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World Energy Perspective

Smart grids: best practice fundamentals for a modern energy system – *Annexes*

World Energy Council

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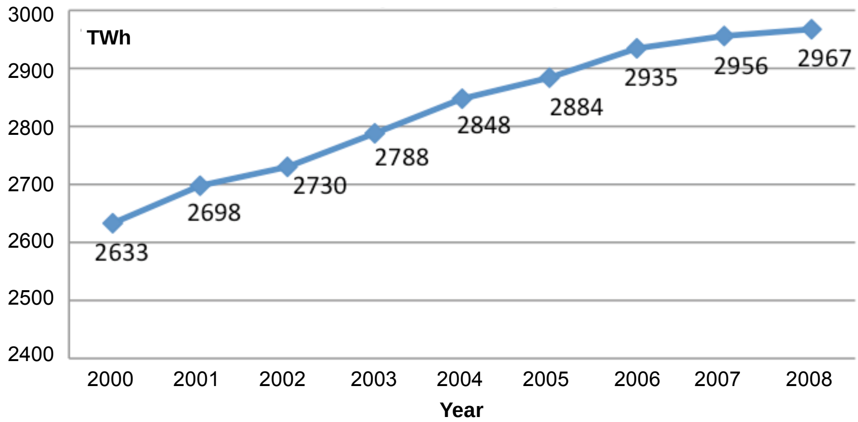
1. Regional contexts and drivers of smart grid development

1.1 Electricity market

The Organisation for Economic Co-operation and Development (OECD) Europe's electricity consumption is estimated to increase by an average of 1.2% per year between 2008 and 2035. Because of a relatively stable population with mature consumption patterns and well-established electricity markets, most of the region's growth in electricity demand is expected to come from those nations with a stronger, population growth (including Turkey, Ireland, and Spain) and from newer European Union (EU) members (including the Czech Republic, Hungary, Poland, and Slovenia), whose projected economic growth rates exceed the EU average.[1]

As shown in Figure A1-1, net electricity consumption[2] has grown on average about 1.5% per year in the EU27 between 2000 and 2008.

Figure A1-1
EU27 net electricity consumption (2000–2008)
Source: U.S. Energy Information Administration (EIA), database



[1] U.S. Energy Information Administration (EIA), 2011: *International Energy Outlook 2011*
[2] Net electricity consumption is computed as generation, plus imports, minus exports, minus transmission and distribution losses.

Figure A1-2
Evolution of the EU's energy mix (1995 versus 2007)
Source: EWEA and Platts Power Vision

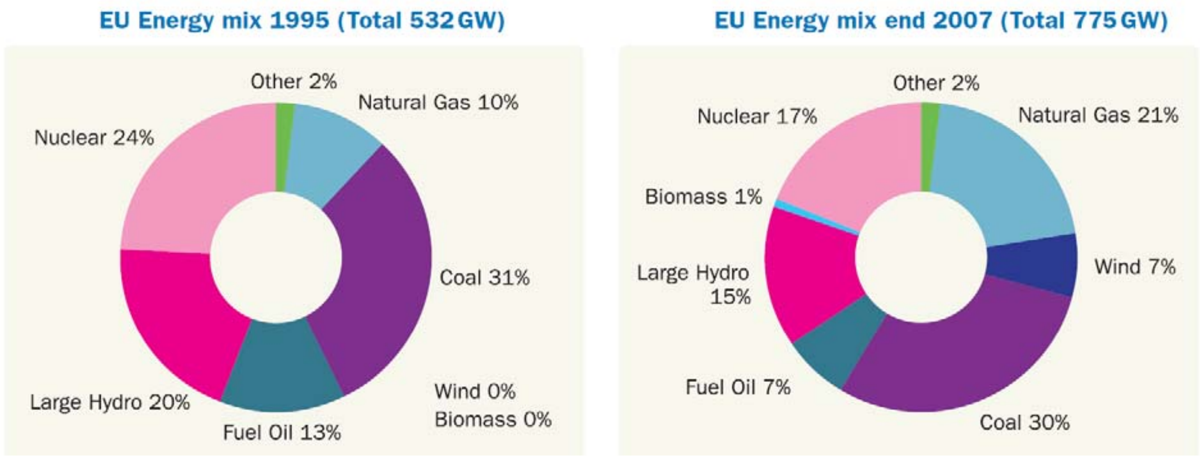
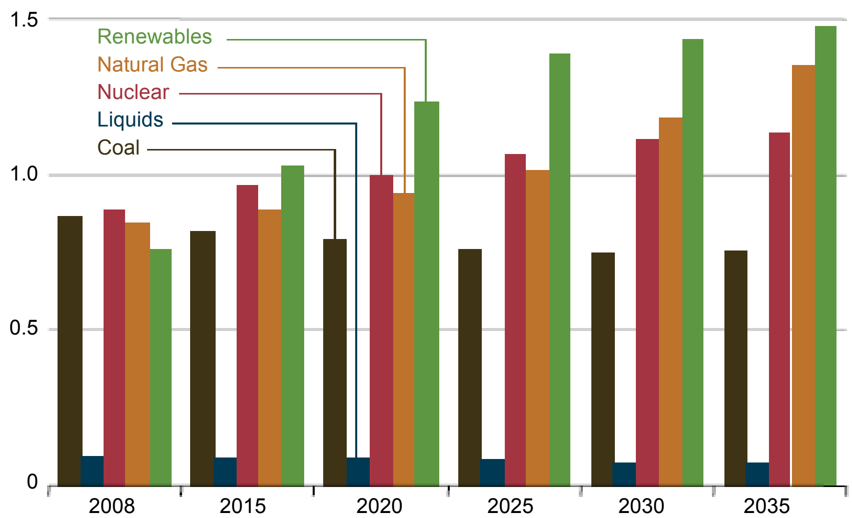


Figure A1-3
OECD Europe's net electricity generation by fuel, 2008–2035, in trillion kilowatt-hours
Source: U.S. Energy Information Administration (EIA), 2011: *International Energy Outlook 2011*



While combustible fuels have served as the backbone of Europe's production mix over the last two decades, Europe is moving away from fossil fuels toward an energy mix in which renewable energies play an increasing role (Figure A1-2).

Going forward, energy produced from renewable energies is OECD Europe's fastest-growing source of electricity generation, increasing by 2.5% per year through 2035 (Figure A1-3).

The main challenges for Europe's electricity infrastructure are the increasing shares of generation from various renewable sources and the ageing infrastructure, besides additional needs for market integration and security of supply.

1.1.1 Quality of the electricity supply

In 2008, the Council of European Energy Regulators (CEER) published the 4th Benchmarking Report on Quality of Electricity Supply 2008. Because different countries use different indicators and different weighting methods to evaluate the quality of supply, comparisons between countries is performed on two groups of

Figure A1-4

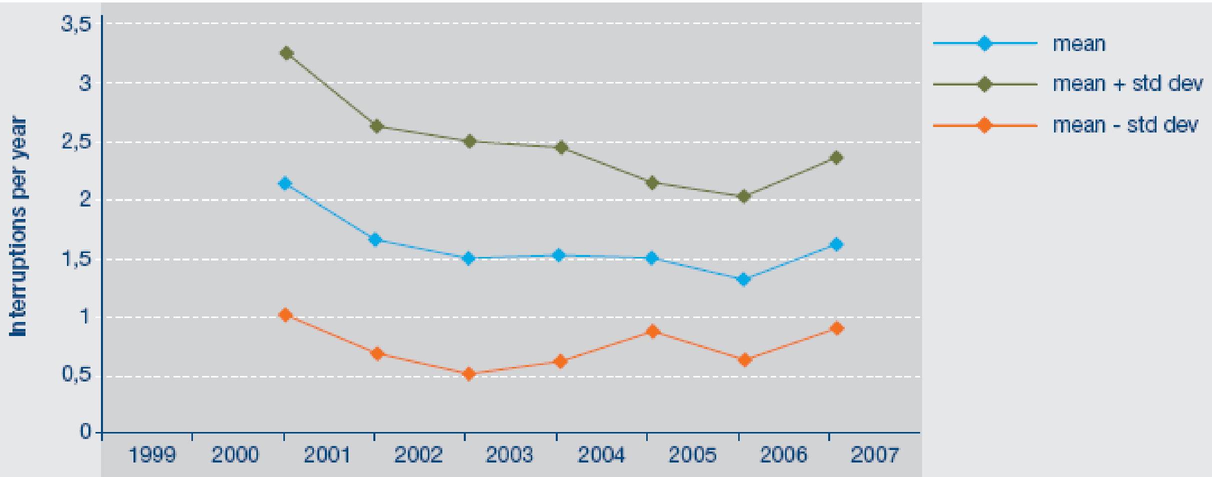
Trends in minutes lost per year excluding exceptional events: non-weighted average and standard deviations over all reporting countries

Source: Council of European Energy Regulators, 2008: *4th Benchmarking Report on Quality of Electricity Supply 2008*

Figure A1-5

Trends in number of interruptions per year excluding exceptional events: non-weighted average and standard deviations over all reporting countries

Source: Council of European Energy Regulators, 2008: *4th Benchmarking Report on Quality of Electricity Supply 2008*



main indicators: minutes lost per year and number of interruptions per year (Figures A1-4 and A1-5).

Figures A1-4 and A1-5 show that the quality of electricity supply, measured in minutes of interruptions per year and in the number of interruptions per year, is improving continuously. Smart meters are already able to collect information of outages, which can be used for statistical purposes and for investigating customer claims regarding the quality of supply; furthermore, it identifies the specific point of delivery affected by the problem. In addition, technical problems can be traced and solved more rapidly, and the continuous supervision of the grid leads to rapid detection of system stress, and thus rapid actions to relieve the network from conditions of peak loading, congestion, and bottlenecks—all measures reduce the duration of outages.

Figure A1-6

Electricity losses (%) in EU27 countries

Source: U.S. Energy Information Administration (EIA), database

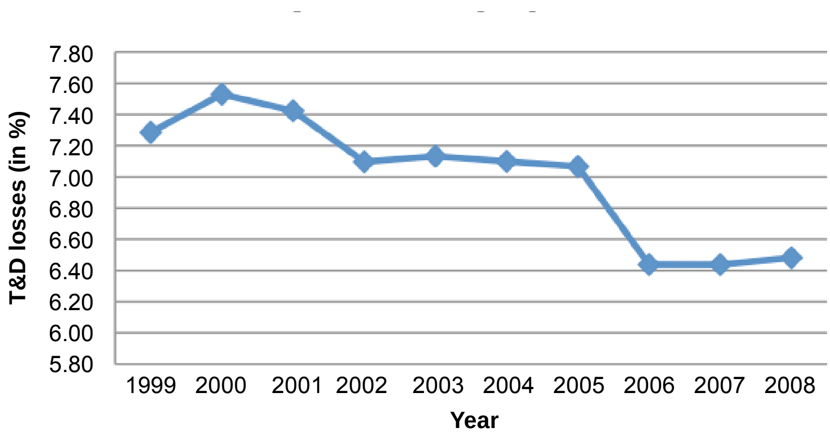
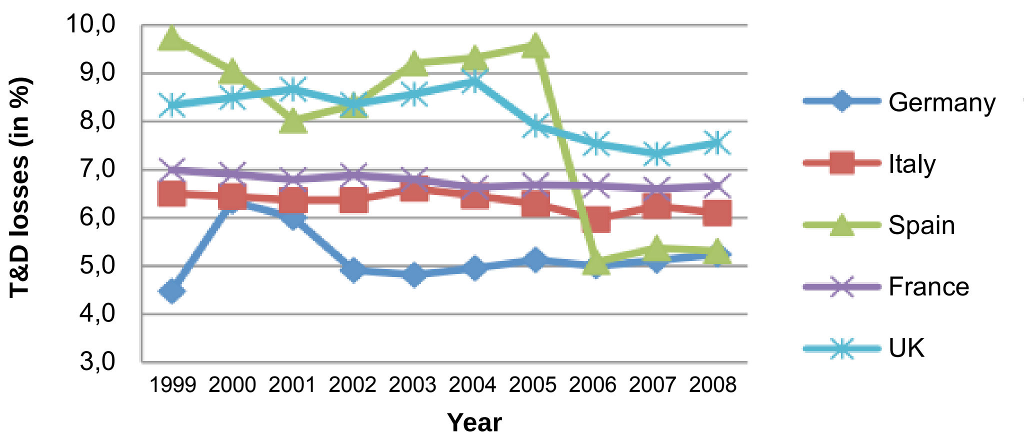


Figure A1-7

Electricity losses (%) in largest EU countries: Germany, Italy, Spain, France, and the United Kingdom

Source: U.S. Energy Information Administration (EIA), database



1.1.2 Network Losses

Losses in transmission and distribution networks represent the single biggest problem in any electricity system. Electric-power transmission and distribution losses include losses in transmission between the sources of supply and the points of distribution and also in the distribution to consumers, including theft. The average network losses in Europe are around 6% (Figure A1-6). The differences between European countries are significant, ranging from less than 1% for Luxembourg to 16% for Estonia. However, figures need to be interpreted carefully, because calculated losses favour countries with large transit power, like Luxembourg. But transit power only passes through high-voltage transmission lines, while about 75% of the losses occur within the distribution network itself.[3] Electricity losses have been estimated based on international energy statistics from the U.S. Energy Information Administration (EIA) and is done both at the transmission and distribution levels (Figure A1-7).

[3] http://www.leonardo-energy.org/drupal/node/2935, accessed 25.01.2012

Figure A1-8

Projected evolution of installed renewable capacities in giga-Watts, from 2010–2020

Source: European Commission (EC), 2011: *Energy infrastructure*

RES type	Installed capacity 2010 (GW)	Installed capacity 2020 (GW)	Share 2020	Variation 2010-2020
Hydro	116.9	134.2	29%	15%
Wind	82.6	201	43%	143%
Solar	25.8	90	19%	249%
Biomass	21.2	37.7	8%	78%
Other	1	3.6	1%	260%
Total	**247.5**	**466.5**	**100%**	**88%**

1.2 Legal and political/policy contexts and drivers

1.2.1 Drivers of smart grids in Europe

Taking into account that the current electricity network in Europe was developed more than 30 years ago and has been designed for one-way energy flows from large, centralized power plants to customers only, Europe's smart grid implementation is being driven by two main challenges:

- The need for networks to be prepared for a low-carbon future with decentralized generation while accommodating various renewable sources.
- The need to replace an ageing infrastructure.

Networks are increasingly required to become more and more flexible to integrate a variety of low-carbon technologies, host an increasing amount of distributed generation, and to deal with a widening range of applications and technologies that rely on electricity as an energy source (such as electric vehicles), which might potentially jeopardize the network's stability.

According to the National Renewable Energy Action Plans (NREAPs),[4] it is estimated there will be approximately 460 giga-Watts (GW) of renewable electricity installed capacity in the EU by 2020, compared with 244 GW total installed capacity in 2010. About 63% of this total is related to intermittent energy sources such as wind (201 GW, i.e., 43%) and solar (90 GW, out of which about 7 GW concentrated solar power or 20%) (Figure A1-8).

It is important to point out that wind and solar energy are characterized by strong daily and seasonal variations. Limited availability and predictability of electricity generation via these technologies are challenges that create new requirements for the entire power generation and transmission system, which strives to maintain a constant balance of generation and load on the transmission network.

1.2.2 Legal and political/policy contexts and drivers

With the view that economic growth and jobs will increase from innovation in products and services, and ensuring that an efficient and sustainable use of natural resources is made, Europe's public authorities (European Commission, European Parliament, and European Council) have launched a number of directives aimed at creating the future energy infrastructure and driving the development of smart grids. The most important ones being considered are the 20-20-20 EU Climate and Energy Package and the Third Energy Package.

[4] European Commission (EC), 2011,: *Energy infrastructure - priorities for 2020 and beyond — A Blueprint for an integrated European energy network*

20-20-20 EU Climate and Energy Package

European energy investments are mainly driven by the EU's climate-change energy 20-20-20 targets, which are to be reached by 2020 and which became law in June 2009,[5] while complying with the three main pillars of the EU's energy policy (security of supply, sustainability, and market efficiency).

- Cut greenhouse-gas (GHG) emissions by 20% compared with 1990 levels
- Increase the share of renewables in the energy mix by 20%
- Cut energy consumption by 20%.

The European Commission (EC) proposed binding legislation to implement the 20-20-20 targets, with three pieces of complementary legislation that affect smart grid investments:

1. A revision and strengthening of the Emissions Trading System (ETS), which is the EU's key tool for cutting emissions cost-effectively. A single EU-wide cap on emission allowances will apply from 2013 and will be cut annually, reducing the number of allowances available to businesses to 21% below the 2005 level in 2020. It is planned that this system will fund the NER300 program, which will provide financing for specific low-carbon and smart grid demonstration projects.[6]

2. An Effort Sharing Decision governing emissions from sectors not covered by the EU ETS, such as transport, housing, agriculture, and waste. Under the Decision, each member state has agreed to a binding national emissions limitation target for 2020 which reflects its relative wealth. The targets range from an emissions reduction of 20% by the richest member states to an increase in emissions of 20% by the poorest. These national targets will cut the EU's overall emissions from the non-ETS sectors by 10% by 2020 compared with 2005 levels. These targets should provide an important push for the development of clean technologies such as electric vehicles and renewable energy sources.

3. Binding national targets for renewable energy, which collectively will lift the average renewable share across the EU to 20% by 2020 (more than double the 2006 level of 9.2%). The national targets range from a renewables share of 10% in Malta to 49% in Sweden. The targets will contribute to decreasing the EU's dependence on imported energy and to reducing GHG emissions.

[5] European Commission; 2011: http://ec.europa.eu/clima/policies/package/index_en.htm

[6] http://ec.europa.eu/clima/policies/lowcarbon/ner300/index_en.htm

Third Energy Package

In parallel with the EU Climate and Energy package, the Third Energy Package, which came into force in September 2009 after being proposed by the EC and approved by the European Parliament and European Council, has pushed the member states, the regulators and network operators to deploy smart meters and smart grids, and more generally to launch innovative programs with appropriate remuneration schemes for the electricity network.

Furthermore, specifically related to the Electricity Directive (2009/72/EC)[7] published on 13 July 2009, a mix of obligations and recommendations to member states to establish appropriate regulatory frameworks (i.e., adequate incentives) is provided to increase efficiencies, foster market integration and security of supply, and support related research activities. These regulatory incentives should encourage network operators to earn revenues, decoupling them from additional sales, and relying instead on efficiency gains and lower peak investment needs, moving from a "volume-based" business model to a "quality- and efficiency-based" model.

Also, related to measures on consumer protection, the Directive explicitly defines provisions obliging suppliers to provide information to consumers. Specifically, the Directive requires member states to define by no later than 3 September 2012 "an implementation of intelligent-metering systems that shall assist the active participation of consumers in the electricity supply market". The Directive defines a target of "at least 80% of consumers shall be equipped with intelligent metering systems by 2020".

The provision of obliging member states to define an implementation plan of smart meters has provided the necessary push in many countries to start the deployment of smart meters:

- France: Issue of a smart meter decree in September 2010 that mandates the installation of 95% of smart meters by 2016.
- Germany: January 2010 law that stipulates the installation of smart meters in new buildings, reconstructions, or by customer requests.
- Finland: Full rollout of smart meters must be completed by 2014.
- United Kingdom: Government given mandate to retailers for rollout of gas and electricity smart meters between 2012 and 2020.
- Spain: The Royal Decree 1110/2007 and Ministerial Order 2860/2007 oblige all electromagnetic meters to be replaced by smart meters by 31 December 2018.

Given the tight relationship between smart grids and smart meters, these implementation plans also require the development of smart grids and should thus address the required regulatory incentives for implementing smart grids. Furthermore, 2011 saw new drafts of smart grid communication and consultation papers that in the future will become

[7] The Electricity Directive (2009/72/EC) can be downloaded from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0055:0093:EN:PDF

law and further push the development of smart grids:

- European Commission Communication on Smart Grids
- Regulation Infrastructure Package (under negotiation in the EU Parliament and European Council).

European Commission Communication on Smart Grids: from innovation to deployment

In April 2011, the EC adopted the Communication, Smart Grids: from innovation to deployment (COM/2011/0202), which provides a set of policy directions necessary to drive forward the deployment of future electricity networks. Specifically, the EC proposes a set of actions related to identify challenges that require being tackled as soon as possible to accelerate smart grid deployment.[8] The EC proposed that the focus should be on—

(a) Developing technical standards;

(b) Ensuring data protection;

(c) Establishing a regulatory framework to provide incentives for smart grid deployment;

(d) Guaranteeing an open and competitive retail market in the interest of consumers; and

(e) Providing continued support for innovation of technology and systems.

With reference to each of the abovementioned issues, the EC intended in 2011 to—

(a) Monitor and follow the development of Information and Communications Technology (ICT) standards at the European and international levels to facilitate the implementation of smart grids;

(b) Monitor the provisions of national sectoral legislation that might take into account the data protection specificities of smart grids. The European Standardisation Organisations (ESOs) will develop technical standards for smart grids taking the ”privacy by design” approach;

(c) Develop regulatory incentives for smart grid deployment, for instance through the development of a network code or implementing act on tariffs, and establishing guidelines to define a methodology for the smart-meter implementation plans of member states, as well as for their cost–benefit analyses;

(d) Introduce minimum requirements for the format and content of information for customers, and for access to information services and demand management, while monitoring the implementation of the Third Package requirements needed to create a transparent and competitive retail market;

[8] The full document can be downloaded at http://ec.europa.eu/energy/gas_electricity/smartgrids/smartgrids_en.htm

(e) Propose new large-scale demonstration initiatives for rapid smart grid deployment, taking into account the needs identified in the European Electricity Grid Initiative (EEGI).

To promote smart grids deployment in Europe through the abovementioned actions, the EC intends to address some regulatory aspects, in particular, in the context of the Third Internal Energy Market Package, the Energy Infrastructure Package, and the mainstreaming of energy policy priorities in different EU funding programmes.

Regulation Infrastructure Package

In October 2011, the EC unveiled its proposal for a regulation on "Guidelines for trans-European energy infrastructure". This blueprint for an integrated energy network has strategic energy networks and storage facilities completed by 2020. The EC has identified 12 priority corridors and areas covering electricity, gas, oil, and carbon dioxide transport networks, with a total estimated investment of €200 billion, of which approximately €140 billion is related to high-voltage electricity transmission systems, storage, and smart grid applications. This investment requirement represents a 100% increase in investment in the electricity sector compared with the period from 2000 to 2010.

The Regulation Infrastructure Package provides policy and regulatory certainty through a stable and appropriate regulatory framework to promote investments[9]:

- Rules to identify projects of common interest (PCI), necessary to implement the priority corridors/areas;
- Facilitate their implementation through accelerated permit granting and enhanced public participation;
- Rules for cross-border allocation of costs and risk incentives;
- Conditions of eligibility of PCIs for EU financial assistance under the Connecting Europe Facility, an investment instrument designed to fund necessary investments.

Within this blueprint, there is a specific chapter on the identification and evaluation of smart grid projects in line with the requirements put forward by the EC. The regulation is currently still under negotiation and shall be carried out in the course of 2012 in line with the missions of a Smart Grid Task Force. In particular, by the end of 2012, the overall deliverables of the Task Force is to establish a process for identifying PCIs once the Regulation on guidelines for trans-European energy infrastructure enters into force.

[9] Further information can be found on the official European Commission website at http://ec.europa.eu/energy/infrastructure/strategy/2020_en.htm

2. Identification of challenges

Ambitious 2020 targets for renewable energy as well as the low-carbon scenarios described in the EU Roadmap 2050[10] ask for a significant mobilization of investments in the coming decades. According to the EC, an investment of around €1 trillion will be needed by 2020 to replace obsolete capacity, modernize and adapt infrastructures, and cater to increasing and changing demand for low-carbon energy. Out of this amount, €140 billion refer to high-voltage electricity transmission systems of European significance, both onshore (€ 70 billion) and offshore (€30 billion), including storage and smart grid applications at transmission and distribution levels (€40 billion).[11]

Notwithstanding such ambitious targets, current tariff schemes in most European countries do not include sufficient incentives to launch the large-scale research, development, and demonstration (RD&D) projects needed, as most of the current tariff structures allow financing of the reinforcement of lines but not necessarily the deployment of "smarter" solutions. Finding appropriate funding for the launch of all the necessary large-scale demonstration projects and consequent deployment of smart grid technologies remains one of the key issues.

More specifically, the challenges can be split into three main areas, each with its particularities:

- Challenges regarding the launch of large-scale demonstration projects
- Challenges regarding the full deployment of smart grid technologies
- Public awareness.

2.1 Challenges regarding the launch of large-scale demonstration projects

The main challenge today is integrating innovative and developed technologies in the system and validating their performance under real-life working conditions. Therefore, a group of electricity transmission and distribution network operators has defined the European Electricity Grids Initiative (EEGI), a common research, development, and demonstration program.

In the scope of Europe's activities, The European Electricity Grid Initiative Roadmap 2010–18 and Detailed Implementation Plan 2010–12 were published in 2010, providing details of large-scale demonstration projects with the aim of testing solutions "performed in a real environment (involving real customers, real voltage, real network, at a scale suited for reliable scaling up and replication) and aimed at proving the viability of new solutions (technology, markets, regulation, customer acceptance) that can offer a potential benefit for the electricity networks and the users."

In this context, these large-scale demonstration projects typically involve electricity system innovation, a natural and legal responsibility of the

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[10] Roadmap 2050: http://roadmap2050.eu/

[11] Compare for the figures: Council of the European Union, 2011*: Commission Staff Working Paper—Energy infrastructure investment needs and financing requirements*

network operators, rather than technology innovation, which is usually pursued by individual technology manufacturers. This system-level innovation therefore involves close cooperation among different stakeholders, where a high level of research and development (R&D) organization is required. For later full deployment of smart grids, the projects require the sharing of all the necessary know-how acquired in large-scale demonstrations, while at the same time protecting the legitimate intellectual property rights (IPR) of companies. Maintaining this necessary balance is a challenge inherent to all demonstration activities.

Furthermore, these large-scale demonstration projects need to consider different distribution system operator (DSO) topologies existing in the network, to find those best technical solutions for specific grid structures to ensure a safe and economical provision of energy. Being able to adequately select the most appropriate DSO topologies where to test technologies is a non-trivial exercise that will always be a challenge needed addressing.

Finally, these large-scale demonstration projects, necessary to be launched prior to a full deployment of smart grids in Europe, require appropriate support funding, given that the benefits incurred from a massive deployment of smart grids are expected to be incurred by all actors in the value chain (generators, transmission system operators, or TSOs, DSOs and customers).

