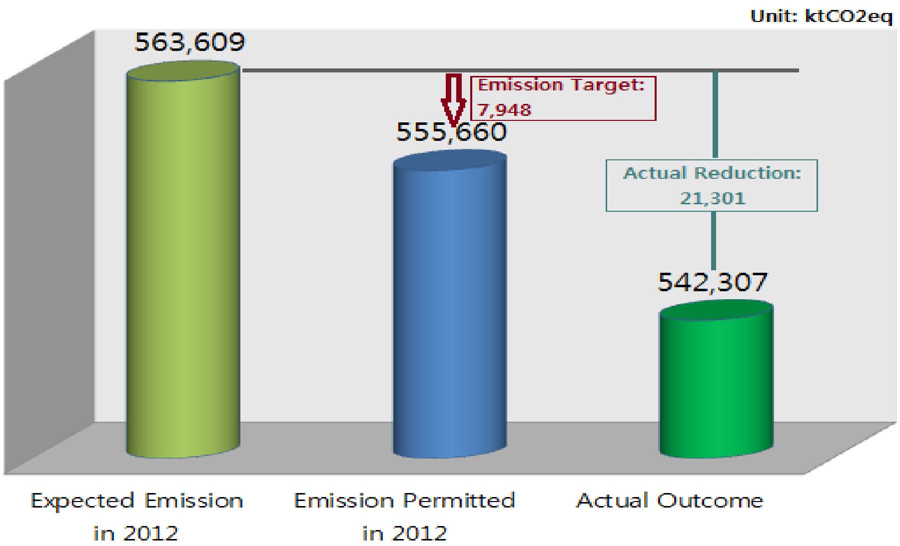
It was designed to encourage public and private partnership in setting energy efficiency and greenhouse gas emission reduction targets with a slew of incentives and penalties (launched in 2012).The scheme has been applied to companies with a record of 125,000 ton of carbon dioxide emissions and 500TJ of energy use in all plants combined or any plants with a record of 25,000 ton of carbon dioxide emissions.

2010	**2011**	**2012 (introduction)**	**2013**
Appointment (governing agency)	Consultation (company-agency) Proposal (company)	Execution (company)	Emission record reporting (company) Result reporting (company) Review (agency) Incentives or penalties (agency)

It was applied to 434 companies in the industrial and power generation, building and transportation sectors and aimed at 1.42 percent emission reduction from forecasts for 2012. Those companies accounted for 61 percent of greenhouse gas emissions in Korea in 2007. The government cut greenhouse gas emissions by 21.3mn ton (3.78 percent of 563.61mn ton emission estimates for 2012). Previously, the government aimed at 8mn ton of greenhouse gas emission reduction in 2012 (1.41 percent of the forecast). Overall, greenhouse gas emission reduction exceeded our estimates 2.7-fold. Greenhouse gas emissions of 21.3mn ton are equivalent to 53.7 percent of net carbon dioxide absorption in Korea (39.64mn ton a year).

Among 434 companies, 90.3 percent or 392 companies met reduction targets. The net reduction by sector are as follow: Petrochemical (6.9mn ton), Steel (5.73mn ton), Semiconductor, Display and Electric and Electronic (5.3mn ton) and Cement (3.87mn ton). Companies rolled out applicable and affordable greenhouse gas emission schemes. For instance, petrochemical company “A” replaced its outdated pre-heaters with energy-efficient products. As a result, the company cut carbon dioxide emissions by 16,000 ton and annual energy costs by W2bn. W1.4bn capex was retrieved in a year. A cement company “B” generated electricity using waste heat from pyro-processing plants and cut carbon dioxide emissions by 65,000 ton. In addition, the company is expected to save up W10bn energy costs every year and retrieve W84bn capex in seven years. An oil refining company "C" slashed carbon dioxide emissions by 205,000 ton after replacing bunker C fuel oil with LNG. The company is forecast to retrieve W20.3bn capex in two years on the back of margin gains.

Figure 5 Greenhouse Gas and Energy Target Management Scheme Review in 2012



Source: Ministry of Trade, Industry and Energy Homepage (2014)

2. Loan Provisions and Tax Benefits for Energy-Saving Facility Set-Up

The government provides loans to companies for setting up energy-saving facilities to encourage participation in energy saving and efficiency upgrades. It aims at fresh financing for companies because financing has been one of the major stumbling block to investment growth. Accordingly, the outlook is positive for private participation in energy campaign. Companies coming up with energy-saving plans, including waste heat power generation, outdated boiler replacement and LED lighting installation, can apply for loans. There are three loan recipients:

- ESCO business: Replacement of aging products with energy-efficient products (LED lighting and boiler), heat-insulation system, industrial process revision, waste heat recycling and air conditioning and heating system.
- Greenhouse gas and energy target management scheme: Plant upgrades with energy-

saving facilities, industrial process revision and fuel conversion. On the contrary, it excludes investment in renewable energy.

- Energy-saving facility set-up.

