UNIVERSITY OF CANTERBURY

Smart Grid

In a New Zealand Context

Andrew Lapthorn

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ABSTRACT

The following report examines the Smart Grid in the context of New Zealand. It begins by developing a definition for what the Smart Grid actually by looking at various international organisations views. Defining the Smart Grid as a modernisation of the existing system to improve efficiency and reliability and that it will be a gradual process of time that has already begun.

The report then goes on to look at Smart Grid progress around the world. It examines work in North America, Europe, Asia and Australia. By examining the government policies around Smart Grids and the various pilot projects that have been implemented globally, a better understanding the progress New Zealand has made can be achieved. A major point that has been noted in this work is the shear size of the investment and resources that have already used in the Smart Grid arena.

The next section of the report looks at international standards development. The focus is on work carried out by the International Electrotechnical Commission the National Institute of Standards and Technology in North America. Both these organisations have developed a Smart Grid standards roadmap outlining a number of current standards applicable to Smart Grids, identifying the gaps in the standards portfolio and developing plans to address those shortcomings.

The report then goes on to examine current Smart Grid progress in the New Zealand context. The various different sectors in the New Zealand electricity industry are examined individually including government, generation, transmission, distribution and retail. The findings show there is already good progress in Smart Grid related goals such as renewable energy generation and peak load management. However, there is still some work needed for aspects such as AMI standardisation.

The report then finishes with a discussion and concluding remarks.

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INTRODUCTION

The current electricity system was conceived more than 100 years ago. The generation was localised and built around communities. The consumer's electricity needs were simple, typically only a few light bulbs, and the system was setup with one way interaction. Over the years, the grid evolved to become more interconnected. This greatly improved the reliability of the system, although the one way interaction from generation to consumer remained. However, with new renewable generation technologies such as solar and wind, combined with new demanding loads like plug in electric vehicles, the existing network will no longer be able to meet the demands of a modern society. The grid will need to evolve, become smarter, to be able to deliver tomorrow's energy needs.

In the last few years, the idea of a smart grid has emerged. Around the world, many governments, organisations and companies are forming strategies and developing technology to modernise the electricity system. The vision is for a system, encompassing the whole electricity supply chain including distribution networks and consumers, which resembles that of Figure 1, combining a variety of technologies and communications for a more robust and efficient electricity system.

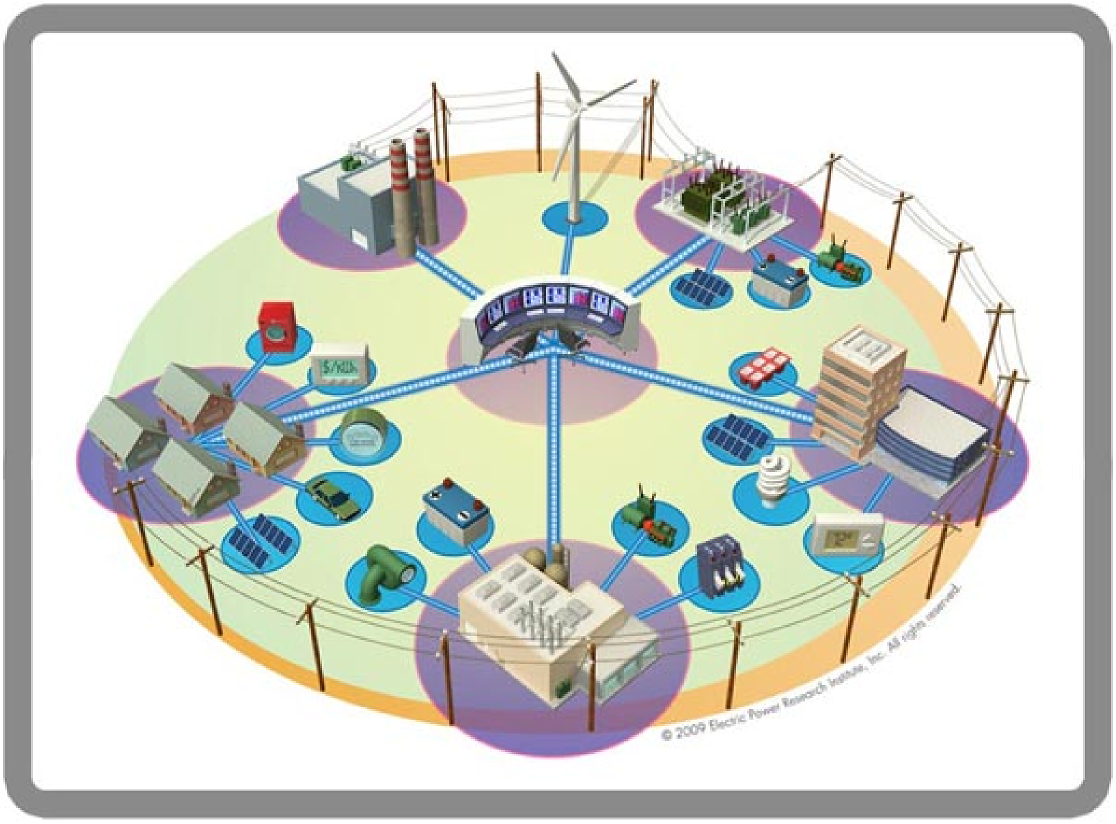


FIGURE 1: A VISION OF THE SMART GRID [1]

However, in New Zealand our plans for the smart grid will likely differ from those in other countries. This is because New Zealand is starting from a different position than the rest of the world. For example, the generation mix in New Zealand is fairly unique compared with other countries, with New Zealand having a large renewable base compared with countries having a large thermal base capacity.

In addition, many countries see load management as an area Smart Grids could improve their system. In the New Zealand context direct control is already widely used via ripple control of hot water heating and contracted interruptible load. However, it must be said that ripple control system would now be considered low spec by today's standards and regulatory and market drivers have over recent years resulted in a general erosion of capabilities. Thus there is a need for the industry to become pro-active in this and other Smart Grid areas.

In researching Smart Grids in a New Zealand context, one finds a staggeringly large amount information related to Smart Grids throughout the world. It must be noted that the information in this report far from all-encompassing but rather seeks to provide a good spread of information about smart grid activities around the world, including some of the standards developments. The research contained in this report was made possible with the support from Transpower New Zealand Limited and the Ministry of Science and Innovation and with editorial support from Prof Neville Watson, Bob Simpson, and John Scott.

WHAT IS A SMART GRID?

The idea for Smart Grids has been around for more than a decade, although its use has gained popularity more in recent times. Many different organisations have their own view on what constitutes a smart grid, with some definitions being functional, some technological, and some benefits orientated. For example, the International Energy Agency (IEA) states in their *Technology Roadmap for Smart Grids* [2].

"A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users."

The International Electrotechnical Commission (IEC) is somewhat more circumspect in their definition of the smart grid [3].

"Smart Grid is today used as a marketing term, rather than a technical definition. For this reason there is no well defined and commonly accepted scope of what "smart" is and what it is not.

The general understanding is that the Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible, interactive and is able to provide real time feedback.

It is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies."

The European Technology Platform for SmartGrids, the organisation responsible for Smart Grid policy in Europe, states that [4];

"The concept of SmartGrids was developed in 2006 by the European Technology Platform for SmartGrids, and concerns an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies."

In North America the Electric Power Research Institute (EPRI) released the report "*Estimating the Costs and Benefits of the Smart Grid*" [5]. In this report they define the Smart Grid based on the descriptions in the Energy Independence and Security Act of 2007:

"The term "Smart Grid" refers to a modernization of the electricity delivery system so that it monitors, protects, and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers and their thermostats, electric vehicles, appliances, and other household devices."

In New Zealand, Allan Miller from the Electric Power Engineering Centre states;

"A Smart Grid can be viewed as modern electricity network that:

- *Interconnects existing large central generators, as well as an increasing number of new renewable generation (such as large scale wind), and distributed generation (such as small scale photovoltaic and other renewables).*
- *Transports and distributes this power efficiently and reliably to businesses and consumers, potentially including a substantial number of electric vehicle charging points and distributed energy storage.*
- *Enables direct customer and consumer participation in the electricity market and optimization of the system through automated factories, buildings, and appliances.*
- *Provides enhanced information from the network on power quality, in order to pre-empt issues and to economically delivery greater reliability, quality, and security of supply.*
- *Hardens cyber security while utilizing existing and new communication networks."*

As can be seen above, there is no standard definition of the "Smart Grid", the term tends to be used differently across the world. For example, in the USA 'Smart Grid' is used widely although it commonly refers to smart metering, or perhaps smart metering + DA (Distribution Automation). In Europe the term smart grid refers to the whole supply chain of transmission, distribution and consumers - of which smart metering is a sub-element.

The common themes from these descriptions suggest that the Smart Grid is a modernisation of the electricity network. The goal of which, is to enable greater reliability and efficiency of the network in the face of changing technologies such as electric vehicles and renewable/distributed generation.

The Smart Grid will enable greater utilisation of existing assets, including enhanced asset management through smart interventions to address real time ratings, condition monitoring, fault prediction, fault position location, and asset end of life prediction, an important aspect to long-life infrastructure utilities. It will assist in meeting the demand and generation requests for new connections in a responsive and cost effective way and it will contribute to overcoming network constraints such as capacity, voltage and fault level that can arise from these connections.

It is worth noting the changes are likely to be a mix of traditional and smart interventions and that some of these changes are likely to be disruptive to the power network, i.e. they are not simply plug in innovations. These smart interventions will invariably require a mix of technology, commercial, regulatory, and customer aspects. They will require increased integration of communication technologies alongside the electricity system and automation of various grid functions.

The introduction of these new technologies will have considerable impact on network company businesses requiring attention to business processes, IT and control system architectures, planning policies, procurement policies, spares and field support, and company skills. It may require new partnerships and interactions with consumers at a much closer level than in recent years.

The transition from innovative demonstration to standard practice is critical because it is only when innovation is deployed at scale are the benefits released to consumers and to wider society in the form of productivity gains, exports, and delivery of government policy goals. These changes will not happen overnight, we will not wake up one day and suddenly the grid is “smart”, but will tend to be an evolution of the grid over the course of many years as new technologies become available.

SMART GRID PROGRESS AROUND THE WORLD

In this section, the progress of Smart Grid development around the world will be investigated. This will not be complete coverage of everything that is happening around the world related to Smart Grids but rather it will highlight some of the more significant regulatory and technical progress being made in various regions throughout the world. By analysing how other countries are implementing their smart grid plans, it will be possible to gain a better understanding of what aspects of the smart grid could work in a New Zealand context and which aspects may not.

NORTH AMERICA

In the United States of America, the federal government, aware of the need for policy regarding the use and development of a Smart Grid, introduced a new subchapter, entitled Smart Gird, into Title 42 of the United States Code, Chapter 152 – Energy Independence and Security in December 2007. § 17381 of the code entitled *"Statement of Policy on Modernization of Electricity Grid"* states;

"It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

(1) *Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.*
(2) *Dynamic optimization of grid operations and resources, with full cyber-security.*
(3) *Deployment and integration of distributed resources and generation, including renewable resources.*
(4) *Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.*
(5) *Deployment of "smart" technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.*
(6) *Integration of "smart" appliances and consumer devices.*
(7) *Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.*
(8) *Provision to consumers of timely information and control options.*
(9) *Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.*
(10) *Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services."*

In order to carry out the goals set out by the above code, the United States government has established a Smart Grid Advisory Committee (SGAC) and a Smart Grid Task Force (SGTF) whose mission is to advise relevant Federal officials concerning the development of smart grid technologies, the progress of a national transition to the use of smart-grid technologies and services, the evolution of widely-accepted technical and practical standards and protocols to allow interoperability and inter-communication among smart-grid capable devices, and the optimum means of using Federal incentive authority to encourage such progress. The SGAC and SGTF are required to report to congress every 2 years concerning the status of smart grid deployments nationwide and any regulatory or government barriers to continued deployment.

