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Smart Grid and Its Application in Sustainable Cities

RG-T2058

Yuri Lee
Juan Roberto Paredes
Soo Hyun Lee

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http://www.iadb.org

Juan Roberto Paredes, Renewable Energy Specialist (jparedes@iadb.org)

Soo Hyun Lee, Energy Specialist (soohyunl@iadb.org)

Abstract

The Energy Division of the Infrastructure and Environment Sector (INE/ENE) of the Inter-American Development Bank has launched a technical cooperation project called "Smart Grid and Its Application in Sustainable Cities" to aid countries in the Latin American and Caribbean (LAC) region. This technical note describes smart grid system elements, indicates their costs and benefits, discusses the smart grid initiative in Korea, and includes the case study of the Korean Jeju Island test bed. The publication assesses the possibilities to transfer and implement these strategies in Latin American and Caribbean (LAC) cities and discusses ongoing experiences in the region.

JEL Codes: Q2, Q3, Q4

Keywords: Korea, Latin America and the Caribbean, Smart grid, Renewable resources, Energy

Table of Contents

List of Figures

List of Tables

Introduction

The Energy Division of the Infrastructure and Environment Sector (INE/ENE) of the Inter-American Development Bank (IDB) has launched a technical cooperation (TC) project called "Smart Grid and Its Application in Sustainable Cities" (TC #RG-T2058) to aid countries in the Latin American and Caribbean (LAC) region. The Knowledge Partnership Korea Fund for Innovation and Technology (KPK) is providing the financial resources for its execution.

1.1. Objective of Technical Cooperation

The objective of this TC is to impart knowledge in the field of smart grid technologies to LAC countries under the framework of the Energy Innovation Center of the Energy Division of the IDB, launched in April 2011.

With support from experienced Korean policy and decision makers, representatives from the public and private sectors and academic world of the LAC region will be able to develop specific strategies to deploy smart grid systems under local conditions. Many policymakers in the region and private clients of the IDB will receive the latest information on state-of-the-art smart grid technologies. The TC will help policymakers from IDB member countries develop country-specific strategies to adopt a smart grid system that is suitable for their respective energy situations and stages of industrial development.

1.2. Background

The LAC region is facing a series of challenges in the energy sector. Energy consumption in the region's countries goes hand in hand with economic growth and thus presses countries to increase their generation, transmission, and distribution capacities to ensure the availability of energy, that is, energy security. Countries are facing challenges to increase their energy efficiency and the share of renewable energy in their energy matrixes. Energy security, energy efficiency, and renewable energy are central to the future of the region's energy sector.

Integrating renewable energy into existing networks poses significant challenges. Addressing them will require not only regulatory changes, but also the introduction of a holistic approach to the way that end-users and their grids manage their energy usage. Countries such as Italy and South Korea have been adopting new distribution models that promote demand-side management in order to increase energy efficiency and allow the introduction of renewable energy. These concepts require a new distribution system that responds more accurately and flexibly to changes in energy demand management and a change in the current concept of the unidirectional network, that is, making grids smarter.

Regarding smart grid applications, there are numerous options with varying levels of sophistication. However, standard among all applications are advanced communication technologies that enable better usage of the assets of existing power systems and consumer access to a wide range of services. A smart grid implies the combination of electrical and telecommunication infrastructure.

Most smart grids have certain defining features. A smart grid provides an interface between consumer appliances and the traditional assets of power generation, transmission, and distribution. This two-way communication allows consumers to better control their energy appliance usage. A smart grid will also optimize the power system assets. For example, due to communication during peak load periods and the likely consumer response to price signals, peak loads will be reduced.

This TC will help the IDB not only to offer policy recommendations aimed at smart energy infrastructure in strategies related to sustainable development in member countries, but also to develop investment loans and policy-based loans related to energy systems. A large amount of funding will be needed to guarantee the actual application of smart grid systems in LAC countries. As a case in point, with 168 companies and 12 consortia participating, the Jeju Island smart grid test bed in Korea is a large-scale project with a total investment of US$239.5 million. The Korean government invested US$69.5 million and the private sector US$170 million. All participating companies were selected through an open-bid process, while the government selected the consortia members. This test bed includes a smart grid system fully integrated with existing electricity infrastructure.

The role of the IDB could be essential in providing financial resources to facilitate the adoption of the smart grid system in the LAC region. The result of this TC will help the IDB to find specific areas of investment in the smart grid system in collaboration with its member countries.

1.3. The Workshop

The International Smart Grid Communication Korea-LAC workshop and training activities were held from April 24–26, 2012, in Jeju, South Korea. Workshops were organized with 24 participants from 13 LAC countries, 77 participants from the Korean government, and Korean participants who were taking part in the smart grid test bed in Jeju Island. The Korean government's policy regarding smart grids was presented, and Korean private participants explained their products and technologies deployed in the test bed. The Korean private participants included LG electronics, SK telecom, KEPCO, POSCO, and KT, some of which have already developed smart grid guidelines for policymakers in charge of the design of sustainable cities and corresponding sustainable energy modules.

1.4. Structure

This technical note describes smart grid system elements, indicates their costs and benefits, discusses the smart grid initiative in Korea, and includes the case study of the Korean Jeju Island test bed. The publication assesses the possibilities to transfer and implement these strategies in LAC cities and discusses the ongoing experiences in the region. It will be distributed to the ministries in charge of sustainable cities and sustainable energy and electricity utilities in the LAC region.

2. Smart Grid

2.1. Smart Grid Definitions

The U.S. Department of Energy defines smart grids as “a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers—mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users’ homes and offices” (energy.gov 2012).

The International Energy Agency (IEA) defines smart grids as follows: "A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids coordinate the needs and capabilities of all generators, grid operators, end-users, and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience, and stability" (IEA, 2011).

The Korea Smart Grid Institute states that "Smart Grid refers to the next-generation network that integrates information technology into the existing power grid to optimize energy efficiency through two-way exchange of electricity information between suppliers and consumers in real time" (Jeju SGTB, 2012a).

2.2. Benefits

Smart grids improve energy efficiency, provide a solution to climate change, and serve as an economic growth engine (Jeju SGTB, 2012a). To improve energy efficiency, smart grid technology optimizes electric power demand and supply management, minimizes electricity loss between power plants and consumers, and saves electricity. Due to reduced peak demand, related costs of building new power plants can be avoided as well. As a solution to climate change, smart grids generate lower greenhouse gas emissions through improved efficiency and use of clean renewable energies. As of December 2011, the total worldwide installed capacity for renewable energy was 565 GW, wind energy capacity 239 GW, small-hydro 184 GW, biomass and waste-to-energy 57 GW, solar 73 GW, geothermal 11 GW, and marine 0.6 GW (Pew Charitable Trusts, 2011). Smart grid technologies will improve the integration of this renewable energy capacity into existing and new grid infrastructure while creating new jobs for the industry as well.

2.3. Major Smart Grid Initiatives by Country

This section provides selective major smart grid initiatives by country, including smart grid policies and pilot projects. Smart grid initiatives in Korea will be described in Chapter 3.

2.3.1. United States

Policies	• 2003 – "Grid 2030," the nation's transition to smart grid technology.
	• 2007 – Energy Independence and Security Act of 2007 (EISA 2007).
	  o Smart Grid Demonstration Program (SGDP): regional smart grid and energy storage demonstrations.
	  o Smart Grid Investment Grant Program (SGIG): grant for electric grid modernization.
	• 2009 – American Recovery and Reinvestment Act of 2009 (ARRA): US$4.5 billion allocation for grid modernization (IEA 2011).
	  o US$3.48 billion for the quick integration of proven technologies into existing electric grids.
	  o US$435 million for regional smart grid demonstrations.
	  o US$185 million for energy storage and demonstrations.

Pilot Projects	• 2007 – New Jersey: Public Service Electric and Gas Company (PSEG) complete time-of-use (ToU) and critical peak pricing (CPP) tests using regular households. • 2007 – Oregon: General Electric and the Public Utility Commission of Oregon (PUCO) install 805,000 smart meters. • 2008 – Maryland: The Baltimore Gas and Electric Company implements a critical peak rebate (CPR) system for four months with a test pool of 1,000 households. • 2008 – Colorado: Xcel Energy announces 100M USD smart grid project. • 2008 – Washington DC: The PowerCentsDC™ smart meter pilot program implements ToU, CPP, and CPR using a test bed of 1,200 household consumers. • 2008 – Dallas, TX: The Center for the Commercialization of Electric Technology (CCET) and TXU Energy chooses consumers to test Peak DR Direct Energy and Reliant Energy. • 2009 – Florida: Miami plans to install one million wireless smart meters (Fehrenbacher, 2009). • 2012 – Massachusetts: 15,000 households in Worcester targeted for a US$45 million investment plan over the next two years (Pilon, 2012). • As of 2011, 152 demonstration projects and 60 implementation projects performed in 45 states. 140,000 programmable communication thermostats (PCTs) and 5 million smart meters installed nationwide (energy.gov 2011).

Sources: Korea Ministry of Knowledge Economy (2010); Hashmi (2011); Jeju SGTB (2012a); KSGI (2012b).

2.3.2. Canada

Policies	• 2006 – Canadian Electrical Code 2006 – Amendments includes smart grid. • 2007 – The Ontario Energy Board mandates to upgrade to AMI. • 2009 – Economic Action Plan (Canada Budget 2009) includes smart grid. • 2009 – Energy Future: Infrastructure, Changes, and Challenges to 2020. • 2009 – Green Energy Act by Ontario, a comprehensive government policy action.
Pilot Projects	As of March 2012, 4.3 million homes in Ontario had installed a smart meter (Jenkins 2012). By 2013, British Columbia plans to install smart meters for all customers.

Sources: Popescu, Roberts et al. (2010); KSGI (2012b).

2.3.3. European Union

Policies	• 2006 – Smart Grids Vision and Strategy
	    o 2007 – Selects five strategic research areas.
	    o 2008 – Selects six strategic smart grid implementations.
	• 2008 – Climate and Energy Package: Three 20 Targets adopted as EU goals by 2020: reduce greenhouse gas emissions by 20 percent, save 20 percent of EU energy consumption, and derive 20 percent of the EU's total energy consumption from renewable energy.
	• 2008 – (Spain) Mandatory replacement of existing meters with new smart meters (IEA, 2011).
	• 2009 – (UK) The British Department of Energy and Climate Change (DECC) and the Office of Gas and Electricity Markets (Ofgem) publish an UK smart grid route map (Electricity Networks Strategy Group 2010).
	• 2009 – (France) Energy Environment Public Corporation (Agence de l'Environnement et de la Maîtrise de l'Energie, or AMDE) created a French smart grid roadmap (Gioria, 2009).

Pilot Projects	• Italy – From 2000 to 2005, the Telegestore project invested EUR 2.5 billion to deploy 31 million smart meters and more than 100,000 automated distribution substations. In 2011, as a result of continuous effort after Telegestore's actions, eight tariff-based funded projects were awarded for advanced network management and automation. EUR 200 million were granted to demonstrate smart grid technologies and modernize the network in Southern Italy (IEA, 2011). • Spain – EUR 24 million invested to the DENISE smart grid program from 2007 to 2010. The utility Endesa will deploy automated meter management for over 13 million customers by 2015 while the utility Iberdrola will install 10 million (IEA, 2011). • Germany – E-Energy Mission invests EUR 60 million to smart grid projects

	eTelligence, EDeMa, MOMA, MEREGIO, and RegModHarz in 2008. • England – £500 million invested to implement smart grids in four cities in 2009. • France – EUR 4 million committed to smart grid technology by 2012 and deploy over 350,000 smart meters by 2017 through the LINKY project. • Netherlands: The Netherlands' Amsterdam Smart City project aims to install clean and intelligent electric vehicle charging stations in 300 locations and increase renewable energy usage percentage by a third.

Sources: Korea Ministry of Knowledge Economy (2010); Jeju SGTB (2012a); Jeju SGTB (2012b).

2.3.4. Australia

Policies	• 2004 – The Essential Service Commission of Victoria, Australia, releases the updated Electricity Customer Metering Code and the Victorian Electricity Supply Industry Metrology Procedure to require interval meters for 2.6 million Victorian customers as well as a paper entitled Mandatory Rollout of Interval Meters for Electricity Customers to announce the timeline's completion by 2013 (Hashmi, 2011). • 2009 – $100 million Smart Grid, Smart City project announced by the government to be the first commercial-scale smart grid in Australia (Hashmi, 2011).

2.3.5. China

Policies	• 2007 – Consolidated Energy Policy declaration "China's Energy Conditions and Policies" (IEEE Smart Grid, 2012). o Rationalize power grids. o Strengthen regional power grids and power transmission and distribution networks. o Develop an emergency response system for power safety and reliability. o Strengthen power demand-side management (DSM). o Exert control over power use for the purpose of conserving energy and increase energy utilization efficiency. o Reinforce the Renewable Energy Law and priority policies for renewable energy electricity. o Renovate rural grid. • 2009 – Strengthened Smart Grid Plan. • 2010 – 12th Five-Year Plan for National Economic and Social Development (FYP) (2011–2015). o Further Development of the power grid. o State grid investments will exceed RMB 17 billion.

	o 15 percent of energy will come from non-fossil fuels by 2020 (APCO Worldwide, 2010).

2.3.6. India

Policies	• 2003 – Electricity Act of 2003: To improve efficiency and capacity of power generation and distribution. o Power distribution: a key issue. o 12 percent energy growth rate per year. o Transmission and distribution line losses average 26 percent of total electricity production, with some states as high as 62 percent. Losses are as high as 50 percent if non-technical losses such as energy theft are included. o Financial loss: 1.5 percent of national GDP and growing steadily. • 2007 – Power for All plan: requires an additional 1TW of capacity by 2012. India plans to expand its power infrastructure by over 100 percent by 2020 to meet the growing demand (UPI, 2007). • 2008 – The National Action Plan on Climate Change: emphasizes solar power.
Pilot Projects	• 2009 – Initiated partnerships with Google and PowerMeter to implement Google's smart meters in major cities such as Mumbai and Delhi (Pahwa, 2009).

Sources: Hashmi (2011); KSGI (2012b).

2.3.7. Japan

Policies	• 2008 – ¥20 billion invested in renewable energy including solar and wind energy. o Integrate solar power generation with microgrid. o Solar power generation target: 34GW (2020), 100GW (2030). • 2009 – Establishment of Technology and Development (T&D) roadmap. • 2009 – Investment plan of ¥30 billion for smart grid technologies including smart meters. The Federation of Electric Power Companies of Japan plans to complete incorporation of solar power to smart grid by 2020.
Pilot Projects	• Promoting smart grid standardization with private corporations; demonstration projects to increase solar power on 10 islands. • 2007 – Many microgrid demonstration sites under operation including Ota-City. • 2009 – Establishment of demonstration site of next generation power transmission and distribution lines. • 2009 – Toshiba, the Tokyo Electric Corporation, and the Tokyo Electric

	Power Company work together to develop and install smart meters for the Tokyo Electric Power's service area starting in 2013. • 2010 – Smart pilot cities (2010–2014) for four selected cities: Yokohama, Toyota, Kansai, and Kita-Kyushu: plans to deploy 2,000 EV in Yokohama and 3,100 in Toyota by 2014.

Sources: Korea Ministry of Knowledge Economy (2010); Jeju SGTB (2012a); Jeju SGTB (2012b).

2.4. Smart Grid Market Trends

The Korea Institute of Science and Technology Evaluation and Planning (KISTEP) (Park and Yong, 2011) identified several major technology and market trends. Smart grid cyber security threats are emerging, and the automated distribution as key smart grid applications and technologies are beginning to trend as well. In Europe and China, smart meters, or advanced metering infrastructure (AMI), are being actively deployed. The market for demand response technologies is expanding, and the importance of data management capabilities is growing. Telecommunications companies are entering smart grid projects in earnest and the action is expanding to the gas sectors.

Pike Research, LLC (Asmus, Lockhart et al., 2012) also identified imminent technology and market trends. They have determined that "architecture" will become a new buzzword in the smart grid technological field as the importance of smart grid design and construct comes into the mainstream. In addition, Pike acknowledged that the intersection of distribution automation and AMI is soon to come. The smart meter deployment phase will also make way for its application phase in order to fully utilize the technology, as microgrids similarly move from blueprints to reality. Pike Research mentioned cyber security threats as well, going along with KISTEP's analysis, and determined cyber security failure risks to be unavoidable. Pike also identified that Asia Pacific's interest in adoption of smart grids and smart grid technologies will continue to flourish. Dynamic pricing will be a debatable topic among different consumer groups, and consumer pushback over smart meters will remain. Activities on home area networks (HAN) will be slowly revisited. In the U.S. market, the stimulus spending on smart grid from ARRA of 2009 will not only generate productive results but concerns as well.

3. Smart Grid in Korea

3.1. Korea's Smart Grid Initiative Background

South Korea has recently emerged as an international inspiration for efficient and healthy energy use through its utilization of smart grid technologies (KSGI, 2012c). President Lee Myung-Bak formally ushered in smart grid technology as a seminal part of South Korea's efforts to convert its economy to become more eco-friendly and efficient by announcing the "Green Growth, Low Carbon" national vision in August 15, 2008, the 60th anniversary of the Republic of Korea's founding.

In November 2009, the Presidential Committee on Green Growth, one of the nation's leading advisors on the smart grid initiative, announced the country's target CO_2 emission reduction for 2020. They released the national vision "Building an Advanced Green Country" and detailed the plans for smart grid execution in a national roadmap. The committee made this roadmap with the viewpoint and expertise of those in the industry, academia, and research institutes. They aimed to reduce the estimated level of CO_2 emission in 2020 by 30 percent despite South Korea's reputation of having the highest rate of growth of greenhouse gas emissions in the Organization for Economic Co-operation and Development (OECD). From 1990 to 2005, South Korea's emission rates doubled. A Five-Year Plan is in motion to promote green growth by regulating carbon prices through a cap-and-trade scheme.