As smart grids become increasingly relevant, the definition of appropriate regulatory frameworks is a possible challenge to their implementation. As observed earlier, current tariff schemes in most European countries do not include sufficient incentives to launch the large-scale RD&D projects needed, as most of the current tariff structures allow financing the reinforcement of lines but not necessarily the deployment of “smarter” solutions.

Large-scale demonstration projects are, however, necessary to validate scaling and replication rules for system innovation, being inherently risky activities. As part of the learning process, innovation-tailored financing mechanisms should therefore give utilities the possibility to reduce the prime mover risk related to testing, on a large scale, not mature technologies. Without appropriate financing schemes, it is difficult to foster the necessary investments required for next project deployments. Finding appropriate funding for the launch of all the necessary large-scale demonstration projects remains a key issue.

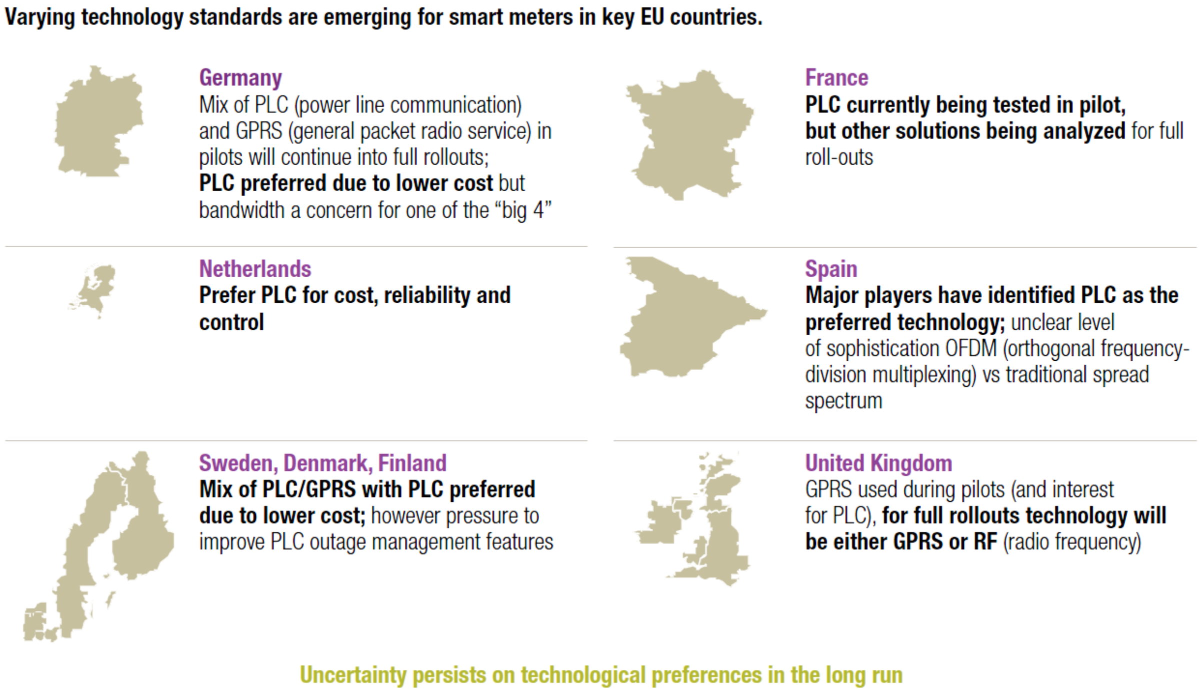
2.2 Challenges regarding the full deployment of smart grid technologies

The first clear challenge relates to selecting the most appropriate technologies for full deployment. More comprehensive adoption has been slowed down by the lack of clear technology standards for smart grid technologies. Furthermore, smart grid equipment and systems are provided by many industry sectors that historically have not worked together, such as equipment manufacturers, information and communication technologists, the building industry, consumer products, and service suppliers (Figure A1-9).

Figure A1-9

Various technology standards for smart meters in key EU countries

Source: McKinsey & Company; 2010: *How Europe is approaching the smart grid*



Specifically, standardization has to be addressed to provide solutions that facilitate future replication. The standardization of solutions and interoperability of technologies will help reduce deployment costs, key if a positive business case is to be made for the full deployment of a smart grid. In this respect, the main challenge today related to full deployment of smart meters in Europe is the definition of a commonly accepted set of functional requirements, ensuring interoperability, without blocking the evolution of innovative technology solutions.

Furthermore, for smart grids in general, elaborating a positive business case that provides benefits to all stakeholders still remains one of the key challenges, necessitating precise definition of how investments are paid, reflecting the fact that benefits are incurred by a wide range of stakeholders. Smart grid projects involve relevant investments and long implementation cycles, and without appropriate business models, there might be little reasons to undertake them.

Moreover, appropriate key performance indicators and the monetization of these benefits need to be identified to properly define a positive business case. The key challenges in this context are—

1. Investments performed mainly by DSO result in benefits to all the value chain (generators, TSO, DSO, customer, society), and not just the DSO.

2. Many benefits (i.e., societal) are difficult to quantify and monetize.

An example of the difficulty in monetizing all the benefits is the introduction of new technologies to the grid (i.e., ICT, automation, fault detection, etc.), which enable new distributed energy resources (DER) to be connected. The benefits accrued are numerous and include those easy to monetize (e.g., deferral of investments in new lines for the DSO), and others that are much more difficult to put a value on (e.g., grid technology enabling clean energy resources, which reduces the country's dependency on fossil fuels, a national strategic objective and benefit).

Finally, as in the case of the large-scale demonstration projects, defining clear regulatory frameworks that support full-scale deployments requires strong action by each national European regulatory authority. Moreover, the early involvement of regulatory authorities after the demonstration stage, besides providing demonstration projects themselves with the necessary financing instruments, would help national authorities to better understand the benefits of the validated innovative solutions before full-scale deployment and define the right regulatory framework to support the rollout.

2.3 Public awareness

One of the toughest challenges to a successful smart grid lies in consumer support, both as consumers and as participants on a massive scale. Therefore, a challenge regarding the launch of the large-scale demonstration projects involves the active participation of the local community in many of the parts, like demand response initiatives.

Close links with local communities and clear communication of the benefits achievable by implementing smart grids need to be shown by demonstration projects to raise public awareness and increase active participation. The lack of customer interest stems not only from the generally low level of awareness among European customers about the size of their electricity bill, but also from their still limited understanding of what a smart grid is and how its implementation creates value. It is of critical importance to explain to consumers in simple terms what a smart grid is, and more importantly, the direct benefits customers will incur with a massive deployment of all necessary technologies.[12]

It is the close collaboration with the local community (i.e., for simplified granting of permits by local authorities, active participation of users in demand-response demonstration programs, etc.) that can determine the success of demonstration projects in drawing relevant conclusions and identifying important lessons, prior to the full deployment of the technologies tested.

Data privacy and data security are important issues raised by data sensing and monitoring functionalities embedded in smart grid solutions, including smart metering that involves personal data. Therefore, assuring the protection and appropriate use of consumer data, supported by standards and certifications for instance, is crucial to create the right trust and involvement of consumers in innovative smart programs. Together with data privacy, cyber security should be guaranteed to preserve grid integrity from external, uncontrolled manipulations.

National governments have indeed the potential to educate consumers on the value of the smart grid, with regard to consumer-oriented issues such as affordability, privacy, cyber-security, health, and safety. While being effective mediators between consumers and the power system, national governments have also the means to ensure their interests in smart grid development and provide

[12] McKinsey & Company; 2010: *How Europe is approaching the smart grid*

incentives to induce the desired active behaviours by also empowering them.

Many countries have started introducing time-of-use (TOU) pricing to induce consumer participation. European-funded projects like ADDRESS and EcoGrid EU are also exploring financial incentives by making consumers vendors in the electricity market, providing consumers with the opportunity to sell power back into the grid and offer ancillary services to network operators.

3. Currently available financing mechanisms and best practice examples

The transmission and distribution grid operation is a regulated business in Europe, and therefore investment decisions in new technology are closely linked to the tariff schemes used by the regulatory body in each member state. According to the recent European Commission Communication on Smart Grids,[13] "regulatory incentives should encourage a network operator to earn revenue in ways that are not linked to additional sales, but are rather based on efficiency gains and lower peak investment needs, i.e., moving from a volume-based business model to a quality- and efficiency-based model."

However, even though appropriate tariff incentives are addressed, such incentives for RD&D projects today are the exception rather than the rule.

[13] European Commission Communication, *Smart Grids: from innovation to deployment*, COM(2011) 2012 Final, Brussels, 12 April 2011

Nevertheless, some European regulators have taken up this challenge, such as Office of Gas and Electricity Markets (OFGEM) in the United Kingdom and the Autorità per l'energia elettrica e il gas (AEEG) in Italy.

Also related to RD&D investments, different public financing mechanisms exist in Europe (e.g., Seventh Framework Programme, NER300, etc.), but additional public funding is still largely needed to cover the costs of priority projects that cannot be delayed to meet the 2020 targets.

3.1 European scale

3.1.1 The Seventh Framework Programme—FP7 (2007–2013)

In 2000, the EU approved The Lisbon Strategy, an action and development plan for the economy of the European Union. Its aim is to make the EU "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion." Within that context, one of the core factors to meet its ambitious goals was what was defined as "the knowledge triangle"—research, education, and innovation.

One of the EU initiatives designed to support this Strategy was the Seventh Framework Programme (FP7), which bundles all research-related EU initiatives together under a common roof, playing a crucial role in reaching the goals of growth, competitiveness, and employment. The broad objectives of FP7 have been grouped into four categories: Cooperation, Ideas, People, and

Capacities. For each category, a specific programme corresponding to the main areas of EU research policy has been defined.

The FP7 has a total budget of €50.5 billion, of which the largest share falls under the Cooperation category, with €32.3 billion destined for collaborative research in the following areas:

- Health (€6.05 billion)
- Food, Agriculture and Biotechnology (€1.94 billion)
- ***Information and Communication Technologies (€9.11 billion)***
- Nanosciences, Nanotechnologies, Materials, and new Production Technologies (€3.5 billion)
- ***Energy (€2.3 billion)***
- Environment (including climate change) (€1.8 billion)
- Transport (including aeronautics) (€4.18 billion)
- Socio-economic sciences and Humanities (€0.61 billion)
- Security (€1.35 billion)
- Space (€1.43 billion).

Related to the research areas included within the Energy theme, Smart Energy Networks was one specifically defined area. In this context, in the most recent list of "call for proposals" the EC opened for the 2012 period within the FP7, projects related to smart grids totalled approximately €30.5 million.[14]

Smart grid projects that have been launched under the FP7 Energy theme include—

- TWENTIES (2010–2013). TSO project aimed at exploring large penetration of wind and other renewable electricity sources in TSO networks.
- ADDRESS (2008–2013). DSO project aimed at the active participation of small and commercial consumers in power system markets and provision of services to the different power system participations in the context of the smart grids of the future.
- GRID4EU (2011–2016). DSO project led by six DSOs in six different EU countries aimed at carrying demonstration pilots of smart grid solutions on a large-scale basis. The project proposes solutions that go through large-scale integration of distributed generation, the improvement of energy efficiency, the enabling and integration of active demand, and new electricity uses.
- MERGE (2010–2011). The Mobile Energy Resources for Grids of Electricity is a €4.5 million, 16-partner collaborative research project supported by FP7. The project, which is the largest research programme FP7 funded, aims to evaluate the impact of the electric vehicles on the EU's electric power

[14] Further information can be found on the European Commission website: http://cordis.europa.eu/fp7/home_en.html

systems and provide solutions for the challenges brought about by their progressive large-scale integration.

Together with issues addressed under the Energy theme, Information and Communication Technologies are key enabling factors toward smart grid deployment. Under the joint Call for ICT Challenge and Energy, the INTEGRIS project has been funded, starting from 2010 for two years. The Intelligent Electrical Grid Sensor Communications project is a $5 million project aiming to provide an ICT system based on a hybrid power line communication-wireless integration, enabling the improvement of the performance of the electricity distribution grid.

3.1.2 NER300 (2010)

The NER300 is the name of the financing instrument managed jointly by the EC and the European Investment Bank and member states. Financing from this scheme comes from the provision set aside in Article 10(a) 8 of the revised Emissions Trading Directive, which set aside 300 million allowances (rights to emit one tonne of carbon dioxide) in the New Entrants' Reserve of the European Emissions Trading Scheme for subsidizing the installations of innovative renewable energy technology and carbon capture and storage (CCS). These emissions allowances are to be sold on the carbon market, and the money (which could be €3 billion taking each price of each allowance at €10) will be made available to projects as they operate. Projects funded under this mechanism will have as a maximum 50% of total project relevant costs financed.[15]

The NER300 includes two main project categories: Carbon Capture and Storage and Renewable Energy Sources. Within the Renewable Energy Sources category, eight subcategories are defined, of which one is specific to "Distributed Renewable Management," i.e., smart grids. The first set of projects was submitted at the end of 2010, and 9 projects had been submitted under the Smart Grids subcategory. Decision on award of projects is expected in late 2012.[16]

3.1.3 Connecting Europe Facility (2014–2020)

The Connecting Europe Facility (CEF) is a new budgetary instrument of the EC aimed at supporting the proposed Regulation Infrastructure Package. The aim of the CEF is to streamline and facilitate EU support to infrastructures by optimizing the portfolio of instruments available, standardizing the operational rules for using them, and capitalize on possible synergies across the three sectors (transport, energy, digital infrastructures). The aim is that a coordinated approach will ensure the largest possible added value, simplify procedures, and reduce collective costs.

The CEF proposal develops a common financing framework for all sectors, including coordinated annual work programmes, a common committee,

[15] NER300: http://www.ner300.com/ accessed 06.08.2012

[16] Further information regarding the NER300 Program can be found at European Commission website: http://ec.europa.eu/clima/funding/ner300/index_en.htm

flexibility between sectoral budgets, increased performance indicators and conditionality, and the shared use of infrastructure-specific financial instruments.

The CEF will have a budget of €50 billion for the period 2014–2020, of which €9.1 billion will be reserved for Energy Infrastructure projects.[17] The complete breakdown is described below:

CEF	€40 billion
• Energy	€9.1 billion
• Transport	€21.7 billion
• Telecommunications/Digital	€9.2 billion
Amounts earmarked in Cohesion Fund for transport infrastructures	€10 billion
Total	€50 billion

3.1.4 The Intelligent Energy—Europe (IEE)

The IEE programme is an EC programme, launched in 2003 and runs to 2013 to support energy efficiency and renewable energy policies, with a view to reaching the EU 2020 targets. Targeted funding with a total budget of €730 million has been provided for innovative projects helping to meet the following objectives:

- Promoting energy efficiency and encouraging the rational use of energy sources;
- Increasing the use of new and renewable energy sources as well as encouraging energy diversification;
- Stimulating energy efficiency and renewable in the field of transport.

3.1.5 Financing instruments to support the Regulation Infrastructure Package

Europe 2020 Project Bonds Initiative (2014 onward)

On 19 October 2011, the EC adopted a legislative proposal launching the pilot phase of the Europe 2020 Project Bond Initiative.

The initiative has two objectives:

- To establish debt capital markets as an additional source of financing for infrastructure projects, and
- To stimulate investment in key strategic EU infrastructure in transport, energy, and broadband.

The aim is to revive project bond markets and to help the promoters of individual infrastructure projects to attract long-term, private-sector debt financing. The Project Bond Initiative would set up a means to reduce the risks for third-party investors seeking long-term investment opportunities. It would thus act as a catalyst to re-open the debt capital market (currently largely unexploited for infrastructure investments following the financial

[17] Official European Commission with additional information regarding the Connecting Europe Facility found at http://ec.europa.eu/commission_2010-2014/president/news/speeches-statements/2011/10/20111019_speeches_1_en.htm

crisis of 2008) as a significant source of financing in the infrastructure sector.

The Project Bond instrument would be fully integrated in the next Multiannual Financial Framework 2014–2020. Until this multiannual financial framework starts, the European Commission proposes setting up a pilot phase in the period 2012–2013 which would facilitate market introduction. Throughout the pilot phase, stakeholders can familiarize themselves with the novel financing structures and give feedback which would then be used to fine-tune parameters of this financial instrument.

Projects would need to provide stable and strong cash flows in addition to being economically and technically feasible. The European Industrial Bank will be responsible for performing an evaluation of these factors in view of its experience with infrastructure financing. Final decision on eligibility criteria still needs approval by legislators.[18]

Horizon 2020 (2014 onward)

Horizon 2020 is an additional financial instrument currently under discussion by European authorities aimed at replacing the FP7 set to end in 2013. The new programme, aimed at research and innovation, is expected to run from 2014 to 2020 with an overall budget of €80 billion.[19]

It is expected that Horizon 2020 will contain the following elements:

- Dedicated budget of €24.6 billion for **science activities**. The aim is that this will provide a boost to top-level research in Europe.
- €17.9 billion aimed at **strengthening industrial leadership** in innovation. This will include major investment in key technologies, greater access to capital, and support for small and medium enterprises.
- Provide €31.8 billion for **a better society** to help address major concerns shared by all Europeans such as climate change, developing sustainable transport and mobility, making renewable energy more affordable, ensuring food safety and security, or coping with the challenges of an ageing population.

Although still in the draft stage, full adoption of the Horizon 2020 is expected to follow the time frame:

- From 30/11: European Parliament and European Council negotiations on the basis of EC proposals;
- On-going: Parliament and Council negotiations on EU budget 2014–20;
- Mid-2012: Final calls under FP7 for Research to bridge gap toward Horizon 2020;

[18] European Commission: http://ec.europa.eu/economy_finance/financial_operations/investment/europe_2020/index_en.htm

[19] European Commission: http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020

- By end of 2013: Adoption of legislative acts by Parliament and Council on Horizon 2020 1/1/2014;
- Horizon 2020 starts; launch of first calls.

It is expected that the new EU financing package will provide additional resources to smart grid projects, mainly into RD&D, piloting, demonstration, test-beds, and support for public procurement and market uptake.[20]

3.2 Regulatory incentives and national funds

As stated earlier, investment decisions are closely linked to the tariff schemes used by the regulatory body in each member state. Tariffs should ensure that network operators are granted appropriate incentives to increase efficiencies, foster market integration and security of supply, and support related research activity. Studies show, however, that appropriate tariff schemes still need to be defined.

According to a EURELECTRIC study of the regulatory frameworks currently in operation in Europe,[21] national regulatory bodies do not adequately support network company requirements for higher levels of investment. The current financing model applied to DSOs has been traditionally geared to simply driving down costs, resulting in ineffective instruments to incentivize grid modernization and upgrading where benefits often accrue beyond the lifetime of a price review period itself. However, it is important to highlight that some national regulators have taken up this challenge and started creating smarter incentivizing mechanisms. Best practices come from the United Kingdom and Italy, where respectively OFGEM and AEEG have put in place tailored incentive mechanisms to encourage network companies to pursue innovation/demonstration projects.

3.2.1 United Kingdom

Innovation Funding Incentive (IFI)

The Innovation Funding Incentive (IFI) scheme is a mechanism introduced by OFGEM to encourage distribution network operators (DNOs) to apply innovation in the technical development of their networks and to invest in appropriate R&D that focuses on the technical aspects of network design, operation, and maintenance. In particular, the IFI instrument was introduced in 2005 through 2010 and allowed up to 0.5% of annual revenue to be spent on innovation. IFI scheme was extended until the end of the next distribution price control review DPCR5.

Registered Power Zones (RPZs)

The RPZ program, running to 2010, was set specifically on the connection of generation to distribution systems and is intended to encourage DNOs to develop and demonstrate new, more cost-effective ways of connecting and operating generation that will deliver specific benefits to new

[20] Official European Commission website with all relevant information can be found at http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=home

[21] DaCosta, Lorenz, and Schlosser: “Eurelectric Paper on Regulatory Incentives for Smart Grids,” CIRED’11

distributed generators and broader benefits to consumers generally. The RPZ provides revenue allowances for demo projects based on output criteria.

Low-Carbon Network Fund

The U.K. government's regulator, OFGEM, launched the Low-Carbon Network (LCN) Fund in April 2010 to support RD&D projects on networks in the United Kingdom. The fund, running through March 2015, provides DNOs projects with a total budget of £500 million (USD 790 million) addressing low-carbon and energy-saving initiatives such as electric vehicles, heat pumps, micro and local generation, and demand side management, as well as investigating the opportunities of smart meter rollouts, while providing security of supply. As such, the Fund should also provide valuable learning for the wider energy industry and other parties.

There are two tiers of funding under the LCN Fund. The First Tier, up to £16 million (USD 25 million) a year, is spread across all DNOs to spend against set criteria. Under the Second Tier, OFGEM provides total funding of up to £320 million (USD 498 million) over the five years for a small number of significant "flagship" projects by holding annual competitions where DNOs will compete against each other. In the first year, 4 projects were awarded Second Tier funding totalling £63.6 million (USD 100 million) through the annual competition and 11 projects were registered under the First Tier.[22]

A Discretionary Funding Mechanism worth £100 million (USD 156 million) over the five-year period enables also OFGEM to reward successful delivery and projects.

RIIO (Revenue = Incentives + Innovation + Outputs)

RIIO are U.K. price control mechanisms providing network companies with incentives to overcome the challenges of delivering low-carbon energy. The regulatory formula is synthesized by OFGEM by the equation, Revenues = Incentives + Innovation + Outputs. Such price control frameworks will be set for an eight-year period (2013–2021), thus assuming a long-term view of finance ability. It is intended to deliver a low-carbon sustainable energy sector with incentives to reward innovation and renew ageing infrastructure. OFGEM in fact expects that energy networks will need to invest £32 billion (USD 50 billion) over the next decade and it is therefore putting more emphasis on outputs.

The DNO is supposed to set out its investment strategy to meet long-term targets, linking anticipated expenditures to the delivery of primary outputs (e.g., reliability and availability, safety, environmental impact, etc.). With the instrument of 'secondary deliverables,' the framework allows DNOs to include expenses aimed at innovative

[22] OFGEM website: http://www.ofgem.gov.uk/Networks/ElecDist/lcnf/Pages/lcnf.aspx

projects where costs would occur immediately, but benefits would only occur within a longer time horizon. These ‘secondary deliverables’ could form milestones in project delivery, implying that network operators will only be allowed to raise revenues from consumers given the milestone is reached. This way, certainty is provided to network operators to engage in long-term investments, while linking their revenues to the delivery of the objectives.

To summarize, the emerging RIIO model puts investment in a long-term context, designing an output-based regulatory framework tailored to foster network companies’ investments on innovation and to promote smarter networks for a low-carbon future.

3.2.2 Italy

Italy’s regulatory body, AEEG, has promoted innovation since 1999, consisting of a general R&D levy in the network tariff. Currently, the levy amounts to 0.03 Eurocent/kWh.

Alongside R&D, AEEG has promoted a competitive process for selected smart grid demonstration activities under the Resolution 39/10. Other innovative regulatory financing instruments for smart grid-related projects are also described.

Resolution 39/2010

In 2008, the Politecnico di Milano, following instructions by the AEEG, studied Italy’s distributed generation (DG) hosting capacity. The conclusions of the study were that, in order to avoid voltage control problems, full exploitation requires new standards for DG interface protection and new communication devices based on open protocols. In the light of this developed work, AEEG approved in March 2010 Resolution 39/10, a regulation that provides extra remuneration guaranteed up to 8–12 years for new strategic investments. The regulation provides an additional 2% extra Weighted Average Cost of Capital (WACC) remuneration for a long-term period of 12 years for selected investments related to smart grids (active distribution network only) and energy efficiency. The regulation described the rules for demonstration projects for smart grids:

- Focused on grids at MV level (1–35kV)
- Implemented where there is a critical situation for DG (flow inversion from MV to HV at least 1%-of-year-hours)
- Rethink and field test new automation, protection, and control systems of distribution networks.

An expert committee was appointed to evaluate and select projects using a key performance indicator approach and a selection of the most cost-effective projects, whose project selection criteria spanned four main domains:

- Size of project (four specific evaluation criteria);
- Degree of innovation in pilot/demonstration project (five specific evaluation criteria);
- Feasibility of project (two specific evaluation criteria);
- Large-scale applicability potential (three specific evaluation criteria).

Resolution 242/2010[23]

To test different market models for electric-vehicle charging services, the AEEG provided financing mechanisms for five new pilot projects, ending on 31 December 2015. In particular, a 728.00 €/year incentive per charging point is provided for the construction and operation of charging infrastructure for electric vehicles. The Authority Direzioni Tariffe e Mercati Office will evaluate the final report of these pilot projects to provide the AEEG with recommendations on the regulation of possible market models, future standardization, and wide dissemination of successful results on a large scale.

Resolution 198/2011[24]

For the new regulatory period 2012–2015, the AEEG's regulation has maintained incentives for selected projects started before 31 December 2011 which follows Resolution 39/2010. For projects to be selected by AEEG from 1 January 2012 onward, an additional 2% extra WACC remuneration will be provided on the smart grid-related assets for a period up to 12 years.

[23] http://www.autorita.energia.it/allegati/docs/10/242-10arg.pdf

[24] Allegato A of the TIT - Testo Integrato Delle Disposizioni Dell'autorità Per L'energia Elettrica E Il Gas Per L'erogazione Dei Servizi Di Trasmissione e Distribuzione Dell'energia Elettrica

3.2.3 Other European Countries

Alongside the tailored regulatory mechanisms described, there are other examples of national frameworks where innovation is fostered.

- Finland: the regulatory model that will apply from 2012 to 2015 will include an innovation incentive allowing a proportion of R&D costs to be passed to customers;
- Portugal: a new option incentivising investments in innovative solutions has been proposed in the public consultation on the Tariffs Code amendment to be applied in the next regulatory period 2012–2014.

Other approaches do not necessarily contradict innovation. For instance, in Austria, a regulation provides inherent incentives to reduce costs and deploy innovative solutions and is also complemented by other sources of funding for demonstration phases.

In Germany, the Incentive Regulation Ordinance (ARegV) has provided since 2009 a revenue-cap regulation promoting the efficient operation of networks and aims at reducing grid fees. However, according to a discussion paper on incentive regulation and return on equity presented within the Innovative Regulation for Intelligent Networks (IRIN) project,[25] ARegV is well suited for pure replacement investments, but shows shortcomings with regard to innovations. Because revenues are

[25] http://www.wik.org/index.php?id=diskussionsbeitraegedetails&L=1&tx_ttnews%5Btt_news%5D=1335&tx_ttnews%5BbackPid%5D=93&cHash=ff0a74079c96bbde7e899a665c723f30

based on individual costs of network operators, the possibility of earning extra profits is restricted to one regulatory period (5 years). IRIN is sponsored by the Federal Ministry of Economics (BMWi) and works on the design of an adequate institutional framework that supports efficient and effective network development toward smart grids.