The Smart Grid Task Force ran a Smart Grid Implementation Workshop on June 2008 in Washington, DC. The workshop was attended by over 140 experts from utilities, equipment manufacturers, state agencies, universities and national laboratories. A detailed report on the workshop findings can be found in [6]. The major findings from the workshop include a general agreement on seven major characteristics of a properly planned, designed, implemented, and operated smart grid. These are;

- Enables informed participation by customers
- Accommodates all generation and storage options
- Enables new products, services, and markets
- Provides power quality for the range of needs in the 21st century economy
- Optimises asset utilization and operating efficiency
- Addresses disturbances through automated prevention, containment, and restoration
- Operate resiliently against all hazards

The workshop also identified a number of metrics that will allow for measuring the progress toward implementation of a smart grid. Examples of some of the measuring metrics for the seven major characteristics listed above are;

- Percentage of customers capable of receiving information from grid operators and the percentage of customers opting to make or delegate decisions about electricity consumption based on that information
- Percentage of distributed generation and storage devices that can be controlled in coordination with the needs of the power system
- The number of smart grid products for sale that have been certified for “end-to-end” interoperability
- The number of measurement points per customer for collecting data on power quality, including events and disturbances
- The amount of distributed generation capacity (MW) that are connected to the electric distribution system and are available to system operators as a dispatchable resource
- The percentage of grid assets (e.g., transmission and distribution equipment) that are monitored, controlled, or automated
- The percentage of entities that exhibit progressively mature characteristics of resilient behaviour

Smart Grid Demonstration Projects

On February 17, 2009, President Obama signed a $787 billion USD economic stimulus package with $43 billion USD allocated for energy and $111 billion USD to go toward infrastructure and science. [1]. As well as the above federal initiatives, a number of utilities in the United States have already begun some smart grid projects.

The Pacific Northwest GridWise™ Testbed Demonstration

This project consisted of two parts, an energy pricing experiment entitled Olympic Peninsula Project [7] and a smart appliance demonstration entitled Grid Friendly™ Appliance Project [8]. The planning for the demonstration began in late 2004, was run from early 2006 until March 2007. It was managed on behalf of the U.S. Department of Energy by Pacific Northwest National Laboratory but involved input from many organisations.

The Olympic Peninsula Project involved coordination of residential electric water heaters and thermostats, commercial building space conditioning, municipal water pump loads, and several distributed generators via two-way communication of load status and electric price signals to manage a constrained feeder. The behaviours of customers and their responses under fixed, time-of-use, and real-time price contracts were compared. Price was found to be an effective control signal for managing transmission or distribution congestion and real-time signals at 5-minute intervals were shown to shift controlled load in time effectively reducing the peak load on the feeder as shown in Figure 2.

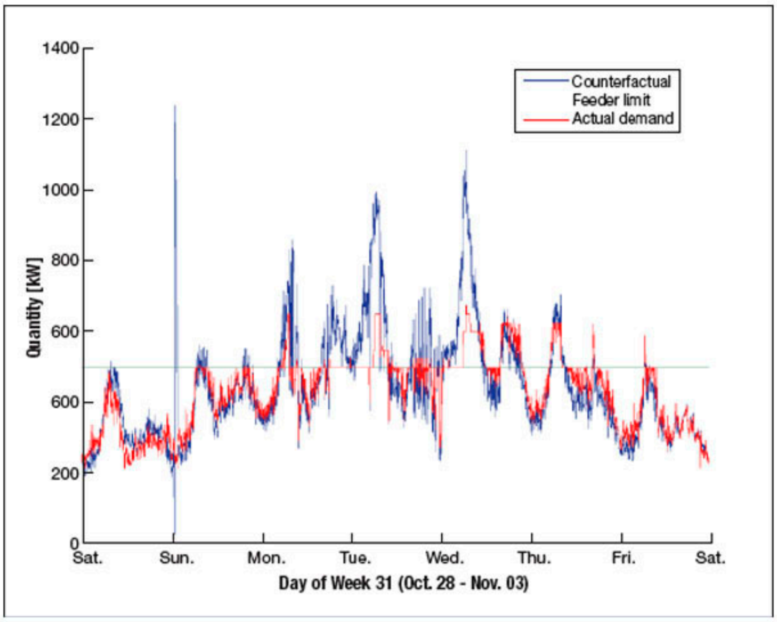


FIGURE 2: DEMAND GRAPH WITH AND WITHOUT REAL-TIME PRICE CONTROLS [7]

[1] JOSIE GARTHWAITE, *"OBAMA SIGNS THE STIMULUS: WHAT'S IN STORE FOR CLEAN ENERGY"*, HTTP://GIGAOM.COM/CLEANTECH/OBAMA-SIGNS-THE-STIMULUS-WHATS-IN-STORE-FOR-CLEAN-ENERGY/

The Grid Friendly™ Appliance Project involved the use of a controller that autonomously detected underfrequency events and requested the load be shed by the appliance it serves. The controller was triggered when the system frequency fell below 59.95 Hz. The project used 150 new residential clothes dryers manufactured by Whirlpool Corporation and 50 retrofitted water heaters. The appliances were modified to shed major portions of their electrical loads when they received signals from their controllers. In total, there were 358 underfrequency events observed during the demonstration, although the sum of the load that was controlled was considered too small to confirm whether this system could control the system frequency.

FIGURE 3: SOME OF THE EQUIPMENT USED IN THE GRID FRIENDLY™ APPLIANCE PROJECT [8]

MAUI SMART GRID PROJECT

This project funded by the U.S. Department of Energy, Renewable and Distributed Systems Integration program. It has a project budget of $15 million USD from 2009-2013 with $7 million from the government and the rest from industry. The project aims to develop and demonstrate a Distribution Management System (DMS) combining distributed generation, energy storage, and demand response technologies. The objective of the project is to increase the use of renewable and distributed generation and decrease peak loads on a distribution feeder by 15%.

Traditionally, Hawaii's electricity is sourced from oil-fired power stations. Recently on Maui 30MW of wind has been installed with another 40MW possible. Additionally, the amount of photovoltaics (PV) installed is increasing. The variability of these renewable resources is causing some significant frequency excursions and voltage sags. The Maui Smart Grid Project aims to address this issue using a diverse set of renewable and other distributed generation, demand response, and various storage technologies incorporated into the project.

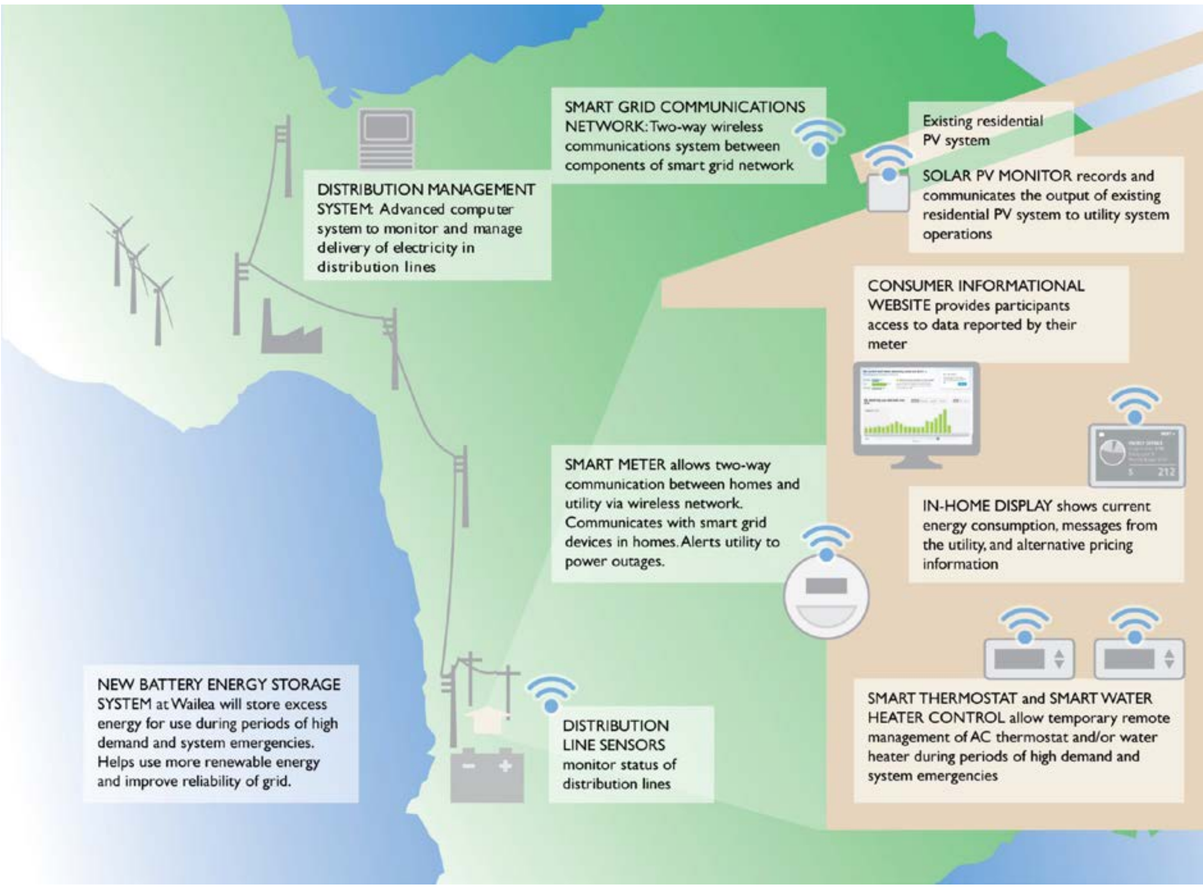


FIGURE 4: OVERVIEW OF THE MAUI SMART GRID PROJECT [9]

Another key aspect of the project is the interoperability of the various components of the system, connecting the legacy nature of the existing grid infrastructure in Hawaii to the newer systems and technology that will be used. The DMS contains control and communications that coordinate advanced metering infrastructure in the homes for demand response signals, building automation, meter information gathering, optimal dispatch of DG, storage and feeder loads, and integrated voltage/VAR control.

PERFECT POWER BY ILLINOIS INSTITUTE OF TECHNOLOGY

The existing distribution system at the Illinois Institute of Technology (IIT) was largely built in the 1960's. Due to increasing demand and the age of critical components, IIT has been experiencing three or more power outages a year at an estimated cost of $500k USD. Because of these factors a significant upgrade of the IIT distribution system is planned.

In combination with the Galvin Electricity Initiative and the U.S. Department of Energy, IIT is developing a new electricity infrastructure for its campus. The new high reliability distribution system (HRDS), called Perfect Power, will include a self-sustaining electricity infrastructure, an intelligent distribution system and system controllers, onsite electricity production, demand response capability, sustainable energy systems and green buildings/complexes, and technology-ready infrastructure.