The national smart grid project is part of the effort to gradually transform the nation's economy and society into ones that are low in CO_2 emissions and more resilient to climate change. In addition, this project is set to be the framework for a revival of the Korean economy. In December 2009, the government selected consortia and signed a contract for the Jeju smart grid demonstration project. The smart grid test bed in Jeju Island serves not only as a focal site for groundbreaking tests and research in the field of smart grid technology, but also to demonstrate South Korea's dedication to this new technology and method of shaping a green-growth nation. This green-growth-oriented mindset can be seen in the Korean government's implementation of policies and projects that reflect the public's support through their cooperation.

In January 2010, Korea released its national smart grid roadmap. A large-scale smart grid demonstration was set in motion to serve as a platform to establish smart grid technologies as an operational and key manner of raising Korea's energy efficiency. The national smart grid roadmap details the nationwide integration of smart grids by 2030, which will save US$47 billion from current energy imports. Furthermore, smart grid-related fields can create up to 50,000 new jobs per year and thus boost the nation's market economy by US$74 billion. What smart grids can bring to the table for South Korea can lead the country's economic development for the next 20 to 30 years. The Korea Smart Grid Institute (KSGI) was created to smooth the transition to a smart grid-oriented nation, the. The KSGI functions as Korea's international agent in initiating smart grid projects and its domestic facilitator of smart grid policies and deployment. The Smart Grid Stimulus Law was enacted in May 2011 and put into effect on November 25 of the same year.

3.2. *The Korean Government's Role and the Smart Grid Policy*

This section is a summary of content from Korea MKE's Smart Grid Roadmap (MKE, 2010).

3.2.1. Technology Development and Commercialization

<table>
<tr><td colspan="2">[Goals]
Develop technologies through their full life cycles, including initial development, standardization, and commercialization.
Propel domestic trade and advance overseas support to create new growth.</td></tr>
<tr><td>Smart Grid core technology development support</td><td>Provide a national support system for renewable power generation, energy storage technology fundamental for electric vehicles, core technology for smart power grids, and security technology.
Energy storage, bi-directional power transfer, security, and development of a core technology development plan will be the focus from 2010 onward.
Key Steps: 1) smart metering system, DC distribution, security, and the like; 2) electric vehicle charging, self-recovering grids, and the like; and 3) large-capacity storage devices.
Core technology development plan that includes security elements and system development.
Security technologies: power distribution network integrated security, mutual authentication device, real-time encrypted communication system.
Secure consistency with green policy by developing technologies related to electric vehicles and renewable energy.
The First National Energy Plan (August 2008).
Renewable Energy Master Plan (December 2008).</td></tr>
</table>

	o Electric Vehicle Industry Activation Plan (October 2009). • Focus on long-term budget commitments to the development and commercialization of related technologies; support private investments in near-term activation. o A new feature of the Jeju test bed was empirical support for early commercialization of the technologies. o Necessary strategic technology alliances with foreign countries and international joint research are being established.
Enabling support for the domestic market	• Establish a smart grid pilot city in 2011 to test and demonstrate the low carbon, green-growth ideology. o The proven technologies and the resulting products and business models demonstrated in the Jeju test bed were used to set a national standard and would receive support with higher priority. A registration and certification system for good business models was developed in parallel. • Promote products with high potential for commercialization, such as electric vehicles, their chargers, automatic meter reading (AMR)/in-home display (IHD), and electric power storage devices. o Regulation and system for technology development and market activation were developed in parallel.
Support for overseas expansion	• Host international conferences regarding the Jeju test bed and operate experiences facilities for overseas opportunities. o 2010: International Conference on Smart Grids (Smart Grid Association). o The demonstration facility was opened before to the G20 Summit in 2010 to establish a foreign market. • Execute Mutual Recognition Agreements with countries that have large investments in the power sector to resolve technical barriers to trade. • Boost the potential export market in developing countries through supporting programs akin to the smart grid climate partnership in East Asia.

3.2.2. Market Support for Successful Products and Business Models

<table>
<tr><td colspan="2">[Goals]
Spread and promote successful byproduct models of the Jeju test bed.
Activate companies' investments and provide incentives for voluntary citizen participation.</td></tr>
<tr><td>Creation of successful models from the Jeju test bed</td><td>Perform demonstrations in the areas of smart place (consumers), smart transportation, and smart renewable led by private companies since 2012.
Establish a process to reflect the results of the national roadmap demonstration.</td></tr>
<tr><td>Support market creation for new technology and products</td><td>Introduce certification system for smart products and provide incentives for purchasing.
Introduce certification system for smart building with AMI systems and smart appliances.
Building Code Article 66, Section 2 – building energy efficiency rating certification system added.
Introduce R&D tax credit for key technological development such as electric vehicles (2012).
Enhance efficiency and renewable energy generation (2012).
Deploy energy storage devices (2015).
Purchase strategic products for market creation.
One million Green Home supply businesses, demand management projects, and smart home projects.</td></tr>
</table>

3.2.3. Infrastructure

<table>
<tr><td colspan="2">[Goals]
Provide aggressive incentives to accelerate infrastructure deployment in early stages.
Establish standardization and certification systems.
Build pool of experts to advance foreign market.
Build security system for smart grid implementation and operation.</td></tr>
<tr><td>Accelerate core smart grid infrastructure deployment</td><td>Invest US$1.25 billion for smart meters and a two-way communication system to support the mandatory installation of smart meters by 2020.
Begin construction of grids capable of bi-directional power transmission (2013).
Apply empirical results from 10 Power IT tasks and intelligent power grid pilots.</td></tr>
</table>

<table>
<tr><td></td><td>

Implement early deployment of charging infrastructure for the seamless deployment of electric vehicles.

Installation of electric vehicle fast charging stations from 2011 onward at service stations, LPG filling stations, public institutions, and large supermarkets.
20 pilot EV chargers in 2011, 100 in 2012, 200 by 2013, and 400 by 2014.
Until 2014, the government will fund the electric vehicle chargers and the private sector will fund operations.
First half of 2010: KEPCO, with infrastructure, installers, and electricity vendors, played necessary roles to support electric car charging infrastructure placement.

</td></tr>
<tr><td>Building standard and certification systems</td><td>

Support for early international standardization and commercialization of smart grid technology and products.

2010: Interoperability Guidelines provide standards.
International commercialization and export support through testing and certification from accredited organizations.

Promote private sector-led standards forums for standard strategies.
Operate Smart Grid International Standards Activities Support Program.

IEC/ISO and other international standards-related professional activities and meetings.
Working Group of international standards at Major Economic Forum (MEF) smart grid field.

Train specialists on smart grid research and development, installation, maintenance, and international standards.

Specialists on technology integration between power and IT.
International standard setting and standards-related activities.

</td></tr>
<tr><td>Building security systems</td><td>

Announce the smart grid security guidelines in 2010.
Support for a national smart grid security system.

Design security architecture supporting national smart grids.
Ensure a secure grid of operations through appropriate security for smart grid technology development.
Anomaly detection via power grid controls systems security.

Establish and manage smart grid security standards and certification.

</td></tr>
</table>

	- Interoperability security standards among various products and technologies. - Smart grid security compliance certification for the maintenance of security and authentication of technologies developed.

3.2.4. Policy and Regulation

[Goals] • Perform early drafting and revision of relevant laws and regulations for convergence between industries to enable new industries and markets. • Establish new legislation for stability of long-term projects.	

Revise related legislation	• 2010: Smart grid deployment and support special law.
	  o Legal foundation for incentives such as financing and tax incentives to accelerate efficient deployment of smart grid.
	  o Industry development plans and committee operations, infrastructure, incentives, pilot city operations, information on protection and security, certification, and funding.
	• Revise the Electricity Act and parking and housing laws for permits and regarding charging station safety.
	  o EV charger safety standards, legal status and power station operators trading standards, station installation, among others reflected by the Electricity Act and regulations for parking and housing-related laws.
	  o Research project on billing system for charging electric vehicles in 2010.
	• Establish policy for energy storage devices to support microgrid systems. As defined by the Microgrid Exchange Group (DOE, 2011), "A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."
	• Set operating rules, terms, and conditions to define the price and supply of the electricity power by consumers who sell surplus energy.

Phased introduction of tariffs in real time	• Switch the current electricity bill system to a cost-based fee system to save power consumption and raise consumer awareness. o Support for vulnerable groups through social consensus based on the general fund budget or the power industry. • Develop a variety of optional rate plans to empower customer choice and conserve power.

	o Real-time Pricing (RTP), Time to Use (ToU), Critical Peak Pricing (CPP), among others. o Based on a flexible electrical plan founded through the empirical success of the Jeju test bed. • Develop different tax rate for EV charger services. o Additional tax for charging electricity to assist commercial charger investment. o Exclusions of the progressive tax rate for residential electricity rates for slow chargers.
Preparing a stable power supply	• Plan for power supply facility expansion to prepare for the development of renewable energy and electric vehicles. o 2010: establish fifth-generation expansion planning. • Establish an emergency power supply system in 2012 in case an electric car-charging grid surges in load. • Introduce intelligent electricity management system.

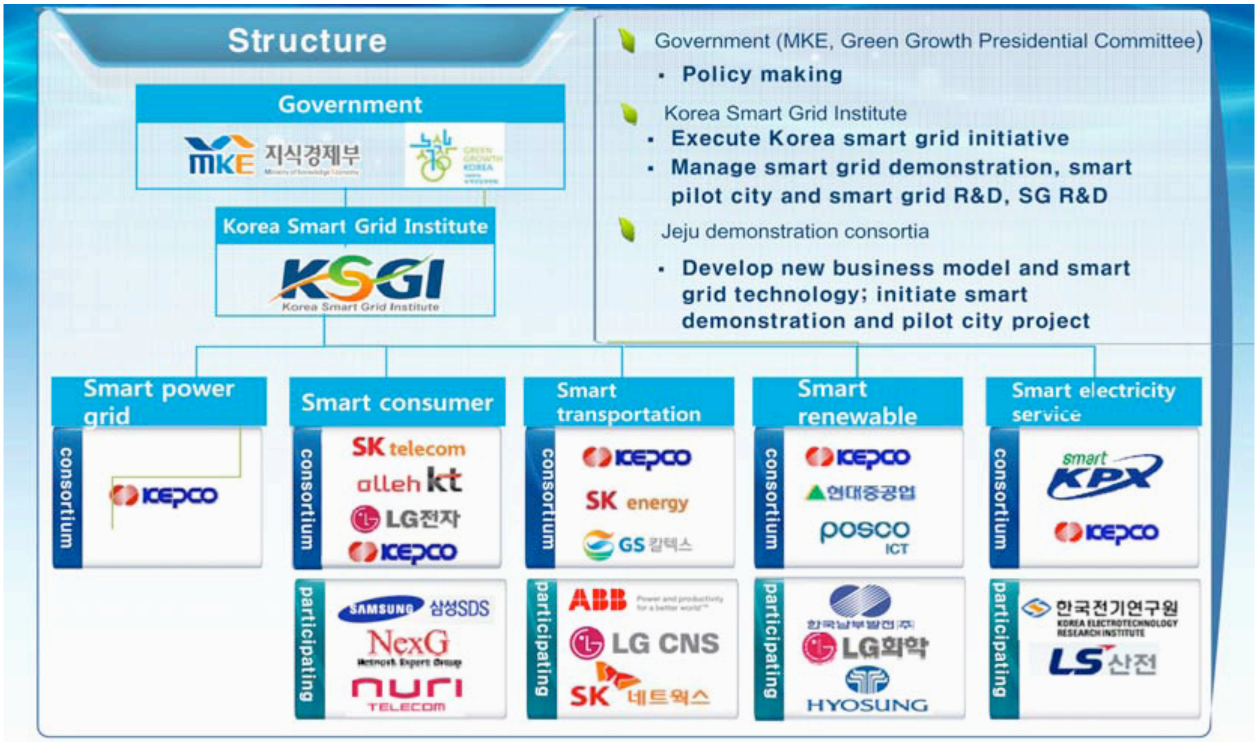
3.3. Korea's Smart Grid Organizational Structure

South Korea's Ministry of Knowledge Economy (MKE) regulates economic policymaking in the energy and industrial sectors. The currently active MKE is a consolidation of many of Korea's former ministries: Commerce, Industry, and Energy, Information and Communication, and Science and Technology. In May 2011, it enacted the Smart Grid Deployment and Utilization Law and provided the framework for smart grid implementation.

The Korea Smart Grid Institute (KSGI) (KSGI, 2012c) was formed in August 2009 to administer Korea's smart grid initiative and related projects. The KSGI's duties include executing Korea's Smart Grid Initiative and managing smart grid-related demonstrations, pilot cities, and R&D. A major responsibility of the KSGI is heading the management of Korea's Smart Grid Roadmap while updating outdated electric power systems. In keeping with the roadmap's vision, the KSGI develops smart grid test beds and pilot cities; policies linked to smart grids also receive support from the KSGI. The KSGI explores conjunctions of electric power and information technology; coordinates collaboration between industry, academia, and research institutes; and works both domestically and internationally to ensure standardization of security and certification in the smart grid field.

The Jeju Island smart grid demonstration received support from and was attended by about 170 renowned Korean companies. These consortia members lead the demonstration in its five domains: smart power grid, smart consumer, smart transportation, smart renewable, and smart electricity service (Figure 1). Members are developing new business models and smart grid technologies thanks to their participation in the Jeju smart demonstration and pilot city project.

Figure 1. Korea Smart Organizational Structure



Source: KSGI (2012c).

3.4. Korea National Smart Grid Roadmap

3.4.1. Overview

During the workshop in April 2012 in Jeju, Korea, MKE shared its current National Smart Grid Roadmap. The vision for the roadmap is that "the smart grid will establish a platform for low-carbon green growth." The roadmap lays out three phases and five domains (Figure 2). The five domains are smart consumer, smart transportation, smart renewable, smart power grid, and smart electricity service. Phase 1 will focus on demonstration and commercialization from 2012 to 2013, which includes the Jeju test bed and smart pilot cities, such as the one in Jeju City, and various selected cities in Korea from 2013 to 2016. Phase 2 will focus on spreading smart grids to other urban areas in Korea until 2020. Phase 3 will focus on the nationwide deployment of smart grids until 2030.

Figure 2. Korea Smart Roadmap

Source: Yang (2012)

Table 1 provides expected benefits from Korea's smart grid initiative.

Table 1. Korea Smart Grid - Expected Results

Area	Results
New job creation	50,000 jobs per year by 2030
Greenhouse gas reduction	230 million tons by 2030
Saving in energy import	US$40 billion by 2030
Export increase	US$42 billion by 2030
Domestic market increase	US$64 billion by 2030
Saving on avoiding new power plant construction	US$3 billion by 2030

Source: Korea Ministry of Knowledge Economy (2010).

3.4.2. Investment Plan

Table 2 provides the total investment plan for each phase of Korea's Smart Grid Initiative.

Table 2. Korea Smart Grid Investment Plan - Total

Area		Phase 1	Phase 2	Phase 3	Total
Government	EV charger	6	211	-	216
	In-home display	17	33	-	51
	Energy storage	-	132	-	132
	EV	9	26	-	35
	Technology development	171	631	1,123	1,925
	Subtotal	203	1,033	1,123	2,359
Private sector	Smart meter	274	961	-	1,235
	In-home display	-	172	287	459
	Communication infrastructure	218	953	16	1,187
	EV charger	-	193	3,973	4,166
	Renewable energy	-	2,684	4,884	7,568
	Service establishment	26	257	261	543
	Power grid	135	553	1,578	2,267
	Technology development	195	988	2,963	4,146
	Subtotal	848	6,762	13,962	21,572
	Total	1,052	7,795	15,085	23,931

Source: MKE (2010).
Note: UNIT: US$ millions.

Table 3 shows detailed investments for technology development.

Table 3. Korea Smart Grid Investment Plan for Technology Development

Area	Phase 1	Phase 2	Phase 3	Total
Smart Place (Consumer)	35 AMI technology development	160 AMI system establishment	478 Bi-directional electricity trade	673
Smart Transportation	122 Pilot charging infrastructure	563 V2G and virtual power plants technology	1,680 EV and charging service commercialization	2,365
Smart Renewable	28 RE power generation platform	130 RE stable integrated operation	388 Large scale RE infrastructure	546
Smart Power Grid	70 Power grid infrastructure	320 City-scale PG implementation	956 Nationwide PG implementation	1,345
Smart Electricity Service	59 Demand utilization infrastructure	273 Diversified electricity service	464 Electricity trade total system	796
Standardization and Certification	28 Infrastructure	81 System establishment and operation	102 International standard	211
Security	24 Architecture and components	93 Interoperability and control	17 Advanced security	135
Total	366	1,619	4,086	6,071

Source: MKE (2010).
Note: UNIT: US$ millions.

3.4.3. Roadmap for the Five Domains

Table 4 presents the goals of the five domains in each phase.

Table 4. Korea Smart Grid Roadmap for the Five Domains

	Phase 1 (2012–2016)	Phase 2 (–2020)	Phase 3 (–2030)
	Demonstration and commercialization and smart pilot city	Wide deployment of smart grid	Completion of project at the national level
Smart Power grid	• smart power distribution operating system • testing and certifying smart power facilities/systems	• digital substation • smart power distribution • Wide Area Monitoring and Control System (WAMS/WACS) • smart power equipment /machines	• total smart grid engineering • energy consulting
Smart Consumer	• Home Area Network HAN • reception portal • smart metering • smart home electronics • green homes • Home Energy Management System HEMS	• green buildings • green IDC • green factories • Building Energy Management System (BEMS) • Factory Energy Management System (FEMS)	• AMI application system
Smart Transportation	• battery, Battery Management System • power train (motor, inverter, etc.) • charging infrastructure • small-scale electric vehicle (EV)	• Vehicle to Grid (V2G) Power Conversion System (PCS) • V2G system • mobile asset management system (AMS) • medium and bulk EV	• Electric Vehicle (EV) Virtual Power Plant (VPP) • advanced EV system
Smart Renewable	• renewable power generation coordinating and stabilization systems • operating equipment/	• facilities/equipment to ensure stable coordination of bulk renewable power generation	• coordinating facilities/equipment for smart renewable power generation • microgrid system

	machines for low-voltage microgrid • power conversion systems/equipment for small-scale power storage facilities	• operating facilities/ equipment for power distribution and substation microgrid • substation facilities/ equipment for medium and bulk power storage	
Smart Electricity Service	• Real-time Pricing (RTP) demonstration project • Demand Response (DR) management project	• real-time DR market • smart power market • power derivatives	• integrative power market • inter-nation power trade

Source: KSGI (2012c).