Table 4 Budget and Execution by Sector (Loan Recipient)

	2009		2010		2011	
	Budget	Execution	Budget	Execution	Budget	Execution
ESCO business	135,000	131,878	135,000	130,736	340,000	285,390
Target setting	140,000	140,523	140,000	138,505	124,585	168,778
Energy-saving facility	243,650	246,249	236,785	242,544	137,200	136,105
Total	518,650	518,650	511,785	511,785	601,785	590,273

Source: KEEI, Korea energy handbook (2013)

The government also offers tax benefits to companies for making investment in energy-saving facilities in accordance with the restriction of special taxation act. Tax deduction for companies investing in energy-saving facilities designated by the Ministry of Strategy and Finance. Tax deduction (10 percent of capex) from corporate tax or income tax (it is restricted to income tax on business income).

II. Smart Grid Policy in Korea

Smart grid refers to a modernized gird that uses information and communication technology for data processing. Smart grids facilitate real time, two-way communication between electricity producers and consumers and by doing so save electricity, supply renewable energy and support the electric vehicle sector. Smart grid technologies include Advanced Metering Infrastructure (AMI), Energy Management System (EMS), Energy Storage System (ESS), electric vehicle and charging station, distributed generation, renewable energy, ICT and intelligent transmission and distribution. Table 5 shows the differences between existing electrical grid and smart grid.

Table 5 Comparison between Existing Electrical Grid and Smart Grid

Existing electrical grid system	Smart grid system
Analogue/electromechanical	Digital/intelligent
Centralized	Distributed
Radial	Network
Manual system restore	Automatic system restore
Fixed rates	Real time rates
Unidirectional data flow	Bidirectional data communication
Utilities-oriented (options are not available for consumers)	Consumer engagement (options are available for consumers)

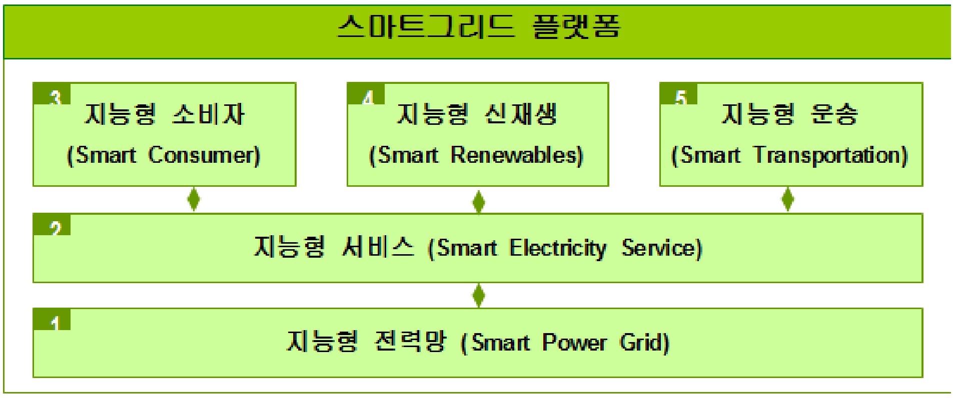
1. Korea's Smart Grid Roadmap in 2010

The Korean government introduced a comprehensive roadmap to promote smart grids nationwide and to coordinate a variety of smart grid projects carried out by different agencies and companies.

The government rolled out the Smart Grid National Roadmap for 2010-2030 in January 2010. The primary goal of the roadmap was to establish the world's first nationwide smart grid in 2030.

- Phase 1 (2010-2012): Test of new technology in a test bed
- Phase 2 (2013-2020): Deployment of technology in urban area and smart consumer
- Phase 3 (2021-2030): Nationwide smart grid

Figure 6 Smart Grid Roadmap



The government enacted the Smart Grid Construction and Utilization Promotion Act with an aim to carry out the first nationwide smart grid project in the world. It prepared laws and institutions to lay a ground for smart grids, all to realize its vision for low-carbon green growth. The government has sharpened its focus on establishing smart grids by putting in a place a comprehensive institutional framework and has adopted the five year basic plan for smart grid. Performance has been reviewed and evaluated every year.

2. Introduction of a Basic Plan for Smart Grid in 2012

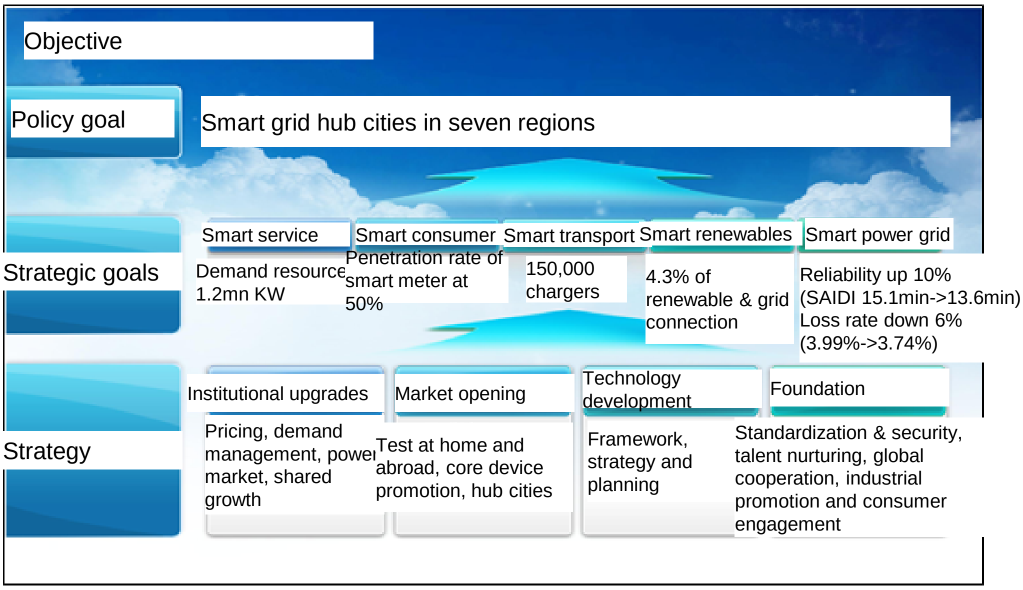
Institutional improvement lowers the entry barrier. A new pricing mechanism has been introduced, under which cost-based rates and consumer engagement are protected. On the demand side, development of new demand resource and increasing the number of aggregators are the top two goals. Electricity market opening lowers the entry barrier. Institutional development increased the participation of small and medium-sized companies and companies from other sectors. The government aims at the market expansion.