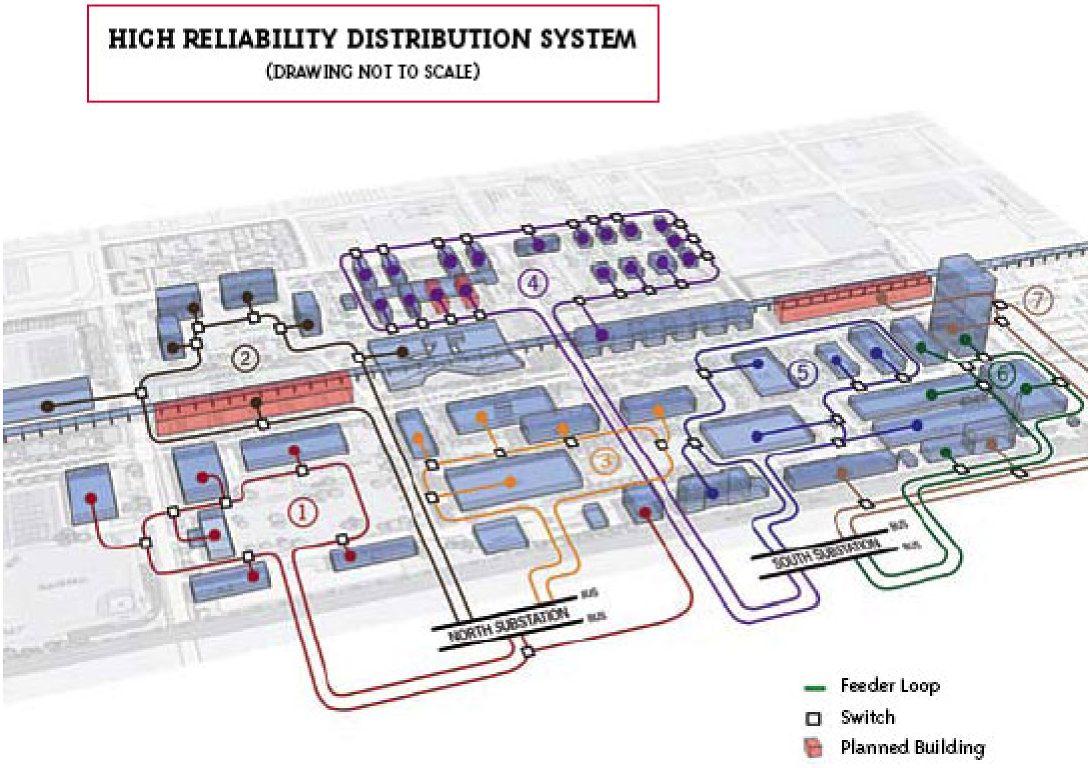


FIGURE 5: DIAGRAM OF THE PERFECT POWER HRDS AT THE ILLINOIS INSTITUTE OF TECHNOLOGY [10]

The project will be implemented in 4 phases and is expected to take 5 years for completion with an investment of $12 million USD. As of February 2010, the first high-reliability distribution loop feeding 5 major buildings on the IIT campus was completed as well as the automation of the university's north substation. This provides the buildings with automatic fault detection and distribution information to allow for improved reliability.

WEST VIRGINIA SUPER CIRCUIT

The West Virginia Super Circuit aims to increase the use of distributed resources to supply power during peak load periods. At the same time the project will demonstrate the use of advanced sensors, communications and control technologies, monitoring, diagnostic, automation capabilities, and two-way communication between load serving entities and electric loads within consumer premises.

The project, principally run by Allegheny Power with support from a number of organisations including the Science Applications International Corporation, West Virginia University and North Carolina State University, aims to reduce the peak power demand on an Allegheny Power circuit (WR-3) by 15%. In addition, it will demonstrate the benefits of the integrated operation of rotary and inverter-based distributed generation, energy storage, advanced metering infrastructure (AMI), Automated Load Control (ALC), advanced wireless communications, and advanced system control technologies such as dynamic islanding and microgrid concepts.

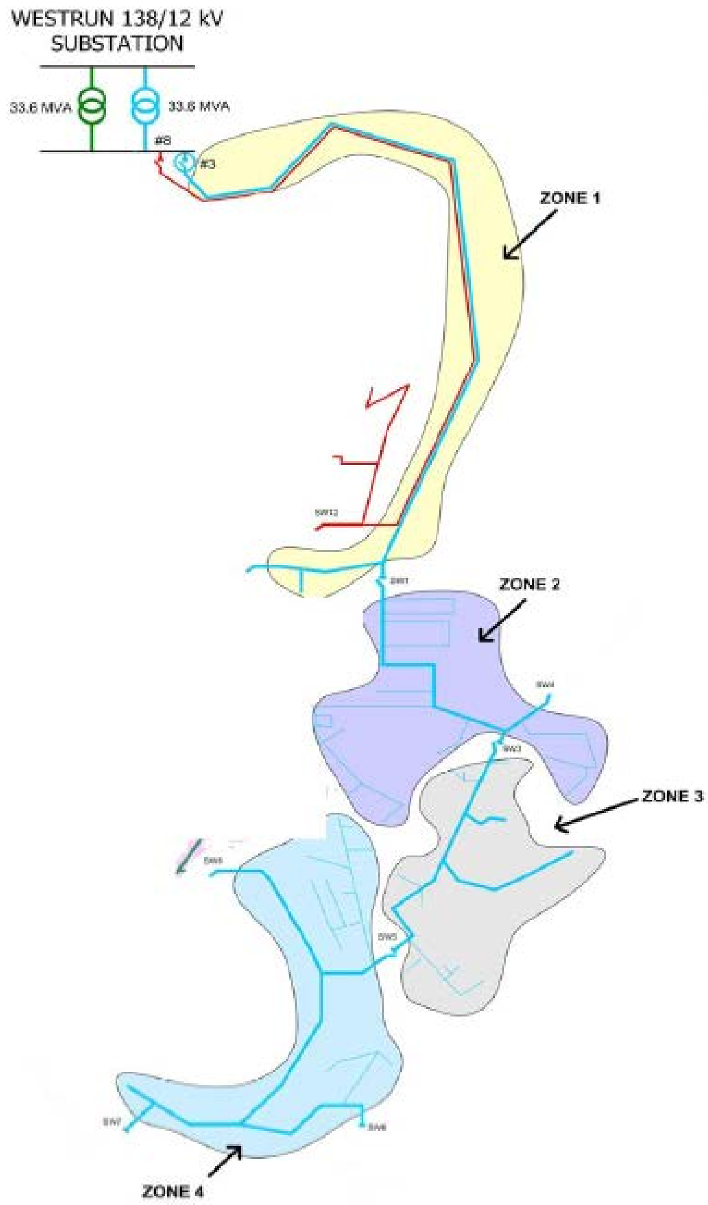


FIGURE 6: THE WEST VIRGINIA SUPER CIRCUIT

The Distributed Energy Resources (DER) for the West Virginia Super Circuit will consist of three 400kW biodiesel internal combustion engines, a 250kW microturbine, a 100kW solar PV system, and two 250kW 8hr battery energy storage systems installed over 4 zones outlined in Figure 6. The DG and storage units will be used to serve peak load demand, improve system reliability, and support microgrid operation in grid-connected and islanded modes.

The AMI will use standard home area network and wide area network protocols, as well as applicable cyber security standards. Interconnection of the PV arrays, natural gas-fired generators, battery storage, and 3 biodiesel ICEs will demonstrate compliance with IEEE 1547. For substation communications protocols, the project will migrate from the legacy Distributed Network Protocol DNP3 protocols to IEC 61850.

BEACH CITIES MICROGRID SAN DIEGO

The objective of the Beach Cities Microgrid project is to conduct a pilot scale "proof-of-concept" test in San Diego, California, of how information-based technologies and DER may increase utility asset utilization and reliability. The project comprises of two components, a DOE portion focused on feeder applications and a California Energy Commission (CEC) portion focused on customer-side applications.

The DOE portion has a budget of US$12M of which US$7.2M was from the DOE and involves the integration of distributed energy resource and reactive power support, Feeder Automation System Technology (FAST), Advanced Energy Storage (AES), Outage Management System/Distribution Management System, and price driven load management.

The CEC portion has a budget of US$2.8M entirely funded by the CEC. The project is smaller sustainable communities microgrid focused on interoperability, AMI and customer DER that is scheduled to mesh with the larger DOE project. The project will look at the integration of remote controlled demand response devices (thermostats), solar panels, battery storage, plug-in hybrid electric vehicles, and grid friendly appliances.

FIGURE 7: BORREGO SUBSTATION, THE LOCATION OF THE BEACH CITIES MICROGRID

The major goals of the project are to firstly achieve > 15% reduction in feeder peak load through the integration of multiple, integrated DER– generation (DG), energy storage and price-driven load management. Secondly, demonstrate capability of Volt-Amps-Reactive (VAr) management. Finally, develop a strategy and demonstration of:

- Information integration focused on security and system architecture.
- Integration of advanced metering infrastructure (AMI)
- 'Self-healing' networks through the integration of Feeder Automation System Technologies (FAST)
- Integration of Outage/Distribution Management Systems (OMS/DMS)
- Automated distribution control to intentionally "Island" customers.

The site selected for the MicroGrid project is the Borrego substation pictured in Figure 7. This was chosen because of the existing solar customers and the possibility of 'islanding' the entire community. In addition there are no residences nearby, plenty of land, and large reliability improvements are possible. The expected completion of the project is in 2012.

THE CITY OF FORT COLLINS ZERO ENERGY DISTRICT

The City of Fort Collins and Fort Collins Utilities in association with Colorado State University (CSU), InteGrid Lab, Spirae, Brendle Group, Advanced Energy, Woodward Governor, Caterpillar, and Eton project will address the RD&D of a coordinated and integrated system of 3.5 MW of mixed distributed resources in Fort Collins, Colorado to achieve a 20-30 percent peak load reduction on two distribution feeders. These two feeders serve the planned FortZED Jump Start Zone, a plan to turn the downtown area and the main campus of CSU into a net Zero Energy District (Figure 8), in which the district creates as much thermal and electrical energy locally as it uses.

FIGURE 8: BOUNDARY OF THE FORTZED DISTRICT

The project will manage 3.5MW of DER in five locations within the FortZED zone. The demand response capabilities will be managed by combining load shedding, variable speed drives, water fountain controls, and heating, ventilation, and air-conditioning (HVAC) demand side management (DSM). The DER managed in each site are listed below.

Site 1: **New Belgium Brewing** - a 200kW PV arrays with AE inverters; a 292kW methane-based Gauscor CHP; a 650kW CAT 3508C methane-based CHP; 135kW of new thermal storage; and 160kW of load shedding potential.

Site 2: **InteGrid Laboratory** - 2x80kW Onan natural gas genset; a 300kW CAT natural gas genset; an 80kW Ingersoll Rand microturbine; an 80kW Bowman microturbine; a 100kW wind turbine simulator; and 10-kW of fuel cells.

Site 3: **City of Fort Collins Facilities** - a 500kW conventional generator with Woodward controls and Eaton switchgear; a 92kW thermal storage; a 5kW PV array; a 62kW HVAC and DSM; and 2x10kW Ford Escapes (PHEVs).

Site 4: **Larimer County** - a 10kW new PV array; and 2x1HP motors for water fountain control.

Site 5: **Colorado State University** - an 80kW thermal storage; an 80kW fan variable speed drives; 21.6kW of water fountain pumps; 3.6kW of hot water heater controls; a 6kW daylight control, and 950kW conventional gensets with Woodward controls and Eaton switchgear.

FIGURE 9: PV ON THE ROOF OF THE NEW PARKING GARAGE IN THE FORTZED DISTRICT

ONTARIO SMART GRID FORUM,

The Ontario Smart Grid Forum was convened in 2008 in recognition of the need to establish a vision for the smart grid and begin facilitating its development. In early 2009, the Forum published its first report, which articulated a vision, reviewed the level of smart-grid development activity in Ontario and around the world, and made recommendations on how various stakeholders in the electricity sector should proceed with grid modernization.

The Forum includes member organizations from Ontario's utility sector, industry associations, public agencies and universities working together to propose a vision for a smart grid in Ontario and examine the many components that comprise it. It is supported by the Corporate Partners Committee, which represents more than 30 private sector organizations active in the smart grid space – including, electric car markets, retailers, energy management companies, systems integrators and equipment manufacturers.

In its most recent report, "Modernizing Ontario's Electricity System: Next Steps," [11] the Forum made a series of recommendations that focus on removing barriers to smart grid development and taking full advantage of its intended benefits. These recommendations include:

- The Ontario Ministry of Energy should conduct an annual survey to assess consumer interest in smart home technologies and how they are influencing consumer behaviour
- An economic development task force should be established to capitalize on the innovation, commercialization and job creation potential of Ontario's smart grid investments
- The Ontario Ministry of Transportation should track electric vehicle registration and provide this information to utilities to help them ensure that local networks can support the increased demand for electricity
- The Independent Electricity System Operator (IESO) and the Ontario Power Authority (OPA), in partnership with others, should develop a framework to promote the deployment of energy storage within distribution networks where it is cost-effective
- The Ontario Information and Privacy Commissioner should track all smart-grid related complaints regarding the use of personal electricity consumption information
- The electricity industry should develop a test-bed environment for companies to assess whether their products and services are compatible with Ontario's advanced metering infrastructure used to support its smart metering initiative
- Industry should move toward greater standardization to ensure that all technologies can work together effectively, and keep Ontario in step with broader international developments, drawing from the work currently being done through the Canadian National Committee of the International Electrotechnical Commission

Local Distribution Companies (LDCs) have been busy deploying smart meters to the remainder of their customer base to fulfill a government commitment to reach all homes (outside of multi-unit buildings) and small businesses by the end of 2010. That target was reached with more than 4.5 million smart meters installed, and roughly half are now feeding customer usage data to a central Meter Data Management and Repository (MDM/R) system.