At a national level, some funding programs are also worth mentioning. Among those, the German Federal Ministry for Economics and Technology‘s funding program “E-Energy” or the Spanish Ministry of Industry, Commerce and Tourism, which support a number of technology platforms for integrating smart systems. The E-Energy technology programme with the aim of stepping up and intensifying the necessary R&D work will run for a 4-year term and receive an overall budget of some €140 million.

Finally, in Sweden a separate funding scheme using public money is available for demonstration projects, whose funding decisions are not made by the national regulatory authority.

Annex 2: North America

1. Regional contexts and drivers of smart grid development

1.1. Electricity market

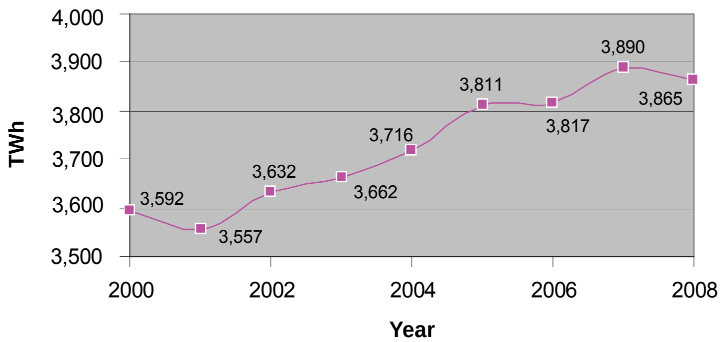
Historically, electricity consumption in the United States grew an average of 1.5% per year from 2001 to 2007 (Figure A2-1).[26] In 2008, the growth trend in electricity consumption ceased as the U.S. entered into an economic recession in December 2007.[27]

Similarly, Canada's electricity consumption grew an average of 1.4% per year from 2001 to 2005 (Figure A2-2). Notably, electricity consumption in Canada in 2006 experienced a drop of 2.3%, mainly due to lower electricity demand from the manufacturing sector.

In North America's generation and resource mix, important changes are occurring. For example, gas-fired generation is replacing coal-fired generation and there are large increases in the variable generation of renewables.[28] The North American Electric Reliability Corporation (NERC) assesses that, by 2021, there will be significant changes in the fuel mix of electricity generation, like coal, and renewables, like wind and solar (Figure A2-3).

The reference case in the EIA's annual International Energy Outlook 2011 for the United States also illustrates an electricity mix shifting toward low-carbon alternatives, as shown on Figure A2-3.

Figure A2-1
U.S. net consumption of electricity (2000-2008)
Source: U.S. Energy Information Administration (EIA), database



[26] U.S. Energy Information Administration (EIA) 2011: *International Energy Outlook 2011*
[27] The National Bureau of Economic Research

[28] North American Electric Reliability Corporation (NERC), 2011: *Long-Term Reliability Assessment 2011*

Figure A2-2
Canada net consumption of electricity (2000-2008)
Source: U.S. Energy Information Administration (EIA), database

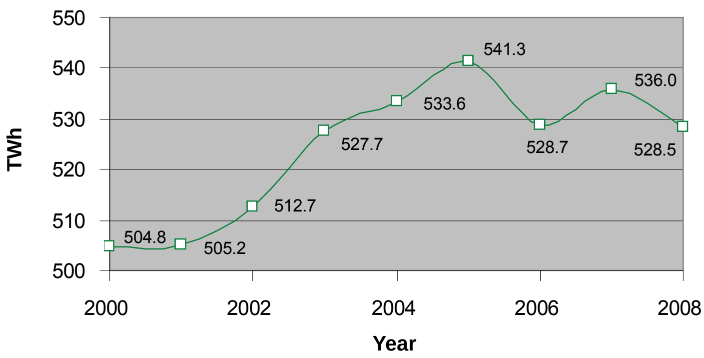
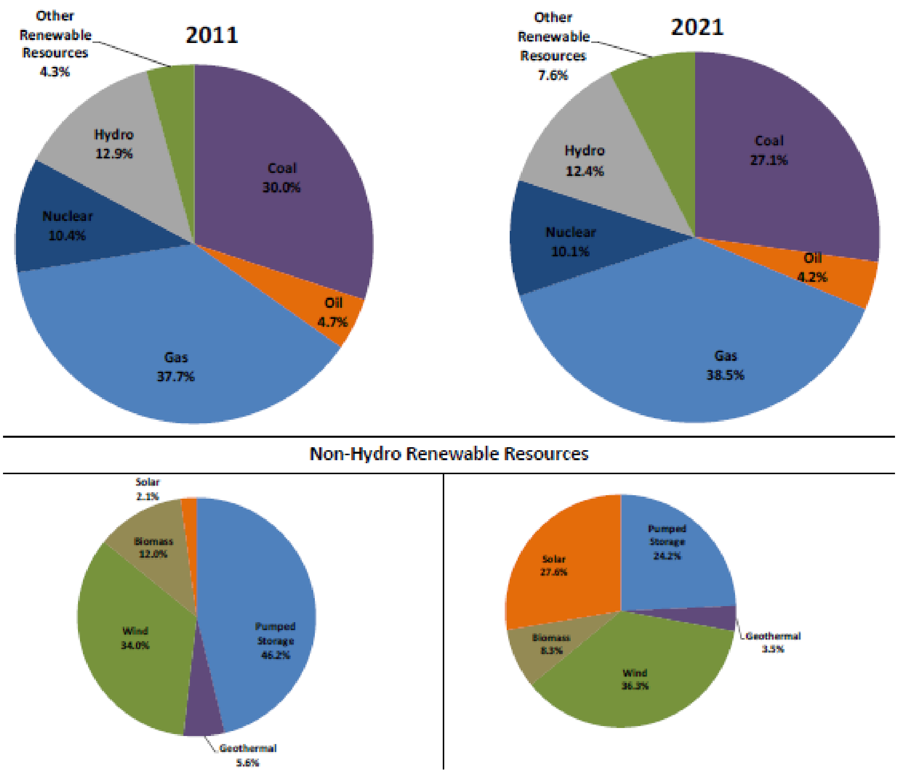


Figure A2-3
North America's current and projected fuel mix of generation capacity
Source: North American Electric Reliability Corporation (NERC), November 2011: *Long-Term Reliability Assessment 2011*



The percent share of total electricity net generation covered by coal will decrease from 45% in 2009 to 43% in 2035 (Figure A2-4), while the total share covered by both natural gas and renewables will increase from 33% in 2009 to a total of 39% in 2035.[29]

With 58% of its electricity generated from hydropower in 2008, Canada is one of the world's largest producers of hydroelectricity. At 363 tera-Watt-hours (TWh) in hydropower generation in 2009, Canada is the third highest hydroelectricity producer behind China and Brazil. As seen in Figure A2-5, Canada's remaining energy mix is made up of nuclear, conventional thermal generation, and other, non-hydro renewables.

[29] U.S. Energy Information Administration (EIA), 2011: *International Energy Outlook 2011*

Figure A2-4

U.S. net generation mix of electricity

Source: U.S. Energy Information Administration (EIA), database

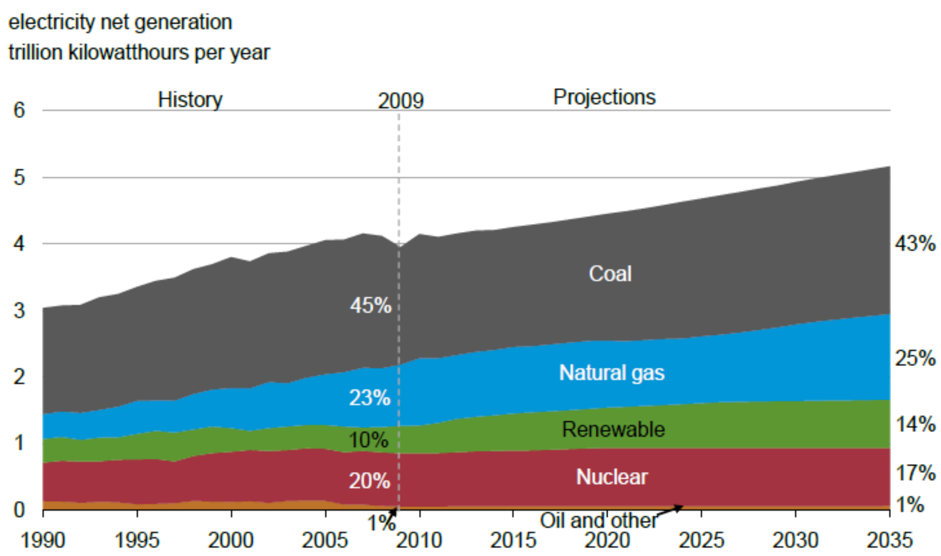
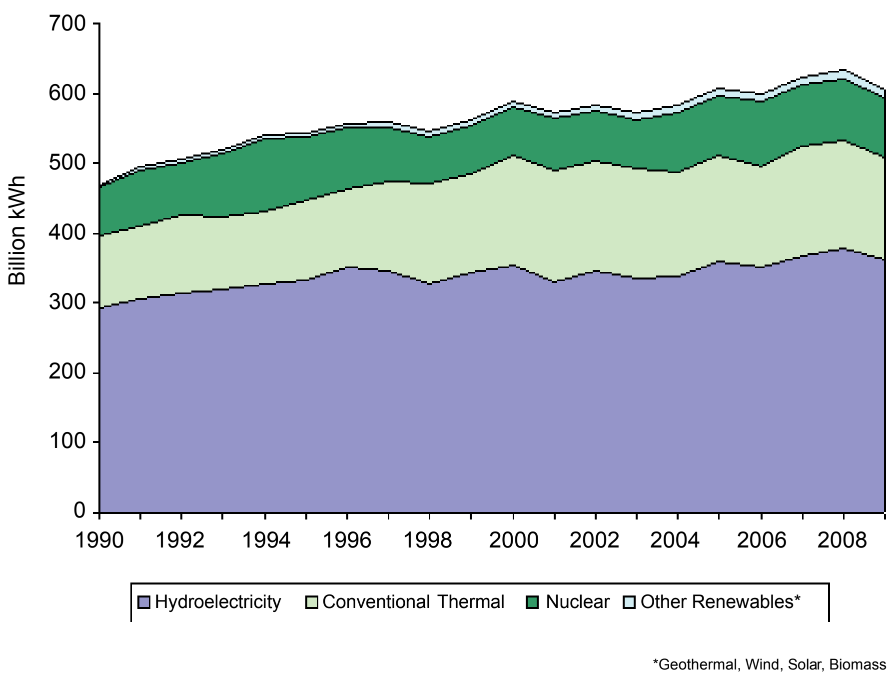


Figure A2-5

Canada's generation mix of electricity

Source: U.S. Energy Information Administration (EIA), database



1.2 Legal and political/policy contexts and drivers

1.2.1 Drivers of smart grids in North America

The 2003 blackout suffered by the northeast portion of North America raised concerns over the ageing and inefficient state of the underlying electric power grid. In its final report in 2004, the U.S.–Canada Power System Outage Task Force concluded that one of the causes of the outage was attributed to the grid's reliability organizations failing to provide effective, real-time diagnostic support.[30] The Task Force recommended reliability improvements to be implemented, which has ultimately led to the creation of the North American Synchrophasor Initiative (NASPI). Under the Initiative, NERC, the U.S. Department of Energy (DOE), and the electric industry have advanced the adoption of synchrophasors, a tool to measure the state of the electrical system and manage power quality. This particular technology was supported by the DOE in 2009, when $126 million out of $3.4 billion in matching grants for smart grid investment projects were awarded to regional transmission operators for the installation of phasor measurement units (PMUs).

The expected growth in investment for transmission and distribution (T&D) infrastructure is based on decades of under-investment. Consequently, this lack of investment has resulted in an inadequate electric power infrastructure to face today's increased focus on renewables. The aged grid serves as a driver for smart grid technologies to be employed while modernizing and increasing the efficiency of outdated T&D infrastructure.

1.2.2 Legal and political/policy contexts in North America

An effective way to drive smart grid investments is through regulation. In the United States, there is paralysing uncertainty in the energy industry around future investments and the subsequent development of a smart grid to increase energy efficiency and support new technologies. This is in part due to failed attempts to materialize a proposed cap-and-trade system for limiting GHG emissions in 2010. With the proposed cap-and-trade program, or any carbon-limiting action like a carbon tax, the United States would take a leading step to drive the smart grid industry. Charging for carbon emissions would discourage the use of fossil-based generation and continue the drive for improving energy efficiency through smart grid technologies.[31]

One of the most important drivers behind the accelerated development of the smart grid in the United States has been the American Recovery and Reinvestment Act (ARRA) of 2009. The ARRA provided $4.5 billion[32] to jumpstart the smart grid. Of the total amount awarded, the DOE distributed $3.4 billion in grants to 100 projects in the form of the Smart Grid Investment Grant (SGIG) Program, and $600 million to 32 projects under the Smart Grid Demonstration (SGDP) Program (Figure A2-6).

[30] https://reports.energy.gov/BlackoutFinal-Web.pdf

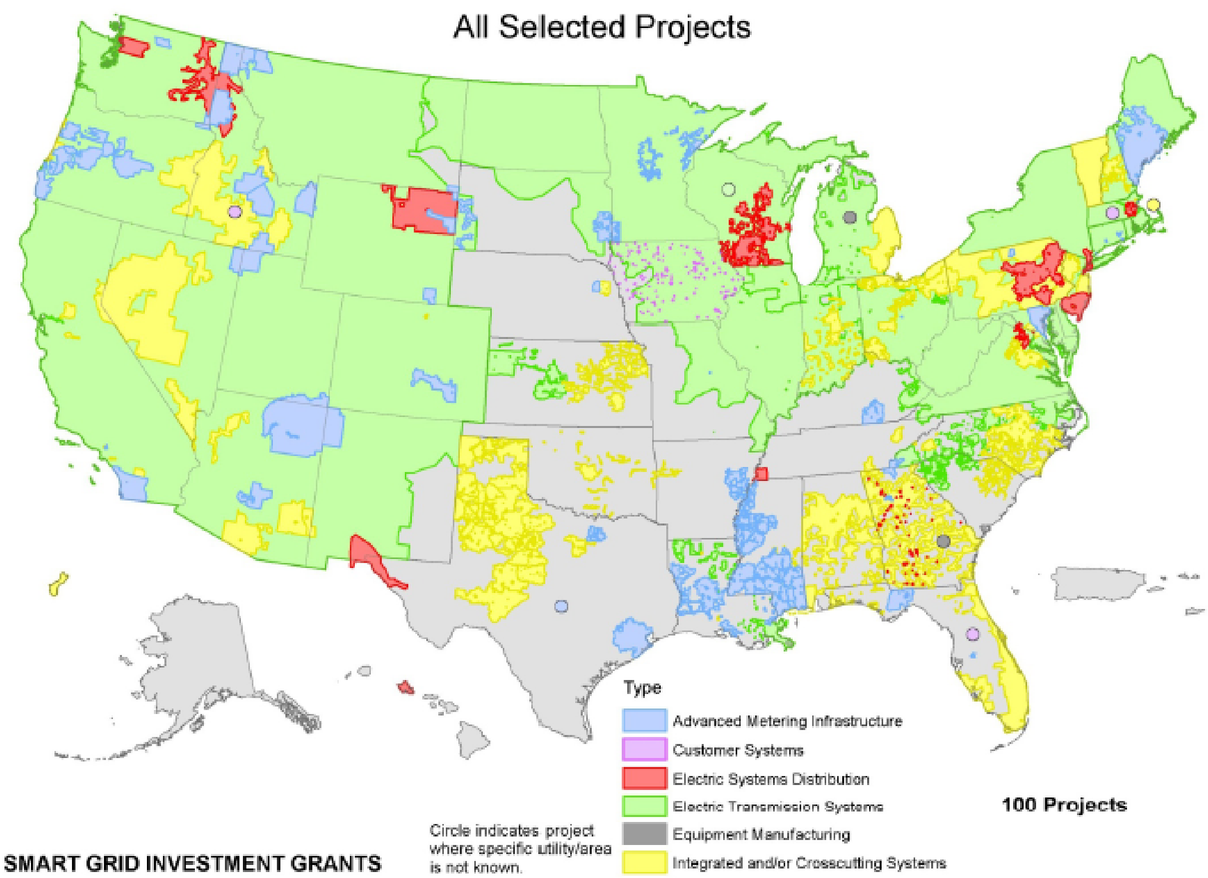
[31] U.S. Department of Energy

[32] www.SmartGrid.gov

Figure A2-6

Smart Grid Investment Grant Program award recipients by state

Source: U.S. Department of Energy



The SGIG projects were awarded under the categories of advanced metering infrastructure, electric distribution systems, electric transmission systems, equipment manufacturing, customer systems, and integrated and/or crosscutting systems. When considering matching funds from private industry, the total budget estimate for the awarded projects is about $8 billion. Additionally, of the total funding, $100 million was allocated to workforce training under the Workforce Training for the Electric Power Sector Program, a key component of smart grid that aims to train the necessary workforce for the development and maintenance of the smart grid.

Renewable Portfolio Standards (RPS) have served as an additional smart grid driver (Figure A2-7). Each state's standards require that electricity producers generate a minimum percentage of electricity from renewable energy resources or install renewable capacity by a specific date. With the influx of intermittent generation from wind and solar resources, the pressure continues to increase the development of smart grids that can optimally use intermittently generated resources.

In consequence to the goals set by the RPS, an unquestionable driver for U.S. smart grid has been the surge in wind turbine capacity that has taken place across the past couple of years. The increasing footprint of this renewable energy resource has not only led to a build-up of segments of transmission infrastructure, but also to the realization that the existing grid needs to be modernized to withstand increasing levels of this intermittent resource. Historically, the wind industry in the United States has been driven by Production Tax Credits (PTCs) awarded in cents per kilowatt-hour, but with the PTC set to expire by the end of 2012, the wind industry and consequently one of the drivers for smart grid investments, faces an uncertain future (Figure A2-8).

Figure A2-7

Renewable Portfolio Standards and goals for the United States as of 3 May 2011

Source: U.S. Federal Energy Regulatory Commission

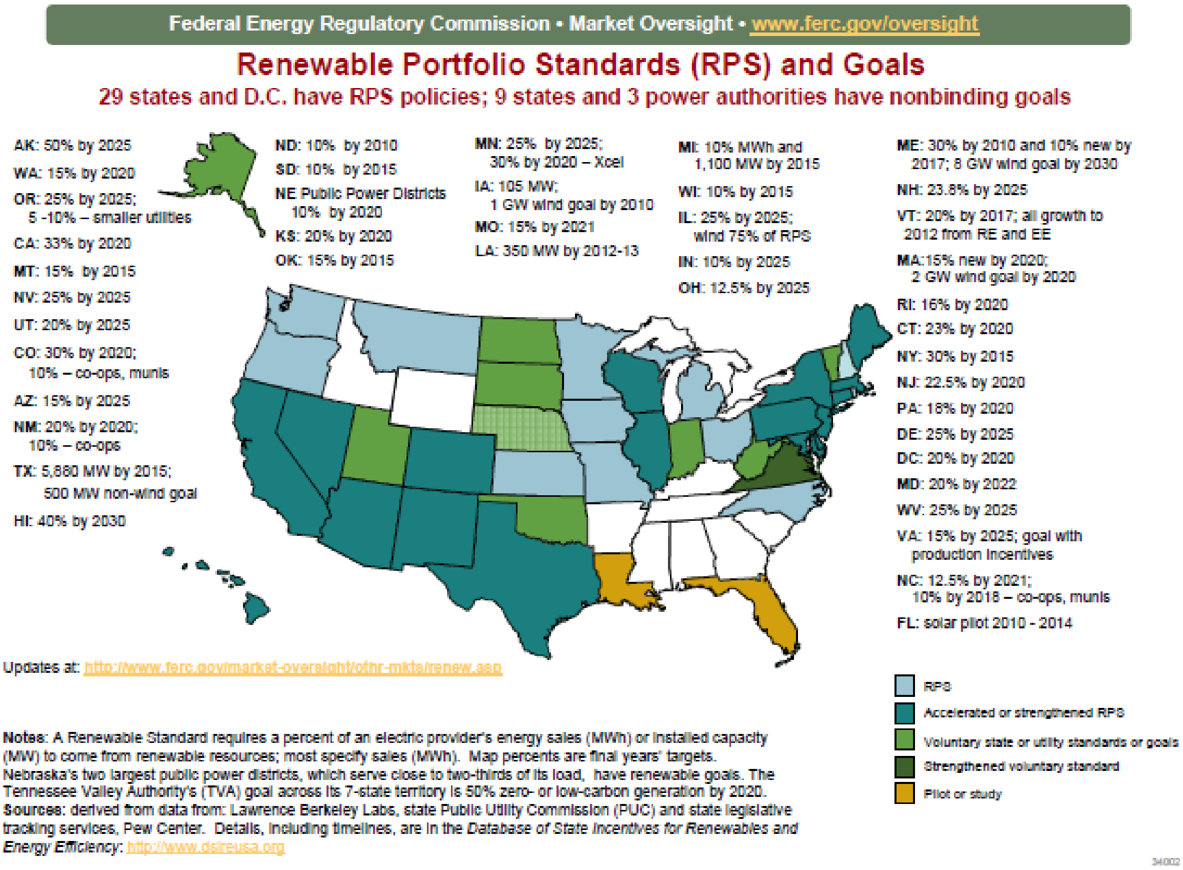
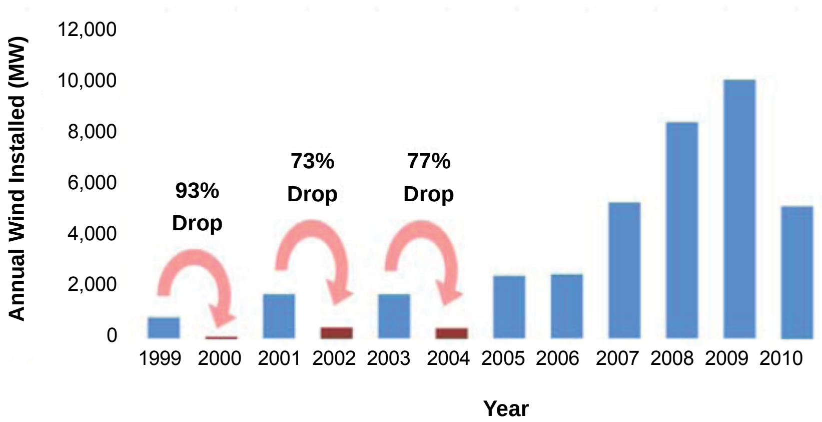


Figure A2-8

Historical impact of expiring tax credits on annual wind market

Source: American Wind Energy Association (AWEA), May 2011, The Reality of U.S. Energy Incentives



However, the Renewable Energy Production Incentive (REPI) Program provides financial incentives through 2026 for renewable-energy electricity produced and sold by qualified renewable-energy generation facilities, which include not-for-profit electrical cooperatives, public utilities, state governments, U.S. territories, the District of Columbia, and Indian tribal governments. These facilities are eligible for annual incentive payments of approximately 2.1 cents per kilowatt-hour (kWh) for the first 10-year period of their operation, subject to the availability of annual appropriations in each federal fiscal year of operation.[33]

In Canada, drivers for smart grid development include the operational benefits brought about by demand response (DR). In Canada, both the Ontario Independent Electricity System Operator (IESO) and the Alberta Electric System Operator (AESO) leverage DR programs within the operations of the electricity market to maintain a reliable and efficient system. In this instance, the system operators are benefitting from a smart grid technology like DR to increase the reliability and energy efficiency of the electric system they are responsible for.

2. Identification of challenges

2.1. Financial and business case challenges

The fact that in the U.S. states continue to face budget deficits does not help to set the right financial environment for smart grid projects. The Centre on Budget and Policy Priorities lists 29 states' projected deficits that in all sum up to $44 billion for the fiscal 2013 starting on 1 July 2012.[34] If these states do not have sufficient funding to incentivize renewable energy and energy efficiency, smart grids and efforts to optimize the delivery of electricity face a tough challenge. As U.S. states attempt to balance their budgets, incentives that drive smart grid development stand to be reduced, if not eliminated altogether.

Utilities face a more obvious challenge with smart grids because they go against their traditional business model. A main revenue driver is increasing energy sales,[35] which conflicts with the concept of saving energy. The business model for utilities needs to accommodate the societal shift to more intelligent electricity networks and reward those with benefits brought about by new technologies.

Uncertainty about the economy is another challenge discouraging capital spending by electric utilities, spending that in large part concerns generation, but also includes the implementation of smart grid technologies. In addition, held-up regulations by the U.S. Environmental Protection Agency (EPA) has added to the uncertainty felt by utility executives whose decisions depend on EPA rulings like the Mercury and Air Toxics Standards and the Cross-State Air Pollution Rule. Final rulings by the EPA will serve as additional drivers for clean electric generation, which in turn will drive the development of intelligent infrastructure like smart grids. In the meantime, this unclear regulatory environment poses as an additional challenge to

[33] U.S. Environmental Protection Agency (EPA): http://www.epa.gov/lmop/publications-tools/funding-guide/federal-resources/energy.html

[34] Elizabeth McNichol, et al., 2011: *States Continue to Feel the Recession's Impact*, http://www.cbpp.org/files/9-8-08sfp.pdf, Washington, D.C.: Center on Budget and Policy Priorities

[35] Dan York and M. Kushler, 2011: *The Old Model Isn't Working*, American Council for an Energy-Efficient Economy, Washington, D.C., http://www.aceee.org/files/pdf/white-paper/The_Old_Model_Isnt_Working.pdf

the development of a smart grid in the United States.

A further, but less obvious challenge is the abundance of natural gas brought about by the shale gas boom. The abundance of shale gas is likely to reduce the growth of alternative renewable energy resources, which in turn drive the development of smart grids. In a paper written by researchers from the Massachusetts Institute of Technology,[36] the authors argue that "[g]as production from shale resources is changing the U.S. energy outlook," but such an environment could end up having a negative impact on the proliferation of renewable generation. At the end of the report, the researchers conclude that it is essential not to allow the big picture to fade out of focus in "treating gas [as] a 'bridge' to a low-carbon future."