- Promotion/distribution: Smart meter, EV charging station and energy storage system
- Demonstration projects at home and abroad: Demonstration projects have been conducted or are in preparation.
- Smart grid hub city: Seven hub cities were chosen.

The government should introduce a plan for systematic technology development. A virtuous cycle of technology development, demonstration and commercialization will help accelerate technological advances. One of the priorities is to beef up development of demand management. Preparatory measures have been taken for industrial promotion.

- Standardization: Smart grid interoperability will be maintained through standardization (development of a standard framework, standardization of relevant areas and assessment test for interoperability).
- Security: A reliable smart grid data protection system was rolled out.
- Industrial promotion: Nationwide and private-led institutions will continue to help promote industrial advances.
- International cooperation: Bilateral and multilateral cooperation will increase.

Figure 7 The First Basic Plan for Smart Grid



3. Establishment of the Jeju Smart Grid Test-Bed

Smart Grid Test-Bed is responsible for demonstration and test of technology and development of a new business model. The AMI (Advanced Metering Infrastructure) and two-way communication network technology have been tested for a consumer-oriented pricing mechanism, DR service and energy information provision. AMI is a real time metering system and Smart meter is a part of the system. Charging infrastructure has improved for strengthening the foundation for charging station and EV rental business. A demand response program was also developed for conservation of energy. Smart consumer aims at creating a management system, under which electricity suppliers and consumers exchange electricity information on a real time basis to forecast supply and demand estimates. Smart transportation aims at improving charging infrastructure for EVs along with technological advances. For Smart renewable, grid stability of renewables will be achieved through high capacity batteries. A new system will be developed to improve electricity efficiency with the introduction of a real time pricing mechanism. For Smart power grid, a series of technologies have been tested for grid upgrades, including intelligent transmission, digital conversion and distribution automation. An automatic recovery system was designed to manage electricity supply and demand in renewable and electric vehicle arenas. In addition, new business models will be developed for supporting new technologies.

4. Strategy for Smart Grid in Korea

Several Smart Cities (7 to 8) have been selected to apply business model from Jeju project to main land of Korea. Individual cities have differentiated identities and domains of Smart grid. It also needed to have different approaches to rural and city areas. For Smart Cities, the technologies such as BEMS (Building Energy Management System) or FEMS(Factory Energy Management System) is necessary. ICT based technology into Smart Grid City is important to create new Smart grid business.

Figure 8 Smart City Platform

IV. Renewable Energy Policy in Korea

A. History of Renewable Energy Policy in Korea

1. Introduction (1970s-80s)

The importance of renewable energy increased after the first and the second oil shocks. The primary focus of the government during the 1970s-80s was to expand supply of renewable energy and alternative energy. Accordingly, the Act on alternative energy was introduced. Under the first basic plan, which was introduced in 1987, the government continued to supply new energy sources, including solar thermal and geothermal energy.

2. Preparation (1990s)

The renewable energy sector growth muted due to global environmental issues and oil price drops. The government strengthened the supply of renewable energy and accelerated technology developments in the reflection of increasing pressure on global environmental issues. However, the government decided to withdraw regulatory measures on renewables due to oil price weakness.

3. Maturity (2000s)

Korea sharpened focus on renewable energy after oil price hikes and an energy demand management mechanism was introduced. The government overhauled renewable energy policies and introduced the second basic plan in 2003, with an aim to accelerate industrialization of renewables based on increased supply and technology development.

4. Growth (2008)

Exponential growth of the renewable energy sector is attributable to a low carbon green growth roadmap in Korea. The government introduced the third basic plan in 2008 and launched the RPS program, which intended to strengthen a market mechanism, develop renewable technology, promote export and accelerate industrialization of the renewable energy sector (sophistication).

B. The Current Status of Renewable Energy Supply in Korea

1. Overview of the Renewable Energy Sector

In 2013, the renewable energy supply amounted to 9.879mn TOE in Korea, 3.52 percent of the primary energy supply. The share of renewable energy in the nation's energy portfolio remains low for the following reasons: 1) Korea's renewable energy potential is relatively limited compared to other countries, and 2) the economy is mainly driven by energy-intensive sectors. In total, waste, bioenergy and hydropower account for 90 percent of renewable energy production, while PV and wind energy account for 6 percent.