The repository is what provides LDCs with the hourly energy consumption of their customers, who can then be billed based on the time of day electricity is consumed and at the corresponding rate set by the Ontario Energy Board (OEB). As of the end of 2010, utilities have switched approximately 1.6 million customers to time-of-use (ToU) billing and are on track to converting the entire customer base. An example of the ToU pricing as used by the OEB is given in Figure 10 and Figure 11 is an example of the monthly "electricity usage statement" issued to the ToU participants by the OEB.

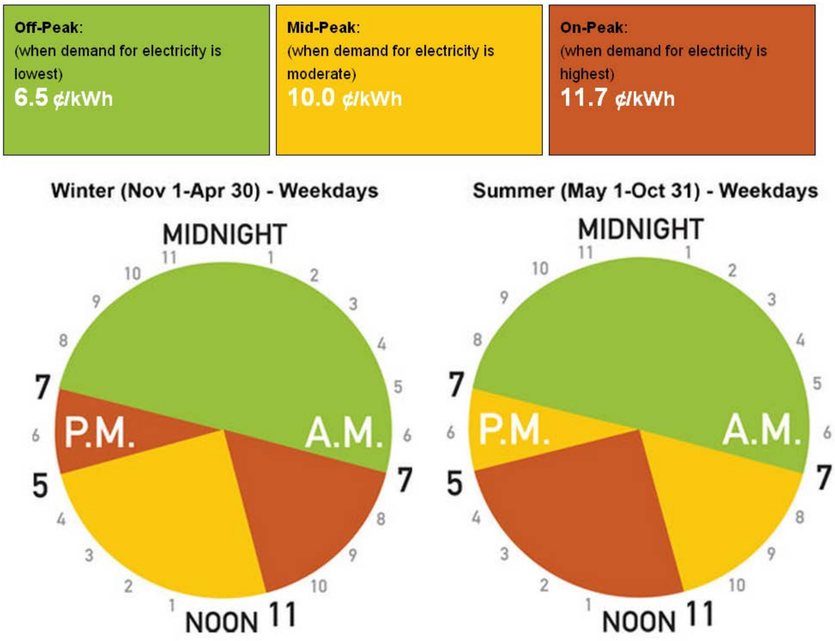
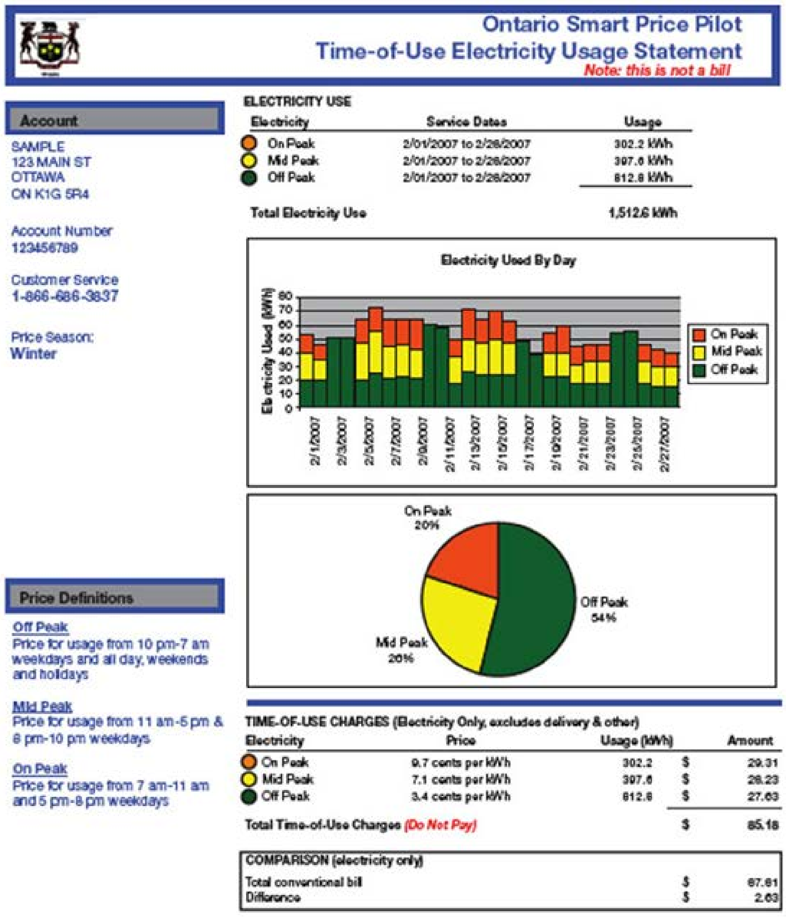


FIGURE 10: EXAMPLE OF THE TOU PRICING USED BY OEB AS OF 1 MAY 2012 [12]



Ontario Smart Price Pilot
Time-of-Use Electricity Usage Statement
Note: this is not a bill

Account
SAMPLE
123 MAIN ST
OTTAWA
ON K1G 5R4

Account Number
123456789

Customer Service
1-866-686-3837

Price Season:
Winter

ELECTRICITY USE

Electricity	Service Dates	Usage
On Peak	2/01/2007 to 2/28/2007	302.2 kWh
Mid Peak	2/01/2007 to 2/28/2007	397.6 kWh
Off Peak	2/01/2007 to 2/28/2007	812.8 kWh
Total Electricity Use		1,512.6 kWh

Price Definitions

Off Peak
Price for usage from 10 pm-7 am weekdays and all day, weekends and holidays

Mid Peak
Price for usage from 11 am-5 pm & 8 pm-10 pm weekdays

On Peak
Price for usage from 7 am-11 am and 5 pm-8 pm weekdays

TIME-OF-USE CHARGES (Electricity Only, excludes delivery & other)

Electricity	Price	Usage (kWh)		Amount
On Peak	9.7 cents per kWh	302.2	$	29.31
Mid Peak	7.1 cents per kWh	397.6	$	28.23
Off Peak	3.4 cents per kWh	812.8	$	27.63
Total Time-of-Use Charges *(Do Not Pay)*			$	85.18

COMPARISON (electricity only)		
Total conventional bill	$	87.81
Difference	$	2.63

FIGURE 11: SAMPLE OF THE "ELECTRICITY USAGE STATEMENT" PROVIDED MONTHLY TO OEB PILOT PARTICIPANTS

Energy management and peak time demand-response is another area of focus. A five-utility pilot project commissioned by the OPA in 2010 equipped 130 homes and small businesses across Ontario with smart thermostats, smart plugs and in-home displays that allowed customers to monitor and manage their energy use inside or remotely via access to an online portal. The technologies also enabled participation in demand-response programs, which represent a future opportunity for home and business owners. The small and large utilities involved in the project – Cambridge and North Dumfries Hydro, Hydro One (Owen Sound), Kitchener-Wilmot Hydro, Toronto Hydro and Waterloo North Hydro – will use the information collected from the pilot to design future energy-management offerings for their customers.

OSGF Recommendations

Following the publication of the Ontario Smart Grid Forum report *Modernizing Ontario's Electricity System: Next Steps* a number of recommendations were made on several key areas of the Smart Grid. These recommendations are [11];

Privacy and Security

- Recognizing that the seven *Privacy by Design* principles developed by the Ontario Information and Privacy Commissioner provide valuable guidance with respect to compliance with applicable privacy laws and protecting consumers, these principles should be considered as best practice in the implementation of the smart grid in Ontario for both regulated and unregulated service providers.
- The Ontario Information and Privacy Commissioner should begin tracking smart grid-related consumer complaints with respect to how utilities and third parties use their information.

Third-Party Access

- Barriers to facilitating third-party access to electricity consumers and their real-time consumption information should be addressed. The Forum and its Corporate Partners Committee will work with industry to resolve outstanding access issues, consistent with the Smart Grid Objectives set out in the government's directive to the Ontario Energy Board.
- A test bed environment should be established devoted to furthering interoperability between emerging products and services, as well as the various proprietary Advanced Metering Infrastructure (AMI) systems deployed across the province as part of the Smart Metering Initiative. The Forum and its Corporate Partners Committee will work with industry to investigate the best path forward.

Consumer Engagement

- Industry and government should work toward meeting the development timelines established in the Smart Home Roadmap to bring greater control, choice, market participation and other benefits to electricity consumers. The Forum will facilitate timely development.

- The interactions between LDCs and third-party service providers in each area of the smart grid value chain, including support for electric vehicles, should be examined with an eye to removing barriers to consumer service adoption. The Forum and its Corporate Partners Committee will work with industry to facilitate this effort.
- The role that aggregators can play in delivering benefits to consumers via the smart grid should be investigated and, where appropriate, specific recommendations should be developed to facilitate their participation in the market. The Forum and its Corporate Partners Committee will work with industry to address this issue.
- Gaps in knowledge specific to the development of the smart grid in Ontario should be identified and, where applicable, research should be advocated aimed at filling those gaps. The Forum will work closely with industry to identify and close knowledge gaps.
- The Ontario Ministry of Energy should conduct an annual smart grid consumer engagement survey to gain insight into how smart grid products/services are benefiting consumers and influencing consumption behaviour. The results of this survey should be shared with industry.

ELECTRIC VEHICLE (EV) INTEGRATION

- The Ontario Ministry of Transportation should track the registration of electric vehicles and ensure that necessary information is provided to the electricity industry in a meaningful and timely manner. Where necessary, legislation and regulatory changes that facilitate this information exchange and protect consumer privacy should be made.
- The source of accurate and timely information about the installation of Level 2 and higher charging stations should be identified and made available to assure the safe and reliable operation of LDC networks. The Forum will work with the automotive and electricity sectors to identify and recommend the appropriate parties and mechanisms for supplying this information.

STORAGE INTEGRATION

- The Ontario Power Authority (OPA) and Independent Electricity System Operator (IESO), in consultation with industry and the Ontario Energy Board (OEB), should jointly develop a framework to promote the integration of distributed energy storage with the grid where it is cost-effective.

STANDARDS

- Industry should take advantage of widely used interoperability standards for defining smart grid specifications. Attention should be paid to the upcoming national recommendations from the Canadian National Committee of the International Electrotechnical Commission and its Task Force on Smart Grid Technology and Standards (facilitated by the Standards Council of Canada), which is monitoring international standards discussions.

Innovation & Economic Development

- A new task force should be established to foster smart grid innovation, technology commercialization and related economic development opportunities, capitalizing on the province's public infrastructure investment in grid modernization. The task force, facilitated by the Forum but not exclusive to its members, would seek the active participation of public- and private-sector organizations in a position to help Ontario realize the broader economic development potential, including export opportunities, related to the smart grid over the longer term.

Measuring Smart Grid Success

- Industry and government, in collaboration with the Forum, should facilitate the gathering of data to support the early benchmarking and ongoing tracking of smart grid "success metrics." These metrics will be used to assess, over time, whether smart grid investments are delivering promised benefits.

Europe

The drivers for Smart Grid in Europe have been in part due to Europe's policy to climate change. In March 2007 the EU's leaders endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. They committed Europe to transforming itself into a highly energy-efficient, low carbon economy. To kick-start this process, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020, known as the "20-20-20" targets. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

The deployment of the Smart Grids priorities is considered as the key and mandatory precondition to make Smart Grids a reality, achieving thus the 20-20-20 targets and, most importantly, to realize the needed customer and societal benefits.