2.2 Public awareness

A notable challenge in the United States has been consumer pushback to smart meter rollouts. For example, in California, Pacific Gas & Electric has been involved in an issue involving customers who oppose smart meters from being installed in their homes due to privacy, health, and safety concerns. The same issue has surfaced in Maine and Illinois. This opposition has led to the respective states' Public Utility Commissions (PUCs) to consider opt-out options, where consumers pay an initial fee and a monthly charge for choosing to opt out of a smart meter.

Alternatively, in tackling the issue of consumer opposition to smart grid technologies, utilities along with regulators have played an important role at increasing consumer awareness to their benefits. For example, in many states like California, Illinois, and Maryland, regulators have made it a requirement for utilities to institute outreach programs meant to educate consumers about the benefits of smart grids before approving deployments. At the same time, federal agencies have supported consumer education by sharing information and best practices on websites like SmartGrid.gov and the Smart Grid Information Clearinghouse (www.SGIClearinghouse.org).

3. Currently available financing mechanisms and best practice examples

3.1 Market-based support instruments

The industry interest for potential smart grid technologies—improving the reliability of the electric power system, increasing operational efficiencies, and accommodating increasing amounts of renewables into the grid—has been expressed in numerous ways. For example, General Electric Corporation (GE) partnered with venture capital firms, including Emerald Technology Ventures, Foundation Capital, Kleiner Perkins, RockPort Capital, and the Carbon Trust to

[36] Henry Jacoby, et al., 2012: *The Influence of Shale Gas on U.S. Energy and Environmental Policy,* International Association for Energy Economics, Cambridge, MA, http://www.iaee.org/eeep/EEEP01_01_A05_Jacoby-EPUB/eeepissue.aspx

distribute $200 million[37] as part of the "GE ecomagination Challenge: Powering the Grid." The initiative, announced in July 2010, invited start-up companies, entrepreneurs, and scientists to share their ideas on how to improve the grid. The winning ideas were awarded $100,000 and had the opportunity to develop a commercial relationship with GE.

At the same time, in late 2011, GE announced it would provide a unique smart grid business model to small and mid-sized utilities. Grid IQTM Solution offers utilities a subscription-based, hosted service "package" as well as smart grid technology that shifts integration, financial, and deployment risks away from the utilities, providing cost-effective smart grid solutions. Since its launch in November 2011, GE has partnered with the City of Leesburg and Electric Cities of Georgia to implement smart grid technologies as part of its first two projects under the new offering.[38] For the City of Leesburg project, the $20 million effort is being funded by $10 million out of the SGIG awarded by the DOE. With the proposed modernized system, the utility estimates it will save $15 million over a period of 20 years.[39]

3.2 National scale (i.e., national funds)

The ARRA of 2009 has been a fundamental instrument to help drive smart grid development. With funding from the ARRA, the DOE invested around $4.5 billion and was matched by industry participants. The projects in part being funded by AARA programs have and continue to validate the business case for smart grid technologies. These funds are being matched by more than $5.5 billion from public and private stakeholders to fund 141 smart grid grants and cooperative agreements for smart grid and energy-storage technologies across the country.[40]

With the intent of validating the business case for smart grid technologies, the Pacific Northwest Demonstration Project,[41] funded in part by the ARRA, involves a partnership among a federal agency, the Bonneville Power Administration, a leading research institute, Battelle Memorial Institute, and other expert organizations. This project will help validate a five-state regional business case involving several technologies like smart meters, demand response, storage, and distributed generation. The results of this project have the potential to influence the necessary business models for other regions.

Another example demonstrating the difference the ARRA has made is the Salt River project (SRP) of Arizona where an ARRA-based grant has allowed the additional deployment of smart meters and in consequence the further development of an

[37] http://www.gereports.com/unveiled-200m-challenge-ev-charger-smart-monitor/
[38] http://www.gedigitalenergy.com/press/Norcross/index.htm
[39] http://leesburgflorida.gov/news/news_item.aspx?item=City_of_Leesburg_Approves_Electric_Smart_Grid_Partnership_with_GE_Energy

[40] United States National Science and Technology Council, 2011: A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future, Washington, D.C.
[41] http://www.smartgrid.gov/sites/default/files/battelle-memorial-institute-oe0000190-final.pdf

advanced metering infrastructure (AMI).[42] "Since 2003, the SRP has installed approximately 500,000 smart meters in its service area. The SRP estimates that this new equipment has enabled it to remotely respond to more than 748,000 customer service requests. As a result, the SRP has saved more than 249,000 labour hours by avoiding unnecessary service calls, has avoided 1.3 million unnecessary driving miles, and has conserved 135,000 gallons of fuel. As a consequence of the energy savings, cost reductions, and operational benefits of the smart meters, the SRP is now introducing an additional 500,000 meters to its service area with the help of a $56.9 million ARRA Smart Grid Investment Grant.[43]

3.3. Local (municipality) scale

On 13 June 2011, the U.S. Department of Agriculture (USDA) announced[44] it would provide $250 million in the form of loans, over a period of 12 months, for the development of rural smart grid projects. This initiative has led to several rural electric cooperatives and utilities to allocate some of the funding to the deployment of advanced meters. For example, in Kansas, the Nemaha-Marshall Electric Cooperative Association stated it would use the USDA loan, in the amount of almost $1 million, to deploy advanced meters.

3.4. Regulatory incentives

To satisfy the U.S. states' RPS, utilities have and will continue to deploy DERs. Responding to RPS to avoid penalties for non-compliance has become an incentive in of itself.

In the most ambitious RPS, California requires for 33% of the state's electricity to come from renewable resources by 2020, but this is not the only state incentive to benefit smart grids. California also provides strong support to solar energy generation in the form of state incentives and programs like the California Solar Initiative. Dating back to 2006, this initiative aims to provide $3 billion in incentives for solar energy projects with the goal of providing 3 GW of capacity by 2016. With this much renewable capacity, California will inevitably have to implement smart grid technologies that allow it to cope with its renewable goals.

[42] Additional ARRA-funded projects can serve as examples to other countries in their smart grid development efforts. The two websites offering further information are SmartGrid.gov and the Smart Grid Information Clearinghouse (www.SGIClearinghouse.org). These websites will be leveraged by the Federal Government to share information and allow for more informed decision-making.

[43] United States National Science and Technology Council, 2011: *A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future*, Washington, D.C.

[44] http://www.smartgrid.gov/federal_initiatives/featured_initiatives/usda_aims_invest_250_million_rural_smart_grid_deployment

Annex 3: Japan

1. Regional contexts and drivers of smart grid development

1.1 Electricity market

Japan's electricity consumption has increased continuously for the last decades; most recently, the growth rate has become saturated (Figure A3-1). The shares of nuclear power, coal, and natural gas have followed the same trend. However, this is likely to change because of the earthquake and tsunami that caused the accident at the Fukushima Daiichi nuclear power plant and its impact on Japan's energy system and the controversial debate it caused around Japan's energy strategy and future energy mix.

The country's power consumption is forecast to grow around 0.9% annually between 2011 and 2020, driven by moderate economic growth, energy conservation measures, economic and industrial structure shifts, and a population decrease (Figure A3-2).[45]

The Japanese government has set challenging goals for renewable energies to reduce CO2 emissions. These challenging targets will mostly be realized by installing solar panels for residential customers (Figure A3-3) and therefore be added to the distribution network. This requires advanced technologies and a regulatory framework that considers these technologies. The integration of renewable power is regarded as the most important driver for the development of smart grid technologies in Japan. To tackle these challenges, Japan's Ministry of Economy, Trade and Industry (METI) has set up a number of committees and study groups.

The Japanese government announced the short-to-mid-term vision for its energy demand–supply structure in October 2011. The vision includes the following three reforms of the energy market considering on-going technology developments:

- On the supply side, the further development and integration of renewable energy is in the focus. For this purpose, regulations on renewable generation facilities will be relaxed. Priority access to the grid should be guaranteed.
- On the demand side, energy efficiency needs to be improved even further. Home Energy Management System (HEMS), Building Energy Management System (BEMS), Battery Energy Storage (BES) technologies and smart meters are promoted by the national policy. Interfaces between utilities and customers will be defined soon.
- Restructuring of the electricity market will be a necessity considering the planned changes in supply and demand sides. Especially, countermeasures of inter-regional transmission system operation and enhancement of national electricity market will be studied soon.

[45] Marketresearch.com: http://www.marketresearch.com/Business-Monitor-International-v304/Japan-Power-6468161/ accessed 26.03.2012

Figure A3-1

Trends of energy mix in Japan, 1973-2008

Source: Ministry of Economy, Trade and Industry (METI), *2010: Energy in Japan 2010*

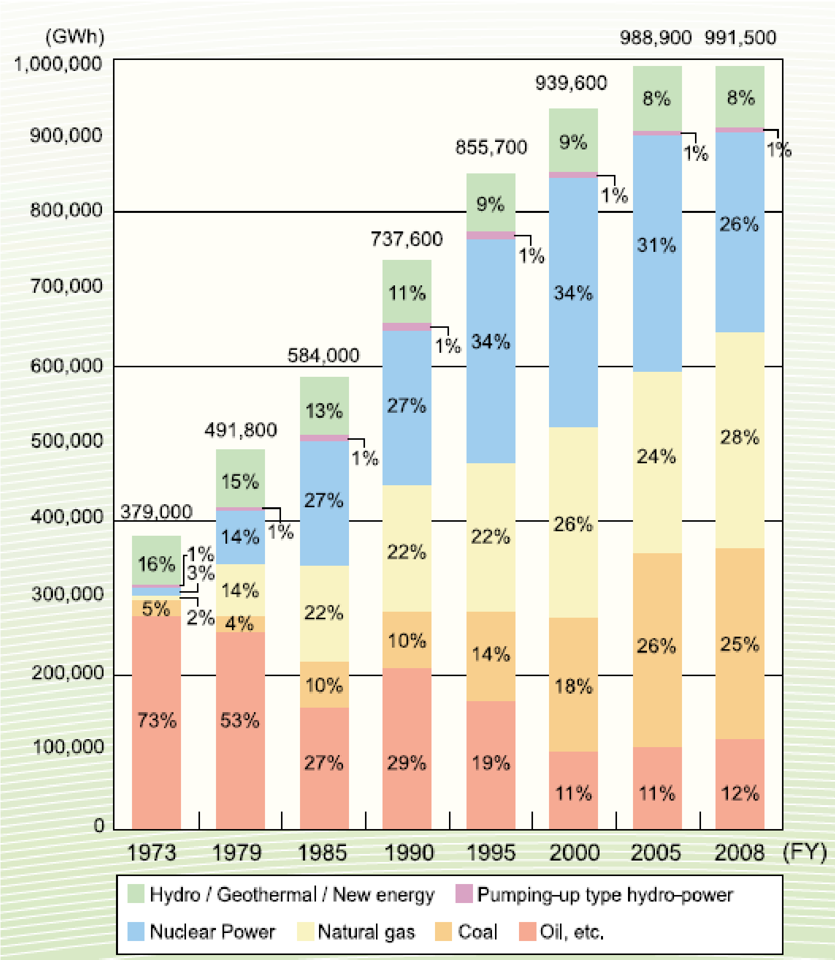
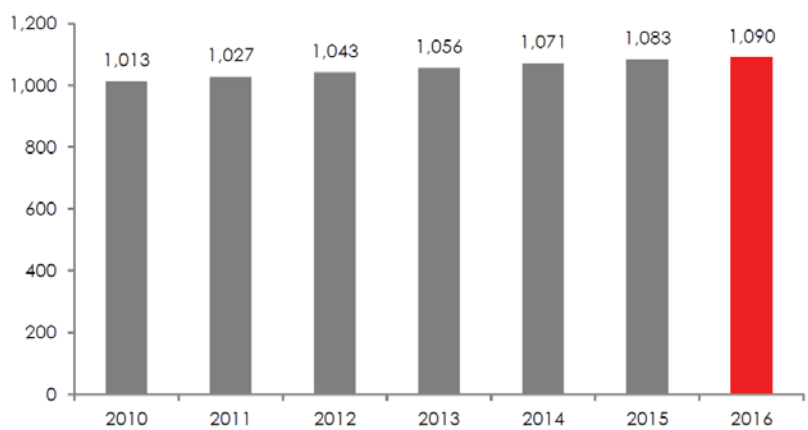


Figure A3-2

Japan's electricity generation forecast (2010-2016 in billion kWh)

Source: Zpryme Research & Consulting, LLC, 2012, *Japan: Tsunami Wakens the Smart Grid*



Source: EIA International Outlook, 2011

Figure A3-3
Target of photovoltaic (PV) generation in Japan

Source: New Energy and Industrial Technology Development Organization (NEDO), Japan, Introduction to Japan's "Smart Community"

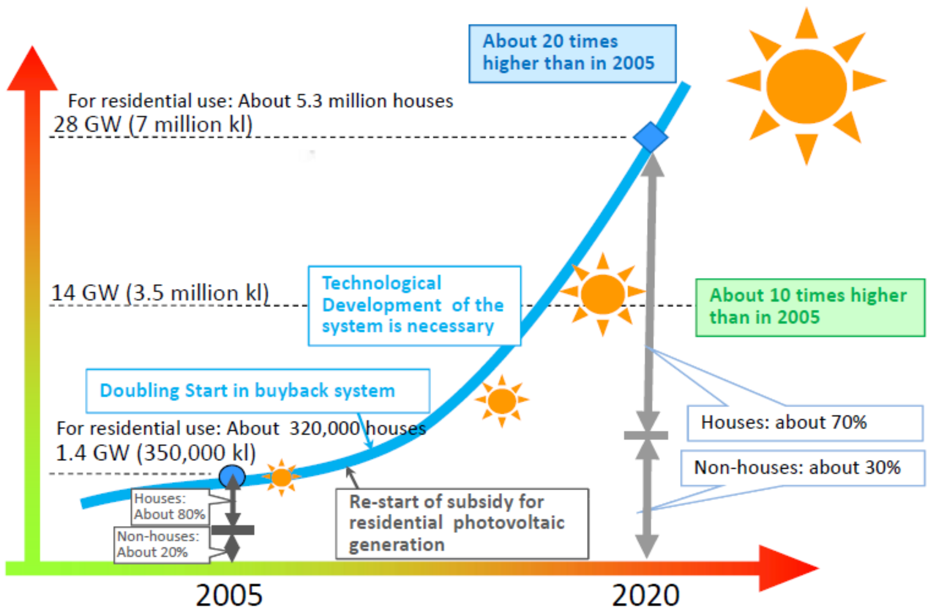
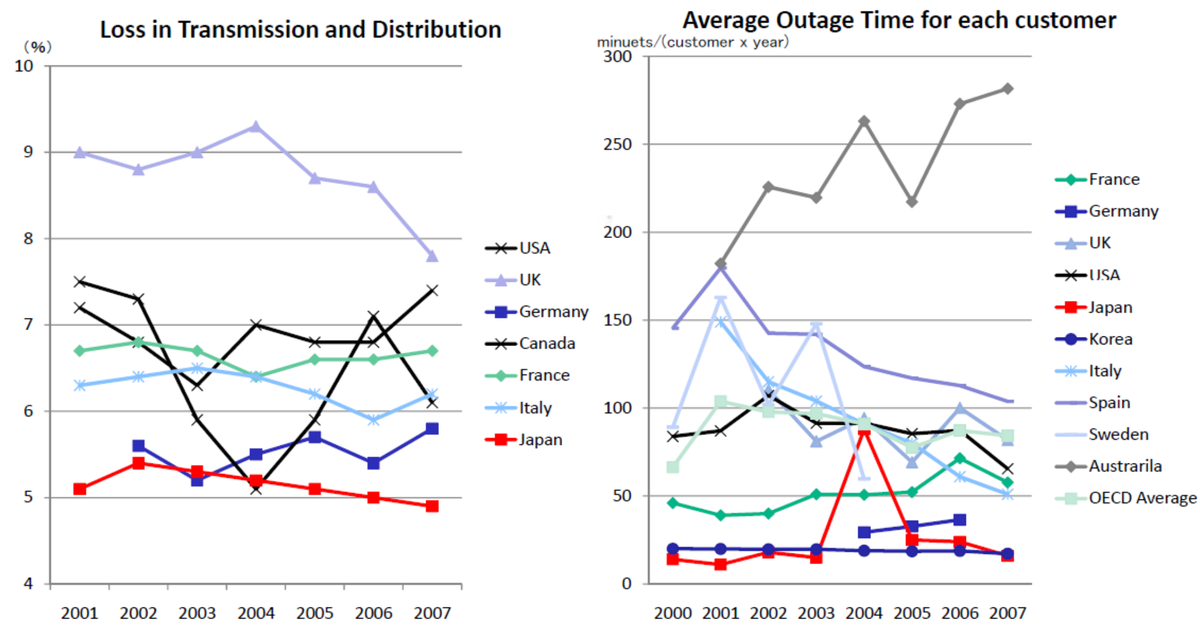


Figure A3-4
High efficiency and high reliability Japan's transmission and distribution network

Source: New Energy and Industrial Technology Development Organization (NEDO), Japan, *Introduction to Japan's "Smart Community"*

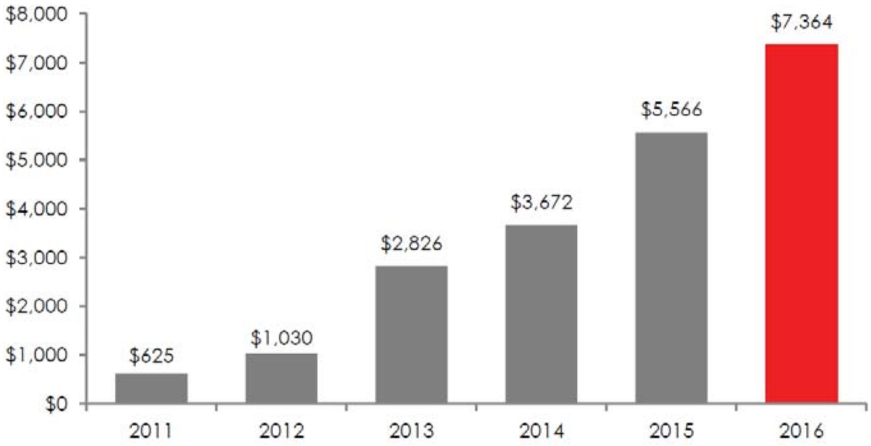


Japan's electric grid is among the most efficient and reliable in the world with average distribution losses of around 5% (Figure A3-4). To meet demand and guarantee a high-quality supply, appropriate investments in the transmission and distribution sector have been made by utility companies, including distribution automation systems which have been deployed to minimize the duration of outages. However, since March 2011, Japan has experienced massive blackouts and

Figure A3-5

Japan's forecast of the smart grid's technology market value (2011-2016 in U.S. million)

Source: Zpryme Research & Consulting, LLC, 2012, *Japan: Tsunami Wakens the Smart Grid*



parts of the country are still closely monitoring daily power consumption.

1.2 Legal and Political/Policy Contexts and Drivers

1.2.1 Drivers of smart grids in Japan

The main drivers are the reduction of CO2 emissions and the further integration of renewable power into the grid. A new feed-in-tariff system, set to start in July 2012, offers a premium price for newly installed solar PV and wind power. Smart grids in this context support the further integration of renewable energy resources, supply security, and economic burden simultaneously. Furthermore, energy efficiency improvements on both the supply and demand sides are the focus of Japan's energy policy. It has therefore been recommended to accelerate the deployment of smart meters by utility companies to provide more sophisticated tariffs, giving customers incentives to cut peak demand and manage consumption more efficiently (Figure A3-5).

1.2.2 Legal and political/policy contexts in Japan

The Strategic Energy Plan for Japan is now under radical review because of to the Great East Japan earthquake and accident at Fukushima Daiichi Nuclear Power Station in March 2011. However, Japan's Strategic Energy Plan has targets for 2030, which were released in June 2010, already included energy efficiency and energy security plans. Japan plans to invest $1.7 trillion in its energy sector until 2020. For example, Japan's 2010 strategic energy plan contains the following initiatives:

(a) Double the energy self-sufficiency ratio in energy supply and the self-developed fossil-fuel supply ratio, and as a result raise the energy independence ratio from current 38% to about 70%;

(b) Raise the zero-emission power source percentage from current 34% to about 70%;

(c) Cut by half the CO2 emissions from the residential sector;

(d) Maintain and enhance energy efficiency in the industrial sector at the highest level in the world; and

(e) Maintain or obtain a large share of global markets for energy-related products and systems.

Japan will fundamentally change its energy supply and demand system by 2030. Therefore, the following measures are specified on the demand side:

- Realizing the smart grid and smart communities by promoting an intensive cross-sectional mobilization of relevant policies, consideration of special zones, demonstration projects both home and abroad, and strategic international standardization.

- Promoting the development, installation of smart meters, and relevant energy management systems (that can record detailed energy supply-demand data and control a variety of equipment), seeking to introduce them for all users, in principle, as early as possible in the 2020s.
- Diffusing fixed fuel cells and developing a hydrogen supply infrastructure, including hydrogen stations for fuel-cell vehicles.

2. Identification of challenges

For utility companies, the cost of the full deployment of smart grid technologies needs to be reflected in and covered by the tariffs. A reduction of electricity prices with smart grid technologies is only possible if the cost of deployment is less than the benefit. Also, cost and benefit of deployment of smart grid technologies depends strongly on regional factors such as load density and energy mix. Therefore, incentives for utility companies and manufacturers to launch large-scale RD&D projects are still needed.

On the other hand, field tests on promising technologies, such as smart meters, are being conducted by the utilities at their own expense.

3. Currently available financing mechanisms and best practice examples

3.1 Market-based support instruments

Tokyo Electric Power Company (TEPCO) announced a recovery plan which includes the installation of 17 million smart meters in households by 2018 and 27 million meters for all residential customers by 2023. TEPCO invited tenders from both Japanese and foreign firms.

3.1.1 Best practice examples for cooperation projects

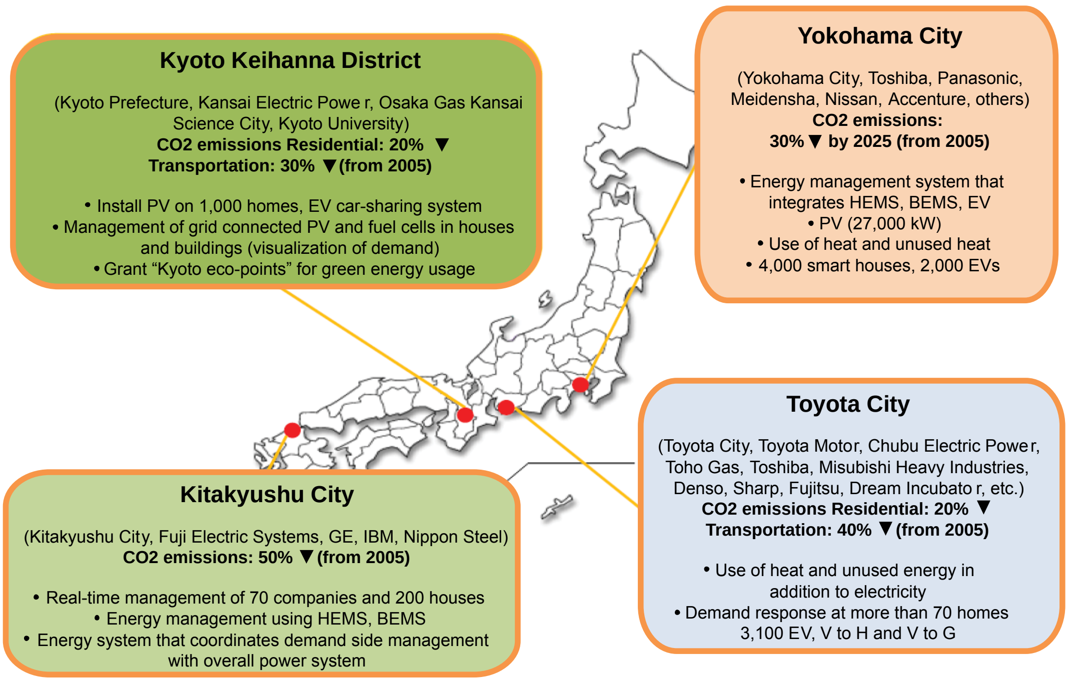
- TEPCO participates in the Global Intelligent Utility Network Coalition, to collaborate with other member utilities to share best practices and solve common issues.
- Ten of the major home technology and power industry companies established the HEMS Alliance consortium to create common technical standards to accelerate the development of energy-efficient home electronics.[46]

3.2 National scale (i.e., national funds)

METI emphasizes measures to smart grid-related technology developments and demonstration projects. For example, METI has a budget of 12.6 billion Yen (USD 157 million) in 2012 for large-

[46] Zpryme Research & Consulting, LLC, March 2012, *Japan: Tsunami Wakens the Smart Grid*

Figure A3-6
Large-scale demonstration projects in Japan
Source: New Energy and Industrial Technology Development Organization (NEDO), Japan, *Introduction to Japan's "Smart Community"*



scale demonstration projects, the "Smart Community Demonstration" in four cities in Japan (Figure A3-6).

In addition, 8.9 billion Yen (USD 111 million) in 2012 is reserved for the development of stable power grids by utilizing advanced technologies.

3.3. Local (municipality) scale

In some cases, local governments offer subsidies for large-scale smart grid demonstration projects. For example, Yokohama city has launched the Yokohama Smart City Project, mainly funded by the national government, but the city made a grant for 4,000 residential customers in Yokohama for the installation of energy-management systems for residential PV.

3.4 Regulatory incentives

At this moment, no regulatory incentives for financing smart grid deployment are available. METI promotes the standardization for communication between smart meters and home gateways. They are considering the possibility that only standardized smart meters can be embedded in regulatory assets for tariff calculation to promote standardization of technologies and promote the energy management system.

Annex 4: Korea (Republic)

1. Regional contexts and drivers of smart grid development

1.1 Electricity market

1.1.1 Electricity consumption trends

In the 2000s, after the Asian financial crisis, the growth rate of electricity consumption decreased from 11.8% in 2000 to 2.4% in 2009.[47]

In 2010, after the recovery from the economic slowdown, the growth rate of electricity consumption went up to 10.1% again (Figure A4-1).