Figure 9 Penetration Rate of Renewable Energy in Korea

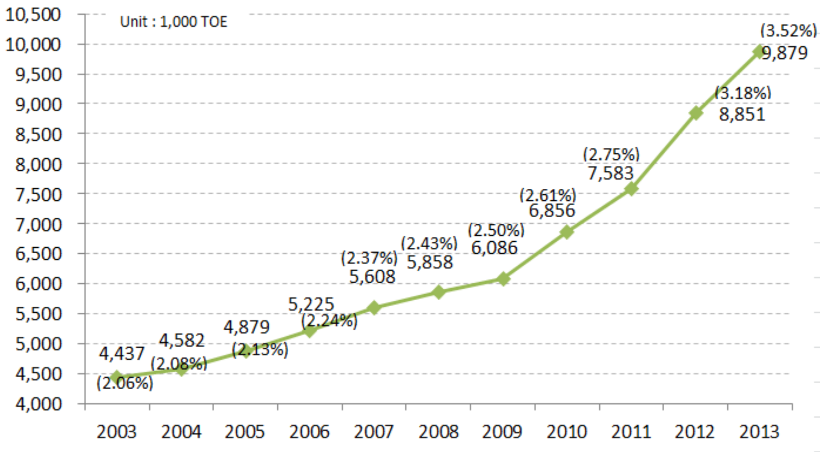
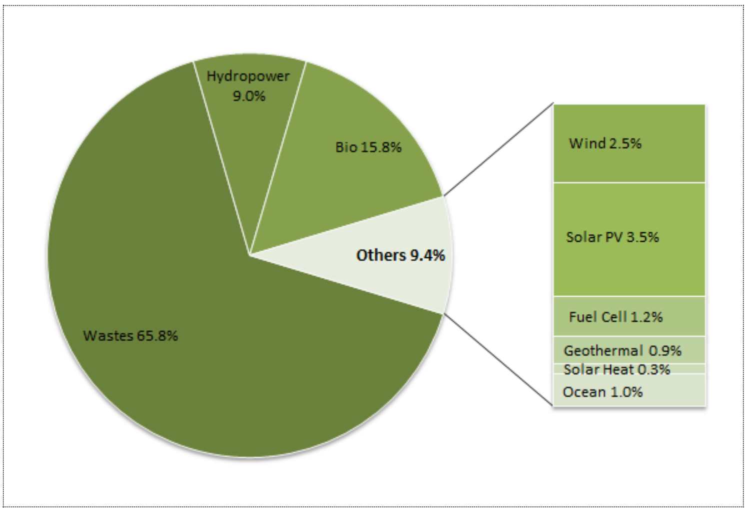


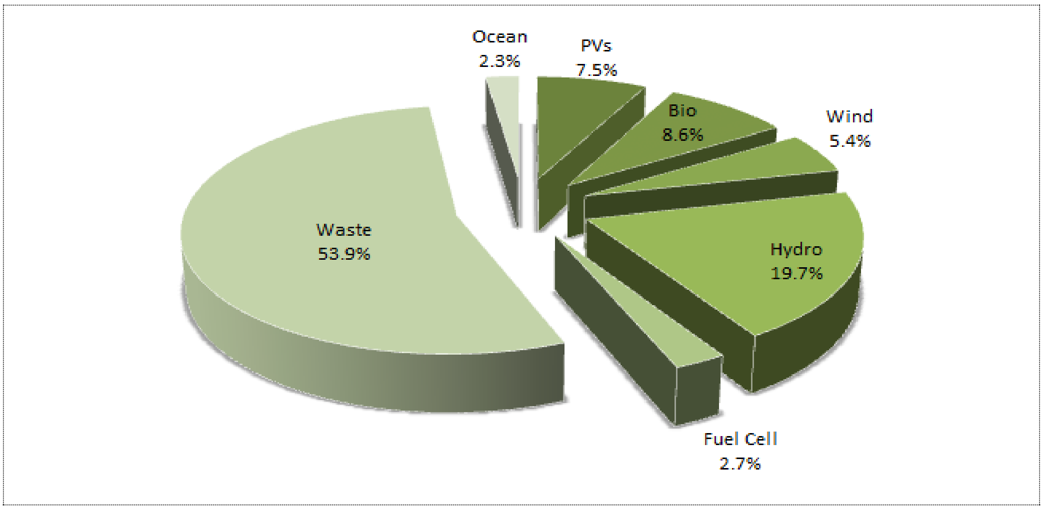
Figure 10 Renewable Energy Mix in Korea (2013)



2. Renewable Electricity Production

In 2013, Korea's gross electricity production from renewables amounted to 21.4TWh, making up 3.86 percent of the nation's total electricity production. Waste and hydropower accounted for 74 percent in the renewable electricity production. Globally, hydropower is the primary source of renewable electricity (81.6 percent). A high share of waste electricity in Korea is attributable to large amounts of industrial wastes in a manufacturing sector-led economy. PV and wind electricity production accounted for 13 percent vs. the global average of 8.9 percent, the OECD average of 18.9 percent and the German average of 54.2 percent.

Figure 11 Renewable Energy Production Breakdown in Electricity (2013)



3. The Renewable Energy Sector in Korea

Increasing supply of renewable energy adds support to economic growth in Korea. Renewable energy producers increased from 134 in 2008 to 200 in 2012 (CAGR 11 percent). Job creation has also increased from 6,496 to 11,836 over the same period (CAGR 16 percent). Revenues expanded at a CAGR of 19 percent from US$3.3bn to US$6.5bn. Exports increased at a CAGR of 10 percent from US$1.7bn to US$2.5bn. The renewable energy sector has emerged as a growth driver of the Korean economy; opportunities are up for grabs for companies, especially for small and medium-sized companies, and the outlook is strong for job creation.