European Technology Platform

The European Technology Platform for Electricity Networks of the Future (ETPENF), also called Smart Grids ETP, is the key European forum for the crystallisation of policy and technology research and development pathways for the smart grids sector, as well as the linking glue between EU-level related initiatives. The ETPENF began its work in 2005. Its aim was to formulate and promote a vision for the development of European electricity networks looking towards 2020 and beyond.

In April 2006 the Advisory Council of the European Technology Platform (ETP) presented its Vision document for Smart Grids [13]. The Vision, for both transmission and distribution networks, is driven by the combined effects of market liberalization, the change in generation technologies to meet environmental targets and the future uses of electricity. Together with the Strategic Research Agenda [14], published in 2007, it described the main areas to be investigated, technical and non-technical, in the short-medium term in Europe. Since then, these documents have inspired several Research and Development programs within the EU and National institutions.

At the end of 2008, based on the contributions and discussions of many people in the EU Member States, the first draft of this Strategic Deployment Document was released [15]. Today this document is formally finalized, and describes the priorities for the deployment of innovation in the electricity networks and the benefits that such innovation will deliver for all stakeholders. The resulting six generic Smart Grids deployment priorities for the short term, highest priority deployment by 2020 have been identified as;

- DP#1: Optimizing Grid Operation and Usage
- DP#2: Optimizing Grid Infrastructure
- DP#3: Integrating Large Scale Intermittent Generation
- DP#4: Information and Communication Technology
- DP#5: Active Distribution Networks
- DP#6: New Market Places, Users and Energy Efficiency

The relationship between the Smart Grids deployment priorities and their dependency on the various stakeholder groups within the electricity supply chain are shown in Figure 12.

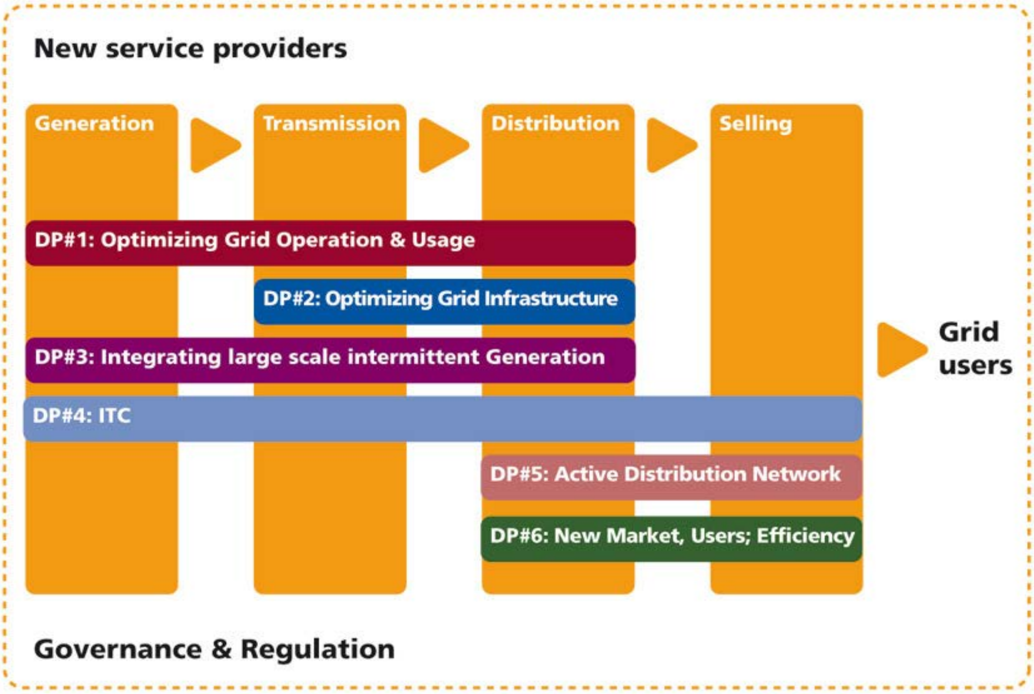


FIGURE 12: SMART GRIDS DEPLOYMENT PRIORITIES' (DP) RELATIONS AND EXTERNAL DEPENDENCIES [15]

An overview of the six deployment priorities is given over the next few pages. A timeline is given as well as some of the key elements and priority components.

DP#1: Optimizing Grid Operation and Use

This deployment priority is about decentralized but well coordinated grid operation, operational security and market-based treatment of electric power flows. The technology R&D has been completed and deployment is for 2008-2012

In order to manage the ever increasing demands for energy trading and security of supply, the existing transmission and distribution networks require improved integration and coordination across Europe. To control electric power flows across Europe and/or national borders, advanced applications and tools, that are already available today, should be deployed to manage the complex interaction of operational security and trading and to provide active prevention and remedy of disturbances.

The key elements and priority components of DP#1 are:

- Wide Area Monitoring (WAM) and Wide Area Control (WAC) systems with regulation of static VAR compensators, optionally in a closed loop, to maximize the use of available transmission capacity while reducing the likelihood of disturbances.
- Distributed state estimators for large synchronous areas with real-time power system security assessment and optimized dispatching with dynamic constraints.
- System operators' staff training covering traditional issues (e.g. power system control) and emerging issues (e.g. electricity market and regulation).
- Coordinated ancillary services, including integration of balancing markets and coordination of reserves throughout the EU grids/control areas - the integration of balancing markets is of particular importance both, for enhanced power system security and for improved market liquidity.
- Steady state and dynamic (transient) simulators with modelling of Renewable Energy Sources and non-linear devices.
- Coordinated operation of power flow control systems (FACTS, phase shifters, etc.) with devices for automatic countermeasures/system defence. These applications exist in component form today but, unless encouraged, not many more will be deployed in the short time. Further work is urgently required to understand how to deploy and validate these solutions in 'closed-loop' operation.
- Regulatory issues of relevance for the defined EU targets should be re-considered to ensure innovative technological solutions are adequately promoted and deployed.

Many of the technical solutions and key concepts required are already available today or easily retrievable from other industrial areas. They can be purchased as over the counter products, ready for use and deployment. The tools and solutions for training, including simulators presently exist. The key issue here is their systematic and coordinated deployment throughout European power systems/networks and based on that, the implementation of the necessary certification and approval systems to ensure continuity and knowledge transfer. An example for the key concepts and elements of the technical architectures and solutions to be achieved by the DP#1 is shown in Figure 13: Illustration of Key Concepts and Elements of DP#1Figure 13.

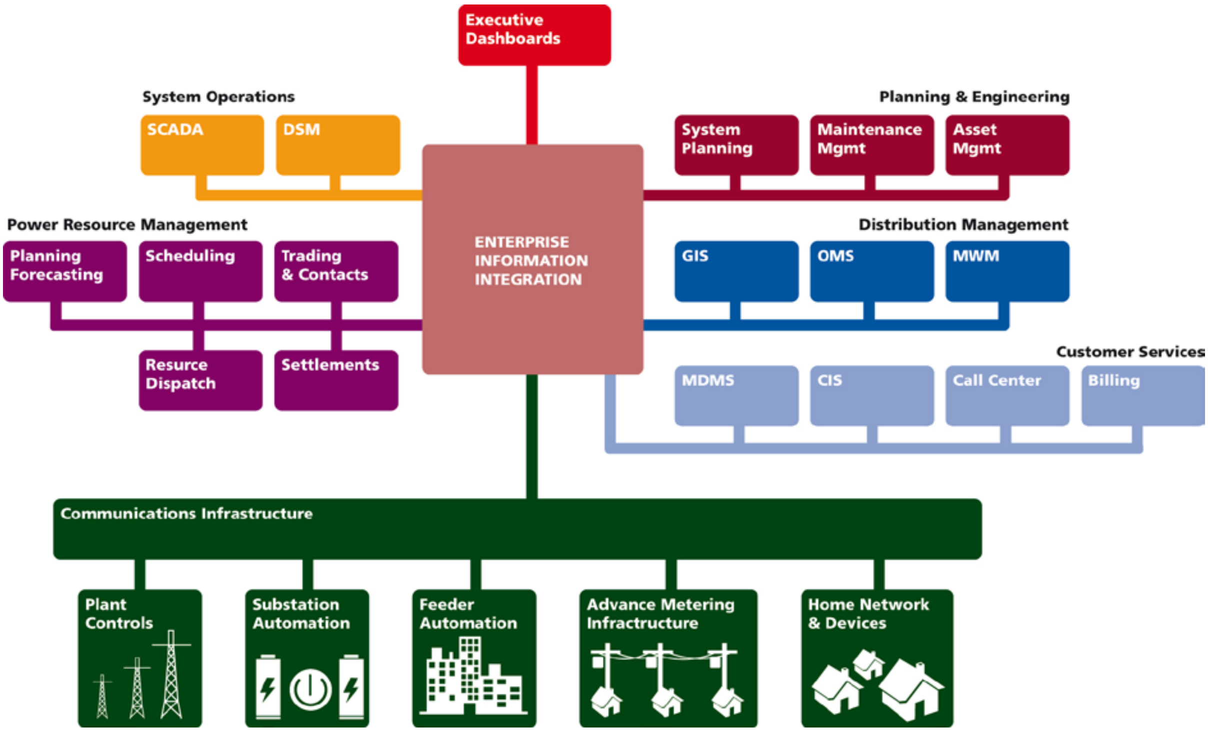


FIGURE 13: ILLUSTRATION OF KEY CONCEPTS AND ELEMENTS OF DP#1 [15]

DP#2: OPTIMIZING GRID INFRASTRUCTURE

This deployment priority is about building new infrastructure, improving and optimizing use of existing facilities. The technology R&D is ongoing and the deployment is planned between 2008 and 2020.

All stakeholders, the EU Institutions and MS must address expanding and building new transmission and distribution infrastructure. The provisions of the urgently needed projects from the European Priority Interconnection Plan should be implemented as soon as possible. New and efficient asset management solutions for the EU transmission and distribution grids are required, as well as coordinated and coherent grid infrastructure planning.

Rather than being only deterministic, coordinated planning should be based on scenarios and include the necessary elements of risk management in order to cope with the increased volatility and uncertainty in location and size of generation and growing intermittent generation.

The key elements and priority components for DP#2 are:

- Expanding the EU grids (notably transmission) with new infrastructure (e.g. HVDC) will depend on accelerating permitting procedures and making them much more efficient than today, especially in the sense of national implementations of the European Environmental Impact Assessment (EIA) Directive.

- New overhead line configurations to increase capacity and reduce electromagnetic fields are required
- Refurbishment/enforcement of the existing high voltage lines by innovative network assets including superconductivity technology
- New asset management and grid planning methods for transmission and distribution
- Development of systems and components to maintain power quality at acceptable levels while encouraging the integration of new types of generators

DP#3: Integrating Large Scale Intermittent Generation

This deployment priority is about integrating large scale on-shore and off-shore intermittent generation, notably wind power. The technology R&D has been completed and expected deployment is 2007-2020.

Large-scale forms of generation, e.g. wind farms and in the future (concentrated) solar thermal generation, require networks to enable efficient collection of the power generated and enable system balancing, either by energy storage, conventional generation or by demand side participation. Off-shore wind energy needs marine power collection networks and reinforcement of the European terrestrial networks. This deployment priority is hence also about promoting and fostering the large-scale integration of renewable energy resources in a manner that meets the requirements of grid security while considering economic efficiency.

The key elements and priority components for DP#3 are:

- Technically viable and commercially affordable solutions for offshore networks for collection of wind power
- Grid connection from offshore networks to the European mainland should consider security and quality of supply, economy and environmental sustainability
- Transnational and cross-border grid re-enforcements on the European mainland should be considered. The present long licensing procedures should be shortened
- Solutions should be developed to allow for efficient and secure system operation of future grids with significant intermittent generation, heavy bulk power and/or not easily dispatchable (e.g. CHP) generation

DP#4: Information and Communication Technology

This deployment priority is about defining the tasks and implementing the necessary standards for Information and Communication Technology solutions in future Smart Grids. The technology R&D and standardization ongoing and expected deployment is between 2008 and 2015.