3.5. Power IT Projects Linked with Smart Grid

Korea's 10 Power IT projects (KSGI, 2012a) aim to turn electric power devices, systems, and technologies in a digital, intelligent, and environment-friendly direction by creating high value-added for electric power services and forging a relationship between electric power technology and information and communication technology (ICT). Power IT is backed by the Power IT National Program and shows Korea's dedication to taking advantage of the electric industry's potential and boosting the economy. Another priority of the program is to revolutionize the field of electric power services and thus raise the standard of such services. The 10 Power IT projects were chosen from a technology development program set up in 2005. The Smart Grid Initiative became associated with the Power IT projects in February 2009, marking the projects as a major part of Korea's Green Growth strategy and vision. The industries marked for improvement by the Power IT National Program and the Smart Grid Initiative will play key roles in the country's economic growth through implementation of the 10 chosen projects by capitalizing on the possibility of adding value to electric power services.

The following are short descriptions of the 10 Power IT Projects.

- Development of Korean Energy Management System:
  - Operate electric power systems using IT solutions to localize and commercialize the energy management system; this program can give Korea the technologies needed to establish an energy management system.
- Development of Intelligent Transmission Network Monitoring and Operation System:
  - Use IT to maximize power transmission facility efficiency and create a risk management system against malfunctions and natural disasters.
- IT-based Control System for Bulk Power Transmission:
  - Develop an Optimal Flexible Alternating Current Transmission System (FACTS) by incorporating IT and local technology into the power system.
- Development of Prototype for Advanced Substation Automation System based on the Digital Control Technology:
  - Develop integrated IT solutions for digital substation operations and integrate electric power devices and systems.
- The Development of Power Equipment Monitoring System using Active Telematics:
  - Build an active telematics system for remote monitoring and diagnosis of power systems and develop measuring technology, sensor equipment, and communication technology that transmit information on results to a regional control center (RCC) and national control center (NCC).
- Development of Intelligent Distribution Management System:
  - Develop an intelligent distribution system for facility management function from substations to customer premises.
- Development of Power Line Communication (PLC) Ubiquitous Technology:
  - Roll out an integrated, broadband network to electric power facilities and develop application technology.
- Power Semiconductor for Dispersed Generation and Industrial Inverter Application:
  - Design and manufacture an Insulated Gate Bipolar Transistor (IGBT).
- Development of integration EMS for the microgrid and application technology to real site:

- Develop modulated and standardized component devices and the design, interpretation tools, and EMS of microgrids.

- Consumer Portal System for IT-based Energy Services Business:
  - Develop a consumer portal system that will be the multiservice platform for the convergence of electric power technology and ICT.

4. Jeju Smart Grid Test Bed in Korea

4.1. Test Bed Overview

The Jeju smart grid test bed is South Korea's premier smart grid project. It encompasses the goals and hopes for the nation's future in smart grid technological advancement and employment opportunities. The location was decided in June 2009 and in December of the same year, the Korean government created consortia to begin the construction of the test bed. The Jeju test bed will be the leader in both size and scope as a smart grid community not only within South Korea, but in the rest of the world as well. It will be the largest in the world (KSGI, 2012c) and thus will allow researchers and developers to fully test and develop new smart grid technologies by integrating them with existing electricity infrastructure. The Jeju smart grid test bed is supported by the Korean Government, the Korea Smart Grid Institute (KSGI), the Korea Electric Power Corporation (KEPCO), the Jeju Special Autonomous Province, the Korea Smart Grid Association, companies joining consortia, various research institutes, and the academic world (KSGI, 2012e).

Basic Information and fast facts (Yang, 2012) about the Jeju smart grid test bed include:

- World's largest scale smart grid test bed
- Schedule: December 2009 to May 2013 (first 18 months to build infrastructure, next 24 months to test the integrated operation of smart grid)
- Total investment: US$200 million (Korean government: US$50 million and private sector: US$150 million)
- Location: Gujwa-eup, Jeju Island (185 km^2, 6,000 households).
- Completed: Phase 1 of the demo project, Gujwa-eup
- On-going: Phase 2, Jeju City (July 2011-May 2013)

Features (Yang, 2012):

- Integrated test bed
- Close collaboration between public and private sectors
- Verification of different power market models
- Open to foreign companies

Participants (Yang, 2012):

- Korean Electric Power Corporation, automakers, telecommunications companies, and home appliance manufacturers (including major companies such as LG, SKT, KT and Samsung); 168 companies, 12 consortia

Timeline (Yang, 2012; KSGI, 2012e):

- December 2004: set out comprehensive measures for electric power IT
- December 2008: established test bed for Power IT
- April 2009: initiated restructuration and expansion of the smart grid demonstration project
- June 2009: selected Jeju as the smart grid test bed location
- November 2009: selected lead organizations for the Jeju smart grid test bed project
- December 2009: selected participating consortia and sign agreement for the demonstration project
- May 31, 2010: one-year anniversary
- June 1, 2011: started Phase 2 of project
- May 2013: completion of the Jeju smart grid demonstration project

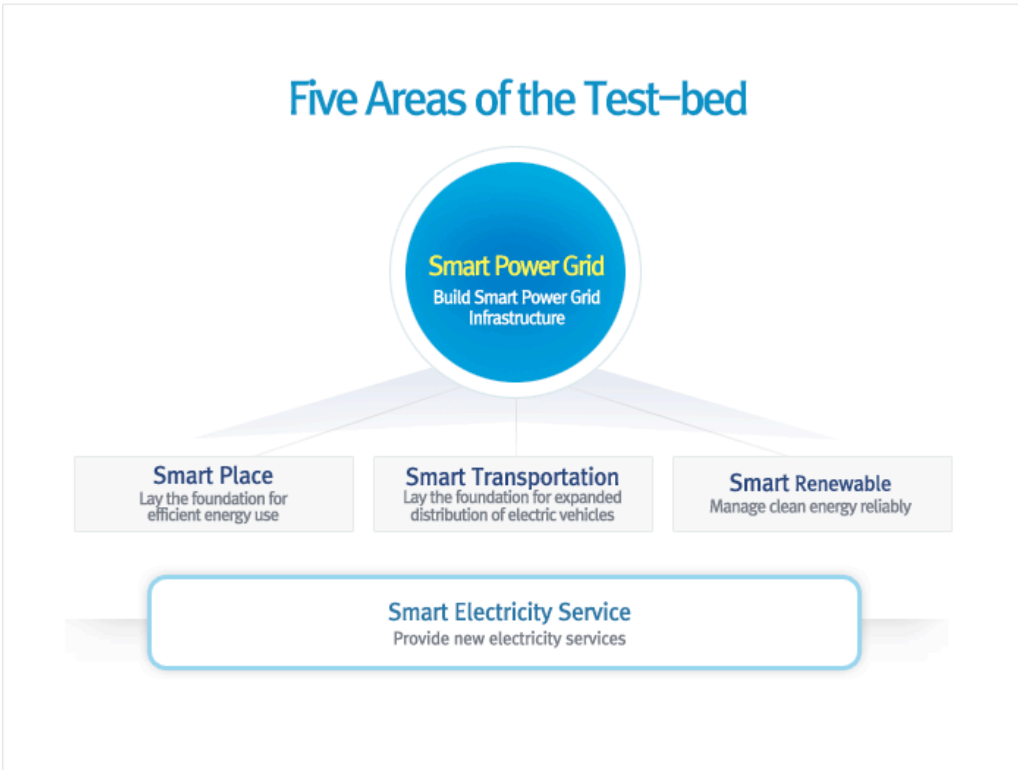
4.2. Test Bed Vision and Goals

The Jeju smart grid test bed is designed to be the biggest and most advanced of its kind. The vision and goals attached to the test bed, primarily focused on the commercialization and development of the viability of smart grid technologies, matches its magnitude (KSGI, 2012d).

The three strategic directions can be divided into national, industrial, and individual standpoints. From the national standpoint, improving energy efficiency and reducing greenhouse gas emissions by building a green energy infrastructure is the main goal. The industrial standpoint will use the rise of the age of green growth as a driving force in the nation's economic development by securing a new growth engine, and the individual standpoint will raise quality of life and consumer satisfaction through voluntary participation in a low-carbon, green lifestyle.

4.3. The Five Domains of the Jeju Smart Grid Test Bed

Figure 3. Five Areas of the Jeju Smart Grid Test Bed



Source: Jeju SGTB (2012j).

The following is an overview of the five domains of Smart Grid in Jeju (KSGI, 2012c).

Smart Place (Smart Consumer): This domain will use the Advanced Metering Infrastructure (AMI) system to reduce needless energy usage and increase its overall efficiency. In doing so, the smart place domain will create and continue to provide a two-way communication energy management system between consumers and suppliers. By 2012, South Korea plans to advance the AMI system and develop a standard for the system. The nation will also commence a large-scale, national smart meter rollout by 2020 and save up to 10 percent more energy than currently through its adoption of smart grid technologies and models.

Smart Transportation: The smart transportation domain aims to establish EV charging infrastructure on a national level and allow consumers to charge during both peak and low-demand hours and re-sell their personally stored energy. By 2012, electric vehicle parts and materials will be developed while a vehicle-to-grid (V2G) system will be implemented by 2020. Possible business models emerging from these developments include an EV and battery rental service and an EV operating management system. An end goal with 2030 as its deadline is to deploy near 2.5M EVs and install infrastructure with the capacity to charge 2,714 EV.

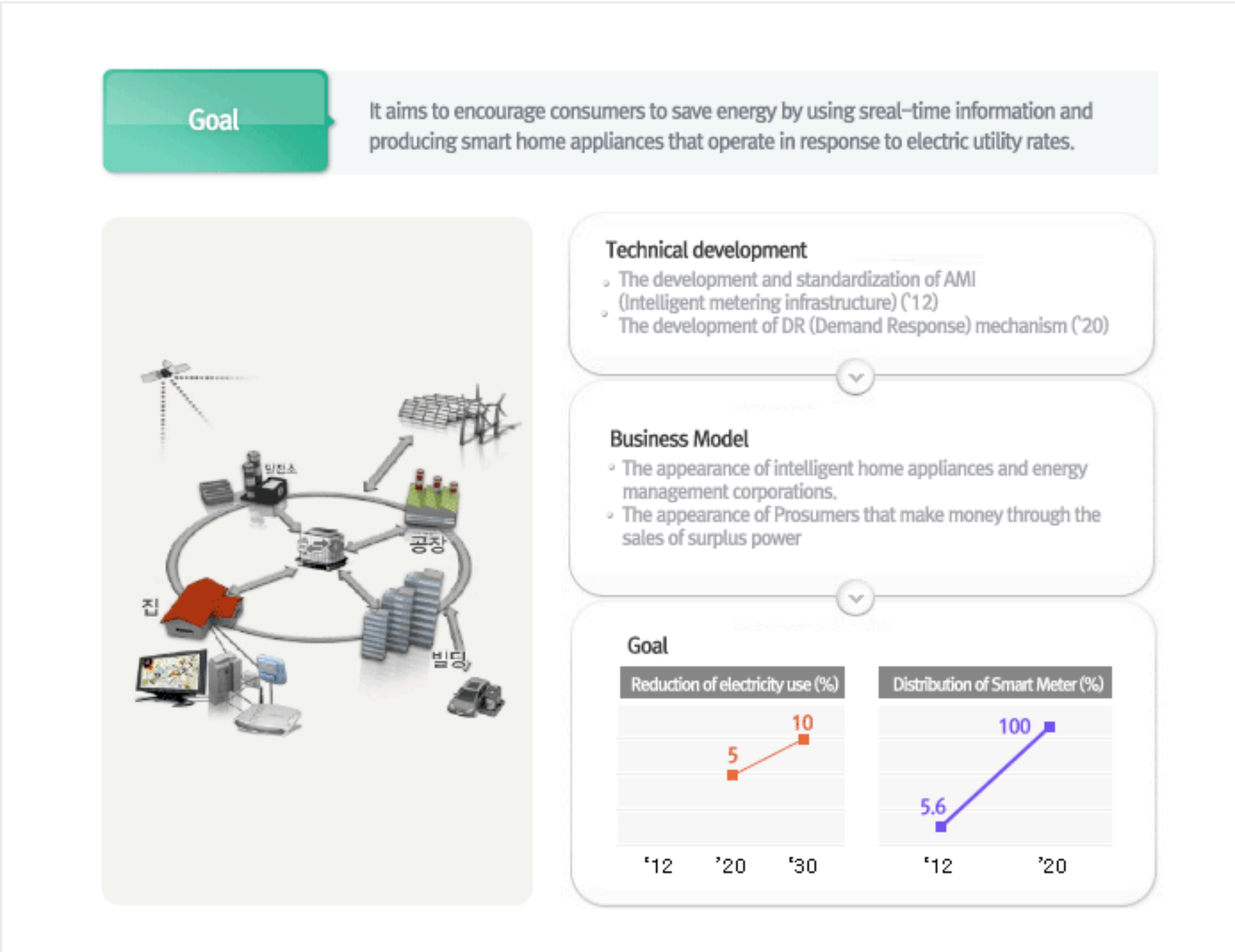
Smart Renewable: Korea's National Smart Grid Roadmap announced the smart renewable domain's goals as creating large-scale renewable energy generation power plants and building green buildings and homes that are energy-independent through their usage of renewable energy. Renewable energy is crucial to reducing greenhouse gas emissions. Key technological developments include a system that helps solve renewable source intermittency problems and an energy storage system for bulk generation from similar sources. South Korea also plans to launch business models that address both the production and sale of renewable energy as well as export of energy storage systems. By 2030, the country plans to increase renewable energy usage by 11 percent and zero net energy buildings by 30 percent.

Smart Power Grid: This domain is in charge of testing distribution and transmission systems while developing a self-automated recovery system. Business models expected to emerge from the smart power grid domain include a testing and certifying system for smart grid technologies and products and the export of these technologies and products.

Smart Electricity Service: The smart electricity domain plans to encourage consumer participation in such services by implementing active pricing rates and an online system for power exchange and by-products. The real-time pricing and demand response system should be set up by 2012, while the online system is due to be launched in 2020.

4.3.1. Smart Place (Smart Consumer)

Figure 4. Five Areas of Jeju Smart Grid Test Bed, Smart Place

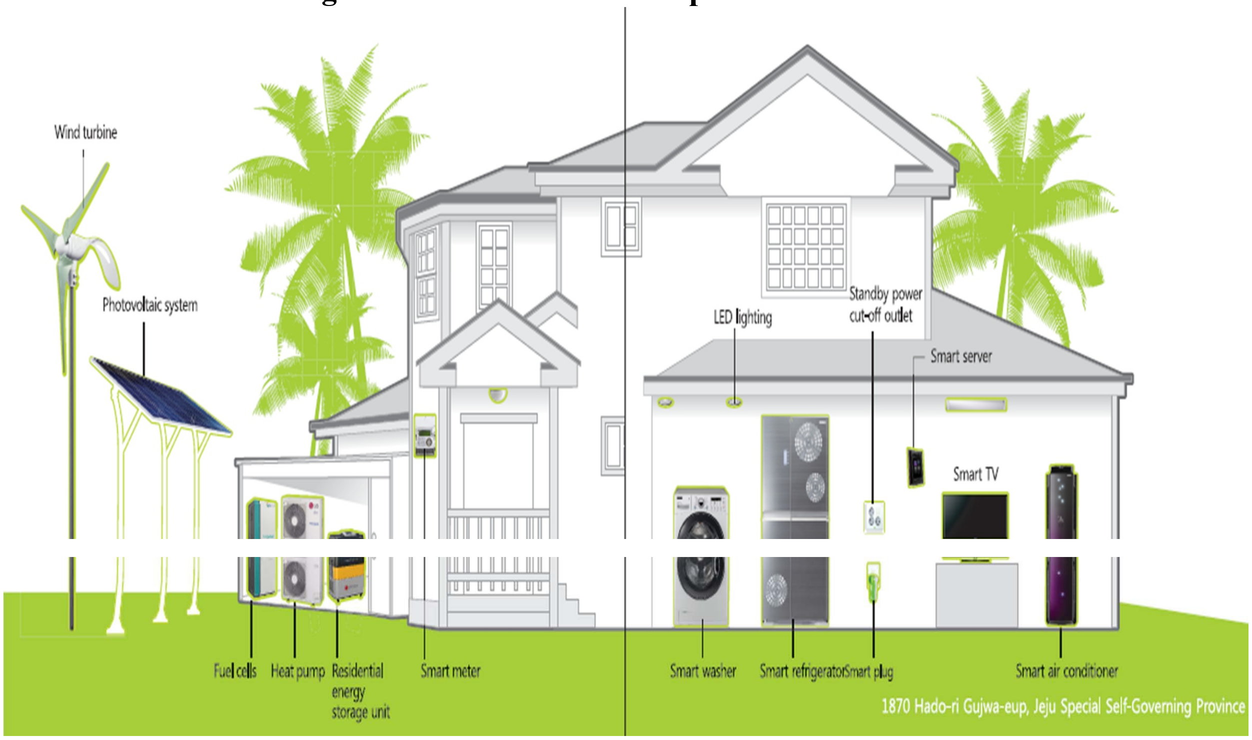


Source: Jeju SGTB (2012g).

LGE Consortium, KT Consortium, KEPCO Consortium, and SK Telecom Consortium are participating in Smart Place. As one of consortia, LGE Consortium verifies business models for customer-oriented energy efficiency. Their pilot project residential area includes 412 households, museums, elementary schools, factories, and warehouses. The LG Smart Grid showroom offers the following:

- A unique smart grid showroom with accommodation and experience
- World-leading verification of international standard compatibility by ZigBee certified appliances
- A consumer-oriented, automated system with customer convenience and lifestyle in mind
- Zero carbon technology by smart home appliances

Figure 5. LG Smart Place Experience Showroom



Source: LG Electronics (2012).

Table 5 provides descriptions and energy savings of Smart Place products, which can be found at the LGE Consortium's experience showroom illustrated in Figure 5. Home Area Network (HAN) architecture connects ZigBee certified home appliances and other products via existing internet networks (Ryoo, 2012).