Table 6 Renewable Energy Sector in Korea

	2008	2009	2010	2011	2012	CAGR
Producer (no.)	134	187	209	225	200	11 percent
Job (cumulative)	6,496	10,000	13,149	14,563	11,836	16 percent
Revenue (US$mn)	3,268	4,463	7,663	9,357	6,467	19 percent
Export (US$mn)	1,710	2,130	3,930	4,770	2,520	10 percent
Capex (US$mn)	1,901	2,955	3,537	4,584	1,385	-8 percent

Source: Korea Energy Economics Institute (2014)

C. Renewable Energy Policy in Korea

1. Feed-in-Tariff (FIT)

a. Overview

The Feed-in-Tariff is a policy mechanism under which the government pays the difference between the standard price and renewable electricity price. The FIT mechanism was designed to promote investment in renewables and to strengthen economic feasibility. If renewable electricity is sold at prices lower than the standard price set by the Ministry of Strategy and Finance, the difference will be covered by the FIT program through government compensation. In other words, the FIT mechanism intends to provide a shelter to renewable energy producers with government compensation for the differential between the standard price and SMP (System Marginal Price). The FIT was launched in Korea in October 2001 and was withdrawn in 2012 following the introduction of the RPS.

2. RPS Renewable Portfolio Standard (RPS)

a. Overview

The Renewable Portfolio Standard is a policy mechanism that places regulatory obligations on electricity suppliers to source a certain amount of electricity from renewables. The government introduced the FIT program to strengthen economic feasibility of investment in renewables. The FIT program ended in 2012 and the government launched the RPS program. The RPS program targeted thirteen major electricity producers whose production capacity surpasses 500MW. Electricity suppliers were required to source 2 percent of electricity from renewables in 2012 and are required to supply as high as 10 percent of electricity from renewables in 2024.

Table 7 Yearly RPS Target

(Unit: percent)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Rate (percent)	2.0	2.5	3.0	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0

Source: Ministry of Trade, Industry and Energy (2014)

3. Comparison between FIT and RPS

Weak points of the FIT mechanism include fiscal spending growth, uncertainty of setting the standard price and a dearth of drivers behind market competition. Under the FIT program, the government--not consumers- is responsible of compensation, weighing on the budget. The government has to calculate a standard price every year to set an affordable target, but it was difficult due to a lack of information about renewable electricity production cost. Moreover, government compensation for renewable energy producers resulted in the lagging competition among renewable electricity producers and among electricity suppliers. The renewable energy production capacity growth for 3 years under the RPS program was 300 percent higher than capacity expansion for 10 years under the FIT program. Under the FIT program, renewable energy production capacity amounted to 986MW in ten years. PV production capacity stood at 497MW. Under the RPS program (2012- 2014), renewable energy production capacity amounted to 4,077MW in 3 years. PV plants registered a total of 1,437MW production capacity.

(Unit: MW)

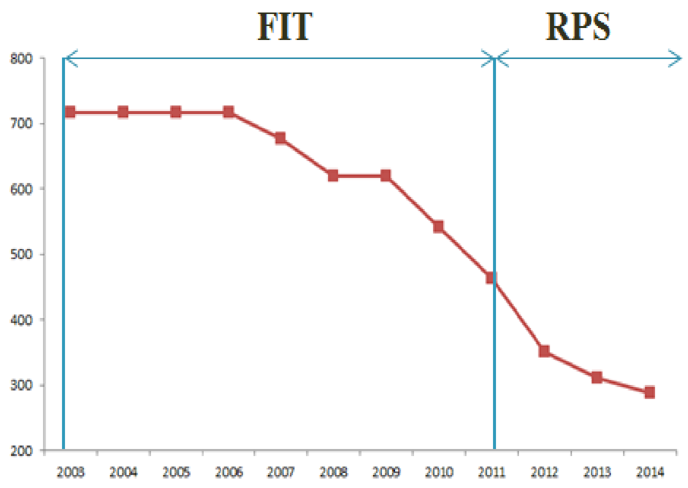
Table 8 FIT and RPS Results

	Renewable energy production capacity	PV production capacity
FIT (2002~2011)	986	497
RPS (2012~2014)	4,077	1,437

Production cost dropped on the back of the PRS mechanism. PV electricity production cost reduced at a CAGR of 4.2 percent under the FIT program. PV electricity production cost dropped at a CAGR of 14.5 percent under the RPS program, and the rate of decline was three times higher with the RPS program.

Figure 12 PV Electricity Price Trends

(Unit: KRW/kWh)



On the negative side, companies failed to meet the RPS target. Companies achieved 65 percent of the RPS target set by the government in 2012 and 67.2 percent in 2013. Consequently, the feasibility of the RPS target came under criticism and reintroduction of the FIT program got some support. The government introduced separate REC multipliers for PV electricity in the reflection of high production cost of PV energy. PV electricity supply topped the RPS target unlike other renewables. Power suppliers stopped supplying PV electricity after meeting a target and therefore raised a flexibility issue of the program.