The application of ICT is a pre-requisite for data exchange between the different market players in the electricity supply chain and for the secure, economic and environmentally benign operation of Smart Grids. The data exchange is realised in two ways:

- On-line data communication for supervisory control and data acquisition in real time,
- Off-line data exchange for operational planning and business purposes (e.g. between Transmission System Operators (TSOs): defence plans, power flow estimation, protection coordination)

A comparative overview of the ICT challenge in terms of status quo and future needs is presented in Figure 14. Today ICT is applied at the transmission and sub-transmission level and ends at the bus-bars of the sub-transmission (110 kV)/medium voltage substations. Different standard protocols at various voltage levels and for different kinds of equipment are used. By large, the medium and low voltage levels are characterized by limited ICT, for economic reasons (left side in Figure 14). Standardized, open information models and communication services for all data exchange within the whole electricity supply chain and electric power supply system are needed. Different ICT technologies should be investigated and tested on site with the goal towards the introduction of ICT into the distribution level relying on the existing communication infrastructure (radio, power line, copper or fibre optics), applied in a cost effective way (right side of Figure 14)

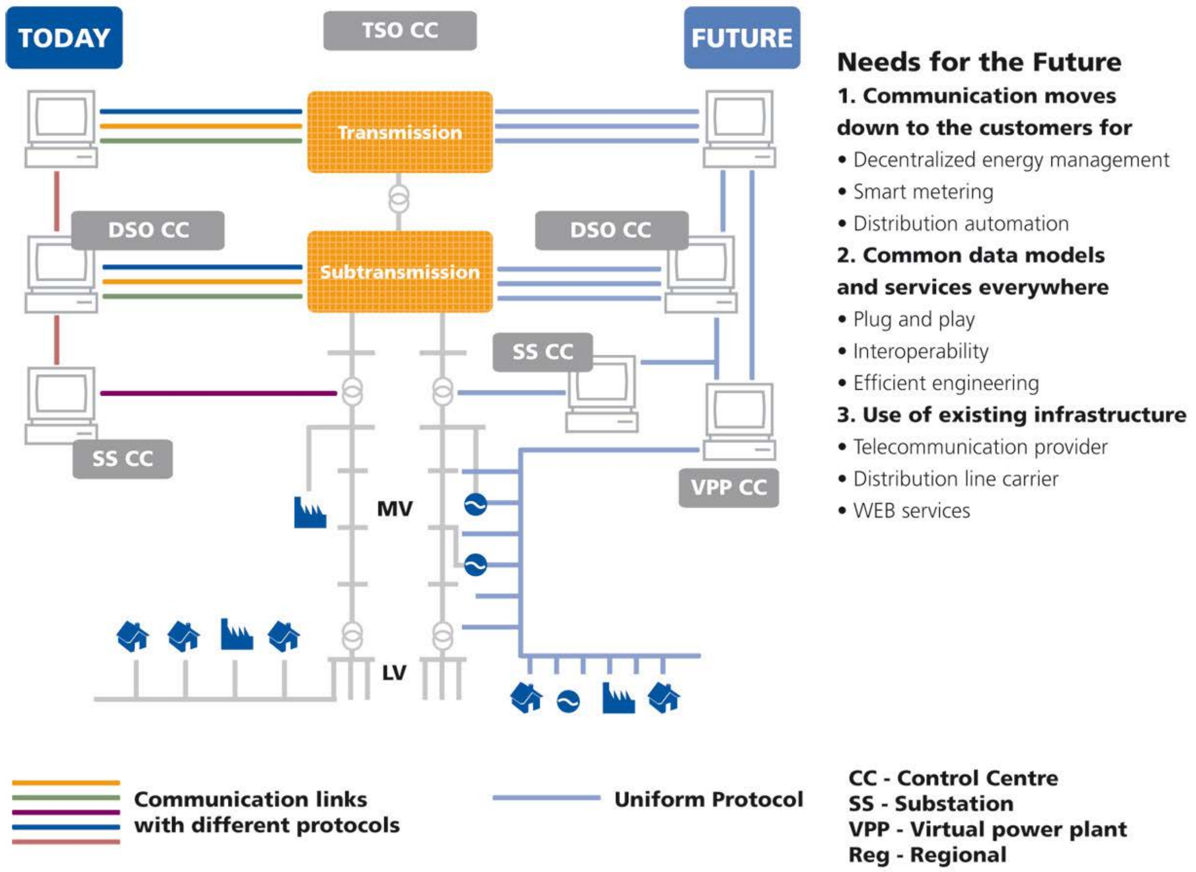


FIGURE 14: CURRENT STATUS AND FUTURE NEEDS FOR ICT APPLICATIONS [15].

The key elements and priority components for DP#4 are:

- Simple, robust, secure and flexible communication infrastructure to allow monitoring, management, control and dispatching operations at all levels down to the distribution and customers
- Common information and data models for all information building blocks, in order to ensure consistent database management, need to be defined at all levels of the power system and electricity supply chain
- Well functioning ICT solutions are essential for maintaining the security of supply and for the efficient interaction of the market players
- A truly competitive situation for all kinds of products relying on multi-vendor strategies can only be achieved with well defined and standardized ICT solutions
- Standardized interfaces are needed between different market participants generators, TSOs, DSOs, VPPs, traders, customers.

DP#5: Active Distribution Networks

This deployment priority details the change in the distribution network, from being “passive” and dependent on human operator’s intervention to an “active” one. This is required due to the increasing complexity of network operations, to the wide deployment of distributed generation and to the increasing challenges in ensuring security and quality of supply. The technology R&D is ongoing for solution availability and deployment should be from 2010 to 2020.

Transmission networks have always provided a balancing and management role in the electric power supply chain, whereas distribution networks have been designed to be passive (“fit-and-forget”) in operation. The challenge is now to provide many of the services found in transmission grids, such as power flow and constraint management, contingency analysis, balancing, in distribution networks. This is required not just because of the increasing deployment of distributed generation, but also because of emerging intelligent building services in both residential and commercial premises, the need for utilizing local generation to support the local network at times of stress on the main grid and because of the anticipated future wide usage of electrical transportation vehicles.

Distribution networks will need to be able to respond or adapt in real-time to the complex interactions of all of these challenges and provide enhanced information to various actors to enable the real-time trading of the various services being provided. This will also enable new actors, such as aggregators, to enter the market to provide VPP and balancing services.

The key elements and priority components for DP#5 are:

- An active network requires effective and coherent visibility of the various devices connected to it in order to allow timely decision making and information flow.

- Centralized manual control needs to be replaced by a distributed control architecture which will be coordinated and integrated into existing control methodologies in order to take advantage of the intelligence that will enhance the networks of the future
- It is necessary to ensure compatibility of all functions and devices also during the transition from the present to the future active distribution grids.
- Besides on-line control and management, the active distribution network will introduce new functionalities, enabled by new tools and solutions relying on dynamic and multifaceted optimization. Modelling of uncertainties in planning and operation required to achieve that, will build upon:
    - Standardization of the data models and communication protocols to ensure minimum overhead and capacity to expand and encompass future requirements;
    - Communication systems capable of coping with the needs in terms of capacity, reliability and costs induced by the new functions.

A typical active distribution networks' structure, coordinated by the Central Controller (CC) and interfaced to the Distribution Management System (DMS) is shown in Figure 15. The technical architecture for an active distribution network has three layers:

1. Copper based energy infrastructure (electricity)
   The actual electricity infrastructure needs to optimize its topology and be adapted through the implementation of power electronic elements in order to cope with the new functions.
2. Communications layer
   A communication network should be implemented as a layer above that of electricity power infrastructure. This network should facilitate overall electricity system connectivity (internet alike) using different communication technologies at the same time and guaranteeing to meet the requirements of speed, quality, reliability, dependability with costs.
3. Software layer
   Active electricity networks will only be possible with the implementation of intelligent elements at multiple nodes of the network, capable of doing locally and independently the maximum number of functions, reporting/requesting from the upper level the minimum possible information necessary. These elements will coordinate their actions with neighbouring ones to cope with the coordinated execution of the operations necessary for the "active network".
   This means multiple software functions for normal operation as well as network reconfiguration, self-healing procedures, fault management and other software tools needed for forecasting, modelling and planning.

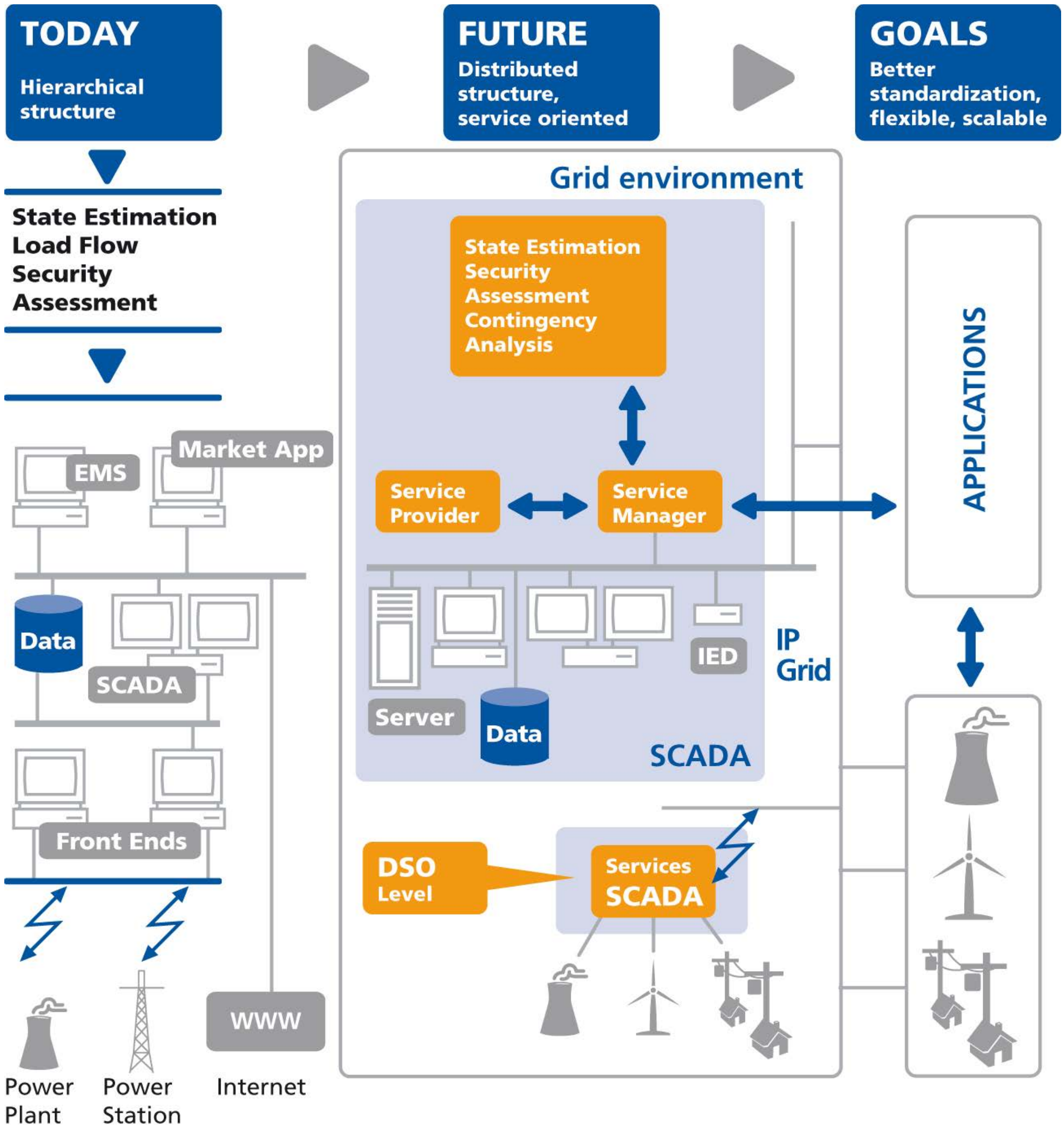


FIGURE 15: AN EXAMPLE STRUCTURE OF AN ACTIVE DISTRIBUTION NETWORK [15]

DP#6: NEW MARKET PLACES, USERS AND ENERGY EFFICIENCY

This deployment priority is about bringing customers as the focus and first line of interest of Smart Grids. The technology R&D is ongoing for solution availability and the deployment will be between 2010 and 2020.