Table 5. Smart Place Products

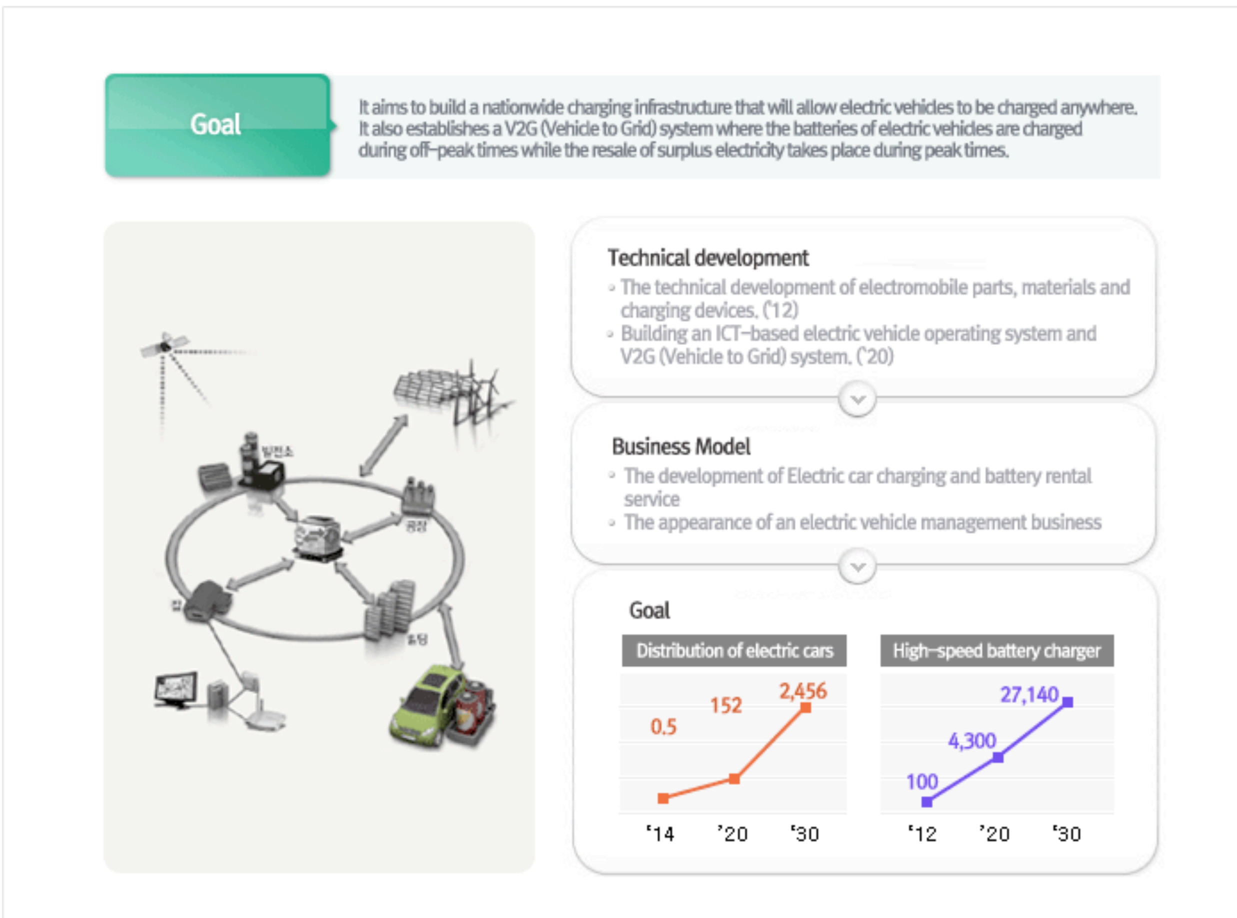
Products	Descriptions	Energy Savings
Smart Server	Smart grid operator controlling a household's energy usage	Saving 10 percent on electric bills per year
Smart TV	Device automatically configuring sleep mode and allowing viewing of a home's entire energy situation at once	Saving 11 percent on electric bills per year Reducing 10Kg of CO_2 per year
Smart Refrigerator	Prudent refrigerator that is always prepared	Saving 11 percent on electric bills per year Reducing 20Kg of CO_2 per year
Smart Washer	A washer scheduling washing with automatic notices of low electric price	Saving 11 percent on electric bills per year Reducing 20Kg of CO_2 per year
Smart Air Conditioner	Smart air conditioner	Saving 11 percent on electric bills per year Reducing 15Kg of CO_2 per year
LED Lighting	Energy-efficient smart lighting	Saving 30–80 percent of energy per year Reducing 7Kg of CO_2 per year
Heat Pump	Heating and cooling device utilizing natural air energy instead of gas or oil	Heating & cooling capacity: 14kW Energy reduction: 2.8toe per year (2.2 ton CO_2reduced)
Photovoltaic System	Smart photovoltaic generator converting sunlight into electrical energy	Peak output power: 15kW Generation: 19MWh per year (11.5tons CO_2 reduced)
Wind Turbine	Smart wind generator converting cool wind into electrical energy	Peak output power: 2kW Generation: 1.2MWh per year (1.7tons CO_2 reduced)
Standby Power Cut-off Outlet	Power line communication outlet disconnecting standby power device by sensing whether or not home appliances are in use	Saving 10 percent on electric bills per year
Smart Meter	Meter measuring real-time energy consumption	Saving 15 percent on electric bills per year
Smart Plug	Standby power plug type tab saving electric bills and blocking energy usage	Saving 15 on electric bills per year
3 Screen UI	Dynamic UI finding household energy information from anywhere at any time through smart phones, IPTV, and web portals	Induce energy savings by providing energy usage data
Residential Energy Storage Unit	Next-generation energy storage unit for efficient energy utilization	Maximize energy efficiency by distributing stored energy
Microgrid	Independent energy island built through	Economy and efficiency in energy

Place	an integrated control and operation of distributed generation and heat sources applied with renewable energy	consumption
Smart Grid Energy Management Center	Management and monitoring of regional conditions, power demands, power generation, electricity price, demand response, and major operations data	Real-time energy savings through CO_2 information provision of power usage and Demand Response reduction and renewable generation

Source: LG Electronics (2012).

4.3.2. Smart Transportation

Figure 6. Five Areas of Jeju Smart Grid Test Bed, Smart Transportation



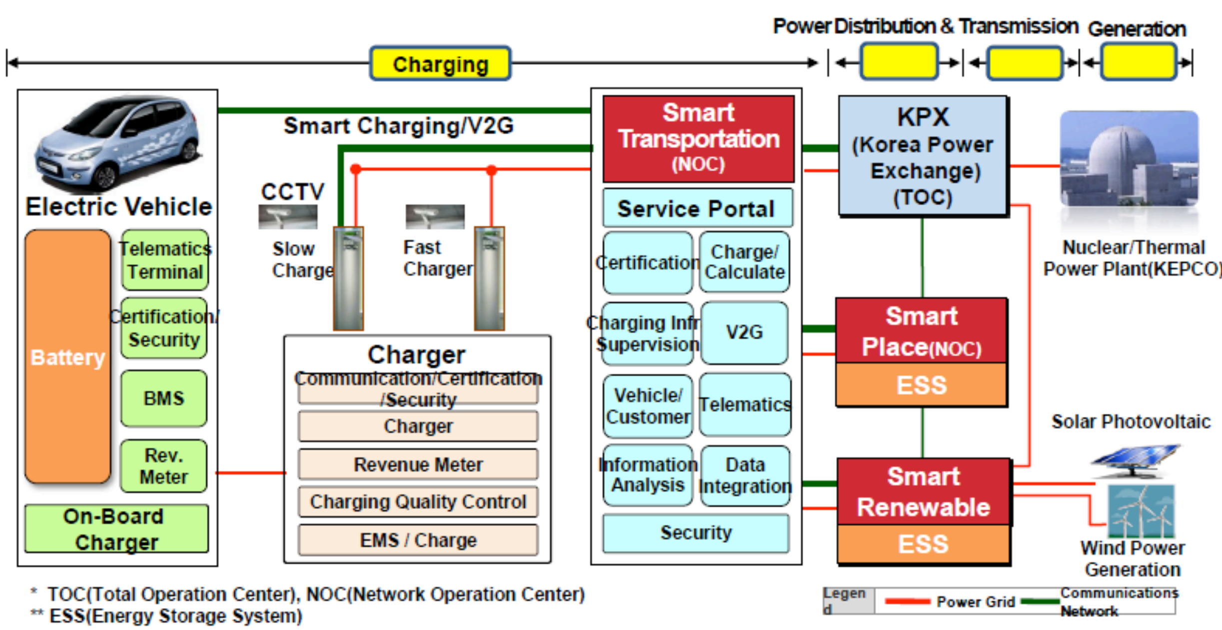
Source: Jeju SGTB (2012c).

KEPCO Consortium, SK Energy Consortium, and GS Caltex Consortium are participating in Smart Transportation. SK Energy Consortium manufactures 16 kWh Battery and

Battery Management System (BMS) for EVs, builds Total Operation Centers, and develops V2G technology. SK installed 66 charging units: 9 Fast Chargers in 6 places, and 57 Slow Chargers in the Jeju test bed. They currently manage 24 EVs and 14 Neighborhood Electric Vehicles (NEVs) that are manufactured (Choi, 2012) by Samsung Reno and Hyundai. Their EV's maximum speed is 130 km/hr, while their driving range is 140 km/charge. GS Caltex develops EV charging infrastructure (Jeju SGTB, 2012d) and develops fast and slow charging solutions, large capacity batteries, and contactless charging solutions. KEPCO also developed systems to manage and monitor charging stations.

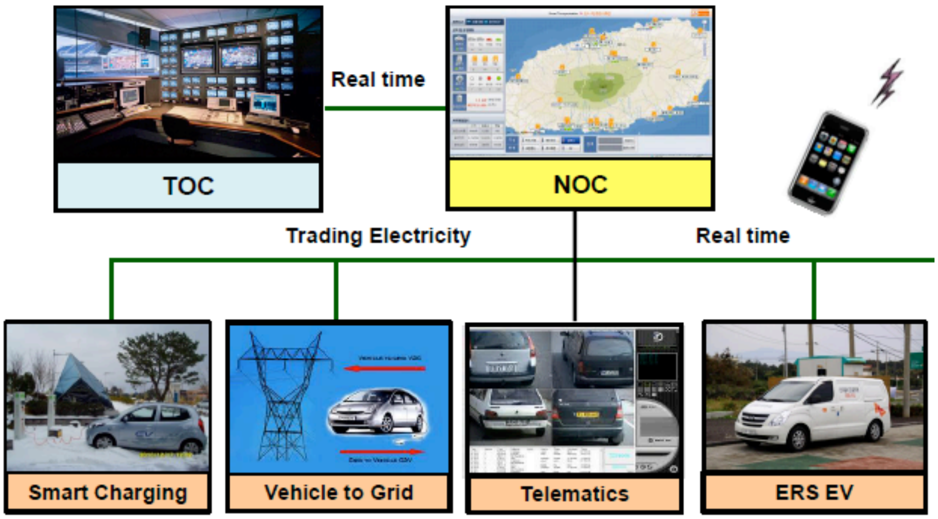
Figure 7 illustrates SK Energy Consortium's Business Model related to Smart Transportation in Jeju Smart Grid.

Figure 7. SK Energy Consortium Smart Transportation Business Model



Source: Choi (2012).

Figure 8. SK Energy Consortium Smart EV Solutions

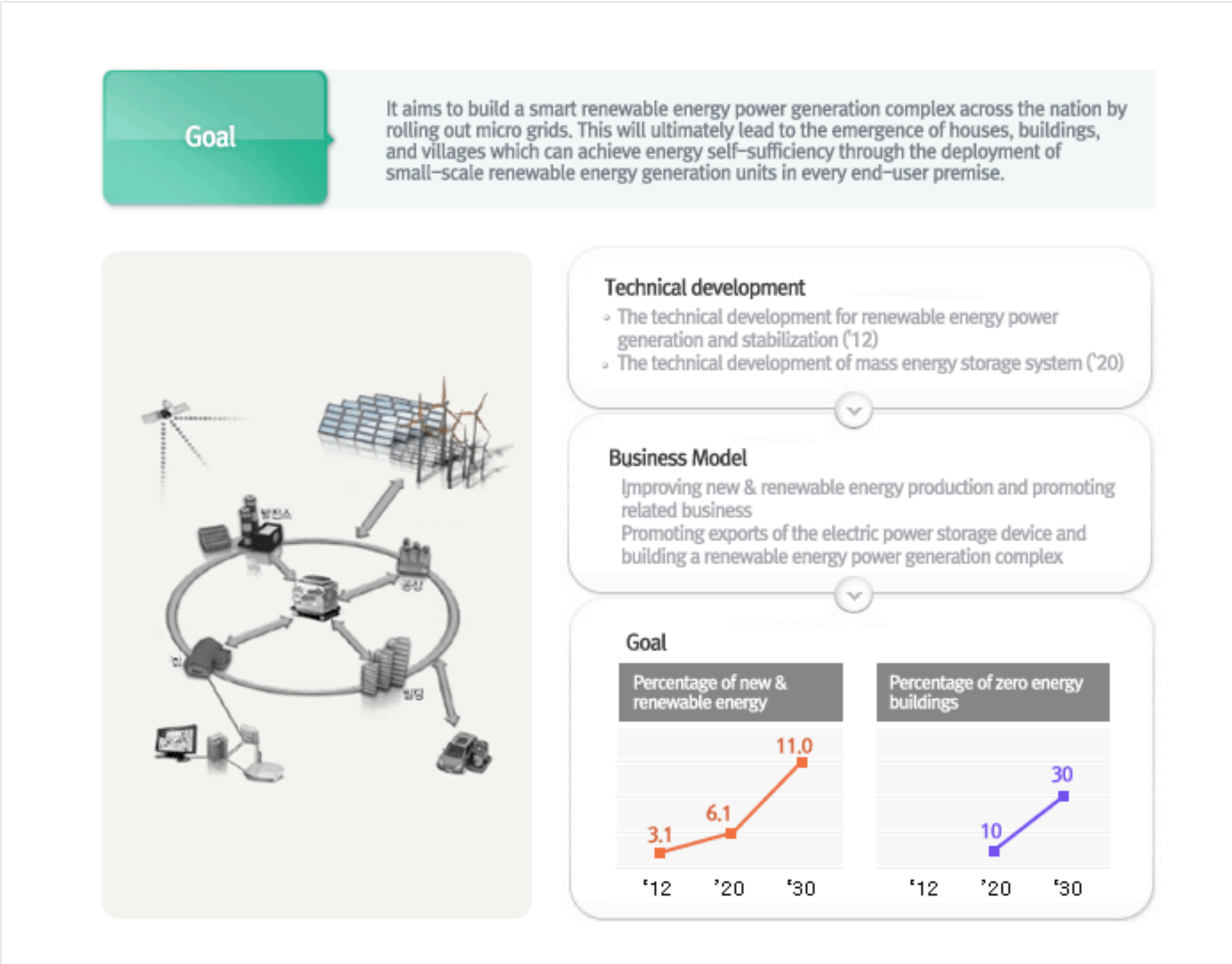


Source: Choi (2012).

The services and technologies demonstrated by SK Energy Consortium in the area of smart transportation can be divided into four areas (Figure 8). The first area is smart charging infrastructure. For consolidated membership services, this infrastructure's integrated network connects fast charging stations, which are similar to current gas stations, and slow charging stations at public facilities. Next, the vehicle-to-grid (V2G) service enables consumers to sell the electricity saved in their EV batteries during the peak demand period. The V2G service demonstration also includes building an infrastructure to integrate EVs to smart renewables such as solar PVs or fuel cells. The third area is a real-time EV management service called Telematics. This service provides EV drivers real-time information on optimum charging station locations, EV battery charging status, and traffic through smart phones. The last area is EV support through emergency roadside services (ERS), car sharing, and car rental. ERS-EV provides fast charging service when the EV batteries are exhausted. Network operation centers (NOC) and total operation centers (TOC) will monitor the EV service status.

4.3.3. Smart Renewable

Figure 9. Five Areas of Jeju Smart Grid Test Bed, Smart Renewable



Source: Jeju SGTB (2012e).

KEPCO Consortium, Hyundai Heavy Industries Consortium, and POSCO Consortium are participating in smart renewable. Smart renewable implementation is grid optimization and microgrid. POSCO Consortium demonstrates smart renewable technologies for wind power output stabilization and construction and operation of microgrids in Jeju (Park 2012).

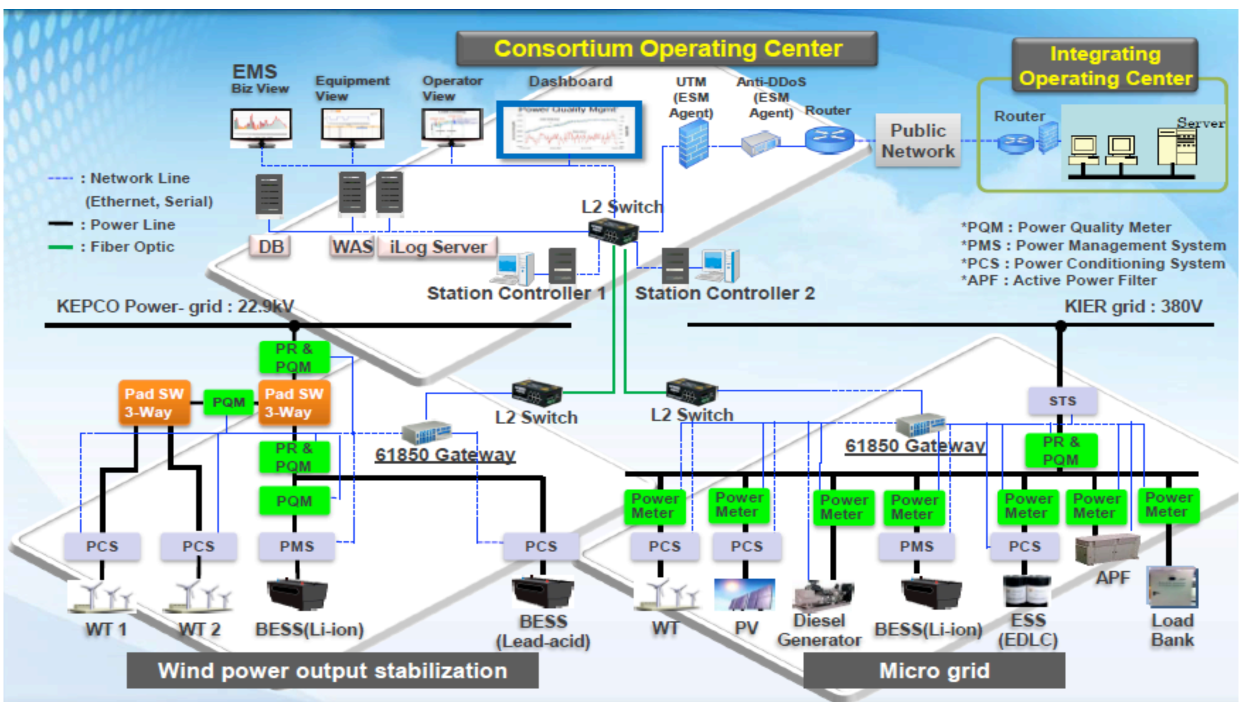
Technologies related to the stabilization of wind power output include EMS output control, power quality compensation devices, performance, and reliability verification of various energy storage systems (ESS), and realization of wind power dispatching functions using weather and facility operation information.