D. Experiences of Renewable Energy in Korea

1. Difficulties and Limitations of Renewable Energy Supply in Korea

Supply of renewable energy has been limited in Korea due to regulatory measures and unfavorable territorial conditions. Korea's lack of natural resources is one of the biggest contributing factors. 70 percent of its territory is mountainous and the land size is relatively small compared to other countries. Korea's dearth of natural resources means natural conditions, including insolation and wind direction, determine price and quality of renewable energy. Peak insolation (kWh/㎡): Korea 1,100, Germany 1,200 / German metropolitan areas 803, northern Germany 900. Wind energy potential (onshore, TWh/y) is same as Germany 3,200 : Korea 130 = 24.6 : 1.

The policy environment is unfavorable with negatives such as low electricity rates. Electricity price stays lower than production cost in Korea, contributing to a steady increase in fossil fuel consumption. Against the backdrop, the supply of renewable electricity has been weakened. Annual electricity consumption growth (percent) shows following trend: 4.5 (2008) → 2.9 (2009) → 9.3 (2010) → 4.5 (2011) → 2.6 (2012) → 0.8 (2013).

Table 9 Electricity Production Cost by Energy Source

(Unit: KRW/kWh)

Nuclear energy	Bituminous coal	Anthracite	Hydropower	Pumped storage	Oil	LNG	PV	Wind	Bio energy	Small hydro
57.6	63.53	91.12	168.97	183.96	212.65	168.52	213.19	128.80	213.19	128.80

Source: Korea Electric Power's monthly report on major electric power statistics (July 2014)

The renewable energy sector is struggling with the public's resistance due to a lack of consensus on renewable electricity generation. Large-scale wind farm construction projects have faced growing resistance from the neighborhoods and increasing complaints about noise, vibration and high frequency. For example, company "A" received a business permit in December 2005. However, a lawsuit was filed against the company with complaints about noise and shadow flicker. Although the company won the case, the project had been postponed for five years. Company "B" has been in litigation with the local community over revocation of a wind farm business permit since 2007. According to Seoul National University's studies in 2012, 93 percent of the public was in favor of renewable energy production, but Koreans agreed on a monthly rise of KRW 1,500 for electricity rates. On the contrary, in Germany, electricity rates rose at a CAGR of 8 percent in 2008-2012 with increased supply of renewable electricity. There was no significant opposition to a price hike and 61 percent of Germans were in favor of increasing renewable energy production. Green electricity prices in Germany (Euro Cent/kWh) present figures like 3.59 (2012) → 6 (2013) → 8 (2014).

2. Korea's Commitment to Renewable Energy Supply and Challenges

a. Efficient Use of Land

The priority should be increasing renewable energy facilities in places with optimal conditions. Korea’s small land size and mountainous territory support cases for increasing building-mount facilities rather than ground-mount facilities. The government provides more incentives to renewable energy producers for installing facilities on existing buildings. In the case of 3,000kW PV facility installation, the government gives 1.0 REC for ground-mount facilities and 1.5 RECs for building-mount facilities. PV facility installations on water surface are eligible for additional incentives. The government gives 1.5 RECs for PV facility installations on water surface.

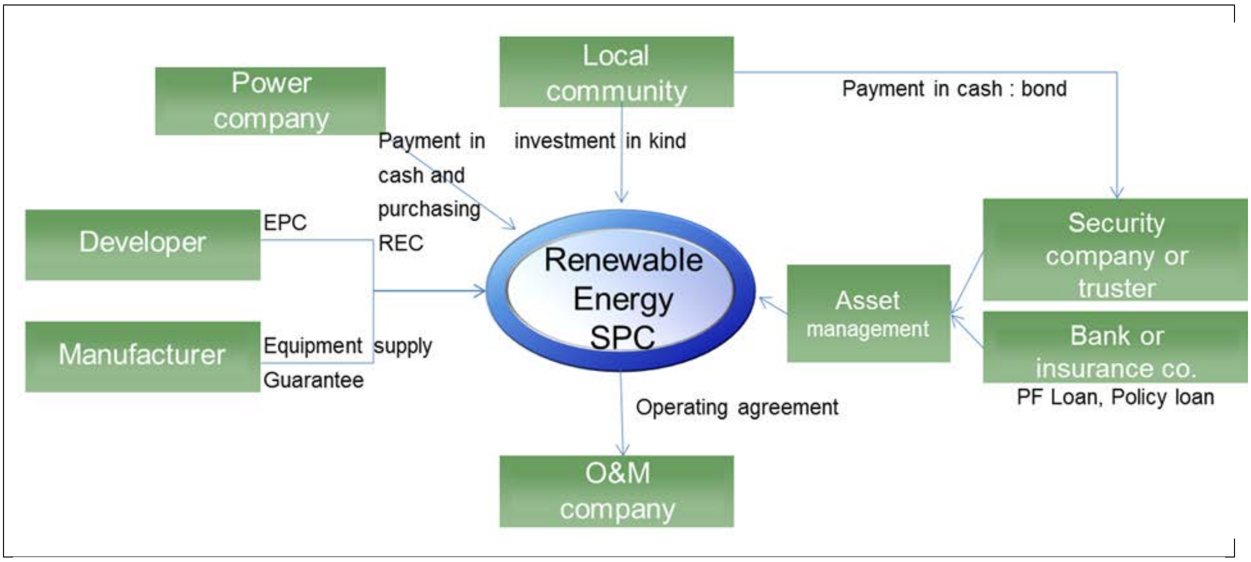
b. Energy Self-Sufficient Project in Island Areas