Diminishing of the differences between transmission and distribution in areas such as ancillary services, grid connection and access, but also quality and security of supply is one of the important characteristics of the whole Smart Grids concept. At the same time, such "democratization" and "decentralization" requires enhanced and strengthened control and management. This is not only necessary to operate the grid securely – adequate control and management solutions are also required to deploy a number of new and emerging concepts successfully and effectively such as the Virtual Power Plants and end-user energy management concepts.

In order to meet future customer needs, a range of new market participants will evolve, such as VPP operators and energy service portfolio managers. Besides transparent and nondiscriminatory grid access and connection for all grid users (generation and demand) this deployment priority is also relying on the necessary technologies in the so called "last mile" of the Smart Grids and is closely related in that sense to Deployment Priority #5. The customers' needs, interests and benefits are clearly the focus of this deployment priority. Moreover, white goods in houses will contribute to the efficiency of the electricity networks in the future but only if there is a coordinated activity between the network, the smart meter (or gateway), the user and the manufacturer of the goods. Revenue streams will need to be in place for such developments to take place. The key elements and priority components for DP#6 are:

- Innovative Customer Interface Devices as bidirectional smart communicators between the customers and the market
    - To give the customer choice in energy supply, it is necessary to develop solutions to increase and optimize information related to energy consumption, improving the interaction between customers and market players.
    - Such devices shall be able to provide the relevant energy information stored in digital or electronic meters to stimulate the consciousness and generate a virtuous new behavior toward energy savings, increasing end-users energy efficiency.
    - Such devices can also work as "energy data providers" for all the smart appliances installed in house, in order to enable load management services.
- Smart energy management for DG and DSR
    - Effective integration of storage and demand response capacity through distributed control.
    - Verification of the potential of demand profile shaping, through the integration of smart and communication-enabled controls of different loads and appliances and related to the storage capacity linked with distributed generation.
- Intelligent Smart Home Controller, providing information on patterns of behaviour, useful for raising awareness of energy consumption and to foster efforts towards real energy conservation / savings
    - Encouraging the customers' active role requires advanced ICT tools able to manage the complexity of multiple inputs, take consequent intelligent actions and provide easy and flexible interaction between the customers and the system
    - The Smart Home Controller should represent the control point and counterpart to smart meters. They will interact closely in order to exchange data.
    - The customers' active role will be focused on setting the rules and priorities of energy use in respect of availability and cost while the daily operations, information and communication will be managed automatically by the Smart Home Controller.

The customers-centric view and their role in the electric power supply chain and market are shown in the Figure 16 below.

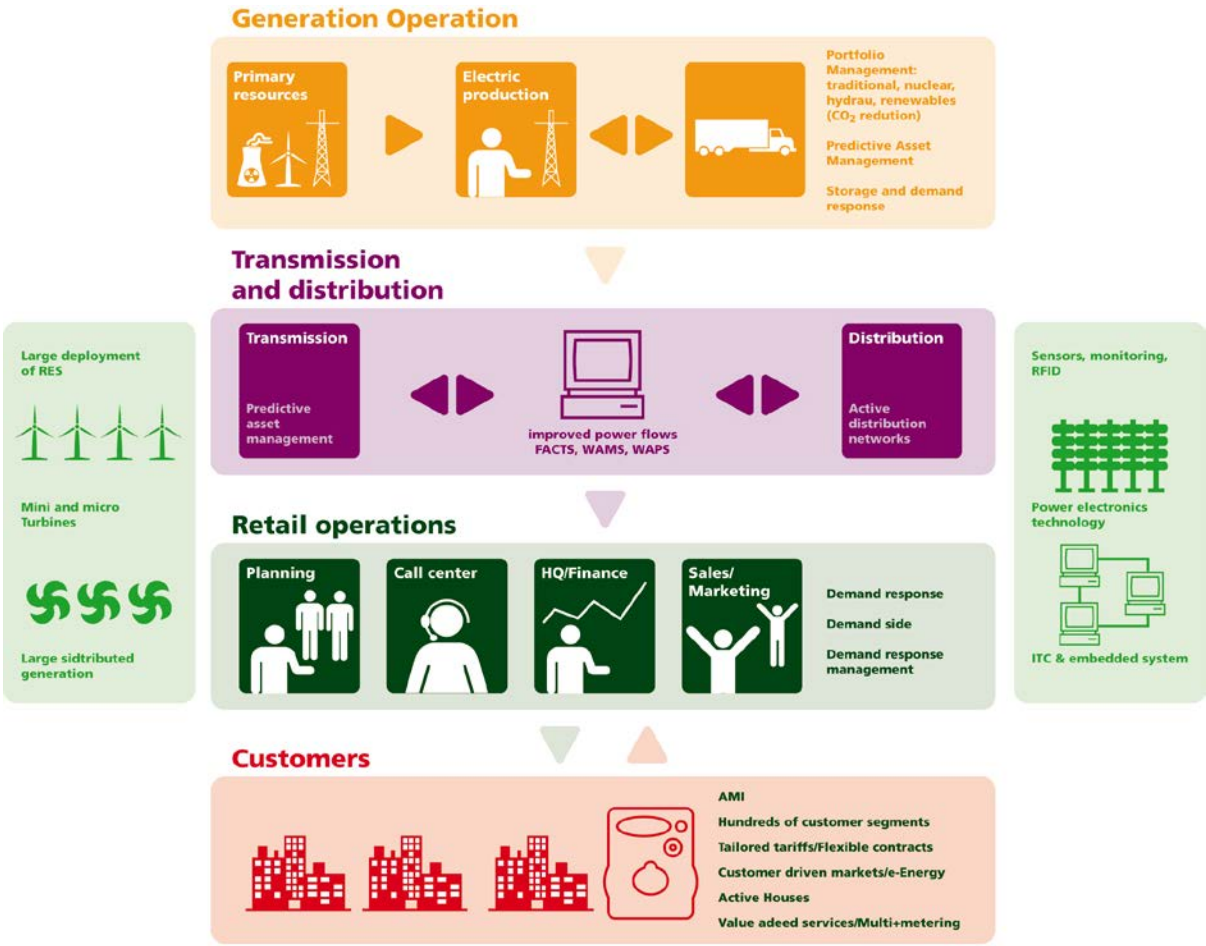


FIGURE 16: CUSTOMER FOCUS OF THE ELECTRIC POWER SUPPLY CHAIN AND MARKET [15]

As well as the above deployment priorities, the Smart Grids ETP outlined in their Strategic Deployment Document, the following recommendations, with key motivation and benefits [15]:

- **Promote the Smart Grids Vision to all stakeholders** – it is vital that there is 'buy-in' to the Smart Grids Vision across all stakeholders for it to be successful.
- **Encourage innovation by network companies and stakeholders** – only the network companies can actually deliver the Vision. They must be motivated for that.
- **Encourage a pan-European approach to the Smart Grids 'project'** – a sustainable future for Europe will increasingly depend on open energy trading. Co-operation between Member States will be increasingly important.
- **Encourage early deployment of Smart Grids technologies and solutions through demonstration projects** – "de-risking" technologies requires demonstration on real networks. Demonstration projects are vital to achieve widespread adoption.

- **Further develop the Smart Grids Business Opportunities to build the case for deployment –** new approaches are needed to take account of the wider benefits of Smart Grids.
- **Engage the demand side –** it is a vital part of the Smart Grids Vision to promote active demand side / user participation.
- **Address technical standards in the electricity and telecommunications sectors –** engage the standards and regulatory bodies from both sectors to ensure that they are in line with the Smart Grids Vision and its needs.
- **Understand and manage the environmental impacts of network development –** stakeholders' concerns must be understood and addressed appropriately.
- **Promote open access to network performance data –** vital for effective functioning of the market, for grid operational security but also for the effective R&D.
- **Develop the "skills" base in the electricity networks sector –** without resolving this problem of resources, any progress will be severely constrained.

United Kingdom

In the United Kingdom (UK) a number of Smart Grid initiatives have been undertaken over recent years. First and foremost is the establishment of the Smart Grid Forum [16] chaired by the government (Department of Energy and Climate Change (DECC)) and the regulator (Ofgem).

The Forum was set up in order to properly recognise the importance of network development as a key part of the low carbon transition following the role that consideration of smarter networks played in the last electricity distribution price control review (DPCR5) that took effect in April 2010. It is expected that consideration of smarter networks will play an even larger part in the next electricity distribution price control review which will commence in 2012.

The Smart Grids Forum will.

- Identify future challenges for electricity networks and system balancing, including current and potential barriers to efficient deployment of smart grids;
- Guide the actions that DECC/Ofgem are taking to address future challenges, remove barriers and aid efficient deployment;
- Identify actions that DECC/Ofgem, the industry or other parties could be taking to facilitate the deployment of smart grids;
- Facilitate the exchange of information and knowledge between key parties, including those outside the energy sector;
- Help all stakeholders better understand future developments in the industry that they need to be preparing for;
- Track smart grid developments and their drivers; and
- Track smart grid initiatives in Europe and elsewhere.

The Forum's scope is broad – looking at the services and functionalities that networks will be required to offer as we move towards a low carbon energy sector. It will therefore consider the network companies' challenges and opportunities relating to distributed generation, the electrification of heating and transport and of course the implications of smart metering on demand side management and active network management. It will address commercial and cultural as well as technical changes and the barriers the network companies face in making these changes.

The Forum has now met on a number of occasions and five work streams have been agreed. These are:

- WS1 – Assumptions and scenarios – this work is led by DECC. It will establish the assumptions and scenarios necessary for the network companies to produce business plans that are consistent with DECC's low carbon transition.
- WS2 – Evaluation Framework – Ofgem is leading this work to develop an evaluation framework that can assess, at high level, alternative network development options. It is intended that the Framework will help inform policy decisions related to smart grids.
- WS3 – Developing Networks for Low Carbon – the DNOs are leading this work to assess the network impacts of the assumptions and scenarios from WS1.
- WS4 – Closing Doors – this work stream brings together stakeholders to identify credible risks to the development of smart grids as a consequence of forthcoming policy decisions which might fail to take full account of the necessary enablers for smart grid development.
- WS5 – Ways of Working – this work stream looks at how the Forum can best pursue its objectives and communicate effectively with stakeholders.
- WS6 - Commercial and Regulatory -this work stream brings together stakeholders to investigate the commercial and regulatory challenges of implementing the smart grid solutions.

Ofgem has now published an open letter consultation inviting feedback on the first stage of the Smart Grids Forum's work to produce an evaluation framework for smart grids. This is an opportunity for stakeholders to offer comments which will be taken account of in the second stage of this work

Low Carbon Networks Fund

There is interesting evidence from Britain to show how regulatory frameworks can greatly facilitate network innovation and its commercial deployment. The energy regulator, Ofgem, regards innovation as a key attribute it wishes to encourage in the interests of customers and in support of government energy policy. As part of the electricity distribution price control arrangements that run from 1 April 2010 to 31 March 2015, Ofgem established the Low Carbon Networks (LCN) Fund.

The Fund allows up to £500m support to projects sponsored by the distribution network operators (DNOs) to try out new technology, operating and commercial arrangements. Interestingly this is awarded on a competitive basis, the network companies have to contribute 10% of their own funding, and there is a strong requirement for partnering and consumer engagement.