Consumption of electricity continued to even in the 2000s as a result of several factors, the main reason being that the metal industry (machinery and equipment, electric and electronics, semiconductor, automobile, etc.), an industry that consumes great amounts of electricity, continued to record the highest degree of growth among

Figure A4-1
Trends in electricity consumption (TWh, %)
Source: KEEI, March 2011: *Mid-term Korea Energy Demand Outlook (2010–2015)*

Year	Residential		Commercial		Industry		Total	
	Consumed volume	Increase rate	Consumed volume	Increase rate	Consumed volume	Increase rate	Consumed volume	Increase rate
2000	37.1	7.3	70.2	19.4	132.3	9.4	239.5	11.8
2001	39.2	5.7	82.7	17.9	135.8	2.7	257.7	7.6
2002	42.3	7.8	91.7	10.9	144.5	6.4	278.5	8.0
2003	44.6	5.4	98.6	7.5	150.4	4.1	293.6	5.4
2004	48.6	9.1	105.1	6.6	158.3	5.3	312.1	6.3
2005	50.9	4.6	114.7	9.1	166.9	5.4	332.5	6.5
2006	52.5	3.2	121.5	5.9	174.7	4.7	348.7	4.9
2007	54.2	3.1	128.2	5.5	186.3	6.6	368.6	5.7
2008	56.2	3.8	134.2	4.7	194.6	4.5	385.1	4.5
2009	57.6	2.4	139.1	3.7	197.7	1.6	394.5	2.4
2010p	61.2	6.2	149.8	7.7	223.2	12.9	434.2	10.1
Annual average increase rate (%)	3.5		7.9		5.4		6.1	

[47] KEEI, March 2011: Mid-term Korea Energy Demand Outlook (2010–2015)

Figure A4-2

Changes in share of electricity consumption taken up by each sector (TWh, %)

Source: KEEI, March 2011: *Mid-term Korea Energy Demand Outlook (2010–2015)*

Year	Residential	Commercial	Industry	Total
2000	15.5	29.3	55.2	100
2001	15.2	32.1	52.7	100
2002	15.2	32.9	51.9	100
2003	15.2	33.6	51.2	100
2004	15.6	33.7	50.7	100
2005	15.3	34.5	50.2	100
2006	15.1	34.9	50.1	100
2007	14.7	34.8	50.5	100
2008	14.6	34.9	50.5	100
2009	14.6	35.3	50.1	100
2010p	14.1	34.5	51.4	100

Note: p refers to tentative figures

manufacturing industries. Furthermore, the demand for cooling rose according to growth of the service industry, which accounts for most of electricity consumption for commercial use. Another important factor is the rapid replacement of oil and town gas by electricity in the energy market for heating, attributable to the persistence of an electricity price that does not reflect production costs and continued high oil prices.

Electricity is expected to continue to grow due to several factors: convenience in use, and changes in lifestyles resulting from a rise in income levels and technological development.

Electricity consumption for the commercial sector recorded an annual average increase rate of 7.9% in the 2000s, thus indicating the fastest growth; however, it rapidly slowed down after the early 2000s, followed by consumption from the industrial sector with an annual average increase rate of 5.4% and consumption for residential sector with an annual average increase rate of 5.1%, going up and down according to climate.

Consumption for the industrial sector, which responds sensitively to the general economy, maintained relatively stable growth of around 5%, together with decreased economic growth (annual average of 4.1%) in the 2000s. However, there was a wide fluctuation in the increase rate, which stood at 1.6% in 2009 and 12.9% in 2010, attributable to base effects from economic recession in 2009 and favourable conditions in the economy in 2010.

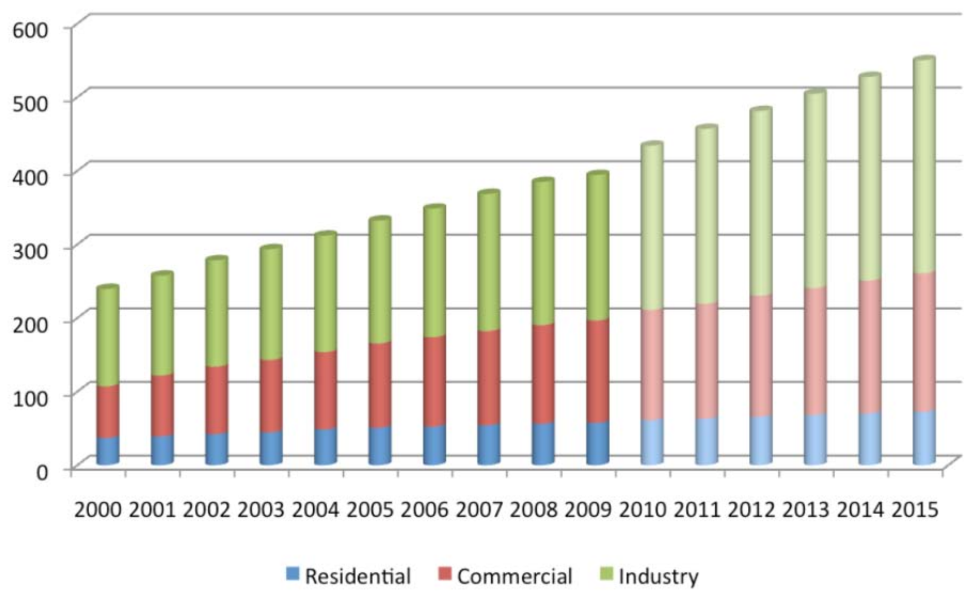
What is most noticeable in terms of changes in the share of electricity consumption taken up by each sector in the 2000s is an upward trend in the share taken up by commercial use and a general decrease in the share for industrial and residential uses. However, the share for industrial use turned around to indicate gradual growth after 2006, while the share occupied by commercial use gradually decreased.

With regard to changes in the share by each sector, electricity consumption for industrial use occupied more than half at 51.4% in 2010. The share occupied by commercial and residential uses was 34.5% and 14.1%, respectively. The share for residential use reached 15.5% in 2000, but the share continually dropped together with a slowdown in consumption after 2004. It stood at around 14% in 2010. The share occupied by commercial use continued an upward trend after recording 29.3% in 2000. It stabilized at the high 34% range after the mid-2000s. The share for industrial use continues to remain in the 51% range after 2003 (Figure A4-2).

1.1.2 Electricity demand outlook

Assuming that the potential economic growth is expected to rise after 2010, electricity consumption is forecast to annually increase 4.9% on average

Figure A4-3
Trends in electricity consumption and mid-term outlook (2010–2015) in TWh
Source: KEEI, March 2011: Mid-term Korea Energy Demand Outlook (2010–2015)



from 434 TWh in 2010 to 551 TWh in 2015 (Figure A4-3).[48]

In 2011, electricity demand is projected to record sound year-on-year growth of 5.3%, with industrial-use consumption leading the increase. This is despite a slowdown in economic growth (6.1%→4.5%) and base effects from a sharp rise in consumption from the previous year (10.1%). If economic growth is maintained at the potential growth rate level (low- and mid-4% range) after 2012, the rate of increase in electricity demand is projected to steadily slowdown from the 5–6% range to the low 4% range.

Electricity demand for industrial use is forecast to indicate the quickest growth of an annual average 5.4% from 2010 through 2015. This assumes steady growth in electricity-intensive industries such as fabricated metal and steel making and according to continued favourable conditions in the economy.

Electricity demand for commercial use is projected to post a comparatively high growth of an annual average 4.7% during the forecast period, owing to a steady rise in both electricity demands for cooling and heating. Late-night electricity for commercial use indicated high growth in the 2000s. The enforcement of relevant regulations in 2006 made new entries impossible. This is why it is difficult to expect an increase in the sector. However, continually high oil prices since the mid-2000s made electricity-based heating costs more affordable than other heating methods. This and the fact that using electricity is convenient, result in forecasts of continuous growth.

Electricity demand for residential use is projected to record an annual average increase rate between 3 and 4% during the forecast period, attributable to a steady rise in demand for cooling and heating as well as increased size and propagation of home appliances, despite a small increase in population (annual average of 0.2%).

The share occupied by electricity demand for industrial use was 51.4% in 2010, but it is forecast to go up to the 52% range in 2011 and gradually grow up until 2015. Electricity demand for residential use is projected to steadily drop from 14.1% in 2010 to 13.2% in 2015. The share of electricity demand for commercial use stood at 34.5% in 2010, which is projected to steadily maintain the low 34% range during the forecast period.

[48] KEEI, March 2011: *Mid-term Korea Energy Demand Outlook (2010-2015)*

Figure A4-4

Transmission facilities expansion outlook (in C-km)

Source: Korea Power Exchange (KPX), 2010, *2010 Annual Report: Electricity Market Trends & Analysis*

Classification	Actual						Plan		
	2005	2006	2007	2008	2009	2010	2013	2018	2024
765kV	662	662	755	755	755	835	1,016	1,024	1,894
345kV	7,990	8,058	8,284	8,310	8,552	8,580	9,690	9,962	10,034
154kV	19,422	20,040	20,149	20,298	20,469	20,777	23,038	24,706	25,883
Sum	28,074	28,760	29,188	29,363	29,776	30,192	33,744	35,692	37,811

Electricity is an energy source that tends to expedite a rise in primary energy by triggering transformation loss during the production process. First of all, to ensure efficiency in electricity demand, there is a need to make charge levels realistic. Current charge levels trigger excessive consumption (especially for heating purposes). A rise in electricity consumption for industrial activities is unavoidable because it is a result of an increase in production. Consumption for residential use takes up only a small percentage of primary electricity demand and its upward trend is slowing down to a more stable level. As such, a sector where there is much potential to bring down electricity demand is buildings (buildings used for industrial purposes, large buildings used by the commercial/service industries and by the public sector, etc.). There is a need to regulate excessive cooling and heating, improve efficiency of lighting fixtures, and continually adopt electricity-saving building management systems.

1.1.3 Transmission network constraints

Although recent electric-power demand has slowed compared with the 1990s, economic growth, upgraded living standards, the convenience of electricity, and its relatively low price led to a continuous rise in power consumption, exceeding the previous average annual economic growth rate. To meet this increased demand, transmission expansion as well as the construction of generators is needed for a consistent supply. Therefore, the construction of transmission and transformation facilities should go hand-in-hand with power-generator construction plans.

The capacity of transmission facilities in 2010 stood at 30,192 C-km, a 1.4% increase from the previous year and below the annual average of 1.5% between 2005 and 2009 (Figure A4-4).

Transmission stability in major congestion areas, such as metropolitan centres and Jeju Island, need to be strengthened while minimizing transmission loss and congestion costs. Also, timely facility expansion in major congestion areas is needed to prevent the emergence of multiple, local T&D providers. However, as more and more people become environmentally aware, residential opposition to facility construction has delayed and even cancelled scheduled expansion, raising uncertainties about the construction plans. Hence, a mid- to long-term review on the status of and plans for transmission expansion should be carried out to break the current deadlock.

Meeting the electric-power demand in the Seoul metropolitan areas where it has always been difficult depends on the appropriate construction of power generation, transmission and transformation facilities. Figure A4-5 shows the power supply and demand outlook for the Seoul metropolitan area.

1.2 Policy contexts and drivers

Three major policy drivers will achieve South Korea's vision of a "low carbon, green growth" future. The first driver is the effort to mitigate climate change. South Korea's GHG emission per GDP is 1.6 times higher than the average of OECD countries. The national GHG emission target is a 30% reduction from a business-as-usual (BAU) baseline by 2020. To achieve this, it is necessary

Figure A4-5

Power supply and demand in the Seoul metropolitan area (in MW, %)

Source: Korea Power Exchange (KPX), 2010, *2010 Annual Report: Electricity Market Trends & Analysis*

Classification	Actual				Plan		
	2007	2008	2009	2010	2013	2018	2024
Generating capacity in the area	14,251	15,880	17,357	17,426	20,679	25,215	25,215
Transmission credit	13,100	11,800	12,700	12,500	15,957	17,317	19,536
Total capacity	27,351	27,680	30,057	29,926	36,636	42,532	44,751
Peak demand	24,327	25,094	27,304	28,368	30,579	34,594	38,191
Installed reserve (margin)	3,024 (12.4)	2,586 (10.3)	2,753 (10.1)	1,558 (5.5)	6,057 (19.8)	7,938 (22.9)	6,560 (17.2)

to establish a low-carbon, green growth infrastructure, including a low-carbon power infrastructure. Expansion of clean energy sources, environmentally friendly transportation, and low-energy appliances is necessary to reduce carbon emissions. South Korea ranked 9th in absolute emission among OECD countries (2007), and ranked 1st in annual increase rate (2005). Therefore, constructing a smart grid becomes necessary to push the supply of renewable energy and electric vehicles, because it is impossible to expand them without a capable, existing power grid. Severe fluctuations of renewable energy output need smart control systems connected to the grid. Also, for electric vehicles, new pricing mechanisms and load balancing technology developments are needed.

The second driver is improving energy efficiency. Due to high oil prices and national resources, the transition to energy self-sufficiency and a low-energy-consumption society is necessary for sustainable growth. The National Energy Basic Plan (2008) sets the target of improving 46% energy intensity between 2007 and 2030 to become a leading country in energy efficiency.[49] Now power consumption has been increased due to low prices and convenience. Total energy consumption increased during 1998–2006 for city gas to 10.2%, for power 7.6%, and for heat energy 6.5%. Power consumption patterns, which have been focused on specific hours, led to a decrease in operation efficiency of power facilities and vast investment cost to construct power plants. A smart grid improves efficiency by dispersion and control of power demand, so South Korea targets a 10% reduction of total power by dispersion of power demand until 2030.

The last driver is pursuing new growth opportunities. The world's smart grid market is projected to grow rapidly; therefore, South Korea needs to create new growth engines in the manufacturing industry. Investments in the world's power sector from 2007–2030 are expected to be USD 13.6 trillion.[50] This huge investment puts more pressure on the growth of smart grids. A smart grid will have a great impact on general industry, including power, heavy electric machines, as well as communication, appliances, construction, and transportation. By combining power and information technology (IT) industries, South Korea can attain a high level of industrial competitiveness within the smart grid industry.

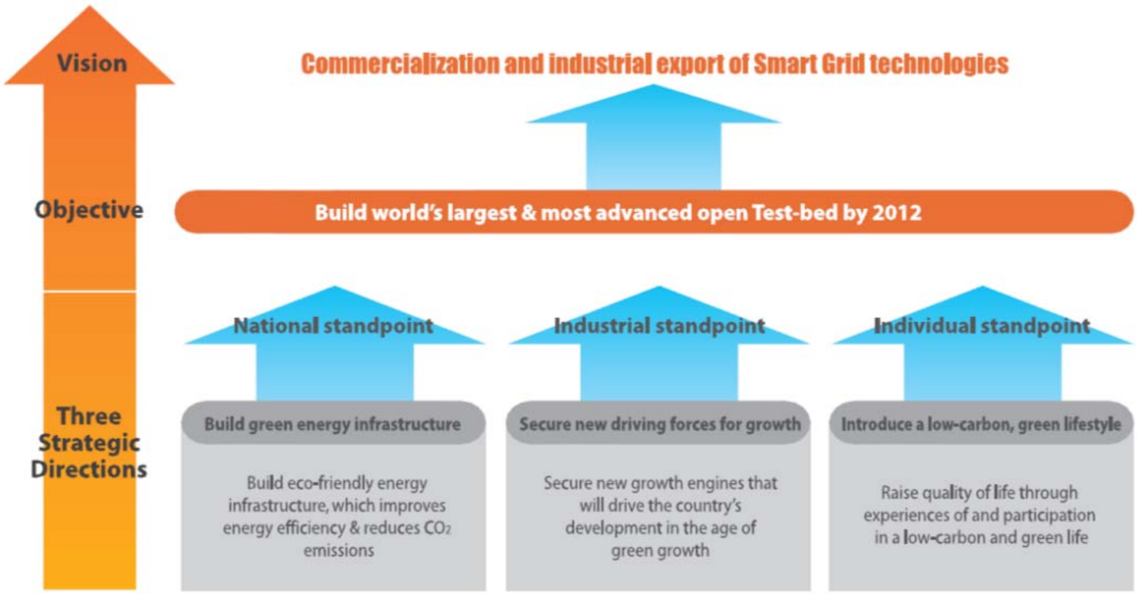
[49] South Korea Energy efficiency report, Trends in global energy efficiency 2011: http://www05.abb.com/global/scot/scot316.nsf/veritydisplay/124041516f0075a1c12578640051c021/$file/south%20korea.pdf

[50] International Energy Agency (IEA), World Energy Outlook 2008

Figure A4-6

Vision and goals of the smart grid test bed on Jeju Island

Source: Ministry of Knowledge Economy (MKE), Korea Smart Grid Institute (KSGI), *For the World's Green Growth – Jeju Smart Grid Test-bed in Korea*



1.3 Current status of South Korea's smart grid

1.3.1 Industrial facilities and infrastructure

South Korea possesses a world-class power and communications infrastructure and has global-leading corporations in related industry sectors. Korea Electric Power Cooperation has invested USD 4.7 billion annually on intelligent transmission and distribution improvements on power quality and efficiency. The power transmission and distribution loss factor was 4.02% in 2008 and blackout time per household was 16.1 minutes, which are the world's best levels. World-class industries of semi-conductor, digital display, and home appliances and related companies are in place. In 2008, South Korea had 2.7% of the world's market share of the home appliance industry (rank 7th), 33.4% of the market share of digital TV, and 23.8% of the market share of mobile phone industry (rank 2nd).[51]

[51]http://smartgrid.jeju.go.kr/eng/contents/index.php?mid=0102

1.3.2 Technology development

Since 2005, South Korea has led in the development of electricity IT and possesses significant technologies in related industries:

- Advanced Smart Meter: A new type of smart meter is under development. The smart meter is classified into economy and standard models. From 2010 onward, 1.3 million units will be installed annually, 1.0 million of the economy type and 0.3 million of the standard type.
- Electric car charger: Various charging methods, including high and low speed, are under development and standardization is being promoted. An electric car charger was supplied in 2011 in a limited amount.
- Energy storage system: Private companies have world-class manufacturing technologies sufficient to supply batteries to the world-leading automobile industries.

1.3.3 Test-bed establishment

In light of the three drivers, South Korea came up with a proactive and ambitious plan to build a smart grid test bed on Jeju Island which will test the most advanced smart grid technologies and R&D prototypes as well as business models. A private consortium will also be established. With the participation of more than 170 private corporations in the IT and energy sectors, testing real-time electricity pricing, electric-car charging infrastructure, and renewable energy will be comprehensive.

1.4 Vision and objectives

South Korea's vision and objectives pave the way for "low carbon, green growth" through smart grids (Figure A4-6). By 2012, the world's largest and most advanced test bed will be completed in Jeju. By 2020, a smart grid for consumers in metropolitan areas selected according to specific criteria will be completed. Lastly, by 2030, the world's first nation-wide smart grid will be built.[52] A nation-wide smart grid will improve overall energy efficiency and reduce CO2 emissions. From an industrial viewpoint, a smart grid will invite economic growth through new export opportunities of smart grid technologies. Finally, from a societal viewpoint, people's quality of life will be improved by lower electricity costs, lower pollution, and a more stable power supply.

Five strategic areas include the following:

- Smart Power Grid means establishing an open power platform and setting up systems for failure forecast and automatic recovery.
- Smart Places are built based on a smart metering infrastructure, setting up systems for automatic energy management.
- Smart Transportation means a nation-wide charging infrastructure, developing V2G (Vehicle to Grid) and ICT systems.
- Smart Renewable will be created through large-scale renewable energy farms, realizing energy self-sufficient green homes and buildings.
- Smart Electricity Services means various electricity pricing schemes, establishing smart electricity trading system.

1.5 Smart grid roadmap

South Korea's five strategic areas are divided into a phase-by-phase implementation plan or roadmap (Table A4-7):

- First Stage (2010–2012): Implementation of construction and operation of the smart grid test bed to verify new technologies;
- Second Stage (2013–2020): Expansion into metropolitan areas and implementation of intelligent systems to consumers
- Third Stage (2021–2030): Completion of nation-wide power grid.

[52] Ministry of Knowledge Economy and Korea Smart Grid Institute; Korea's Smart Grid Roadmap 2030—Laying the Foundation for Low Carbon, Green Growth by 2030; www.smartgrid.or.kr

Figure A4-7

South Korea's smart grid roadmap

Source: Ministry of Knowledge Economy (MKE), 2010.1, *Smart Grid National Roadmap*

Implementation direction by phase	First Stage (2010–2012)	Second Stage (2013–2020)	Third Stage (2021–2030)
	Construction and operation of the smart grid test bed (technical validation)	Expansion into metropolitan areas (intelligent systems for consumers)	Completion of nation-wide power grid (intelligent power grid)
Smart power grid	Real-time grid monitoring; digital power transmission; optimal distribution system	Predict possible failures in power grids; connect the power system with those of other countries; connect the power-delivery system with distributed generation and power-storage devices	Self-recovery of power grids; operate an integrated-energy smart grid
Smart place	Power management of intelligent homes; various choices for consumers including various rates	Smart power management of buildings and factories; encourage power production by consumers	Zero-energy homes and buildings
Smart transport	Build and test electric-vehicle charging facilities; operate electric vehicles as a pilot project	Expand electric-vehicle charging facilities across the nation; maintain and manage electric vehicles	Make the presence of charging facilities commonly available; diversify charging methods; utilize portable power-storage devices
Smart renewable	Stable connection of renewable energy development; 0perate micro grids by connecting distributed generation, power storage devices and electric vehicles; expand utilization of power-storage devices and distributed generation	Optimal operation of the power system with micro grids; expand the application of power-storage devices	Make renewable energy universally available
Smart electricity service	Consumer choice of electricity rates; consumers selling renewable energy; operate pilot study of real-time supply	Promote transactions of electrical power derivatives; implement real-time pricing system nationwide; voluntary market participants participate	Promote various types of electrical power transactions; promote the convergence of the electricity-based sectors; lead power market in Northeast Asia

2. South Korea's policy directions for implementing the smart grid roadmap

2.1 Technology development and industrialization

Future directions to support technology development and industrialization include promoting technology-development life cycles which lead to technology standardization and commercialization, and the creation of new economic growth engines through the expansion of domestic and international markets.

2.1.1 Key technologies for smart grids

South Korea prepared a national plan to support energy storage technologies and core technologies for IT as well as security technologies, which are key factors for the integration of renewable energy and electric vehicles. From 2010, plans for key technologies for energy storage, bidirectional transmission as well as the security technologies have been developed. Phase-by-phase key strategic techniques are as follows:

1. Smart metering system, DC power distribution, and security
2. Electric-car charging method and self-restoration grid
3. Mass storage systems.

Furthermore, security technologies and systems will be developed that include the integration of security systems into distribution networks, mutual authentication, and real-time coded communication.

2.1.2 Invigoration of the domestic market

A pilot city will be selected as a hub to demonstrate smart grid and low-carbon green growth. Technologies, products, and the best business models validated through Jeju test bed will have priority for the setting of national standards and promoting their deployment. The business model registration system runs parallel with the development of the certification method. From 2011, electric-vehicle charging stations and electricity storage have been promoted by the Korea Smart Grid Institute together with the government according to the roadmap.

2.1.3 Exporting to international markets

South Korea is planning to expand international market opportunities through the international conference on the Jeju test bed and the operation of Smart Grid Information Center. The Smart Grid Information Centre houses a fully functioning total operating centre (TOC), which is the main brain of the island's sprawling smart power grid. The Information Center was also installed to inform foreign investors about technologies and products.

South Korea has tried to resolve Technical Barriers to Trade (TBT) by signing Mutual Recognition Arrangements (MRA) with the country that puts large investment on power sector. MRA is an international agreement by parties to recognize one another's conformity assessments. However, TBT with its technical regulations, standards, testing, and certification procedures creates obstacles to trade.

In addition South Korea supports the program for developing countries such as the East Asia Climate Partnership, which includes smart grids, to pioneer potential export markets.

2.2 Deploying the tested smart grid model

South Korea plans to promote the tested model through phase-by-phase diffusion and the earlier creation of tested components and systems through the Jeju test bed. Companies will be actively recruited to invest and the public asked to participate. Since 2010, the validation of smart consumer and transportation choices as well as renewable energy has been pushed by a consortium of private companies. Also, the supplementary system which reflects the experiences of test bed to the national roadmap will be provided.

2.2.1 Creating a market for new technologies and products

To promote selling smart grid technologies in an expanded market, smart product certification programs and incentives for purchasing related products have been introduced. A certification program for smart buildings with an AMI system and smart appliances for residences were also introduced. The Building Law, an energy efficiency rating of buildings, is included in the certificate system.

The implementation of time-limited R&D tax credits on technology developments of key sectors, such as electric vehicles, renewable energy power generation, and power storage systems have been promoted. The completion year for electric vehicles is 2012, for renewable energy power generation is 2013, and for power storage systems is 2015.

Strategic purchases of products that create new or expand existing markets are being supported. These purchases support the million green homes project, the demand management, and the smart house project.[53]

2.3 Rapid build-up of related infrastructure and systems

South Korea's future directions for smart grid infrastructure and systems include incentives in early stages to build infrastructure, the establishment of standards and certification for the international market, and a comprehensive security program for the safe construction and operation of the smart grid.

2.3.1 Establishment of key infrastructure

South Korea established a smart-meter-obligation-system to set up a bidirectional communication system and to provide smart meters for all consumers by 2020. From 2013, the improved

[53]http://www.kemco.or.kr/new_eng/pg02/pg02040602.asp; http://www.solarthermalworld.org/content/one-million-green-home-programme

power network will be established for bidirectional power transfer. It will reflect data from test-bed results and ten electricity IT projects in South Korea.

Installing the charging infrastructure for electric vehicles is planned in stages. From 2011, the installation of fast chargers will be promoted at gas stations, LPG stations, public institutions, and supermarkets. The number of fast chargers will start at 20 in 2011, 100 in 2012, 200 in 2013, and 400 in 2014. The government will install these chargers until 2014, and then private companies will share financial support, necessary for operating the site. The long-term plan of implementing a supply of charging stations was prepared and confirmed in the first half of 2010. In the plan, the power supplier, installers, and electricity distributors each have specific responsibilities of charging infrastructure.

2.3.2 Establishment of standards and a certification system

South Korea supports the international standardization and the commercialization of smart grid technologies and products. Standardization guidelines for interoperability were prepared in 2010. Through testing infrastructure and acquiring international qualification export and commercialization will be supported. International standards will be supported with meetings on international standards such as the IEC/ISO, and will include the participation of domestic experts in the MEF Smart Grid Working Group on international standards. Furthermore, the development program for human resources on international standards, R&D, and deployment and maintenance is part of the project. Human resources for new technology combining electricity and IT and for setting the international standards need to be developed as well.