The SMP price remains high in off-grid communities in island areas, adding a financial burden to residents. In off-grid communities in island areas, electricity production cost, mostly from diesel generators, is 4-14 times greater than electricity rates. Off-grid communities in island areas can open a new frontier through convergence of different industries, including renewables and the local industry (tourism). Renewable electricity, including wind and PV, should be provided in advance to communities where SMP price is relatively high such as Jeju Island.

c. Profit Sharing with Local Communities

A benefit sharing mechanism has been introduced to enhance acceptance of renewables and to help increase income. Profits will be shared with residents living within a 5km radius of generators. There are four stakeholders of Business structure. First one is Local community which Invest cash and land lease. Next developers support design, construction and installation of power plants and facilities. Third one is Electricity producer. They are in charge of Investment and REC purchase. Finally, financial institutions carry out assistance for contractors and invest management and profit guarantee. In more details, financial institutions engage in contracts with contractors to guarantee security of investment. A professional entity (crowd funding operator) is involved in attracting investment from residents.

Figure 13 Profit-Sharing Business Structure



d. Intermittent Renewable Energy Sources and Grid Stability Issues

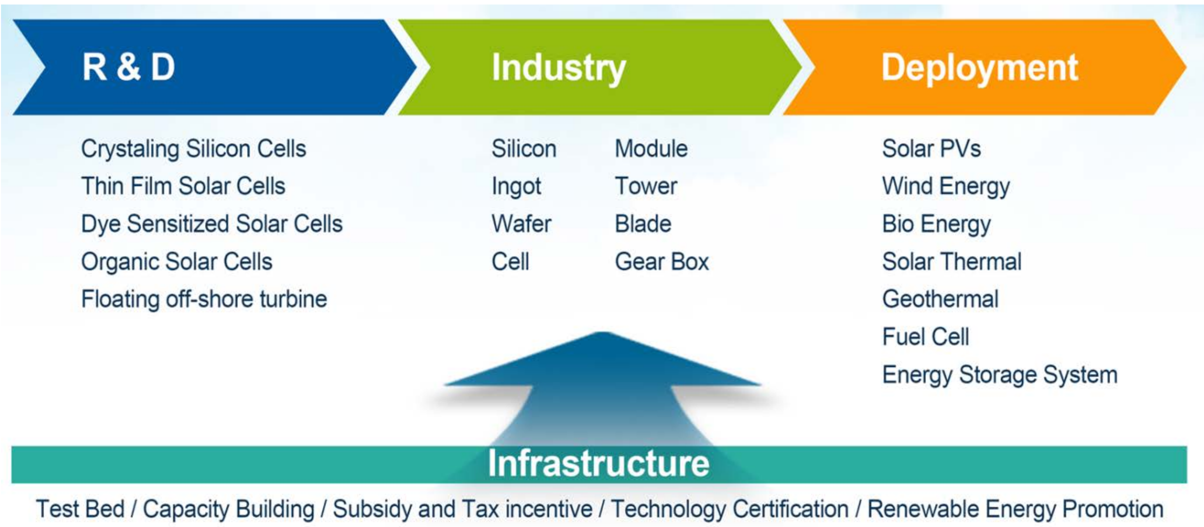
Grid stability will be maintained if the share of electricity from intermittent energy sources, including PV and wind, in total electricity supply remains around 10 percent. According to the IEA's report in 2014, six regions in its research were found to have maintained grid stability after the share of intermittent renewable energy rose to 25 percent. Under the most pessimistic scenario, grid stability was protected, while the share of intermittent renewable energy in energy supply amounted to 5-10 percent. Lawrence Berkeley National Laboratory found in 2010 that the power grid system operated well while sourcing 13 percent of electricity from wind energy. According to GE Energy's research in WestConnet in 2010, there was no disruption in supply when the share of intermittent renewable energy rose to 10 percent. In Korea, the share of PV and wind electricity amounts to 0.5 percent of the total electricity generation, and the government aims at 7.5 percent in 2035. Therefore, grid stability issues should be put aside. Electricity storage system holds the key for grid stability in off-grid communities such as island areas. In off-grid areas, the share of renewable electricity is high. Therefore, ESS is necessary to stabilize output and voltage fluctuations.

In Korea, electricity sales are prohibited if it is supplied from power facilities with the production capacity less than 10kW. Net-metering is allowed. Net metering refers to the method of accounting for electricity production, under which the excess electricity produced from renewables is fed into the grid, and vice versa. Electricity produced from facilities with production capacity topping 10kW is available for sales. The law is under revision to raise production capacity standard to 75kW or higher in the reflection of huge cost burdens related to electricity sales (subscription fee, annual membership fee, commissions and a device for monitoring sales volume).

3. Korea's Suggestions to LAC Countries

It has been perceived in Korea that renewable energy development is based on creating a virtuous circle between Research and Development (R&D), industrial policy, dissemination policy and infrastructure. In other words, supply-oriented energy policy would not contribute significantly to decrease a high level dependence on costly imported energy any more. R&D should lead to expand not only domestic renewable energy deployment but related industry and export. Renewable energy infrastructure should also play a key role to support R&D, industry, and deployment of renewable energy. Each sector of the virtuous circle in Figure 8 has a different role for renewable energy development.