Technologies related to microgrid include the design and construction of a microgrid operating system, a connecting operation with various distributed powers such as wind, PV, diesel generators, power quality improvement and output stabilization, and secure load following operation capability during independent operation.

The energy management system (EMS) at the smart renewable domain's operating center manages energy efficiency and optimizes the energy generation plan. By analyzing and predicting power demand and generation of renewable energy, plans can be made to maximize energy outputs while minimizing loss. Long-term predictions include predictions 24 hours ahead, revised every five minutes based on pattern recognitions from historical data. Short-term predictions do the same but in situations of two hours ahead.

Wind power stabilization has been seen with BESS performances. Three microgrid simulations with separate scenarios are possible: microgrid with BESS, microgrid with BESS for renewable, and microgrid for grid connected. Simulation results verify the performance and support of BESS regarding peak shaving, lowering electricity fees, and loads for power companies.

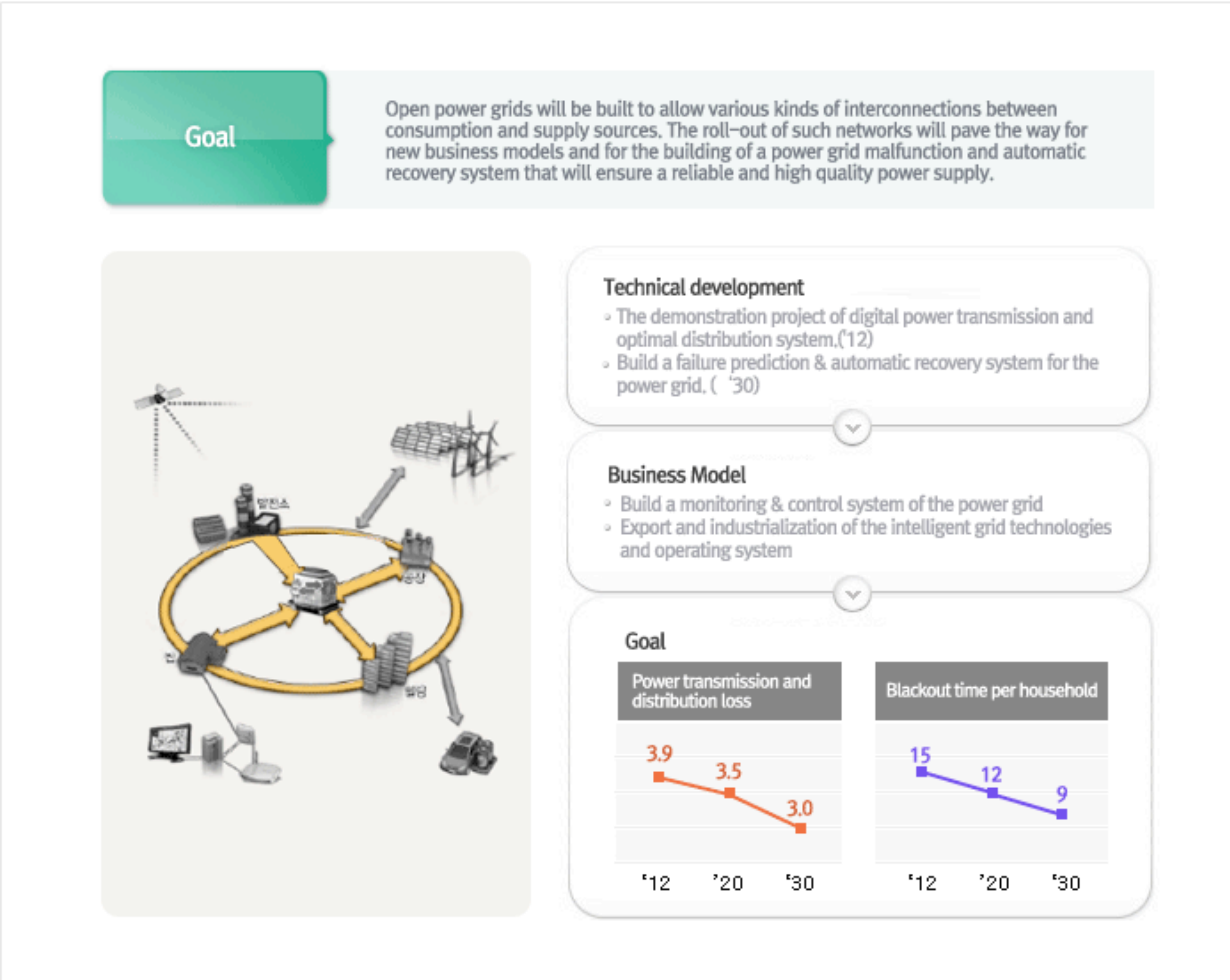
Figure 10. POSCO's Smart Renewable Configuration



Source: Park (2012).

4.3.4. Smart Power Grid

Figure 11. Five Areas of Jeju Smart Grid Test Bed, Smart Power Grid

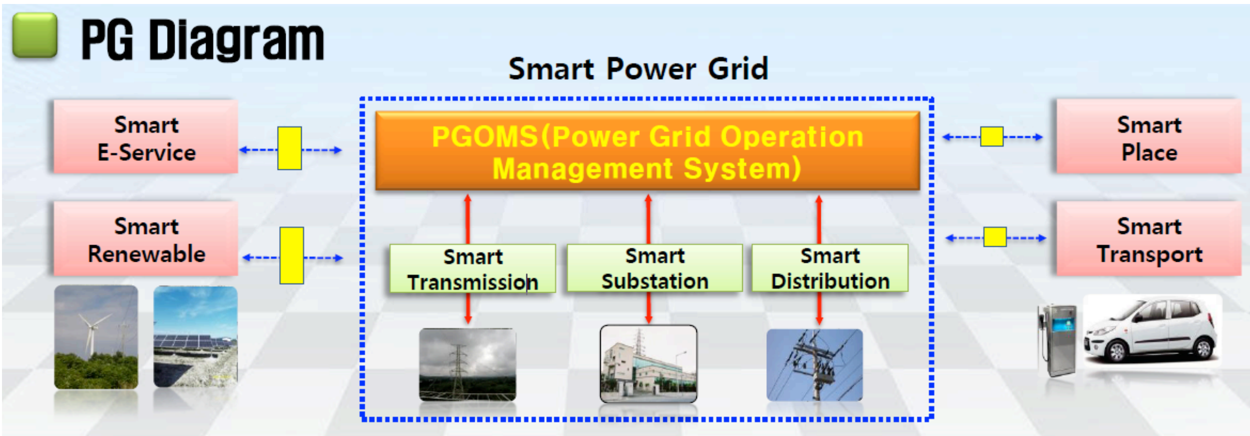


Source: Jeju SGTB (2012f).

KEPCO is the lone consortium participating in the Jeju test bed's smart power grid domain. The domain's central aim is to deploy smart power grids throughout Korea on a national scale and apportion 10 percent of the country's total power generation to come from renewable energy. In monetary terms, a USS$3 billion cost reduction and US$4 billion in sales to overseas markets are the goals (Hwang, 2012). KEPCO demonstrated and verified smart power grids in real test fields and secured interoperability among the smart renewable, smart transportation, and smart home domains.

KEPCO's involvement in the smart power grid domain can be categorized as either smart transmission, smart substation, smart distribution, or power grid operation management systems (PGOMS), as seen in Figure 12.

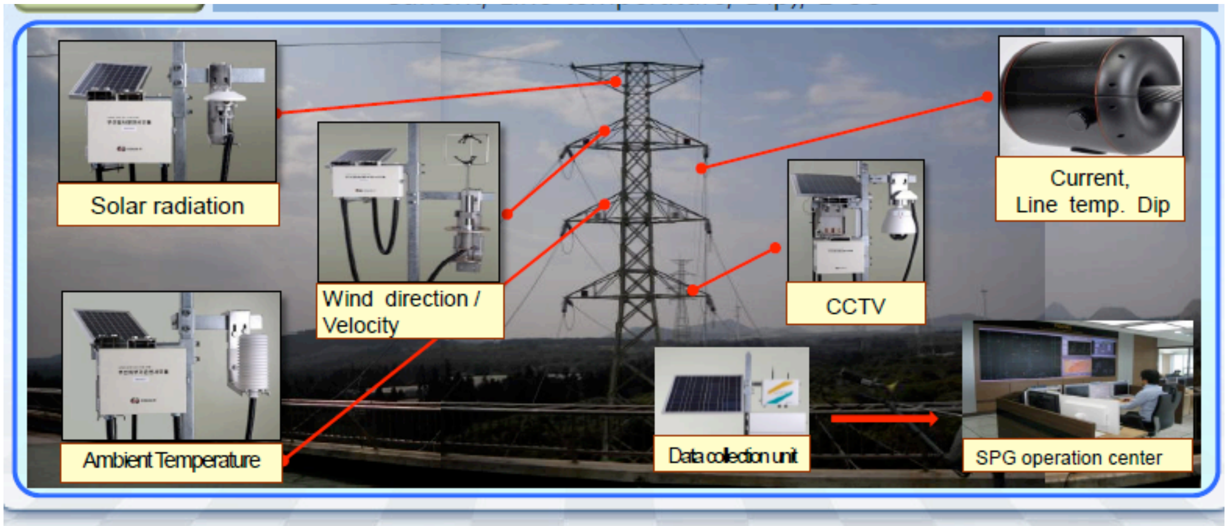
Figure 12. KEPCO's Smart Power Grid Diagram



Source: Hwang (2012).

The technologies and services to be demonstrated in the four areas are as follows (Hwang, 2012). In the smart transmission area, five sensors and one operating system are tested while monitoring transmission lines are operating in real time. The sensors measure a variety of factors, including solar radiation, wind direction, wind velocity, ambient temperature, current temperature, and line temperature. The operating system takes this information and calculates transmission line capacities in real time. Another test is done on the reactive power compensators with a voltage management system to reduce power loss and stabilize the grid itself by controlling reactive power. As of April 2012, one voltage detection device, two reactive controllers, and one voltage control system had been set up.

Figure 13. KEPCO's Smart Power Grid - Smart Transmission

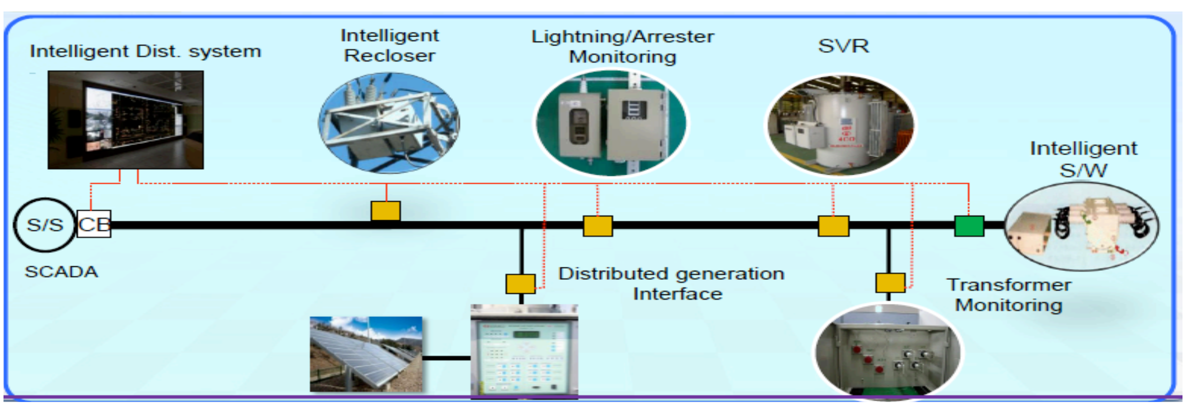


Source: Hwang (2012).

In the smart substation area, there are three kinds of testing facilities with 26 sets of intelligent electronic devices (IED). A set of monitoring systems, along with 12 sets of phasor measurement units (PMU) (2 located in power plants, 10 in substations), monitor grid stability in real time and prevent blackouts.

For the smart distribution area, technologies being tested and developed include intelligent reclosers, lightning arrester monitoring units, distributed generation interfaces, and supervisory control and data acquisitions (Figure 14).

Figure 14. KEPCO's Smart Power Grid - Smart Distribution

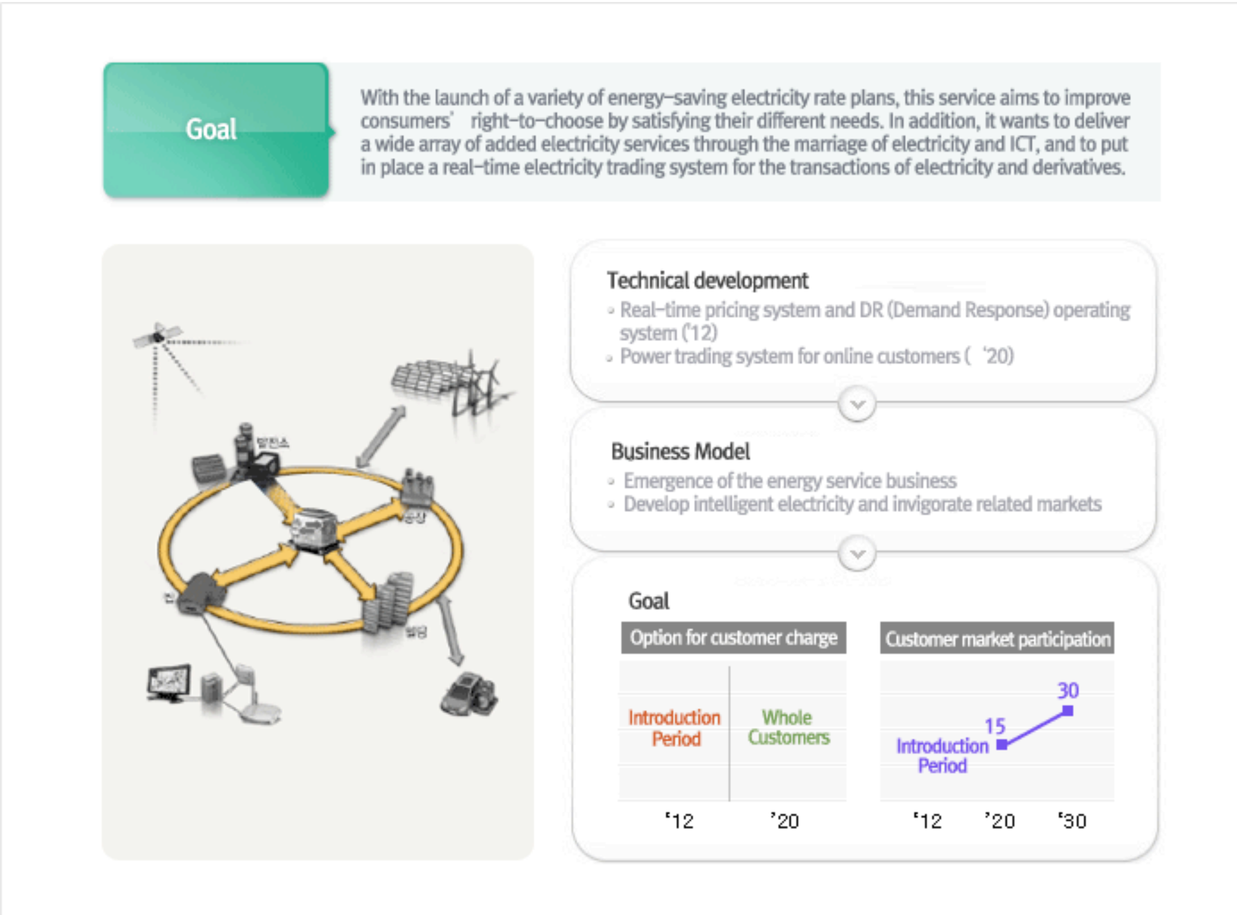


Source: Hwang (2012).

The PGOMS integrates and operates systems connected to the power grids. Field related technologies include Maintenance Management Systems (MMS), Fault Event Analyzers (FEA), Condition Monitoring Diagnoses (CMD), sensors, and sensor networks.

4.3.5. Smart Electricity Service

Figure 15. Five Areas of Jeju Smart Grid Test Bed - Smart Electricity Service



Source: Jeju SGTB (2012h).