2.3.3 Deployment of a security system

In 2010, security guidelines for the safe deployment of a smart grid were established. According to the guidelines, the government will support the deployment of an appropriate security system. More specifically, security options include the following: a security architecture plan for the national smart grid, technology for ensuring safe operation of the grid, and an active security control system that detects anomalies in the grid's operation.

Besides security standards, certification systems for maintenance need to be in place. A verification system of compliance with standards, which ensures interoperability between different technologies and products, needs to be developed.

2.4 Laws and institutional infrastructure

Any modifications or revisions of laws and institutional infrastructure must support the long-term deployment of a national smart grid and the expansion of smart grid technologies and products into new markets. In 2010, South Korea enacted the Smart Grid Deployment and Support Act to augment existing legislation.

2.4.1 Amendments of related legislations

Incentives such as special fund and tax preference were part of the deployment and management strategy early on. The Act includes an industry development plan, committee management, infrastructure construction, incentives creation, model city management, an information security system, and funding method. Standards for safety and the licensing of charging stations needs to be amended to related electricity, parking, and housing sections of the Act. Safety standards for electric-vehicle chargers, the legal status of station owners, and station deployment standards will also be included in relevant sections of the Act.

The deployment and support of energy storage systems needs to be prepared to establish micro grid systems. As such, the electricity market regulates the price that consumers receive for selling surplus electricity.

2.4.2 Phase-by-phase introduction of a real-time pricing mechanism

Various pricing mechanisms for consumers such as real-time pricing, time of use, and critical peak pricing need to be developed to broaden choice and encourage more energy savings. The new system, a flexible electricity pricing based on the results of Jeju test bed, will be applied to a pilot city.

To encourage the deployment of charging stations, a lower charging service fee needs to be reviewed. The additional service fee on the charging price for collecting investment costs needs to be reviewed. Also, the exemption of progressive tax rate on electricity price for home chargers will be reviewed.

Current electricity billing needs to change to cost-based fee systems to encourage consumers to save more electricity. Support for the lower-income group needs to switch to a direct scheme through social consensus by utilizing general budget or an electricity industry fund.

2.4.3 Policy for a stable power supply

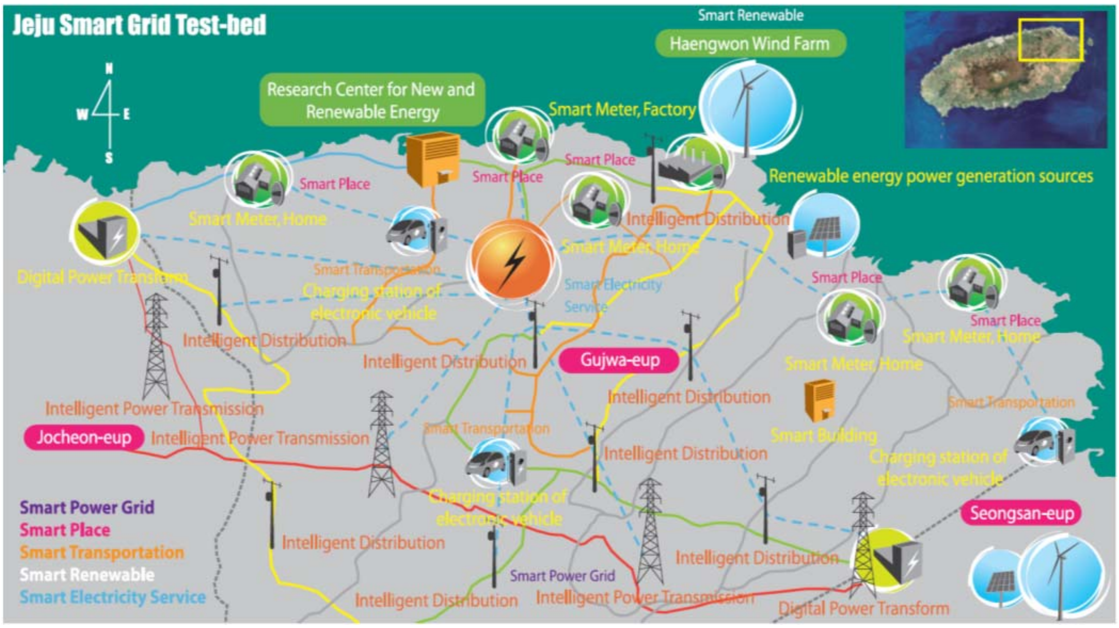
The expansion of renewable energy and electric vehicles mean that the power supply considers demand in the long term. This outlook was reflected in the 5th Power Supply and Demand Plan 2010.[54] An emergency power supply system will be prepared by 2012 for the sudden increase in the power load due to electric vehicles. Also in 2010, the government introduced a safe electricity management system for consumers.

3. Currently available financing mechanisms

The total costs for the successful deployment of a smart grid are estimated at USD 25 billion by 2030, including USD 6.4 billion for technology development and approximately USD 18.6 billion in infrastructure. To develop key technologies, approximately USD 6.4 billion of investment is needed by 2030, including USD 0.4 billion in the first phase and USD 0.8 billion in the second

[54] Ministry of Knowledge Economy Korea Power Exchange, December 2010: The 5th Basic Plan for Long-term Electricity Supply and Demand (2012~2024)

Figure A4-8
Jeju smart grid test-bed
Source: Ministry of Knowledge Economy (MKE), Korea Smart Grid Institute (KSGI), *For the World's Green Growth – Jeju Smart Grid Test-bed in Korea*



phase. Government and private sector invest together in technology development, and then gradually expand the private sector's burden according to the technology's maturity. Therefore, in the first step, the government–private investment ratio is 50:50; in the second step, 40:60, and in the third step, 25:75.

In the first step, technology development and investment size was estimated by considering various opinions from the Smart Grid Roadmap Working Group of experts, corporations, and institutions. Estimates are based on the assumption that technology development fund size increases 10% annually after the second step. The investment demand estimates for smart consumer, standards, security and smart service will be separately calculated because they need relatively lower investment demand.

Private and government investment on infrastructure will reach approximately USD 18.6 billion by 2030. Government invests USD 0.5 billion and the private sector invests USD 18.1 billion by 2030. To create a market for new technologies and new products, the government needs to support the strategic purchase of the public infrastructure. Investment by private sector is estimated based on the voluntary efforts and the obligation which are compulsory factors after government's efforts to boost the smart grid market. This includes investments in smart meter deployment, electric vehicles, smart grids, and renewable energy efficiency.

Overall, in South Korea, investment in the smart grid project was initiated by its government. Then, through market creation and a stimulating regulation framework, the private sector is expected to invest more in the project.

4. Test-bed Implementation: Jeju in South Korea

South Korea's smart grid test bed is located in the Gujwa-eup, Jeju Island area, covering about 6,000 households (Figure A4-8). This test bed will serve as the foundation for the commercialization and industrial export of smart grid technologies through establishing the world's largest demonstration project under real-world conditions. The test bed has two separate phases. The basic stage (December 2009–May 2011) was the construction of the infrastructure. The expansion stage (June 2011–May 2013) is the integrated operation environment.

Figure A4-9

Participants in South Korea's national roadmap

Source: Ministry of Knowledge Economy (MKE), 2010.1, *Smart Grid National Roadmap*

Areas	Leading companies	Participating companies	Budget (in billion won)
Smart Place = Smart Consumer (96 companies	SKT	SAMSUNG Electronics, KCTV, etc. (total 29 companies)	Government: 17 Private: 81.5
	KT	SAMSUNG SDS, SAMSUNG C&T Co., ROOTECH, OMNISYSTEM, etc. (total 14 companies)	
	LG	LG POWERCOM, GS E&C, GS EPS, etc. (Total 15 companies)	
	KEPCO	TAIHAN, NURITELECOM, etc. (total 38 companies)	
Smart Transport (43 companies)	KEPCO	SAMSUNG SDI, LOTTE DATA COMMUNICATION COMPANY, KAIST, LG Telecom, etc. (total 22 companies)	Government: 13 Private: 36
	SK energy	SK Networks, RENAULT SAMSUNG Motors, etc. (total 14 companies)	
	GS Caltex	LG CNS, ABB Korea, etc. (total 7 companies)	
Smart Renewable (29 companies)	KEPCO	KOSPO, HYOSUNG, LS Industrial System, etc. (total 16 companies)	Government: 11 Private: 31.4
	HYUNDAI Heavy industries	MAXCOM, ISEL System Korea, etc. (total 6 companies)	
	POSCO	LG CHEM, LTD., WOOJIN Industrial System, DAEKYUNG Engineering, etc. (total 7 companies)	
Smart Power Grid	KEPCO	-	Government: 19.5 Private: 9.8
Smart Electricity Service	KEPCO, KPX	-	Government: 6 Private: 12

According to the National Roadmap, the test bed is divided into five strategic areas: smart power grid, smart place, smart transportation, smart renewable, and smart electricity service. Currently, about 12 consortia (171 companies), consisting of smart grid-related companies, including power, communication, transportation, appliances, and so on are participating in testing technologies and developing business models (Table A4-9).

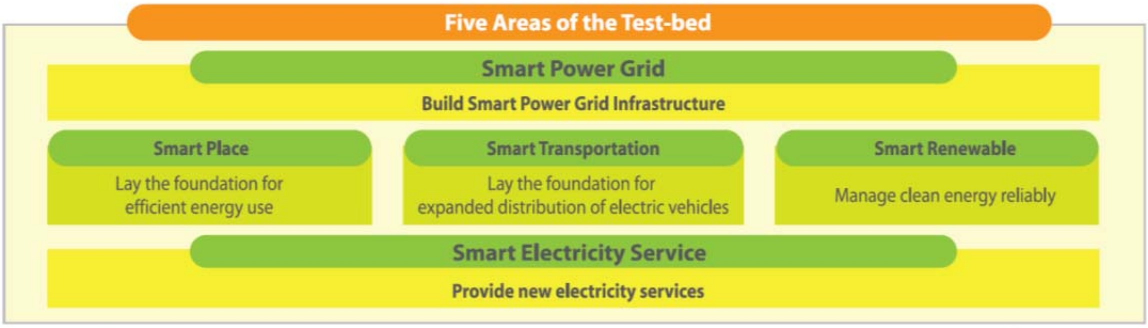
The South Korean government is promoting many efforts to attract private industries' participation in the Jeju test bed project. Particularly, a total of 68.5 billion won (USD 60.8 million) budget will be invested in the Jeju smart grid to establish a foundation to test domestic and international power exchange in a TOC, with the participation of various private industries. Private industries are planning to invest 171 billion won (USD 151.9 million) in the test-bed project and they expect to dominate the smart grid market in advance. Therefore, the Jeju test bed is expecting a total of 239.5 billion won (USD 212.7 million) invested.

The Jeju Smart Grid Project is promoting two separate phases within four years (by 2013), and is currently in the process of the second year of the basic stage, infrastructure building (Figure A4-10).

Figure A4-10

Overview of implementation plans of the Jeju smart grid test-bed

Source: Ministry of Knowledge Economy (MKE), Korea Smart Grid Institute (KSGI), *For the World's Green Growth – Jeju Smart Grid Test-bed in Korea*



Phase-by-Phase Implementation Plans

Phases	Period	Key focus areas	Key contents
Basic stage (Infrastructure building)	2010-2011	Smart Power Grid, Smart Place, Smart Transportation	- Linking grid networks and consumers, grid networks and electric vehicles
Expansion stage (Integrated operation)	2012-2013	Smart Renewable, Smart Electricity Service	- Provide new power services - Accommodate renewable energy sources to the power grid

The SK consortium is implementing PV to 200 households in the test-bed area for the foundation of a microgrid. They also developed the AMI, Smart Meter (SM), Data Concentration Unit (DCU), GateWay, etc., supporting real-time information, metering, and remote control.

Meanwhile, in response to the real-time power market, a foundation for various service and business model verification is also being considered as part of the test bed. Additionally, they allocated 35.5% of government funds to four Jeju traditional companies to create local jobs. A major component of the second year is to collect 1,000 households and provide 20 services and test business models by constantly advertising the test bed. They will build the AMI infrastructure for 1,000 households and install PV for the 200 households. There is also a plan to look for an energy management system that connects to the TOC, AMI security enforcement devices, perform rapid After Service.

The KT consortium successfully completed the first year of smart grid service for general consumers through providing and educating them with an energy monitoring service and an operation centre for the 200 households. They strive to develop smart grid advanced technology through power-communication convergence and integration. They developed a smart device (Smart Box/Tag), power device (digital watt-hour meter), communication (Fiber to the Home, FTTH), Energy Management System (EMS), and App (monitoring service) and also conducted interconnection and testing.

The second year of the KT consortium targeted 1,000 households to test energy-efficient service, adapt and test DR and a load management solution, to test a TOC connection operational design and WiBro through KT's operation centre. These are expected to operate with PV development system, power management system, and household storage system. Also, they plan to reinforce security through smart meter and KT's operation centre's security solution and to test the AMI-SUN interconnection for interoperability and standardization.

Another participant company in the smart consumer sector is the LG consortium. They "over-supplied" test consumers by contact-type advertising and installed the Smart Grid environment in advance to solidify the consumers' participation. Also, they provide the optical network for all the test participation consumers. In the second year, they will provide a smart-metering service and expand facilities and system installation. Particularly, this includes additional installations of the smart meter and security function, the Zigbee smart plug installation, expansion of smart server and Zigbee Home Area Network (HAN), smart appliance installation, power storage system installation, additional installation of PV, small-scale wind turbine installation, electric-vehicle charger installation, and group micro grid installation. They are planning to establish an integrated platform, smart metering data management system, and security control system of operating centre, and to develop energy-care service, new power exchange service design, and Smart Energy Management System, Demand Response/Real Time Pricing system.

The KEPCO consortium of smart consumer area held several briefings and public hearings for residents to better understand the smart grid project, and it gathered 570 households' participation. They established a foundation of standardization to secure interoperability among various solutions proposed by the 35 participating companies. Although there were many conflicting project objectives and interests among participating companies, through reconciling their ideas and interests, they were successful in securing interoperability. In the second year, they plan to establish smart consumer facilities, such as smart meter, modem, and DCU and to promote network connection and security and system security control system. They are expected to design DR rates in connection with consumer participation in the DR resource management service, and to conduct a test of total AMI service on 300 households by reading the power and water meter together.

The next major sector is smart transportation. In the first year and the plan for the second year of the KEPCO consortium, charging-device infrastructure development for electric vehicles, charging-period interface standardization, charging-station algorithm development, charging-device trial products, and tests with Hyundai Motors are on-going. In addition, the development of related systems, such as charge payments, customer service, real-time monitoring of charging stations, and designing an operation centre are in process. They also analysed the Jeju test-bed charging infrastructure requirements and the establishment of a control plan, and the development of electric-vehicle navigation. Then, the KEPCO consortium is expected to install a Smart Transport Operation Centre, and optional services, and to complete a demonstration of the charging process, such as installation and testing of charging infrastructure, car verification, and charge payment in the second year. Additionally, they are planning the development of a reduced-cost charger and participating in the national standardization of charging connectors, communication protocols, and charging cables.

The SK energy consortium is testing electric-vehicle development and charging-station installation. A rapid type of charger has been designed, and production will begin in the second year. Developing a two-directional On-Board Charger instead of a one-direction unit, lays the foundation for the Vehicle to Grid (V2G) project. In the second year, using the database from the first year, they are expected to expand the electric-vehicle project by technology development and networks among EV-charging stations. In addition, they are planning to develop related technologies by performance improvements of 12 of 8 kWh, 13 of 16 kWh battery packs, and installing Battery Management System communication/controls, expanding charging stations (48), and developing 50-kWh charging stations. They are planning to perform simulations of the V2G service through previous impact assessments of the fast charger installation and the safety of the existing grid. Also, there will be development of electric vehicles that will ensure a 100-km drive with a one-time charge.

The GS Caltex consortium established a foundation to test various project models by successfully completing the first year's project plan. In the second year, they are trying to develop various project models through alliances with related companies. Particularly, they will produce a 50-kWh fast charger and a 70-kWh slow charger, along with installing an ICT-based operating system (including charging infrastructure and an operation system, a security system, and fare calculation system). In addition, development of WiBro base navigation, location-base real-time vehicle location and condition information, and smart phone service will be promoted, and the development of EV-only power storage system is planned.

Another major sector is smart renewables. The Hyundai Heavy Industries consortium plays a critical role in that area. They completed a basic design of a test-bed network and facilities [large-scale, energy-storage devices, power quality devices, Power Conversion System (PCS), EMS, etc.] based on field studies and assessments. In addition, they prepared a power-market bidding strategy, established EMS composition, and a wind power system basic plan. In the second year, they will operate optimum design and infrastructure for unit field application, and plan to derive smart grid control/operation scenarios. Also, they will promote an energy-storage-system battery, PCS, power-quality-device production and performance assessment, EMS, elliptic curve cryptography, communication network design and installation.

Stabilizing wind power output and researching the effective operation of micro grids in the first year and basic engineering and the basic design project for the second year project complete the POSCO consortium's project objectives. They actively participated in smart grid standardization and security settings, through the Standardization/Security Working Group. In the second year, they are planning to design an operation system for stabilizing renewable energy output and to design a micro gird energy management system for maximizing renewable energy. They will analyse micro grid-operation characteristics and the optimum protective relay system. The POSCO consortium is aiming to install and test a smart output stabilization system for large-scale wind power, and to establish a micro grid operation platform applicable for cities, islands, and industry. For this reason, they will install micro grids by connecting various renewable energies, such as wind power and PV, to storage devices to promote effective operation of the system.

The smart electricity area is another important component for the Jeju smart grid test bed. The KEPCO consortium on smart electricity established a system for a total operational centre, and they analysed data linkage, defined detailed characteristics between TOC–consortium, and installed CIM-based international standardization data to ensure compatibility within systems in the first year. In the second year, they are planning to promote test-bed virtual market mechanism enactment, total operation centre market/operation system establishment, test-bed market/operation simulation, renewable energy output estimation method/system development, and various areas of system technology development of the test bed.

Another participating company, the KPX consortium, completed the development of previous day/real-time market design and rule and optimization of development program in the first year. Also, they developed a computer-based technical specification system of total operation centre. Through a total operation centre, the realization of key market functions, such as bidding, development plan, and pricing mechanisms, are in place. In the second year, they are planning to promote total platform installation, realize a comprehensive dashboard, build a security control centre, and customer service portal system with real-time pricing with the communication network.

Annex 5: China

1. Regional contexts and drivers of smart grid development

1.1. Electricity market

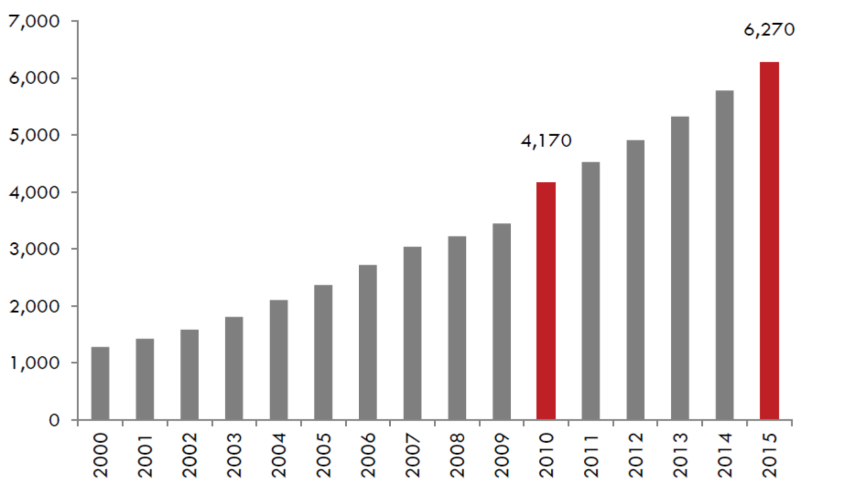
With the rapid development of China's economy and its people's rising standard of living, the country's electricity production and consumption is increasing at high speed. Between 2006 and 2010, power consumption increased on average 9.9% per year, while the installed power-generating capacity increased by 10.3% annually. In 2010, power consumption reached 4 trillion kWh and total installed power-generating capacity was up to 950 million kW. Since 2010, China has the second largest generating capacity in the world. National power supply and demand is overall balanced and satisfies current economic and social needs. However, there are some uncertainties, such as the shortage of coal, shortage of water in reservoirs, occasional shortages of power supplies in some places (Figure A5-1).

In China, the power grid is mainly constructed by the State Grid Corporation (SGCC), the coverage of which is no less than 8.5 million square kilometres (88% of the total land area in China), providing electricity to more than 1 billion people (more than 80% of total population). The SGCC plays a decisive role in the construction of smart grid in China.

Figure A5-1

China's Projected Net Electricity Generation (2000-2015 in billion kWh)

Source: Zpryme Research & Consulting, LLC, January 2011, *China: Rise of the Smart Grid*

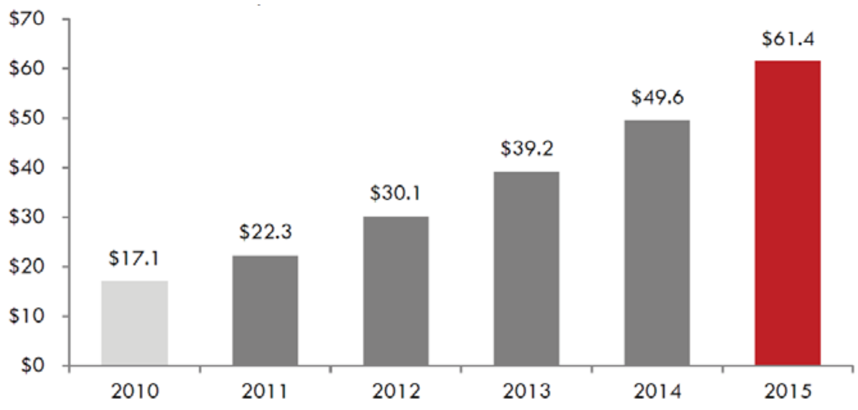


Source: U.S. EIA & The China Electricity Council

Figure A5-2

Projected smart grid equipment and technology market in China (2010-2015 in U.S. billions), compound annual growth rate (CAGR) = 29.1%

Source: Zpryme Research & Consulting, LLC, January 2011, *China: Rise of the Smart Grid*



1.2 Legal and political/policy contexts and drivers

Due to its different national conditions, development phases, and distribution of energy resources, China's power grid is very different from those of other countries. China's power grid is required to be "strong" as its energy resources and production facilities are distributed unevenly in China. It is necessary to install Ultra High Voltage (UHV) power lines that support long-distance and large-capacity transmission (higher than 800 kV). Smart grids are required to enable the power grid system to be efficient, flexible in terms of operation and control, highly automated, and have a self-adaptation mechanism. Due to the large-scale exploration and utilization of renewable energies, such as solar and wind power, the integration of renewable energy power is a matter of urgency. At the end of 2009, about one-third of installed wind turbines in China were unable to be connected to the grid. And for those who were connected, they often had to shut down when wind was at its peak because the existing grid is too weak to handle the unpredictable, intermittent nature of wind.

The Chinese government has acknowledged these facts and made them part of its "12th Five-Year-Plan (2011–2015)". It is estimated that the total value of China's smart grid market will nearly triple over the next five years from USD 22.3 billion in 2011 to USD 61.4 billion in 2015 to deliver over 6 trillion kWh to more than one billion customers and energy intensive factories (Figure A5-2).[55]

China promised to reduce its carbon footprint 40 to 45% below 2005 levels by 2020, while increasing non-fossil fuels for about 15% of its energy.[56] According to Renewable Energy Law of P.R. China, the integration of renewable energy into the grid is highly encouraged and supported by the Chinese government. Such power grid enterprises are expected to sign agreements with similar power-generation enterprises, which have been granted licenses or filed applications for approval to purchase electricity generated by the renewable-energy power generation projects within their range of power grids and provide the respective power grid services.

In 2009, the SGCC announced a plan for the development and construction of a "strong smart grid" in three phases with a total cost of $100.8 billion by 2020[57]:

1. Planning and pilot phase (2009–2010), in which the focus is on developing a "strong smart grid", technical standards and

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[55] Zpryme Research & Consulting, LLC, January 2011: *China: Rise of the Smart Grid*

[56] Larry West, About.com Guide, 26 November 2009; China Promises to Cut Greenhouse Gas Emissions at http://environment.about.com/b/2009/11/26/china-promises-to-cut-greenhouse-gas-emissions.htm

[57] Zpryme Research and Consulting, LLC, January 2011: *China: Rise of the Smart Grid*

management practices, R&D in key technologies and equipment manufacturing, as well as pilot work at all links of the power grid;

2. Comprehensive construction phase (2011–2015), in which efforts are made to speed up the construction of a UHV power grid and urban/rural distribution network, to build a smart grid operation/control and interactive service system, and to achieve major breakthroughs and extensive use of key technologies and equipment;

3. Improving and perfecting phase (2016–2020), in which a unified “strong smart grid” is established, the proportion of clean energy installed capacity will reach as high as 35%, “plug and play” is supported in distributed power supply, and smart metering is applied widely throughout China.

The “12th Five-Year Plan” (2011–2015) for China’s power-generation industry points out that, during this period, the emphasis is on strengthening the technical innovation and pilot use of smart grids, accelerating the amendment and improvement of relevant standards by systematic evaluation and analysis of smart grid pilot projects, and ensuring fast development at different links of the power grid system.

The nine key tasks include[58]—

1. Large-scale, grid-connected, intermittent renewable energy technology
2. Grid technology to support electric vehicles
3. Large-scale energy storage systems
4. Intelligent distribution technology
5. Intelligent grid operation and control
6. Intelligent transmission technology and equipment
7. Grid information and communication technologies
8. Flexible power transmission technology and equipment
9. Integrated comprehensive demonstrations of smart grids.

2. Identification of the financial and business challenges

A large amount of the capital for the development of smart grid mainly comes from the SGCC and other enterprises generated from the revenue of selling electricity. Some of the renewable energy surcharges and profits from the selling price can be

[58] SGT Research Smart Grid Times & Consulting, 14 May 2012: *SGT Insight. 2012 China smart Grid Outlook*

used as investment capital for the enterprises. Another part of the capital comes from bank loans and corporate bonds. Projects usually need large investments, have a long construction period with poor liquidity, and companies face a high return on investment (ROI) pressure. It is, therefore, urgent to make policies relating to fund raising and tax cuts, and create innovative fundraising means.