Figure 14 System for Renewable Energy Development



First, the main strategy for renewable energy technology R&D is to develop a basic technology and an application technology with different way. At the beginning step of technology development, it is desirable to set up the basic technology in university research labs and government institutes, aiming for securing and industrializing core technology within 10 years. Since then, it is necessary that private enterprises develop application of the technology.

Secondly, in the industrial policy, providing financial support and tax relief is the most important things to improve industrial competitiveness of domestic technology. Because renewable energy industry is uneconomic and its market is still in the early stage, the government support is essential. In order to strengthen competitiveness of the domestic industry, therefore, companies need easy access to project finance and tax incentives to reduce costs.

Third, deployment policy is to focus on illustrating and diffusing domestically developed renewable technology. For example, wind-power generation usually require a 100year*turbine level ‘track record’. Prior to build generation, domestic turbine technology should be demonstrated and evaluated.

Lastly, the integrated governance system is necessary to be consistent in carrying out a renewable energy policy. Reestablishing a role between organizations involved in renewable energy is primary step. Next step would be formed a continuous consultative group and a special organization to ensure an active and successful implementation of renewable energy policy. It is also significant to reinforce manpower in research, management, production and technical work by training renewable energy experts. Furthermore, technology certification service is urgent to secure reliability and internationalize industry standards. In addition, government can promote renewable energy to increase public acceptance for renewable energy deployment.

V. Conclusions

This report presents the analysis of experiences in sustainable energy development in Korea. The objective of this paper is to analyze and document specific development experiences related to sustainable energy development in Korea, to participate in the exchange of relevant lessons with one or more partner organizations in Latin America and Caribbean Countries (LAC), and to participate in presentations and discussions of the learning that emerged from those experiences, in order to:

- Provide policy-makers in both LAC and Korea with a broader range of sound policy options on development, including lessons related to promoting innovation and entrepreneurship in these areas.
- Share know-how regarding design and/or implementation of select policies, foster greater effectiveness.
- Promote partnerships between Korea and organizations in LAC, individuals, entrepreneurs, and businesses.

In addition, the report focused on the issues related to energy efficiency, smart grid, and renewable energy policy in Korea. We summarize them as follows:

- In view of Korea's high dependency on energy imports (96 percent), improving energy efficiency is of fundamental importance.
- Overview of energy efficiency and smart grids implementing mechanism and policy trends over time in Korea.
- Adjusting or reforming energy tax rates are necessary for stable funding since financing has been one of the major obstacles for energy efficiency investment in Korea.
- Establishing a demand management system based on approaches such as Smart grids is an efficient way. Smart grids facilitate real time, two-way communication between electricity producers and consumers and by doing so save electricity, supply renewable energy and support the electric vehicle sector.
- The foundation for commercialization of Smart grid was laid through the establishment of Jeju Smart Grid Test Bed, including development of Advanced Metering Infrastructure (AMI), Energy Management System (EMS), Energy Storage System (ESS) and other key technologies.

- A new Smart grids business eco-systems can be created in Smart Cities. Promoting new businesses in areas such as smart grid and renewable energy will create a new growth engine for economic growth.
- Korean experiences to solve the problems in renewable energy deployment will be useful to LAC countries. Korea has unique system focusing on R&D, commercialization, industry and infrastructure which are connected with virtuous circles.
- Overview of renewable implementing mechanisms and policy trends over time in Korea and achievement of implementation on renewable energy including policies and programs such as FIT, RPS and other.
- Challenges and implications to meet renewable target on future energy mix in Korea.
- Integration of intermittent renewable energy into electricity network.
- Providing emerging and innovative approach to promote renewable energy in Korea.

Reference

GE Energy. 2010. “Western Wind and Solar Integration Study”, NREL/SR-550-47434. Golden, CO: NREL.

IEA. 2012a. World Energy Indicators.

IEA. 2012b. World Energy Outlook.

IEA. 2014. “The Power of Transformation-Wind, Sun and the Economics of Flexible Power Systems”

KEEI. 2013a. Korea Energy Handbook.

KEEI. 2013b. “The Development of the Mid- and Long-term Strategies of Energy Demand Management and the Sectoral Energy Saving Policies”.

KEEI. 2013c. Yearbook of Energy Statistics.

KEEI. 2014a. “The Fourth Basic Plan for New & Renewable Energy Technology Development, Application, and Deployment”.

KEEI. 2014b. “The Fifth Energy Use Rationalization Basic Plan”.

KEMCO. 2011. Korea Energy Management Corporation Homepage.

KOREA SMART GRID ASSOCIATION. 2012. “The Study of Smart Grid AMI Technology”

KOREA SMART GRID INSTITUTE. 2010. “The Case Study of Smart Grid in Global Context”

KOREA SMART GRID INSTITUTE. 2012. “The Study of Smart Grid and Energy Policy for LAC Regions”

LBNL. 2010. “Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation”, Lawrence Berkeley National Laboratory, LBNL-4142E.

Lee, C.Y., 2014. “A Study on Community Renewable Energy Power in South Korea”, Korea Energy Economic Institute Research Paper.

MOITE. 2014. Ministry of Trade, Industry and Energy Homepage.

MOITE. 2012. “The Road Map for Deploying Smart Grid”