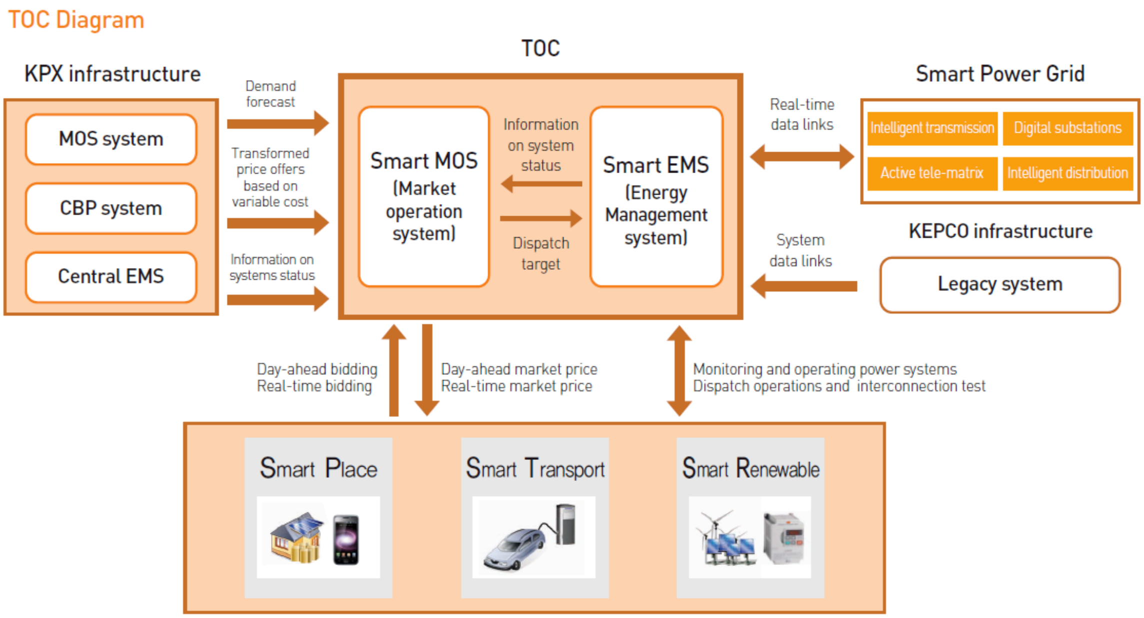
KEPCO and the Korea Power Exchange (KPX) are dual participants in the smart electricity service domain. KEPCO implements total operation center (TOC) infrastructure systems, which include operating system platforms, security control centers, management systems, and performance analysis and monitoring systems. KEPCO also provides emerging electricity services such as real-time utility rates, customer service portals, demand bidding, and price determination systems (Figure 16).

Figure 16. KEPCO's Total Operation Center (TOC) in Jeju

Source: Jeju SGTB (2012i).

KPX builds and operates the TOC with KEPCO. As Figure 17 illustrates, at the Smart Electricity Service Total Operation Center in Jeju, the smart market operation system (MOS) and the energy management system (EMS) control the varied power supply and demand resources and enable real-time bi-directional electricity trading.

Figure 17. TOC Diagram



Source: KPX (2011).

4.4. Phase One Completion Report

The first phase of the Jeju smart grid test bed was completed in May 2010. It focused primarily on three out of the five domains: smart place, smart transportation, and smart renewable (KSGI, 2012c).

Smart Place: The development of energy monitoring infrastructures, along with the installation of smart grid products and the recruitment of residential houses, is the main focus. In addition, each consortium developed a network operation center (NOC), management solutions, and various electricity billing systems.

- Constructed a NOC for each consortium
- Installed 550 residential AMIs/100 solar PVs
- Installed energy monitoring devices

Smart Transportation: After establishing EV charging infrastructure standards, EV chargers and a two-way communication network between the charging station and the operation center were installed. The remodeling of existing gasoline-powered cars to EV and their deployment are currently in progress. Chargeable EV power supply standards and a payment system for charging bills were developed as well.

- Activated 73 Electronic Vehicle (EV) charging infrastructures
- Deployed EVs
- Constructed infra operating system
- Designed a security system
- Developed a suitable method of payment

Smart Renewable: A series of different demonstration products, including wind power generator EMS, PCS, and BESS, have been produced and tested. A demonstration center, a communication network, and a security system have been completed.

- Constructed a renewable generation plant
- Designed systems to stabilize intermittency
- Developed a data center model coordinated with total operation center

Smart Power Grid: The onsite installment, production, and planning of a demonstration plant were completed. The plant's components include an intelligent distribution automation system, an active telematrix, a telecommunication network system, and a performance evaluation tool. A standard-base information security and management policy for interoperability has been developed.

Smart Electricity Service: For interoperability among the heterogeneous network of a smart grid environment, the TOC total platform has been developed. For an onsite, real-time total controlling environment, a demonstration electricity market and system management system was developed.

4.5. Next Steps

Phase Two of the Jeju smart grid test bed consists of testing, operating, and verifying the smart grid products and infrastructure that have been developed and deployed. With continued support from the government, each consortium will present and analyze various business models. The national standard and certifying and evaluating services will be incorporated into business outcomes. Smart grids will be expanded into commercial buildings and industrial regions (KSGI, 2012c).

Smart Place: AMI infrastructure and smart grid equipment for commercial and residential buildings will be demonstrated. Data connections between the NOC and TOC will be improved. A real-time payment system and demand response services will be also demonstrated.

Smart Transportation: EVs through a car rental system and new services such as V2G and V2V will be demonstrated to improve EV usages. The Korean Industrial Standard (KS) will ensure interoperability between various electric vehicles and their chargers. Additional business models will be developed.

Smart Renewable: Stabilization of renewable electricity production from sources and improvement of the management system of the electricity market are the main objectives. Business models regarding microgrids and component commercialization will be developed.

Smart Power Grid: Additional demonstration products and data connection will be developed and tested. Smart power transmission, active telematrix, a smart power distribution system, and a power transmission total monitoring system will be the major focus.

Smart Electricity Service: Electricity markets, management, and demand response will be advanced. Business models using a real-time payment system will be analyzed.

5. Implementing Smart Grid in Latin America and the Caribbean

5.1. The IDB's Energy Innovation Center

In April 2011, the IDB launched the Energy Innovation Center. The center was created in response to energy challenges that countries in the LAC region are facing today. Some of the main challenges with respect to the development of clean and smart energy technologies are the lack of sound public policies, predictable regulatory frameworks for attracting investments, and sufficient support to research and development efforts. To help overcome these obstacles, the center will leverage resources from the IDB and its partners to facilitate the implementation of projects, policy reform, and knowledge dissemination activities by accessing IDB funding.

The Energy Innovation Center aims to:

- promote energy innovation and cutting-edge technology for renewable energy, energy efficiency, and energy access
- serve as a regional hub for energy knowledge exchange and dissemination.
- translate ideas into projects

The center has partnered with governments and other stakeholders selected from the private sector—both within and outside the region—that are deemed eligible to provide support for sustainable energy innovation, knowledge dissemination, technical assistance, capacity building, and financing and co-financing of energy sector projects. Among current partnerships are the U.S. Department of Energy, the government of Japan, the government of Korea, and the province of Alberta, Canada. As of 2012, an executive director and five specialists from Canada, France, Japan, Korea, and Spain are working at the center.

The Smart Grid and its Application in Sustainable Cities workshop in Jeju was carried out as one of the knowledge transfer activities planned by the Energy Innovation Center with the sponsorship of the government of Korea.

5.2. Smart Grid Initiatives in the LAC Region

In this chapter, smart grid initiatives in the LAC region countries are presented along with each country’s energy situation. These countries share knowledge and experience through workshops and forums with support from international organizations such as the IDB, the IEA, and the Economic Commission for Latin America and the Caribbean (ECLAC).

While many countries in the LAC region are still considering smart grid technologies and seeking resources, some have already begun to embrace smart grids. Brazil, Ecuador, and Mexico are already implementing smart grids in pilot projects, while Colombia and Uruguay are working on smart grid road maps. Chile and Honduras have also started smart grid initiatives by installing AMRs.

5.2.1. Barbados

Barbados's electricity capacity in 2009 was 0.24 GW (REEEP 2012), and it was entirely dependent on heavy fuel oil and diesel. Barbados's oil demand is about 10,000 barrels per day (bbl/day). This is far in excess of local supply, which is near 1,000 bbl/day. The island is 166 square miles, and the national electrification rate is 98 percent, according to the prime minister's office.

A US$10 million Energy Smart Fund from the IDB has been established to support renewable energy and energy efficiency. It is expected to save US$283 million in the next 10 to 15 years by decreasing energy dependency on fuel oil and increasing the usage of renewable energy to 30 percent over the next 10 to 20 years (Caribbean 360, 2011).

The Barbados Ministry of Energy and the Environment designed and built the Barbados Solar House (Green Island Inc. 2008) in 2007 to serve as a practical example of solar energy. The fully functioning house is well equipped with modern appliances, covers 750 square feet, boasts a 2kWp solar system and batteries, and does not depend on the electricity grid. According to the prime minister's office, it also plans to install power monitors in 3,000 households.

5.2.2. Brazil

Brazil, the host country of the 2014 World Cup and the 2016 Summer Olympics, is the tenth largest consumer of energy in the world (IEA, 2012). Brazil's installed power capacity in 2009 was 106.2 GW, 81 percent of which was renewable, and the national electrification rate in 2009 was 98.3 percent (IRENA, 2012; REEEP, 2012). Seventy-seven percent of Brazil's power generation was from hydroelectric energy (Coviello, 2012), and 90 percent of the national matrix is already coming from renewable sources (Araujo, Grudtner et al., 2011). Brazil's renewable energy capacity saw an increase of 49 percent from 2006 to 2011. This rate of growth is one of the highest in the world (The Pew Charitable Trusts, 2011).

Brazil invested US$6.9 billion (UNEP BNEF, 2011) in renewable energy (US$2.4 billion in biofuels, US$2.4 billion in wind, US$1.2 billion in small hydro, and US$0.9 billion in biomass and waste to energy) in 2010, and will invest US$60 billion in electrical energy between 2010 and 2013 (Pica, Vieira et al., 2011). For the next 10 years, Brazil will install 63 million smart meters, making it the largest AMI market (Zpryme, 2011).

The Brazilian Ministry of Mines and Energy (MME) has established a working group to study and plan smart grid programs (Pinto, 2012). The MME determined that a smart grid infrastructure in Brazil would reduce technical and commercial losses, improve the quality of the power supply, and achieve energy efficiency. In 2011, Abradee (Pinto, 2012), the Brazilian Association of Electric Power Distribution Utilities, performed a cost-benefit analysis in the areas of smart metering, automation, distributed generation and electric vehicles, IT and communication, public policies for R&D, equipment manufacturing, services supply chains, and the consumer perspective.

The following are some smart grid pilot projects being undertaken in Brazil (Pinto, 2012): a) the Sao Paulo Power Company (Companhia Paulista de Força e Luz, or CPFL) operates a smart substation; b) the State Electric Power Company (Companhia Estadual de Energia Eletrica, or CEEE) has acquired power line carrier experience; c) the distribution company CELG has developed supervision of electricity supply for medium- and low-voltage consumers using different communication technologies; d) the distribution company Ampla is preparing a case study of the implementation of a smart city at Búzios; e) the Pernambuco Energy Company (Cia Energia de Pernambuco, or Celpe) installed a smart grid on Fernando de Noronha Island, an island with severe environmental constraints; and f) Eletrobras operates a smart grid at Parintins, a city in the Amazon region.

A recent ECLAC publication describes the following initiatives: (Nigris and Coviello, 2012).

- Smart metering projects by the Ceará Energy Company (Companhia Energética do Ceará, or COELCE)
    - Installed 100 smart meters and two concentrators in Fortaleza
    - Scheduled the next project in Niteroi, Rio de Janeiro
- Smart City Búzios (Cidade Inteligente Búzios) project by Ampla
    - Deploying a living lab for testing among 10,400 customers
    - Assisting the government in drafting smart grid-related laws
    - Installing an efficient public lighting system as the first step
    - Implementing smart meters for all customers, self-healing for medium voltage networks, and distributed generation
    - Deploying EVs and intelligent buildings
- Ampla

    - Developed the Ampla Chip, an advanced smart metering system to reduce energy theft
    - Installed smart meters for 540,000 customers, the largest such project in Latin America

More Smart Grid initiatives driven by companies such as CEMIG, AES Eletropaulo, CELESC, and COPEL are described as follows (Pica, Vieira et al., 2011):

- Cities of the Future in Minas Gerais (CEMIG)
    - Started in 2009 in Sete Lagoas, a city with a population of over 200,000 and more than 80,000 customers
    - Automation of measurement, substations, and energy distribution grid, telecommunications systems, operational computer systems, and management and integration of distributed generation
    - Results:
        - New real-time tariffs and billing model
        - Energy cost and loss reduction
        - Power grid efficiency improvement
        - Management and control optimization
        - Service quality improvement
- Smart Grid in Sao Paulo (AES Eletropaulo)
    - R&D pilot project to develop a smart distribution system that integrates advanced equipment and information systems
    - Smart grid implanted in Ipiranga, Sao Paulo over a circuit with 4.4 km of overhead and underground cables making up the distribution grid
- Companhia Paranaense de Energia (COPEL)
    - More than US$330 million investment until 2014
    - Curitiba digital city project
    - Automate all operational keys and reclosers supplying 650,000 units
    - Build 700 km new power grids
    - Install fuel station for electric taxi at Afonso Pena International Airport in Curitiba
- Micro Grid of Sustainable Energy (CELESC)

- The R&D pilot projects are a) demand response in Florianópolis, b) measurement system in Blumenau and c) Planning District Distribution Network and Generation of Sustainable Energy.
- The Florianópolis project includes the installation of 10,000 units of load control devices and 3,500 units of smart meters.
- The Blumenau project includes the replacement of existing meters with smart meters, the establishment of communication systems between each meter and the substations, and the creation of a control center.

Besides the above-mentioned initiatives, the InovCity Aparecida project is the largest, most advanced smart grid project in Brazil. The city of Aparecida is located in Sao Paulo state, 168 km away from the capital. It has a population of 35,000 and a size, including rural and urban regions, of 121 Km^2. Aparecida was chosen because it represents the diversity of the municipalities and customers in the EDP Brazil service area (Marcondes, 2012).

The project includes the installation of over 13,500 smart meters that have been developed by Ecil Energia in partnership with EDP Bandeirante. These meters have already been approved by the National Institute of Metrology, Quality and Technology (INMETRO). The installation plan includes 1,600 monophasic, 11,000 biphasic, and 1,400 triphasic meters, as well as 485 triphasic indirect Feeder Distribution Transformers (TAD). The meters will be interconnected using ZigBee, a radio frequency technology, through a wireless mesh network that connects the private networks to a public data network and sends the information to EDP Bandeirante. As of December 2011, 11,127 smart meters had been have been installed, and the remaining meters were expected to be installed by December 2012.

5.2.3. Chile

Chile's electricity capacity in 2010 was 15.94 GW, 36.8 percent of which was renewable, and its national electrification rate was 99 percent (REEEP 2012). Chile has faced recent energy shortfalls and heavily depends on hydro (41 percent) and fossil fuels (58 percent) (REEEP, 2012). More than 70 percent of the fossil fuels are imported.

The Renewable Energy Law and 20/20 in 2008 mandates that 10 percent of Chile's energy production will be renewable by 2024 (REEEP, 2012). In 2010, Chile invested US$960 million in renewable energy (UNEP BNEF, 2011). Installed capacity from renewable sources including mini-hydro, geothermal, wind, biomass, and solar is 734MW, and its gross potential is estimated to be 190,067MW (Jiménez, 2012).

The Smart City Santiago project, conducted by Chilectra, installed 100 smart meters for residential consumers in Santiago. The project also includes remote control and automation of medium-voltage networks, technology solutions enabling active demand, efficient public lighting, and EVs (Nigris and Coviello, 2012).

The Chilean government also performed a pilot project in Huatacondo, an isolated rural town with 100 inhabitants, for 10 hours a day. Eighty-four PV panels, an energy storage system with 96 lead-acid batteries, and a wind generator with 3kW capacity were installed. The government will soon be launching a tender for a pre-feasibility study on a pilot project in the far-south Chilean region of Magallanes.

5.2.4. Costa Rica

Costa Rica's electricity capacity in 2009 was 2.49 GW, of which 75.2 percent was renewable, and its national electrification rate was 99.3 percent (IRENA, 2012). The power generation is 80 percent from hydroelectric, 12 percent from geothermal, and 8 percent from other sources.

The National Power Sector Development Plan (2005–2009) states that installed capacity will be doubled every 15 years, taking it from 1.96 GW in 2006 to 3.85 GW in 2021 (REEEP, 2012).

5.2.5 Colombia

Colombia's electricity capacity in 2009 was 13.5 GW, of which 67.1 percent was renewable, and its national electrification rate was 95.6 percent for national interconnected systems and 65.2 percent for non-interconnected zones (IRENA, 2012). Power generation is 64–77 percent from hydroelectric, and 23–33 percent from fossil fuels (ranges given due to seasonality effects). The use of fossil fuels has increased since the mid-1990s following droughts in 1992. Colombia is a major Latin American coal exporter and a net oil exporter.

Colombia has great potential for renewable energy. Large hydropower potential is estimated at 93 GW, with additional small hydropower estimations of 25 GW. Colombia's wind regime is among the best in South America, with a potential value of 21 GW. Solar power resources are also significant.

In November 2010, 125 participants from private, public, and academic sectors developed a smart grid roadmap for Colombia (Aldana, Cespedes et al., 2011) and introduced the Colombia Inteligente smart grid initiative. Current smart grid research and projects (Barreto, 2012; Millan, 2012) in Colombia include a power control system based on a Phasor measurement unit (PMU), eRenewables (wind and solar power), and eMobility (public and private electric transportation).

5.2.5. Dominican Republic

The Dominican Republic's electricity capacity in 2006 was 3.39 GW and its national electrification rate was 88 percent (REEEP, 2012). Power generation is 86 percent from fossil fuels and 14 percent from hydroelectric. The country faces energy blackouts regularly.

Technical (12 percent) and non-technical (30 percent) losses are 42 percent. A law concerned with electricity theft was enacted in 2007 (REEEP, 2012). Smart meters with consumption monitoring and communication features have been installed to decrease energy theft.

In 2007, the Dominican government passed a law (Guzmán Ariza and Associates, 2012) to promote investment in the renewable energy sector by providing tax incentives.

In 2008, 470 MW of hydroelectric capacity was added (14 percent of total energy generation), and an additional 762 MW will be added by 2012. A U.S. company, Sunovia Energy Technologies, began installing the Dominican Republic's first solar energy plant of 20 MW in 2009.

The country's wind power potential is estimated to be at least 10 GW, and three wind parks were licensed to generate 190 MW in 2008. In 2011, a private local power company invested US$100 million for the nation's first large scale wind power project for 33 MW (Jimenez, 2011).