Creating an interactive and market-oriented power grid system needs more flexible and open pricing mechanisms. The price of electricity is a key factor, driving consumers to participate and shift their consumer behaviours to reduce peak load times. Hence, a flexible pricing mechanism can effectively help consumers benefit from smart grids.

3. Currently available financing mechanisms and best practice examples

3.1 Market-based support instruments

As the leading player in the construction of the smart grid in China, the SGCC has played a positive role in carrying out pilot projects by means of independent investment and public tendering, attracting investment from technical service providers and equipment manufacturers, and helping them to participate in these projects. It is estimated that the SGCC will invest a total of 1 trillion Chinese Yuan ($100.8 billion) by 2020 across the three phases of its power grid plan[59]: the 1st phase ended in 2010 with $9.2 billion; the 2nd phase from 2011–2015 will invest $45.8 billion; and the 3rd phase from 2016–2020 will invest $45.8 billion.

3.2 Local (municipality) scale

In 2010, pursuant to the requirement of the SGCC for developing a strong smart grid, the Beijing Electric Power Company worked together with Shenzhen State Power Technology Communication Co., Ltd. to establish a pilot project in Shunyi Hua Zhong Yuan Resort with a smart grid of five energy sources, including natural gas, solar power, battery, grid-connected inverter, and electric power.

3.3 Regulatory incentives

The National Development and Reform Commission of China has developed policies to guide the onto-the-grid electricity prices of renewable energy and to encourage enterprises to construct renewable energy power projects. These policies include “Notice of the National Development and Reform Commission on Improving onto-the-grid Solar Photovoltaic Electricity Price”, “Notice on Improving onto-the-grid Wind Power price”, and “Notice on Improving onto-the-grid Biomass Power Price”.

[59] Zpryme Research & Consulting, LLC, 2011: *Smart Grid Insights 2011*

Annex 6: India

1. Regional contexts and drivers of smart grid development

1.1 Electricity market

India is home to more than 17% of the world's population, but currently consumes only 3–4% of the world's electricity. India's two biggest challenges are high losses—both electrical ("technical") and financial ("commercial" due to both non-payment and theft)—and the shortage of supply.

India now has the fifth largest electricity grid in the world and the world's third largest transmission and distribution network. However, the demand from increased economic activities and the rising living standard of the population has led to a situation where the supply of energy falls short of the demand. India's power industry is facing major challenges: huge supply shortfalls, power theft, poorly planned distribution networks, and inefficiency in metering and bill collection. India's transmission and distribution losses are among the highest in the world, averaging 26% of total electricity production. Taking into account energy theft, total losses are as high as 50%.[60] The per-capita consumption of electricity in India was about 814 kWh in 2011. Only about 90% of the villages are electrified. The country continues to have a great mismatch between demand and supply and experienced energy and peak shortages to the tune of 8.5% and 10.3%, respectively, from 2010–11.

1.2 Legal and political/policy contexts and drivers

Though there are enormous deficiencies in basic infrastructure, India is still considering investments in smart grid technologies. The reason is that, ultimately, for India to continue along its path of aggressive economic growth, it needs to build a modern, intelligent grid. It is only with a reliable, financially secure smart grid that India can provide a stable investment environment for the electricity infrastructure, a prerequisite to fixing fundamental problems with the grid. Without this, India will not keep pace with the growing electricity needs of its cornerstone industries and it will fail to create a growth environment of its high tech and telecommunications sectors.

Smart grids can bring together reliable metering and revenue collection, thereby leading to better energy accounting. This would pinpoint the causes and sources of losses, which can be then rectified. Reliable energy accounting will plug sources of theft and reduce commercial losses.

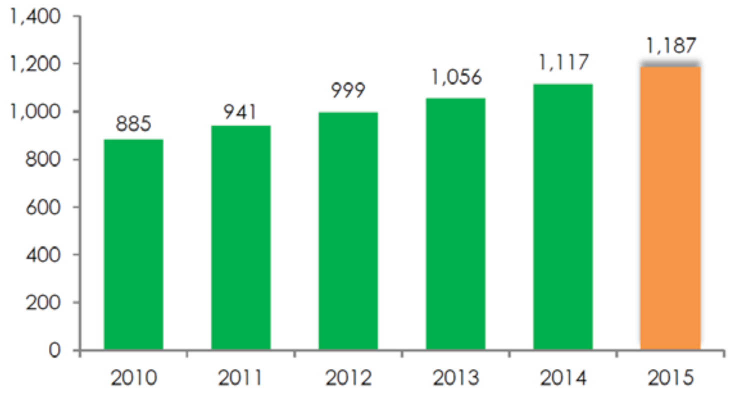
For India, managing peak load is also a key driver. Since energy cannot be stored for longer duration on a large scale, the energy supply has to be increased or demand has to be reduced. At present, in Europe or North America, an increase in peak load demand is managed by peak-load plants, which are run at high cost. If India follows the Western model, the price of electricity would rise drastically. The alternative option is reducing

[60] Zpryme Research & Consulting, LLC, September 2011: *India: Smart Grid Legacy*

Figure A6-1

India's projected electricity generation (2010-2015 in billion kWh), compound annual growth rate (CAGR) = 6.0%

Source: Zpryme Research & Consulting, LLC, September 2011: *India: Smart Grid Legacy*



demand through demand-side management and variable pricing for peak and off-peak hours, which can be achieved only through a smart grid (Figure A6-1).

The emphasis on a smart grid in India is due to a host of demanding factors, which are threatening the energy security of the country. Power could be one of the limiting factors stemming the growth of India's economy. To bring in efficiencies and quickly address the burgeoning demand of electricity, smart grids in India are more of a necessity than an option. The primary issues driving the implementation of smart grids in India include—

- **Increased power demand.** As one of the world's fastest growing economies, power generation and distribution have not kept up with demand neither in quantity nor in quality.
- **Lower electricity penetration/access.** Large swathes of rural areas of India are yet to be electrified. Energy access for all cannot be ignored if the country wants to progress sustainably.
- **Improvement of operational inefficiencies and losses.** There is an urgent need to optimize the use of electricity, manage loads, mitigate operational inefficiencies, and reduce technical and non-technical losses.

1.3 Government initiatives toward a smart grid

1.3.1 India Smart Grid Task Force (ISGTF)

The Government of India formed the India Smart Grid Task Force in 2010 as an inter-ministerial group and will serve as the government focal point. It is a body composed of officials from different government departments and is primarily meant for understanding and advocating policies in smart grid technologies.

Major functions of the ISGTF are—

- Ensure awareness, coordination, and integration of diverse activities related to smart grid technologies
- Promote practices and services for R&D of smart grids
- Coordinate and integrate other relevant inter-governmental activities
- Collaborate on an interoperability framework
- Review and validate recommendations from the India Smart Grid Forum.

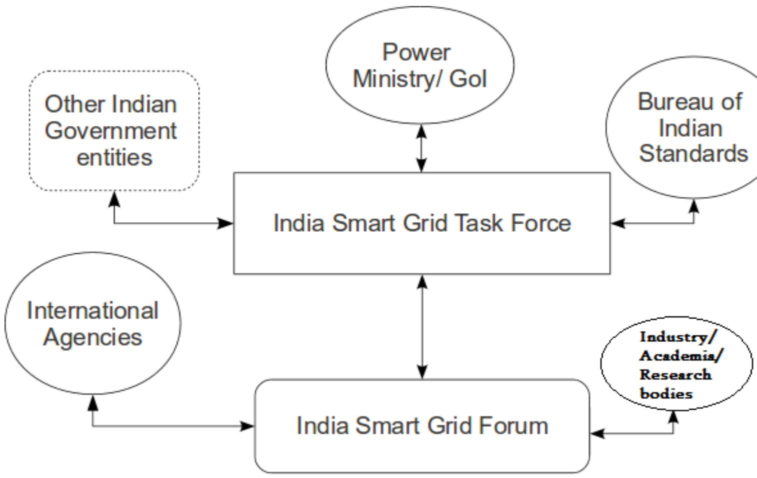
Five working groups of the ISGTF tackle specific tasks:

- WG1–Trials/pilot on new technologies
- WG2–Loss reduction and theft, data gathering, and analysis

Figure A6-2

Information flow and hierarchy diagram of the ISGTF and the ISGF

Source: Desi Smart Grid, 2012, India Smart Grid Forum and India Smart Grid Task Force



- WG3–Power to rural areas and reliability and quality of power to urban areas
- WG4–Distributed generation and renewables
- WG5–Physical cyber security, standards, and spectrum.

One of the key recommendations made by the ISGTF is to have eight different smart grid pilots (completely funded by Indian agencies) to establish a knowledge base and develop proofs-of-concept in various categories across all parts of the country. Later, the number of smart grid pilots was increased to 14 and are waiting for government approval.

1.3.2 India Smart Grid Forum (ISGF)

The Government of India also formulated the India Smart Grid Forum in 2010 as a non-profit, voluntary consortium of public and private stakeholders with the prime objective of accelerating development of smart grid technologies in the power sector. The ISGF has roles and responsibilities complementary to the ISGTF and reports its findings to it (Figure A6-2).

The goal of ISGF is to help the power sector deploy smart grid technologies in an efficient, cost-effective, innovative, and scalable manner by bringing together key stakeholders and enabling technologies. The ISGF will coordinate and cooperate with relevant global and Indian bodies to leverage global experience and standards, and will highlight any gaps from India's perspective. The ISGF's recommendations will be advisory in nature. The ISGF will seek the best practices in the world and develop a roadmap for smart grid solutions appropriate for India's needs and conditions.

The ISGF operates in a layered structure with different working groups focusing on different aspects of smart grid. A Core Group composed of founding members is responsible for overall coordination of the working groups. Members of the Core Group and working groups are decided by elections and a few nominations from government agencies. The Forum is open to voluntary memberships from all appropriate interested entities. There are different categories of membership with different rights and responsibilities based on the entity size and other status such as government, regulator, non-profit organisations, industry, utility, etc.

Seed funding for the ISGF was provided by the Ministry of Power (~USD 100K). Governance of the ISGF is overseen by a Board of Governors drawing from Industry (four seats), Utilities (two seats), and Research/Academia (one seat) with a term of two years. Funding of the ISGF will come from the annual membership fee from all members based on their categories.

India's Smart Grid Vision as expressed by the ISGF includes five fundamental objectives:

- **End of Load Sharing**—peak load shifting through a combination of direct control and differential pricing [demand response/dynamic];

- **Reliable Power**—robust systems with self-healing capabilities, a system that complements diagnostic devices which enables the network provider to minimize blackout times through monitoring;
- **Cheaper Power**—dramatic improvements in aggregate technical and commercial (AT&C) losses, real-time monitoring load sources;
- **Shifting Peak away from Costly Power**—better utilization of assets;
- **More Sustainable Power**—integration of green and renewable resources on a massive scale, enough to increase energy independence.

The work of ISGF has been divided working groups who will concentrate on specific areas:

- WG1: Advanced Transmission
- WG2: Advanced Distribution
- WG3: Communications
- WG4: Metering
- WG5: Load Control
- WG6: Regulatory and Policy
- WG7: Architecture and Design
- WG8: Pilots and Business Models.

1.3.3 Distribution reform, upgrades, and management (DRUM)

The Ministry of Power, Government of India, and the U.S. Agency for International Development (USAID)–India jointly designed the Distribution Reform, Upgrades and Management [61] (DRUM) Project with the purpose of demonstrating "the best commercial and technological practices that improve the quality and reliability of 'last mile' power distribution in selected urban and rural distribution circles in the country." The project is in synch with the Indian Government's policy on power sector reforms, the Electricity Act of 2003, and the Re-Structured Accelerated Power Development and Reforms Program (R-APDRP) scheme.

The overall programmatic goal of the DRUM Project is to demonstrate commercially viable electricity distribution systems that provide reliable power of sufficient quality to consumers and to establish a commercial framework and a replicable methodology adopted by India's financial institutions for providing non-recourse financing of DRUM activities and programs. Specific anticipated results include—

- Improved power distribution
- Better availability and quality of electricity
- Enhanced commercial orientation and drive
- Improved consensus on the distribution reform process

[61] http://www.powermin.nic.in/whats_new/pdf/DRUM_training_programme1.pdf

- Enhanced viability of the sector
- Strengthened Distribution Reform initiatives of the Ministry of Power
- Enhanced efficient utilization of R-APDRP funds
- Innovative financing mechanisms.

1.3.4 Re-Structured Accelerated Power Development and Reforms Program (R-APDRP)

<u>Introduction</u>

R-APDRP is a form of stimulus package aimed to stir the state distribution utilities to reform and strengthen the distribution infrastructure. The R-APDRP in 2008 focused on actual and demonstrable performance in terms of AT&C losses.[62] Two expressions, AT&C and T&D losses, have been used to describe losses in India. AT&C loss is basically the difference between energy input and energy for which revenue is realized after accounting for collection efficiency, and to this extent, it differs from T&D losses. It is the sum total of technical loss, commercial losses, and shortage due to non-realisation of total billed amount. T&D losses take into account only technical losses in the T&D system.

This program is designed to take 3–5 years to implement and has two parts—Part A and Part B. The program is concerned with ICT and the enablement of power systems and investments in power infrastructure in an effort to first measure and then mitigates losses associated with operating inefficiencies and energy theft. The primary goal of the program is a reduction in losses, with subsequent portions focusing on physical re-engineering of the grid as indicated by ICT-driven data.

The focus of the programme is on actual, demonstrable performance in terms of sustained loss reduction. Currently, there is no accurate or verifiable GIS data on the power flowing in and out for most towns and cities of the country. Energy auditing and accounting would be possible only once a system has been established to measure and map the electricity flow of a place. This data would become the ”baseline data” on which further improvements would be gauged. Establishment of reliable and automated systems for sustained collection of accurate baseline data, and the adoption of IT in the areas of energy accounting are essential before taking up the regular distribution-strengthening projects.

<u>Programme Coverage</u>

The R-APRDP will cover urban areas—towns and cities with populations of more than 30,000 (10,000 in case of special category states). In addition, in certain high-load density rural areas with significant loads, works of separation of agricultural feeders from domestic and industrial ones, and of High Voltage Distribution System (11 kV) will also be taken up.

Further, towns and areas for which projects have been sanctioned in the X Plan R-APDRP shall be considered for the XI Plan only after either

[62] http://www.apdrp.gov.in/Forms/Know_More.aspx

completion or short closure of the earlier sanctioned projects.

Proposed Scheme

Projects under the scheme shall be taken up in two parts. Part A shall include the projects for establishing baseline data and IT applications for energy accounting/auditing and IT-based consumer service centres. Part B shall include regular distribution-strengthening projects.

Part A includes the preparation of baseline data for the project area covering consumer Indexing, GIS mapping, metering of distribution transformers and feeders, and automatic data logging for all distribution transformers and feeders, and supervisory control and data acquisition/data management system (SCADA/DMS) input. It would include asset mapping of the entire distribution network at and below the 11-kV transformers and include the distribution transformers and feeders, low-tension lines, poles, and other distribution network equipment. It will also include the adoption of IT applications for meter reading, billing, and collection; energy accounting and auditing; MIS; addressing consumer grievances; establishment of IT-enabled consumer service centres, etc. The baseline data and required system shall be verified by an independent agency appointed by the Ministry of Power. The list of works is only indicative.

Part B includes renovation, modernization, and strengthening of 11 kV-level substations, transformers/transformer centres, re-conducting of lines at 11-kV level and below, load bifurcation, feeder separation, load balancing, HVDS (11 kV), aerial bunched conducting in dense areas, replacement of electromagnetic energy meters with tamper-proof electronic meters, installation of capacitor banks and mobile service centres, etc. In exceptional cases, where the sub-transmission system is weak, strengthening at 33-kV or 66-kV levels may also be considered.

Funding Mechanism

1. The Government of India through the Ministry of Power will provide 100% loans for Part A of the R-APDRP schemes, which shall include projects for establishing baseline data and IT applications for energy accounting/auditing and IT-based consumer services, etc.

2. The Government of India will provide up to 25% (90% for special category states) loans for Part B of the R-APDRP schemes, which shall include regular distribution-strengthening projects.

3. Power Finance Corporation Limited, a government-owned lending institution focused on the power sector, will do the counter-party funding and coordination activities required for the programme.

Conversion of Government Loan to Grant

1. The entire amount of the government loan (100%) for Part A of the project shall be converted into grant after establishment of

the required baseline data system within a stipulated time frame.

2. Up to 50% (90% for special category States) loan for Part-B projects shall be converted into grant in five equal tranches on achieving 15% AT&C loss in the project area on a sustainable basis for a period of five years.

3. If the utility fails to achieve or sustain the 15% AT&C loss target in a particular year, that year's tranche of conversion of loan to grant will be reduced in proportion to the shortfall in achieving 15% AT&C loss target from the starting AT&C loss figure.

Implementation of the R-APDRP

A Steering Committee, under the Secretary (Ministry of Power), composed of members of various government departments, oversees the implementation of R-APDRP. The functions of the Steering Committee are separated as follows:

- Sanction projects, including modification or revision of estimates; monitor and review the implementation of the scheme
- Approve the guidelines for the operation of various components of the scheme including the approval of the charges to be paid to the implementation agencies
- Approve and sanction activities to be taken up by the Ministry under the smart grid implementation part of the scheme
- Appoint agencies for verification and validation of the baseline data systems, for verifying the fulfilment of the programme conditions by utilities
- Approve conversion of loan into grant upon fulfilment of the necessary conditions.

Status of implementation

Projects in 1,401 towns have been approved in the 29 states of India under Part A at a cost of Rs 56.5 billion (~USD 1 billion). Under Part B, 775 projects worth Rs 148.54 billion were sanctioned (~USD 2.7 billion).

2. Identification of challenges

2.1 Financial challenges

2.1.1 Poor financial status of state distribution utilities

In India, electricity is a matter on which both the central and state governments have specific, and sometimes overlapping, powers, and this further complicates technical- and investment-related decisions. Most of the distribution companies of India are owned by state governments. There is always political pressure to keep the tariffs down and distribute electricity at low rates to certain sectors like agriculture and small industries. There are problems of low recovery of revenues. This has pushed most distribution companies into dire losses. This leaves the states utilities with hardly any funds to upgrade distribution networks. Hence, the states in general look toward the central government to provide funding and technical direction for strengthening the distribution system.

2.1.2 Non-involvement of private utilities

The Indian distribution system is fraught with high theft, weak infrastructure, politically motivated decision-making, and lack of GIS data. Many private companies shy away from being involved in the distribution business due to lack of clarity of profits owing to the abovementioned reasons.

2.1.3 Limited sources of funding

Currently, smart grid projects are at an early stage in India and are being implemented as pilots in various places. The funds for these projects come mostly from the government or external grants. Once the basic infrastructure is well established, many new parties will have clarity in the wires business and will invest in the distribution sector.

2.2 Business case challenges

The urgent power-system needs in India are not necessarily the same as those in advanced industrialized countries. The same goes for the most important power system constraints. Generally, not all smart grid technologies are equally relevant worldwide. In India, the really useful technologies will be those that help constrain peak demand and peak-load growth at reasonable costs while cutting losses.

2.2.1 Unique expectations from smart grids

First, many solutions adopted in highly industrialized countries will not work on a large scale in places like India. Hence, it is the government which should lead the way in smart grid implementation, showcasing its benefits in loss reduction, integration of renewable energy, better power quality, and efficient utilization of power assets.

Second, India's most urgent problems and needs are not the same as those in developed countries. India and other countries at a similar developmental stage are not worried about labour costs associated with reading meters as much as the accuracy of billing. India is more concerned about the burgeoning demand for power and its access by the masses. India urgently needs to provide an efficient means to address these for fast and inclusive growth of the economy as a whole.

2.2.2 Lacunas at the implementation level

The central government has now and previously devised several policies toward strengthening the distribution infrastructure. However, a lack of support at implementation levels has resulted in far less than satisfactory implementation of the policies. The primary reasons for failure at the implementation levels are lack of incentive for the implementing parties, lack of adequate skilled workers, lack of transparency of the systems, and lack of political will. The policies, formulated by the central government, are expected to be implemented by the distribution utilities run by the state governments. In most policies, there are no incentives to motivate workers toward the policies. Neither was there any disincentive in case they failed to do the needful. The lack of control over the implementing counterparty has been the primary reason for weakening of policy implementation in the past.

3. Currently available financing mechanisms and best practice examples

3.1 Market-based support instruments

India's Bureau of Energy Efficiency is partnering with IBM to create the country's first smart grid project (5/18/2011). IBM will conduct a cost-benefit analysis on various smart grid initiatives as part of India's National Mission for Enhanced Energy Efficiency (NMEEE). NMEEE is one of eight national missions promoting policy and regulatory initiatives, financing mechanisms, and business models to promote the market for energy efficiency. The focus of the analysis will determine India's readiness for deploying smart grid technologies. It will also develop a framework for adopting new smart grid technologies and identifying regulatory frameworks. The analysis will calculate return on investment for a range of smart grid projects planned across India.

3.2 National scale (i.e., national funds)

The R-APDRP scheme is the primary source of government funding and will serve as a precursor to the implementation of mass-scale, smart grid technology in India. As detailed above, the government will provide loans to utilities for the implementation of infrastructure that will be converted into grants on the achievement of specific milestones. The total fund for this programme is estimated at Rs 511.8 billion (~USD 9.3 billion). The Ministry of Power has allocated USD 44.3 million specifically for the implementation of smart grid projects across the country.

4. Current implementation of smart grids in India

- The USAID, Ministry of Power, the Central Power Research Institute, and Bangalore Electricity Supply Company have come together for a pilot project in Electronic City to cover around 17,500 domestic and business users.[63]
- The SGTF is currently coordinating eight pilot projects across the country's national electricity grid. For the next 18 months, these projects will provide an indication of what the overall framework for a detailed national plan will be.[64]
- A smart micro grid designed for renewable energy sources has also been commissioned at The Energy Research Institute's Gurgaon campus with the Ministry of New and Renewable Energy.[65]

[63] http://174.142.82.201/bescom/smart grid/
[64] http://articles.economictimes.indiatimes.com/2012-01-08/news/30604500_1_power-ministry-pilot-basis-projects
[65]http://www.teriin.org/themes/sustainablenergy/renewables.php

- The Bureau of Energy Efficiency is partnering with IBM on a project that would conduct a cost–benefit analysis on various smart grid initiatives and the deployment capabilities for smart grid technology.[66]
- In India, managing peak load is key driver as peak power plants will add an untenable margin to the cost of electricity in a developing nation. The Mangalore Electricity Supply Company's smart grid project will seek to scale back demand rather than cut it off entirely, allowing customers to meet critical demand needs while giving critical institutions uninterrupted supply.[67]
- North Delhi Power Ltd., itself a consortium between the government and Tata Power, partnered with GE for various smart grid solutions. The U.S. Trade and Development Agency extended NDPL a grant of USD 0.6 million for a smart grid project in northwest Delhi intended to reduce blackouts and increase reliability. NDPL is considered a smart grid technology leader in India rolling out smart metering infrastructure and automated meter reading.[68]

[66] http://www-03.ibm.com/press/us/en/pressrelease/34559.wss
[67] http://www.infraline.com/Details/karnatakas-power-grid-set-to-get-smartmescom-trying-out-new-technology-bescom-to-soon-follow-suit-45332.htm
[68] http://www.ndpl.com/DisplayMedia.aspx?mid=1427&RefIds=1

Annex 7: Brazil

1. Regional contexts and drivers of smart grid development

1.1 Electricity market

Brazil has different infrastructure needs from those of OECD countries: needs like long-distance power lines, large-capacity transmission, and centralized efficient operation and control. In fact, Brazil’s priority is building a grid able to host enough capacity for the rising demand for electricity.

Brazil has the largest electricity market in South America. Its installed capacity is comparable to that of Italy and the United Kingdom, although with a much larger transmission network. The country depends highly on hydroelectricity generation, which meets over 80% of its electricity demand. This reduces the country's generation costs relative to countries with more diverse supply mixes.

In Brazil, large government-controlled companies dominate the electricity sector of generation and transmission. Federally owned Eletrobrás holds about 40% of capacity (including 50% of the Itaipu Binacional Hydropower station), with state-companies CESP, Companhia Energetica de Minas Gerais (CEMIG), and Copel controlling 8%, 7%, and 5%, respectively, of generation capacity. Currently, only about 27% of generation assets are in the hands of private investors. Considering the plants under construction, as well as the concessions and licenses already granted by Agência Nacional de Energia Elétrica (ANEEL), this figure is expected to grow to 44% over the next five to six years. Private capital participation in the generation business will likely represent 50% of the installed capacity in the years to come.

The National Interconnected System (SIN) comprises the electricity companies in the south, south-east, center-west, north-east, and part of the north region. Only 3.4% of the country's electricity production is located outside the SIN, in small isolated systems located mainly in the Amazonian region.

1.1.1 Installed capacity

Generation capacity is 116.8 GW shared among the different companies. About 80% of the electricity fed into the national grid is estimated to come from hydroelectric generation, with over 25% coming from a single hydropower plant, the massive 14-GW Itaipu dam, located between Brazil and Paraguay on the River. Natural-gas generation is second in importance, representing about 10% of total capacity. Brazil has two nuclear power plants, Angra 1 (657 MW) and Angra 2 (1,350 MW), both of them owned by Eletronuclear, a subsidiary of the state-owned Eletrobrás.

1.1.2 New generation projects

<u>Hydroelectric plants</u>

Three major projects are under construction: Jirau (3,300 MW) and Santo Antônio (3,150 MW), both on the Madeira River in the state of Rondônia, and Belo Monte Dam (11,000 MW) in the state of Pará, on the Xingu River.

Nuclear plants

Electronuclear was granted permission to reassume construction of Angra 3, a 1,350-MW plant.

Thermoelectric plants

Currently, the development of gas-fired thermoelectric power is somewhat jeopardized by the lack of secure gas supplies. In fact, having a secure gas contract is a prerequisite to build a new thermoelectric plant and to participate in a new energy auction to counter the risk of unavailability of gas supplies. Petrobrás put in operation two LNG terminals that would overcome this risk. Also several thermoelectric plants are converting their machinery to dual-fuel capacity (oil and gas).

In Brazil, capacity addition traditionally lagged behind demand growth. Electricity demand is expected to continue to grow at a quick pace. Investment is therefore needed to boost generation and transmission capacity because there is limited excess supply.

1.1.3 Access to electricity

Brazil, together with Chile, is the country with the highest access rate in Latin America. The power sector in Brazil serves more than 50 million customers, which corresponds to about 97% of the country's households, who have access to reliable electricity.