With IDB financing, the government is rehabilitating distribution networks in order to contribute to loss reduction and improve the quality of the electricity supply and the efficiency of distribution utilities and the sector as a whole.

5.2.6. *Ecuador*

Ecuador's electricity capacity in 2009 was 4.939 GW, of which 43.8 percent was renewable, and its national electrification rate was 92.2 percent (IRENA, 2012). Power generation is 47 percent from thermoelectricity, 46.6 percent from hydroelectric, and 0.06 percent from wind power. A program called Power Grid 2020 (Matriz Energética para 2020) is being developed to increase hydroelectric energy to 80 percent by 2020.

Although Ecuador is a net electricity surplus country, it experiences electricity shortages during the October–March dry season. For example, in 2007, Ecuador imported 4.73 percent of its total generated capacity from Colombia.

The government has two main initiatives in the smart grid field. The first is the Integrated System for the Management of Electricity Distribution (Sistema Integrado para la Gestión de la Distribución Eléctrica, or SIGDE) project. Its main objective is to improve the management of distribution companies through standardization, the introduction of smart technologies including ICT, and adoption of a general information model. The first phase foresees the improvement in electricity services to 2.4 million users through the incorporation of a SCADA Outage Management System–Distribution Management System (OMS-DMS). The second project, carried out by the dispatch authority CENACE, is designed to improve grid stability through phasor measurement. The advanced metering infrastructure program by the electric utility in Guayaquil with the adoption of more than 20,000 smart meters is worth mentioning as well.

5.2.7. *Haiti*

Haiti's electricity capacity in 2006 was 0.27 GW, with a national electrification rate of 34 percent, according to the Latin American Energy Organization (OLADE), or 10 percent according to the United States Agency for International Development (REEEP, 2012). Power generation was 72.5 percent from thermal electricity and 27.55 percent from hydroelectric before the 2010 earthquake. Technical and non-technical loss is estimated at over 55 percent, among the highest in the world. The IDB approved a US$12 million loan to develop Haiti's energy sector framework in June 2012 (IDB, 2012).

5.2.8. Honduras

Honduras is the second largest country in Central America. Honduras' electricity capacity in 2009 was 1.697 GW, 36.1 percent of which was renewable, and its national electrification rate was 70.3 percent (IRENA, 2012). Power generation is 56 percent from heavy fuel oil, 33 percent from hydroelectric, 6 percent from diesel, and 5 percent from biomass.

Energy is transmitted and distributed almost exclusively by the National Electricity Company (ENEE), with the exception of certain isolated systems in which private companies manage energy generation, distribution, and marketing. Additionally, ENEE generates nearly 35 percent of all the system requirements; private companies that sell their production to ENEE produce the rest.

In 2010, ENEE approved about 50 renewable energy projects with capacities ranging from 2 to 160 MW. Many of these projects will interconnect to the system through 34.5 kV distribution lines. Several of them are already under construction and are expected to be operational by the end of 2017. While most of the projects will produce electrical energy using hydropower, the range of sources also includes biomass, wind and, geothermal. Moreover, there are new requests for the installation of additional renewable energy projects, mainly new wind projects, whose approximate capacity in the next four years is estimated to be 400 MW. The first 100 MW wind farm is already operational.

In June 2007, President Zelaya declared an "energy emergency" to manage the country's energy crisis. Given the situation of the Honduran electrical system, which is expected to be upgraded with a significant share of renewable energy, including wind and possibly solar energy, the implementation of a smart grid has become urgent. Mainly due to non-technical losses, total electricity losses increased to 25 percent in 2006 (REEEP, 2012). To solve this problem, ENEE initiated a US$300 million project with the Israeli LR Group Ltd. to install 500,000 smart meters with a remote cutoff feature to respond to suspicious usage (Nielsen, 2012).

Currently, 40,000 AMR meters have been installed, and the goal is to reach 100,000 in the next five years. This equipment will constitute a modest base for the introduction of a smart grid. To complement the equipment, the measuring administration system (MDM), which is being integrated with the commercial management system, will be improved.

Modifications are also being introduced in the tariff system, which will enable the adoption of smart grids. The goal of these actions is to promote the micro-distributed generation and application of net metering.

5.2.9. Jamaica

Jamaica's electricity capacity in 2006 was 1.5 GW, with a national electrification rate of 90 percent (REEEP, 2012). Power generation is 90 percent from oil, 1.5 percent from coal, 2.2 percent from hydroelectric, and 1.4 percent from biomass. Over 90 percent of the country's energy is dependent on imported oil. In 2005, the government developed an energy strategy increasing liquefied natural gas consumption to reduce national energy vulnerability. The efficiency of electricity generation is low mainly due to the aging electricity generation infrastructure. Electricity loss in transmission and distribution is 23 percent due to outmoded infrastructure and theft.

Jamaica has great potential for renewable energy. Solar radiation is high, at an estimated 5 kWh/m^2 per day. The government has begun developing an ethanol industry from sugar cane together with Brazil.

The National Energy Policy Green Paper 2006–2020 includes renewable energy development, and the government aims to achieve 15 percent renewable energy by the year 2020.

5.2.10. Mexico

Mexico's electricity capacity in 2009 was 59.3 GW, of which 22.7 percent was renewable (IRENA, 2012; REEEP, 2012). In 2008, its national electrification rate was 97 percent (REEEP, 2012). Power generation is 75.3 percent thermal, 19 percent hydro, and 5 percent nuclear (REEEP, 2012). The government announced its 2007–2012 National Infrastructure Program in 2007, to invest US$25.3 billion in electricity infrastructure.

Smart grid R&D activities (Castro and Gómez, 2012) from the Electrical Research Institute (IIE) include a smart grid roadmap developed by Mexico's state-owned utility, the Federal Electricity Commission (Comisión Federal de Electricidad, or CFE), a large-scale integration of intermittent renewable energy, an IEC 61850 profile for the CFE's distribution substations, advanced metering infrastructure, home energy management systems, a photovoltaic inverter, distribution operation modeling and analysis, and semantic interoperability for the CFE's smart grid.

5.2.11. Panama

Panama's electricity capacity in 2009 was 1.82 GW, 48.3 percent of which was renewable (REEEP 2012). The national electrification rate was 88.1 percent (IRENA, 2012). Power generation is 55.3 percent from hydroelectric and 44.7 percent from thermal. The power sector was privatized in 1998. The National Energy Secretariat (Secretaría Nacional de Energía de Panama, or SNE) plans to conduct a study to adopt smart grid (Nigris and Coviello, 2012).

5.2.12. Uruguay

Uruguay's electricity capacity in 2009 was 2.62 GW, 66.6 percent of which was renewable, and the national electrification rate was 98.3 percent (IRENA, 2012; REEEP, 2012). Power generation in Uruguay is 63 percent from hydroelectric, 34 percent from thermal, and 3 percent from non-conventional renewable energy. Although power generation is a competitive activity, Uruguay's state-run power utility, UTE, generates most of it. The UTE performed transmission and distribution. The electrification rate is 98.8 percent for 1,307,000 clients, with 40 percent of them in Montevideo (Chiara, 2012).

Successful smart grid experiences in Uruguay include nationwide coverage of a telecommunication network, quality of service, telemetering for generators and large consumers, and public lighting. The UTE's Smart Grid Master Plan is in development and will be completed by 2013. In 2012, UTE will purchase 30 EVs for pilot use in Montevideo.

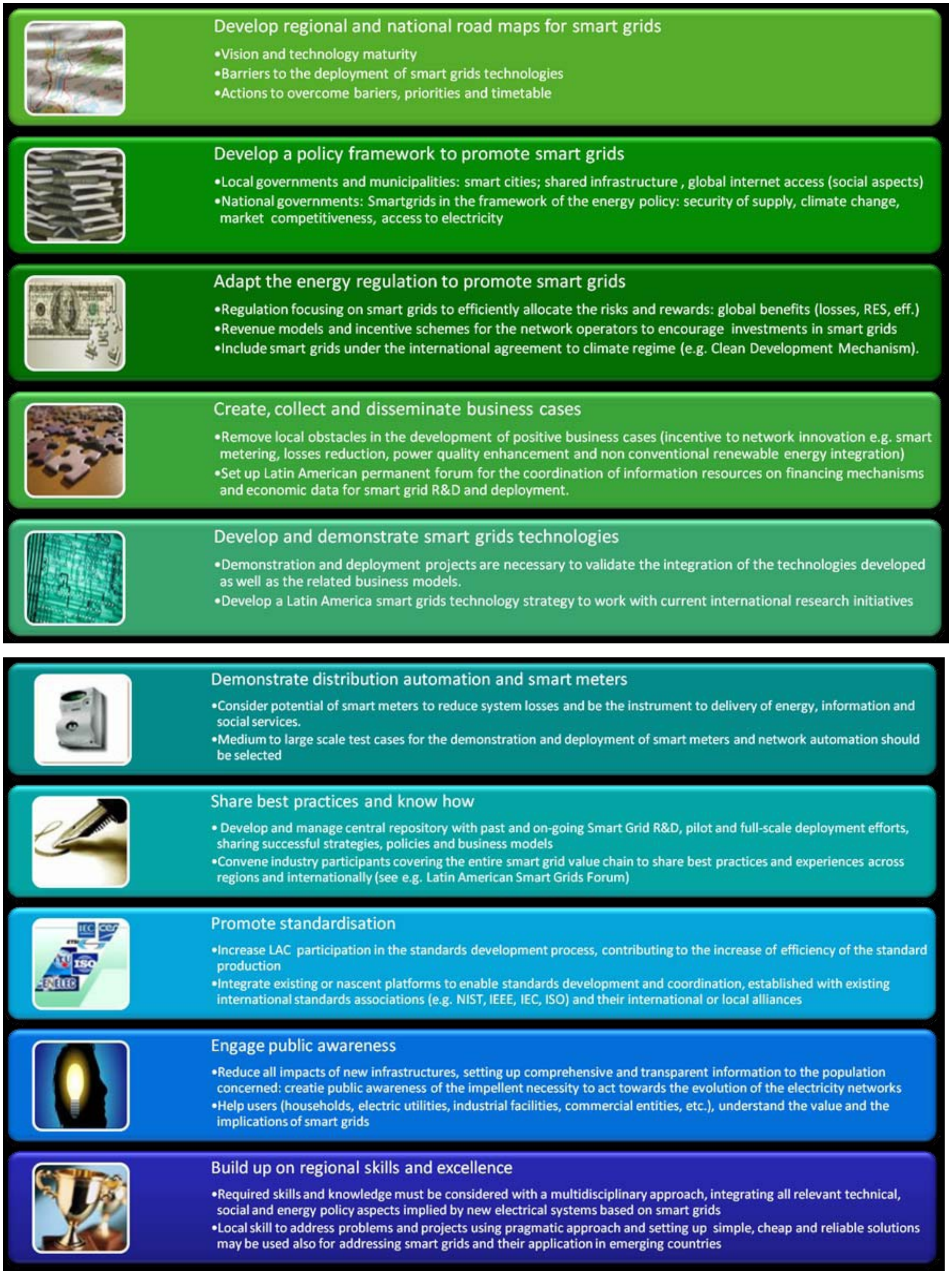
Wind energy, distributed generation, microgeneration, demand management, rural electrification, and preventing non-technical losses are identified as the country's priority smart grid applications. By 2015, 1000 MW of wind energy will be integrated into the grid and will supply more than 20 percent of the nation's electricity demand.

5.3. Further Work on Smart Grids in the LAC Region by other Institutions

The IEA published a Smart Grid Technology Roadmap in 2011 to serve as a guide to government and industry on achieving a 50 percent reduction in greenhouse gas emissions by 2050 (IEA, 2011).

At the Jeju workshop, ECLAC presented the regional perspective on smart grids. It was pointed out that electricity theft is a major energy issue throughout the LAC region, even within large cities (Coviello, 2012). Electricity services in LAC countries face both safety and quality issues mainly due to their outdated power networks. Smart grids with smart meters, distribution automation, and distributed generation are proposed as part of the solution. ECLAC presented the following ten recommendations to policymakers for smart grid development in the LAC region.

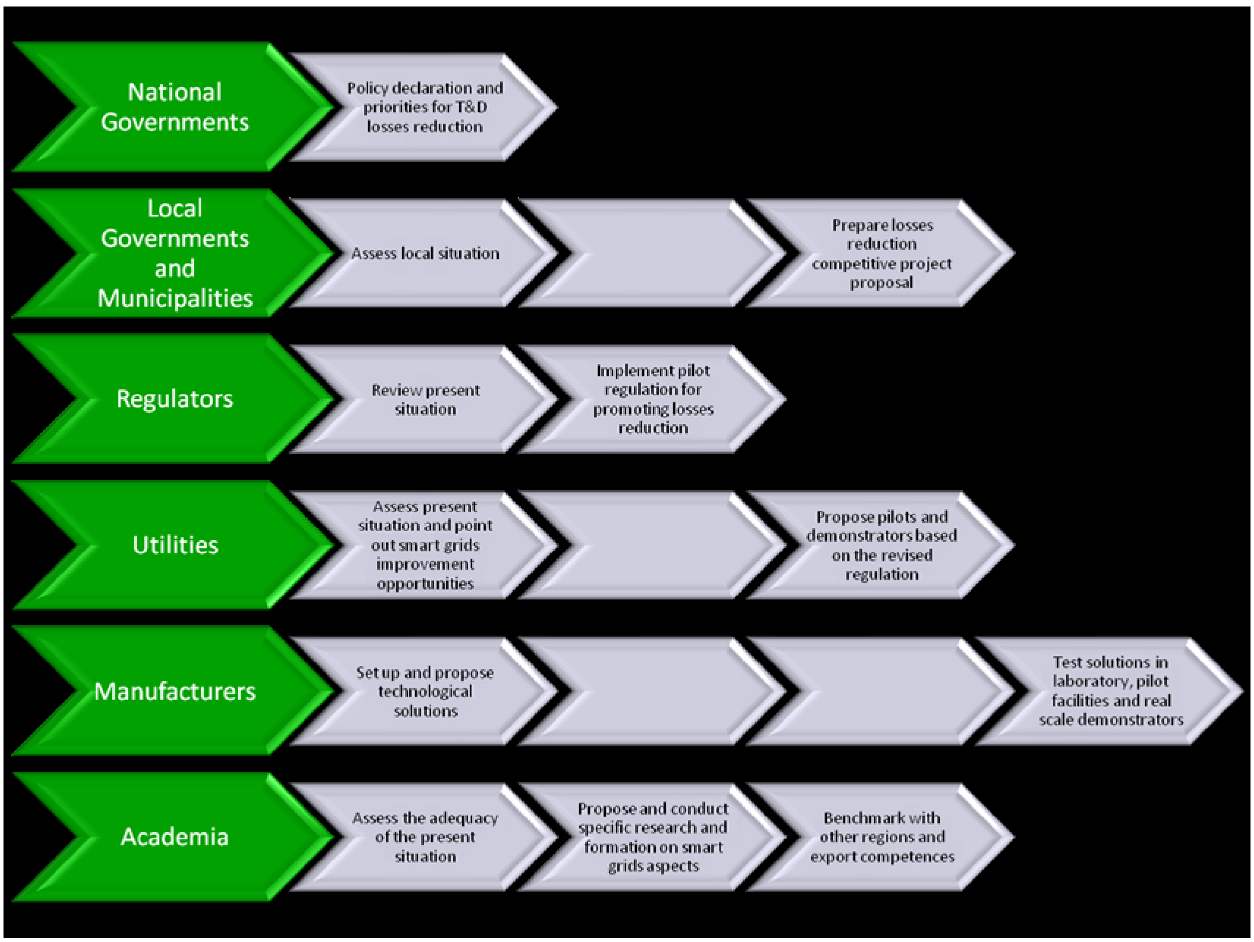
Figure 18. Decalogue for Smart Grids in the LAC Region



Source: Coviello (2012).

Shortly after the Jeju workshop, ECLAC published *Smart Grids in Latin America and the Caribbean,* a report on their two-year study. It presented test cases from six countries in the LAC region: Brazil, Chile, Jamaica, Mexico, Panama, and Uruguay. ECLAC shared its findings in the areas of generation, non-conventional renewable energy sources, distributed generation, transmission systems, distribution systems, metering equipment, level of distribution losses, regulation, and human capacity. The ten recommendations listed in Figure 18 were described, along with smart grid initiatives in Brazil, Chile, and Panama (Nigris and Coviello, 2012). Figure 19 presents immediate actions that were presented at the Jeju workshop.

Figure 19. The Way Forward – Immediate Actions



Source: Coviello (2012).

5.4. ***Workshop Survey Result Analysis***

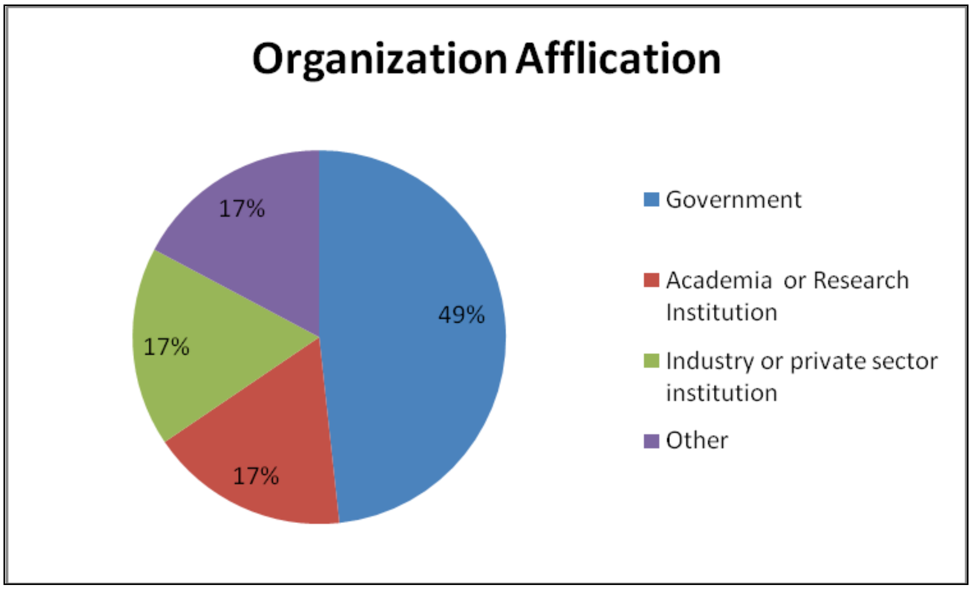
5.4.1. *Objective of Survey*

After the workshop, attendees completed a survey to ascertain the value of the activity in terms of knowledge transfer as a monitoring and evaluation strategy. The aim was to measure the knowledge of the attendees from the LAC region about smart grids before and after the workshop and fieldtrip in Korea.

5.4.2. *Organizational Affiliations*

49 percent of the participants were from the government, 17 percent from academia or research institutions, 17 percent from industry or private sector institutions, and 17 percent of them were from other fields.

Figure 20. Organizational Affiliations



Source: Authors' elaboration.

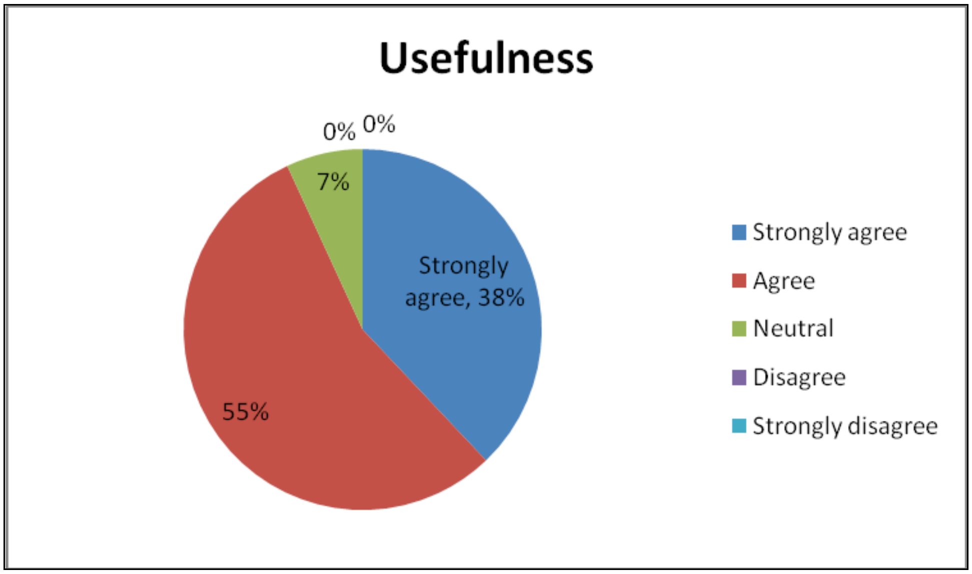
5.4.3. *Knowledge Improvement*

Eighty-two percent of the participants improved their knowledge regarding smart grid technologies by at least 25 percent as a result of the workshop.

5.4.4. Knowledge and Information Obtained from the Workshop

The next question was about the utility and applicability of the information obtained from the workshop. Thirty-eight percent of the participants strongly agreed and 55 percent of them agreed that the information was useful, while 7 percent were neutral about whether the information received at the workshop was useful for implementing sustainable cities in their respective countries.

Figure 21. Knowledge and Information Obtained from the Workshop

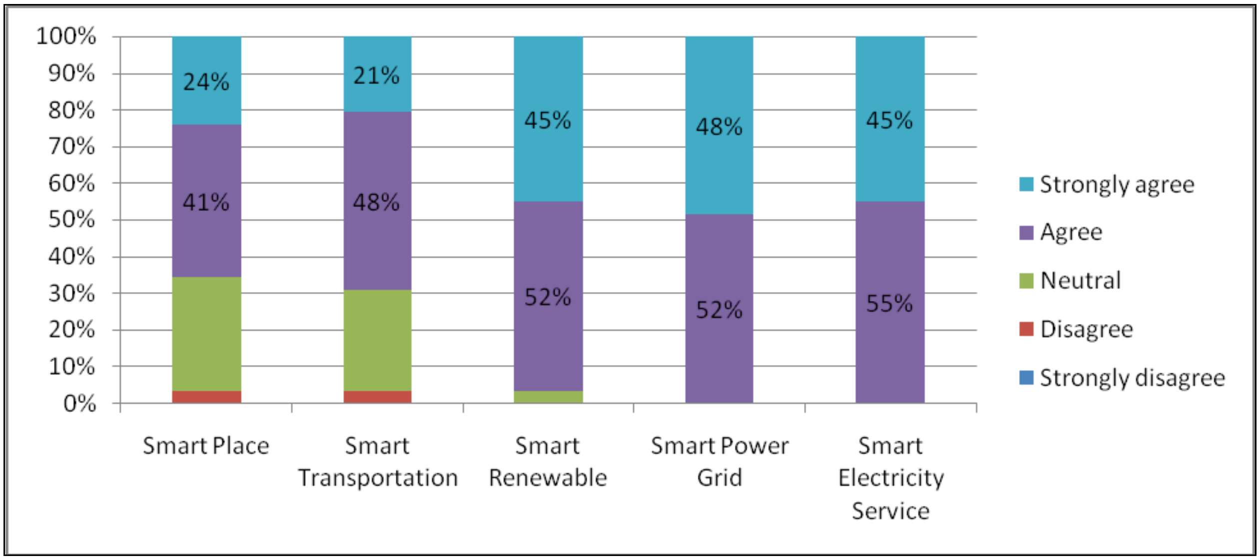


Source: Authors' elaboration.

5.4.5. Applicability of the Technologies

The survey asked the attendees' opinions regarding the applicability of the implementation of the technologies or the five Jeju test bed smart grid domains for their countries (see Figure 22 for the results).

Figure 22. Applicability of Technologies

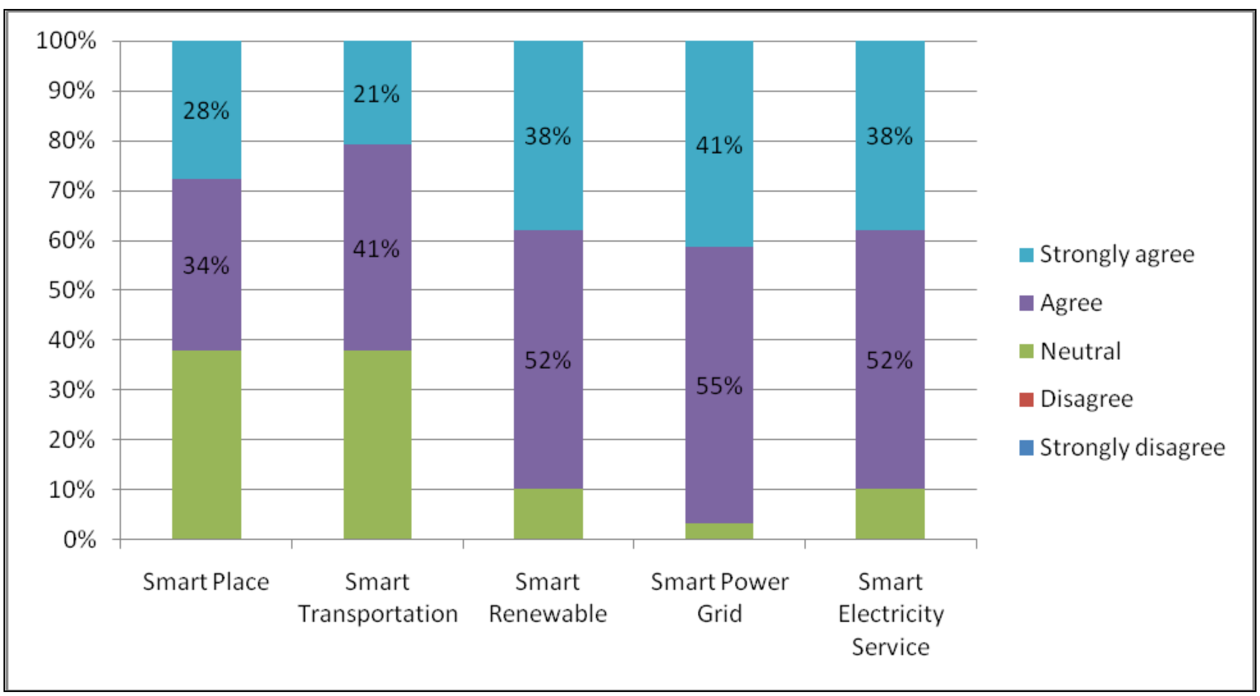


Source: Authors' elaboration.

5.4.6. Applicability of Lessons Learned

The survey asked the attendees' opinions regarding the applicability for their own countries of the lessons learned or best practices from implementing the five Jeju test bed smart grid domains (see Figure 23 for the results).

Figure 23. Applicability of Lessons Learned

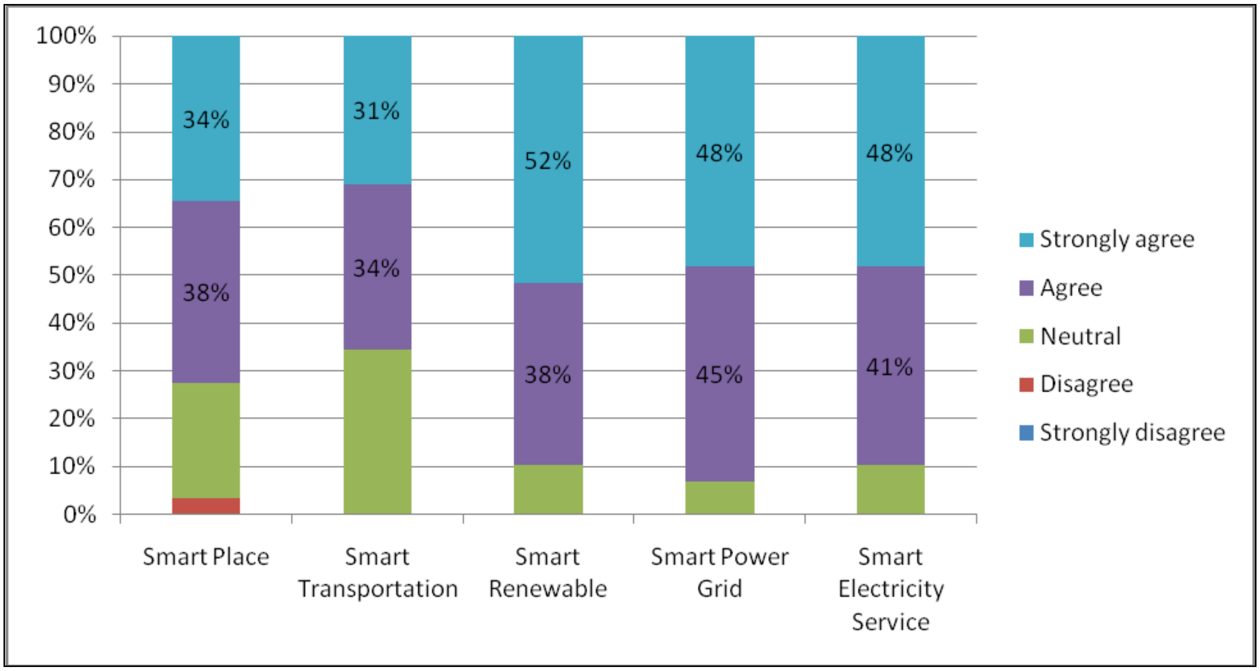


Source: Authors' elaboration.

5.4.7. Applicability of Goals and Visions

The survey asked the attendees' opinions regarding the applicability in their own countries of the goals and visions of the five Jeju test bed smart grid domains (see Figure 24 for the results).

Figure 24. Applicability of Goals and Visions

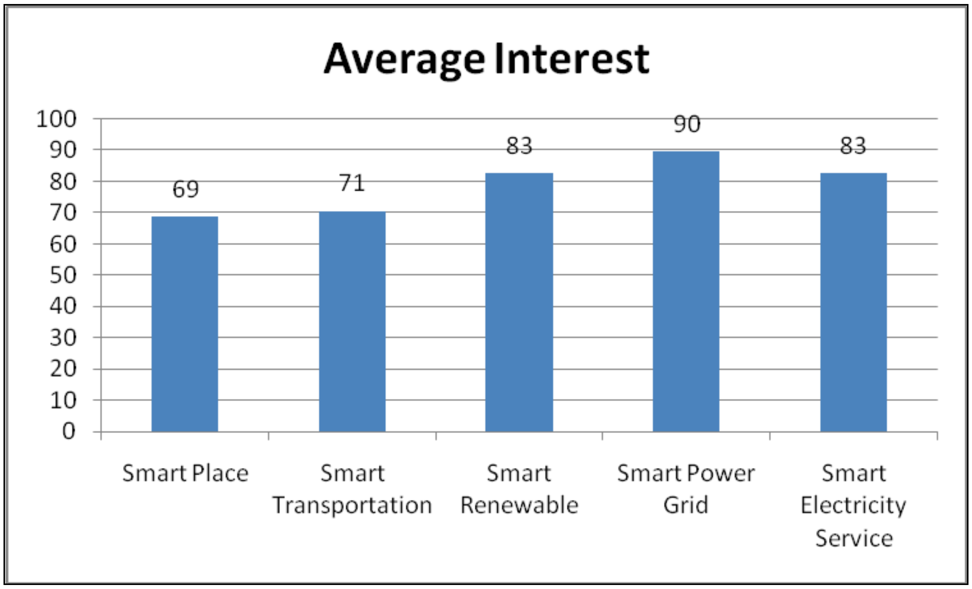


Source: Authors' elaboration.

5.4.8. Interest in the Five Domains

The survey asked about the attendees' interest in each of the five Jeju smart grid domains. The results show attendees' level of interest in smart power grid, smart renewable, smart electricity service, smart transportation, and smart place.

Figure 25. Interest in the Five Domains

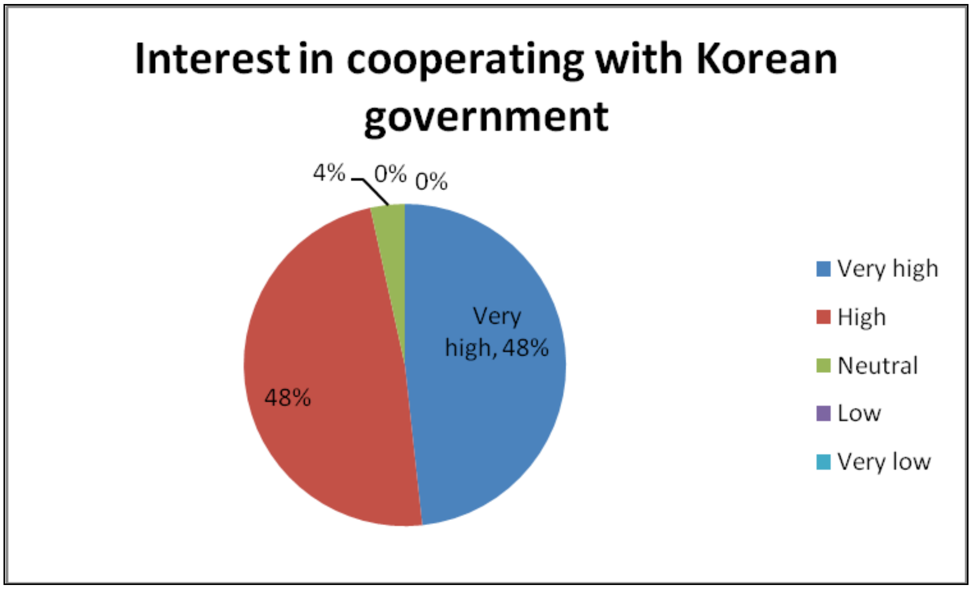


Source: Authors' elaboration.

5.4.9. Cooperation with the Korean Government

When asked about their interest in cooperating with the Korean government, specifically in receiving technical and financial assistance, 48 percent of the participants responded "very high," another 48 percent of them "high," while 4 percent responded "neutral."

Figure 26. Cooperation with Korean Government

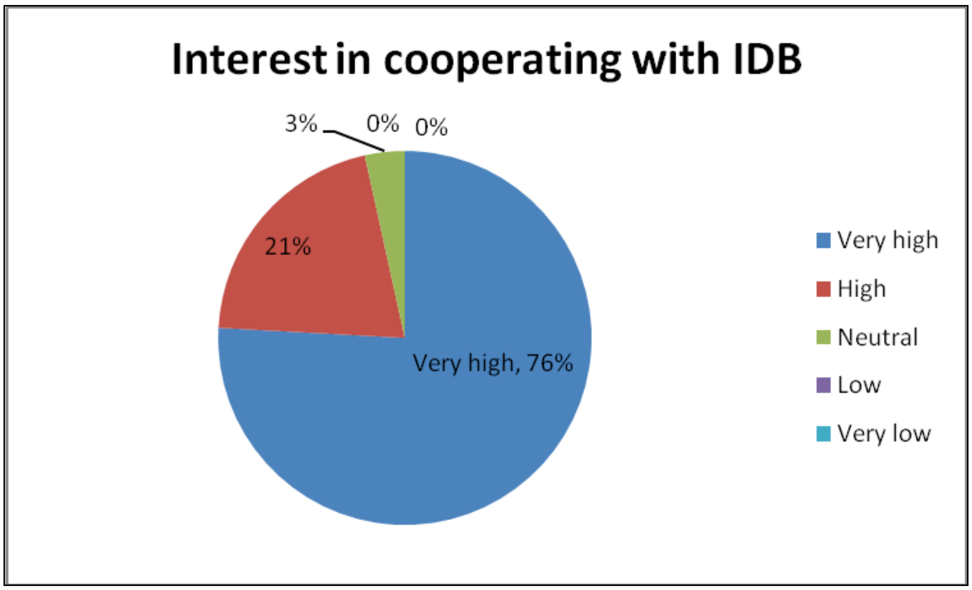


Source: Authors' elaboration.

5.4.10. Cooperation with the IDB

With respect to their interest in working with the IDB to support smart grid development in their own countries through technical and financial assistance, 76 percent of the participants responded "very high," another 21 percent "high," while 3 percent were neutral.

Figure 27. Cooperation with IDB



Source: Authors' elaboration.

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