1.1.4 Service Quality

Distribution losses

Distribution losses were on average 14%, whereby north and northeast regions have higher values and theft rates which is a major problem that a smart grid can help to reduce.

Transmission

Brazil's transmission system is 101,426 kilometers long and gaining growing importance because adequate transmission capacity is essential to manage the effects of regional droughts, allowing power to move from areas where rainfall is plentiful. Transmission has remained almost exclusively under government control through both federal (Eletrobrás) and state companies (mainly Sao-Paulo-CTEEP, Minas Gerais-Cemig, and Parana-Copel) until recently. However, under the new sector regulatory model, there are about 40 transmission concessions in Brazil. Most of them are still controlled by the government, with subsidiaries under Eletrobrás holding 69% of total transmission lines. Eletrobrás controls a great part of electric generation, transmission, and distribution systems of Brazil through its subsidiaries. Eletrobrás is a mixed economy and open capital stock corporation. The federal government holds 52% of the ordinary shares of the company, and thus, it is the majority stockholder. The Eletrobrás companies operate in an integrated way, with policies and guidelines defined by the High Council of Eletrobrás System (Consise), consisting of the presidents of the companies, who meet on a regular basis. In the capacity of holding, Eletrobrás

Figure A7-1

Main transmission lines – Eletrobrás System

Source: Eletrobrás

controls a great part of the electric-power generation and transmission systems of Brazil through six subsidiaries: Eletrobrás Chesf, Eletrobrás Furnas, Eletrobrás Eletrosul, Eletrobras Eletronorte, Eletrobrás CGTEE, and Eletrobrás Eletronuclear. In addition to being the principal stockholder of those companies, Eletrobrás, in the name of the Brazilian federal government, holds 50% of the capital of Itaipu Binacional Hydropower station (Figure A7-1).

Distribution

In Brazil, there are 64 utilities with distribution concessions and about 64% of Brazilian distribution assets are controlled by private sector companies. These companies supply electricity to about 68.9 million clients. In distribution, Eletrobrás controls the companies Eletrobrás Amazonas Energia, Eletrobrás Distribution Acre, Eletrobrás Distribution Roraima, Eletrobrás Distribution Rondônia, Eletrobrás Distribution Piauí, and Eletrobrás Distribution Alagoas (four of them operate in the Amazonas Region).

Renewable energy resources

In Brazil, hydroelectricity supplies about 80% of total electricity demand. Apart from biomass, which accounts for about 3.5% of total generation capacity, no other renewable energy source besides hydroelectricity plays a relevant role in the energy mix. However, the potential for wind energy, which is concentrated in the northeast, is very large (about 140 GW, which exceeds current installed capacity). There are projects for the development of biomass, solar, and wind energy, but these are still on a relatively small scale.

1.2 Responsibilities in the electricity sector

1.2.1 Policy and Regulation

The Ministry of Mines and Energy (MME) has the overall responsibility for setting policy in the electricity sector while the Brazilian electricity regulatory agency, ANEEL (which is linked to the MME), is the regulatory Agency created in 1996 by Law 9427. ANEEL's function is to regulate and control the generation, transmission, and distribution of power in compliance with existing legislation and the directives and policies dictated by the Central Government. The National Council for Energy Policies (CNPE) is an advisory body to the MME in charge of approving supply criteria and "structural" projects, while the Electricity Industry Monitoring Committee (CMSE) monitors supply continuity and security.

The Operator of the National Electricity System (ONS) is a non-profit, private entity created in August 1998 responsible for the coordination and control of the generation and transmission installations in the SIN. The ONS is under ANEEL's control and regulation.

The Power Commercialization Chamber (CCEE), successor to Mercado Atacadista de Energia Electrica, is the operator of the commercial market. The initial role of the operator was to create a single, integrated commercial electricity market regulated under published rules. This role has become more active since CCEE is now in charge of the auction system. The rules and commercialization procedures that regulate CCEE's activities are approved by ANEEL.

Finally, the Energy Research Company was created in 2004 with the specific mission of developing an integrated long-term planning for the power sector in Brazil. Its mission is to carry out studies and research services in the planning of the energy sector in areas such as power, oil, and natural gas and its correlates, coal, renewable energy resources, and energy efficiency, among others. Its work serves as input for the planning and implementation of actions by the MME in the formulation of a national energy policy.

The Brazilian electricity model is fully deregulated, which allows generators to sell all of their "assured energy" via freely negotiated contracts with consumers above 3 MW or via energy auctions administered by CCEE. Under this model, distributors are required to contract 100% of their expected demand.

1.2.2 Legal and political/policy contexts and drivers

Brazil, similar to the United States and Europe, is currently challenged with an ageing infrastructure (grid modernization); however, Brazil is also facing a vast increase in energy consumption, which is expected to growth by 60% between 2007 and 2017. Furthermore, the modernization of utilities is not equally distributed among Brazil's regions.

These two major drivers represent a very large opportunity to develop smart grid technologies in the country. Unfortunately, these facts are not well understood by the policy makers, and consequently private, national, or regional funds that would support in future smart grid projects are reduced to almost zero. Despite this fact, some progress is underway based in the initiative of few utilities.

A major topic when focusing on the modernization of distribution and considering smart grid technologies is Advanced Distribution Automation (ADA). ADA is distinct from traditional distribution automation (DA). Traditional DA has been concerned with automated control of basic circuit-switching functions. ADA comprehends complete automation of all the controllable equipment and functions in the distribution system to improve strategic operation of the system. In total, ADA will be a revolutionary change to distribution systems, as opposed to simple, incremental improvements to DA.

In Brazil, this revolutionary change will occur in an evolutionary manner due to the tremendous investment in legacy systems and the rate of technological progress and, specific in our case, due the lack of funds. However, some projects are already underway, like the EletrobrásEnergia+ that will install 1,700 reclosers with communication. CEMIG intends to install 4,000 reclosers. Other distribution companies have similar projects. The aim of these projects is to have a full fault location, isolation, and service restoration system in operation. Integrated Volt Var Control is not being considering in any future expansion planning of utilities.

Due to the fact that Brazil has also massive non-technical losses, nearly two times higher than the world's average, through illegal connections and theft, AMI would reduce losses and detect them faster.

The media distinguishes between the local and the national grid. It tends to associate smart grids with local or distribution grids, whereas the intelligent, interconnecting backbone provides an additional layer of coordination above a local smart grid. However, smart grid projects always intend to allow continental and national interconnection. Backbones fail without causing local smart grids to fail; therefore, the system needs to be seen as one. Brazil, as already mentioned, has a strong, large, and interconnected centralized system. The SIN comprises the electricity companies in the south, south-East, center-West, north-east and part of the northern region. Only 3.4% of the country's electricity production is located outside the SIN, in small isolated systems located mainly in the Amazonian region. An important drive is to continuously upgrade the SIN technologies. The use of PMUs is a good example.

About 80% of the electricity fed into the national grid is estimated to come from hydroelectric generation. As regards the use of renewable energy, Brazil is in a favourable position. So, a major drive is to keep this position in the future and even improve with the use of other forms of renewable energy. The potential for wind energy, which is concentrated in the northeast, is very large (about 140 GW, which exceeds current installed capacity). There are projects for the development of biomass, solar, and wind energy, but these are still on a relatively small scale.

Distributed Energy Resources are major drivers behind the ADA vision in Brazil. DERs may be owned by either a consumer or supplier of electricity and can operate either independently or interconnected with the grid. In Brazil, it is envisaged that the use of both forms of DER power production offer unique challenges to both the existing distribution system and the ADA vision. Some of those challenges are unintentional islanding, changes in radial feeder power flow, reverse power flow in distribution networks, loss of effective voltage regulation, ferro-resonance voltage swings, harmonic injection and distortions, voltage fluctuation and flicker, and over current-protective device coordination. Some of the technologies like bidirectional reclosers, smart sectionalisers, power conditioners, and advanced relaying schemes address these challenges and the future planning of grid modernization in Brazil will include these technologies.

Brazil has no experience with demand response, and smart grids enable a variety of programs that reduce peak demand, including time-of-use pricing and critical peak pricing, direct load control, and indirect load control.

- The majority demonstration projects in Brazil focusing on AMI will address time-of-use pricing and indirect load control using AMI data to improve programs. Time-of-use pricing was recently regulated by ANEEL for low-voltage consumers (white tariff) which will require the use of smart meters.
- As regards direct load control, although Brazil lacks experience, there is a great opportunity to undertaking a range of trials to better understand what can, and importantly cannot, be implemented to manage peak demand issues.
- All trials must investigate two key factors—technology and customer acceptance. Residential demand management continues to be a key plank of investigations into, and trials of, potential peak demand management strategies. This relates to the fact that in some regions of Brazil well-documented peak demand issue is the use of residential air conditioning. This targets home air conditioners by remotely switching off their compressors, but not their fans (to ensure comfort levels are maintained).
- The trials operate for some minutes over a number of hours of peak demand on hot summer days. Such hours are typically late afternoon and early evening. Using around 1,000 volunteer households in Australia, for example, trials to date indicate a 19–35% reduction in peak load where direct load control demand management is utilized.

2. Currently available financing mechanisms

Currently, there are no available financing mechanisms either market-based support instruments or national scale (i.e., national funds) or local (municipality) scale. The only instrument available is regulatory incentives, R&D funds that support the majority of demonstration projects, described next. The ANEEL, the national electric energy agency, is the government agency that regulates the energy sector in Brazil. All energy companies in Brazil, except for wind turbines, solar, biomass, small hydro, and cogeneration qualified, collect 1% of its net operating income to a Fund for Research and Development, according to Law No. 9991 enacted 24 July 2000. Part of the Fund (40%) is intended for R&D projects coordinated by the ANEEL.

3. Demonstration projects

Several utilities are managing smart grid pilots, including—

- Ampla, a power distributor in Rio de Janeiro State owned by the Spanish utility Endesa, which has been deploying smart meters and secure networks to reduce losses from illegal connections.
- AES Eletropaulo, a distributor in São Paulo State, has developed a smart grid business plan using the existing fiber-optic backbone. Also, there is a plan to digitalize its substations.
- CEMIG has started a smart grid project in Sete Lagoas City 70 km from Belo Horizonte based on system architecture developed by the IntelliGrid Consortium, an initiative of the California-based Electric Power Research Institute (Conviver and Cities of the Future Projects). CEMIG's total investment until 2013 is R$ 45 million (USD 22 million), and includes implementing and developing the infrastructure needed for new technologies.

3.1 Conviver and the Cities of the Future Projects

Sete Lagoas was the town chosen for joint implementation of CEMIG's joint projects, as its population and consumer contingent already ensures a sample of the Company's market. The Univer Cemig campus in the town was another deciding factor, as it has a model grid and laboratories for technology tests and facilities for training the team. In addition to the Conviver and Cities of the Future projects, CEMIG is setting up a joint venture for an experimental PV solar generation plant, which will be the first in Minas to be connected to the distribution grid and the second to produce solar power commercially in Brazil. The project is estimated to cost R$40 million (USD 20 million).

The Conviver Project was created in 2006 and is part of the Smart Energy Program—Intelligent Energy. Its aim is to take information on correct, safe, and regular use to the communities, and adjust consumption by families with low purchasing power to their financial reality. Through visits by the Conviver agent, it also works to regularize electrical connections, give guidance on the benefits of the social tariff and exemption from ICMS, negotiate debits, and analyze risk situations involving electricity. Conviver expects to include about 7,500 families and also replace about 37,500 compact fluorescent lamps, 750 low-power consumption refrigerators, and 750 efficient showers.

The first steps to implement the pilot Cities of the Future project will be the modernization of part of the metering systems, comprising new meters and telecommunications systems, which enable data to be exchanged between field equipment and computer systems. With the new equipment, testing will be done on sending and receiving data such as power consumption, as well as alarms to indicate power outages and other supply problems in real time. For consumers, the new meters will allow for greater control over electric energy consumption thanks to computer applications also to be provided by CEMIG. In this way, consumers may optimize their use of electricity. To CEMIG, implementing advanced metering infrastructure means a new relationship level with its consumers and a technological challenge to be overcome.

LIGHT, CPFL, and ELECTRO have also developed smart grid business plans.

3.2 The Parintins Demonstration Project

The Parintins project will develop the reference model of smart grid technologies for the six distribution companies of Eletrobrás, based on a demonstration pilot project in the city of Parintins, an island in Amazonas River.

The Amazon Rainforest covers most of the Brazilian Amazon region. The Amazon Region in South America is defined by the basin of the Amazon River. The Amazon Region biome occupies approximately 4.1 million km² within Brazilian territory, representing around 7% of the world's vegetation cover. The region also contains 20% of the world's non-frozen water supply, and 80% of the water available within Brazil's territory.

In the Amazon hydrographic basin, the principal river is the Amazon itself. It is considered the world's most voluminous river, depositing between 200,000 m³ and 220,000 m³ of water per second into the Atlantic Ocean. It is a humid and hot area that will impose severe climate conditions on the technological components of smart grids (smart meters, communications parts, and sensors). At the site, several potential solutions will be evaluated to meet the needs of advanced metering infrastructure and advanced distribution automation. Around 1 MW of local diesel generation will be replaced by photovoltaic panels installed on house roofs.

The Parintins project has USD 15 million for R&D. The city has about 100,000 inhabitants with 15,000 consumers. The generation is local with 25 MW installed capacity, all diesel.

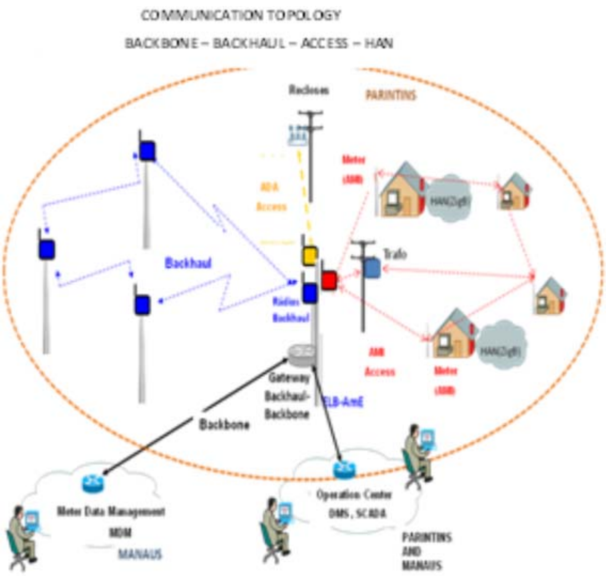
The project calls for—

1. The replacement of all residential and small commercial meters (15,000) connected on low voltage with digital smart meters and communication modules that provide full AMI functionality:

Figure A7-2

Communication Topology – Parintins project

Source: Eletrobrás



- Capable of measuring and recording usage data minimum hourly base.
- Allowing consumers to participate in all types of price-based demand response programs.
- Providing the utility with key data and functionality that address power quality.
- Supporting bidirectional and net metering where the meter can record energy flow in either direction and calculate net usage.
- Have remote reading and remote connect and disconnect capability.

2. The installation of 15 reclosers, with bidirectional communication, a first step for ADA system will permit integration of both AMI and ADA in the backhaul level.

3. The installation of a bidirectional telecommunication system:

   - For both ADA and AMI, the communications hardware and software creates a two-way network between meters, reclosers, sensors, and the backbone that connects Parintins to Manaus (Figure A7-2). All data will be transmitted via a backbone to Eletrobrás Distribution Company headquarters in the region (Manaus).
   - It will evaluate several potential solutions to meet the needs of power meters and distribution automation. It will test four solutions of access communication, three wirelesses, and one PLC for the rural area (Figure A7-3). The wireless devices are 450-MHz point to multipoint, 900-MHz mesh multipoint to multipoint, and a mesh Zigbee solution developed by a Brazilian utility. At another level, a backhaul of 2.4 GHz and 5.8-GHz dual radio will be installed that will collect data from AMI and from ADA.

4. Metering in the MV/LV 300 distribution transformers for energy balance and operational purposes (including temperature measurement);

5. Replacement of diesel generation by photovoltaic panels installed on the roofs of houses and small commercial consumers (around 500 houses), directed connected to a low-voltage grid.

6. It is also planned to include support for a consumer Home Area Network (HAN) that will provide information on current energy consumption and prices (Figure A7-4).

Figure A7-3
Access Communication Areas – Parintins project
Source: Eletrobrás

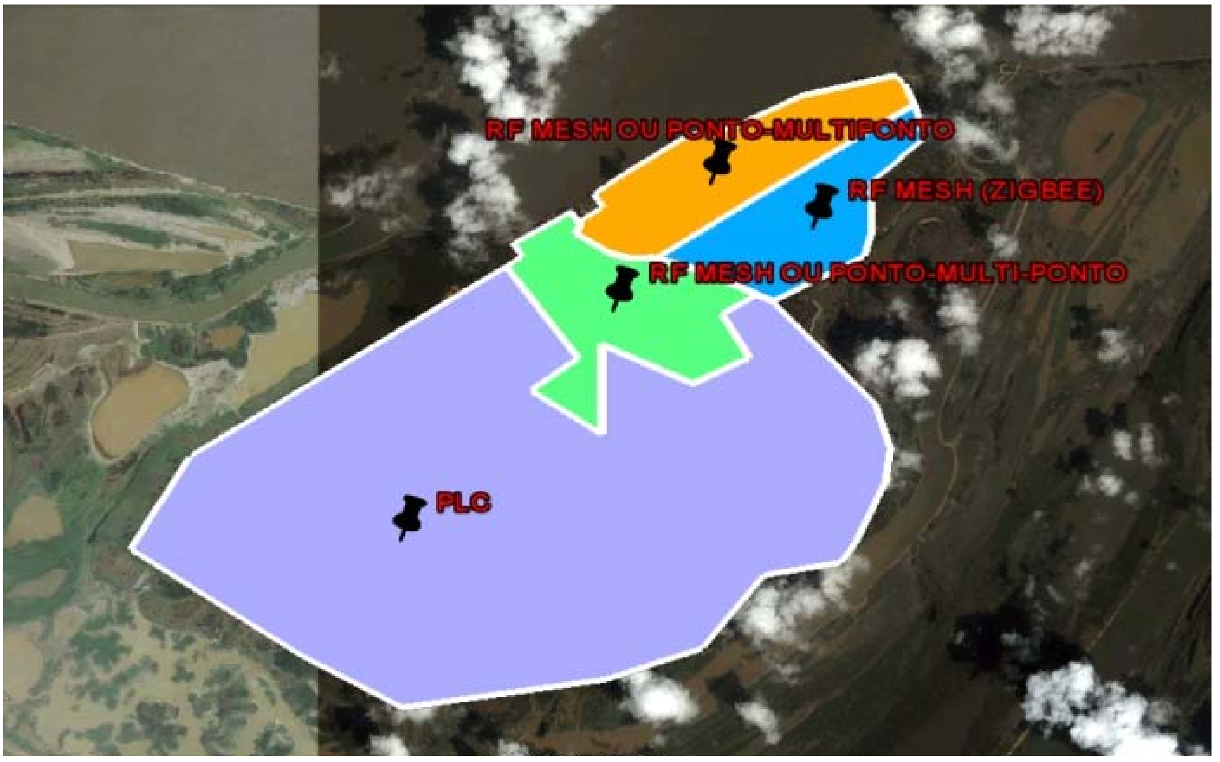
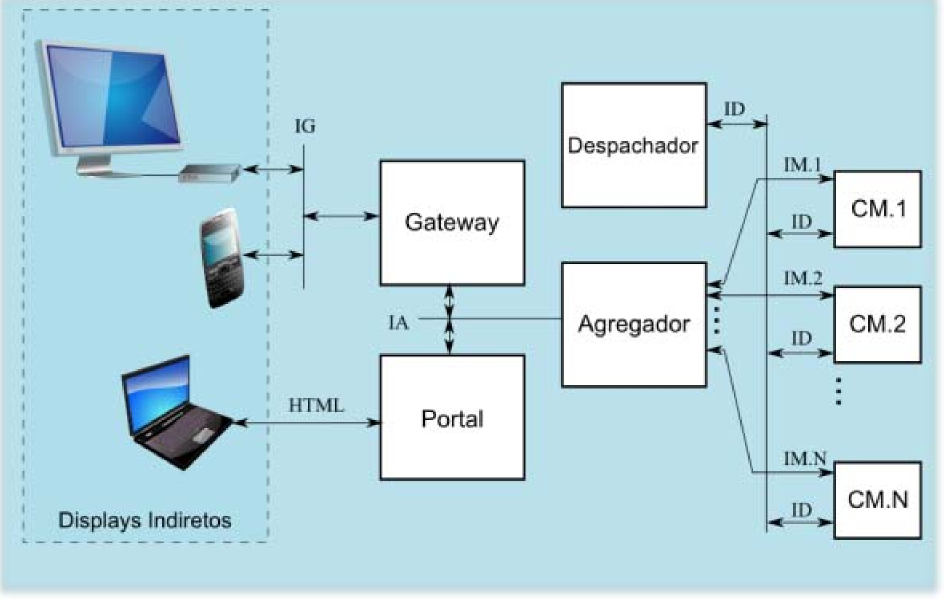


Figure A7-4
Consumer participation model – Parintins project
Source: Eletrobrás



Many consumers will choose to get information on energy usage, pricing, and trends from a website portal available to them via the Internet and mobile phones.

7. An effective implementation of advanced AMI and ADA requires an installation of a Meter Data Management (MDM) system, a modernization of the actual operation centre, and the modification of supporting IT systems, which will make possible to manage the enhanced operational environment and take advantage of the new data captured by AMI system. In the first step of the project, the interoperability and the integration of systems will be done as show in Figure A7-5.

3.3 Energy + Project

The Eletrobrás Distribution Companies Improvement Project is a USD 709-million modernization project, partially financed by the World Bank (USD 495 million). The project will improve the financial and operational performance and the commercial management of the six distribution companies by reducing electricity losses, increasing bill collection rates, and improving quality of service.

The AMI is one of the activities—investment is estimated at USD 252 million and will include the installation of reading equipment and telecommunication systems to manage metering, reading, and monitoring consumption of medium- and large- consumer's low voltage.

The key areas related to the smart grid include—

1. AMI
    - Replace meters with smart meters; total of 9,000 medium-voltage consumers.
    - Replace meters with smart meters; total of 115,000 low-voltage consumers with consumption above 600 kWh/month.
    - Install modern meters in 780 medium-voltage feeders.
2. Modernization of Eletrobrás Distribution Utilities Management Information System (MDM, BILLING, GIS, and others).
3. Install 1,700 reclosers.

3.4 META Project

Part of the Ministry of Energy Technical Assistance aims to install smart grid labs in the Eletrobrás Electric Power Research Center that will support strategic activities for MME and the Brazilian Electrical sector on smart grid, financed by the World Bank:

- A PMU Lab—to test equipment and to develop researches related to the concept of synchrophasors that are important tools to the operation of very large power systems;
- A Power Smart Grid Lab—to develop and to test power equipment (generators, inverters, loads) related to smart grids up to 1 MVA.

Abbreviations and acronyms

AEEG	Autorità per l'energia elettrica e il gas (Italy)
AESO	Alberta Electric System Operator
ADA	Advanced Distribution Automation
AMI	Advanced Metering Infrastructure
ANEEL	Agência Nacional de Energia Elétrica (Brazil)
ARegV	Innovative Regulations Ordinance (Germany)
ARRA	American Recovery and Reinvestment Act of 2009
AT&C	aggregate technical and commercial
BAU	business as usual
BEMS	Building Energy Management System (Japan)
BES	Battery Energy Storage (Japan)
CCEE	Power Commercialization Chamber (Brazil)
CCS	carbon capture and storage
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CEMIG	Companhia Energetica de Minas Gerais (Brazil)
CMSE	Electricity Industry Monitoring Committee (Brazil)
CNPE	National Council for Energy Policies (Brazil)
DA	distribution automation
DCU	data concentration unit
DER	distributed energy resource
DG	distributed generation
DNO	distribution network operator
DOE	U.S. Department of Energy
DR	demand response
DRUM	Distribution Reform, Upgrades, and Management
DSO	distribution system operator
EEGI	European Electricity Grid Initiative
EC	European Commission
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
ESO	European Standardisation Organisation
ETS	Emissions Trading System (European Union)
FP7	Seventh Framework Programme (Europe)
GE	General Electric Corporation
GHG	greenhouse gas
GW	giga-watt
HEMS	Home Energy Management System (Japan)

ICT	information and communications technology
IEA	International Energy Agency
IEE	Intelligent Energy–Europe
IESO	Independent Electricity System Operator (Ontario, Canada)
IFI	Innovation Funding Incentive
IPR	intellectual property rights
IRIN	Innovative Regulation for Intelligent Network (Germany)
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
IT	information technology
kWh	kilowatt-hour
LCN	low carbon network
MDM	meter data management
MERGE	Mobile Energy Resources for Grids of Electricity
METI	Ministry of Economy, Trade and Industry (Japan)
MME	Ministry of Mines and Energy (Brazil)
MRA	Mutual Recognition Arrangements
NASPI	North American Synchrophasor Initiative
NERC	North American Electric Reliability Corporation
NMEEE	National Mission for Enhanced Energy Efficiency (India)
NREAP	National Renewable Energy Action Plan (European Commission)
OECD	Organisation for Economic Co-operation and Development
OFGEM	Office of Gas and Electricity Markets (United Kingdom)
ONS	Operator of the National Electricity System (Brazil)
PCI	project of common interest (European Union)
PCS	power conversion service
PMU	phasor measurement unit
PTC	production tax credit
PUC	Public Utility Commission (United States)
PV	Photovoltaic
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
R&D	research and development
RD&D	research, development, and demonstration
REPI	Renewable Energy Production Incentive (United States)
RIIO	Revenue = Incentives + Innovation + Outputs
ROI	return on Investment
RPS	Renewable Portfolio Standards
RPZ	Registered Power Zone

SCADA	Supervisory Control and Data Acquisition
SGCC	State Grid Corporation of China
SGDP	Smart Grid Demonstration Project
SGIG	Smart Grid Investment Grant (United States)
SIN	National Interconnected System (Brazil)
SM	smart meter
SRP	Salt River Project (Arizona, United States)
T&D	transmission and distribution
TBT	Technical Barriers to Trade
TEPCO	Tokyo Electric Power Company
TOC	total operating centre
TOU	time-of-use
TSO	Transmission System Operator
TWh	tera-watt-hour
UHV	Ultra-high voltage
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
V2G	vehicle to grid
WACC	Weighted Average Cost of Capital

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