There are two tiers of funding which are available under the LCN Fund. The First Tier is designed to enable DNOs to recover a proportion of expenditure incurred on small scale projects. Under the Second Tier of the LCN Fund, Ofgem facilitates an annual competition for an allocation of up to £64million to help fund a small number of flagship projects. In the first year, 4 projects were awarded Second Tier funding totalling £63.6million through the annual competition and 11 projects were registered under the First Tier. These projects involve the DNOs partnering with suppliers, generators, technology providers and other parties to explore how networks can facilitate the take up of 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 that smart meter roll out provide to network companies. As such the Fund should also provide valuable learning for the wider energy industry and other parties.

Ofgem have recently announced the winners of the 2012 second tier competition. Of seven proposed projects, five were selected for funding. A list of the winning projects can be found below.

- Accelerating Renewable Connections (submitted by Scottish Power Distribution)
- Customer Load Active System Services (submitted by Electricity North West)
- Flexgrid - Advanced Fault Level Management in Birmingham (submitted by Western Power Distribution)
- Innovation Squared (submitted by Southern Electric Power Distribution)
- Smarter Network Storage (submitted by Eastern Power Networks)

Orkney Smart Grid

The Orkney smart grid in Scotland, commissioned in 2009, is one of the few projects worldwide that is not simply ‘grant-funded’ as a demonstration. It has benefited from regulatory financial incentives, but has been implemented by the network company as a mainstream commercial development that paves the way for wider applications in their business plans. The smart grid has enabled the same amount of renewable generation to be connected to Orkney’s distribution network as would have been made possible by conventional network reinforcement at a fraction of the cost.

Work on the smart grid began in 2004, when Scottish and Southern Energy Power Distribution (SSEPD) initiated studies with the University of Strathclyde to address the issue of capacity constraints on the electricity distribution network which were limiting the potential for renewable generation developers to harvest the significant renewable energy resource on the Orkney Isles.

An innovative new Active Network Management (ANM) approach was devised to make better use of the existing network by instructing generators to control their output, in real time, to match the available network capacity. This led to the creation of a spin out company, Smarter Grid Solutions (SGS), to develop and deliver an ANM system to meet SSEPD's objectives.

The ANM was switched on in 2009. It allows the power flows at several points on the network to be monitored, and power flows from multiple new renewable generators to be controlled. The technology is based around a central controller, which collects data from 'pinch points' geographically distributed around the network.

The central controller identifies when power flows are approaching the limits of the network power rating and sends instructions to generators to reduce their output in time before problems occur. The system is designed to be fail safe to protect the network if generators do not respond correctly to control signals within specified time limits.

By 2012, almost 20MW of new renewable generation has agreed contracts to connect to the Orkney system as a result of the smart grid.

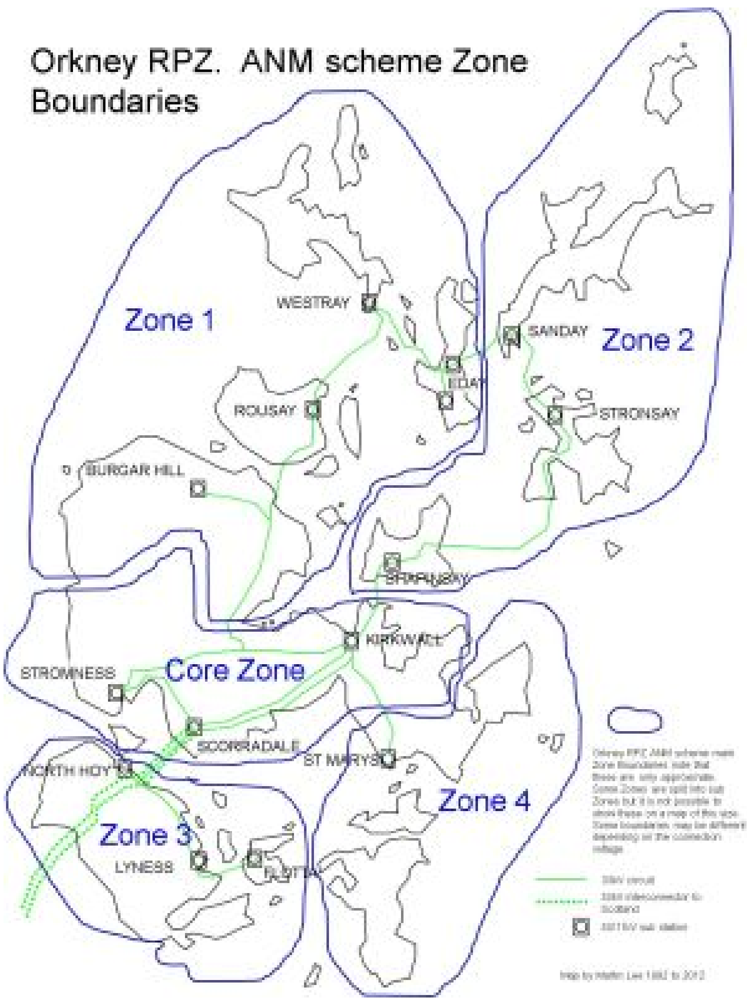


FIGURE 17: ORKNEY SMART GRID ZONES

EUROPEAN SMART GIRD PROJECTS

In the last few years, initiatives on Smart Grids, with different aims and results, have been growing in number and scope throughout Europe. Substantial public and private investments have been made in research and development (R&D), demonstration and deployment activities. A survey has been conducted by the European Commission's Joint Research Centre Institute for Energy (JRC-IE) to start a data collection effort to develop a catalogue of Smart Grids projects in Europe and to carry out a qualitative analysis of their results. The JRC-IE published a reference report in 2011, "*Smart Grid projects in Europe: lessons learned and current developments*" [17], with the results from the survey. The work is intended to be the first of a series of snapshots that the JRC will periodically prepare on the development status of Smart Grids in Europe to offer a basis for discussion among Smart Grid stakeholders and promote the sharing of knowledge, experiences and best practices.

The JRC-IE report has identified 219 Smart Grid projects currently being developed in Europe. The total budget of the collected projects is currently in excess of €5 billion. A recent report by Pike Research [18] forecasts that during the period from 2010 to 2020, cumulative European investment in Smart Grid technologies will reach €56.5 billion, with transmission counting for 37% of the total amount. The report also suggests that by 2020 almost 240 million smart meters will have been deployed in Europe.

A Geographical distribution of investments and project categories can be found in Figure 17. As can be seen from Figure 17, deployment projects (mainly smart meter roll-outs) cover the lion's share of investment commitments, about 56% of the total, while R&D and demonstration projects account for a much smaller share of the total budget. Most R&D and demonstration projects are small to medium size with €4.4 million for R&D projects and about €12 million for demonstration projects on average.

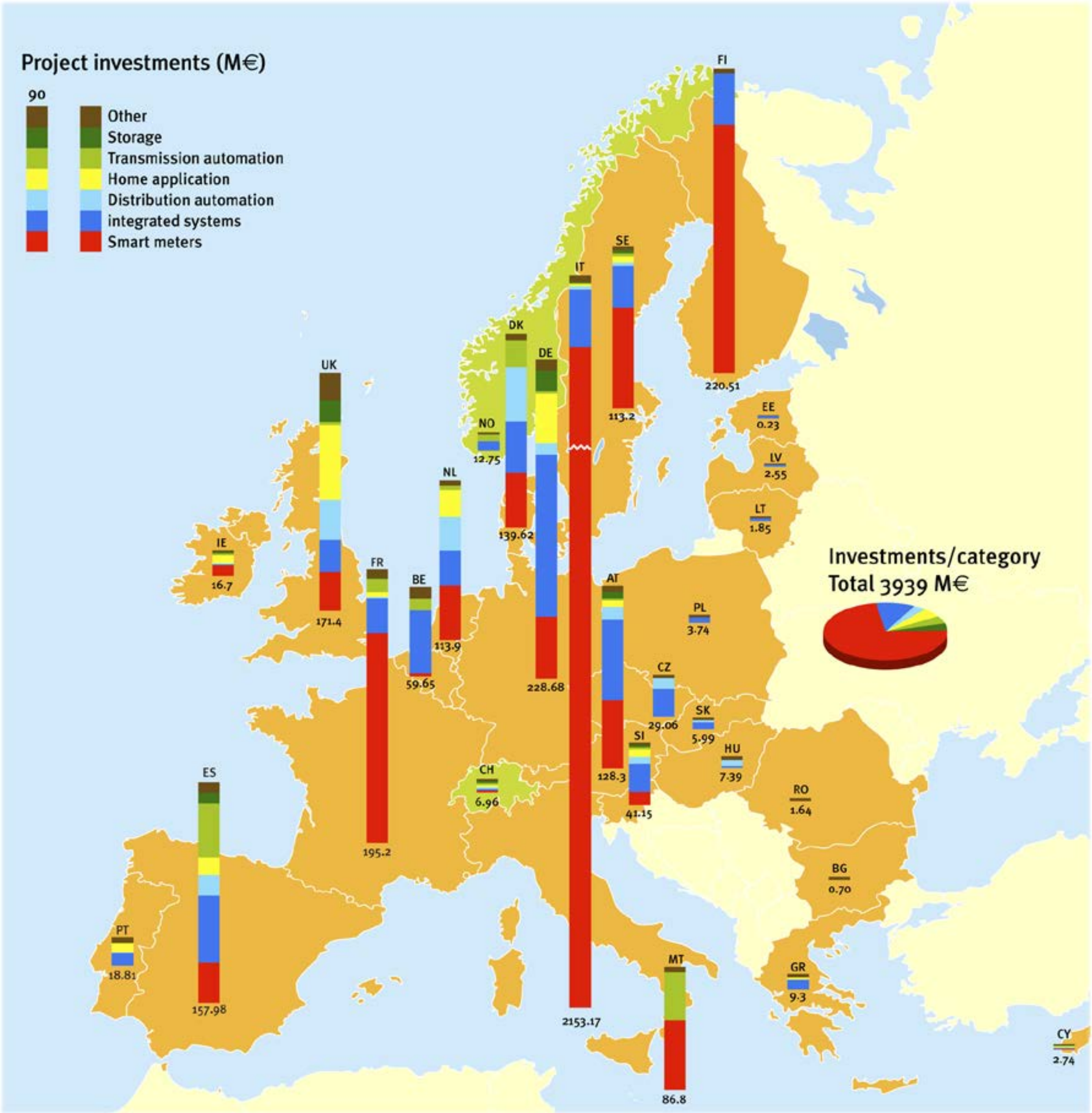


FIGURE 18: GEOGRAPHICAL DISTRIBUTION OF INVESTMENTS AND PROJECT CATEGORIES[2] [17]

Figure 17 shows remarkable differences in the distribution of project categories in Europe. Generally speaking, the investment pattern and project categories coverage in different countries is strongly influenced by different starting points in the adoption of the various Smart Grid solutions and by national circumstances. Investments depend crucially on regulation, generation and consumption structures in each country. For example, countries with large penetration of renewables such as Germany may favour developments that increase hosting capacity (i.e. Transmission Automation, Integrated System, Storage), whereas countries with a high share of flexible electricity use (e.g. space and water heating) such as United Kingdom may favour investments that promote Demand Response (i.e. Distribution Automation, Integrated System, Home Application, Smart Meters).

[2] This figure does not include the total budget of the Swedish smart meter programme (estimated budget €1.5 billion), as not enough details were made available at this stage.

The most represented project categories, which also attract the highest level of investments, are Smart Meters and Integrated Systems. About 27% of the projects collected in the catalogue fall in the Smart Meters category; these projects involve the installation of about 40 million devices for a total investment of around €3 billion. Estimates forecast about 240 million smart meters to be installed by 2020 [17].

SMART METERING

The introduction of smart metering systems in Europe has received an important regulatory push by the European Union's Third Energy Package provisions and especially Annex I.2 of the Electricity Directive [19]. The Annex explicitly asks Member States to assess the roll-out of intelligent metering systems as a key step towards the implementation of Smart Grids and to roll out 80% of those that have been positively assessed. Many Member States have already started implementing provisions in their legislation, while some others are still lagging behind. Independently of the legislative and regulatory framework, in some Member States utilities have started to introduce smart meters as a means to modernise the grids and to bring about operational changes, i.e. reduce non-technical losses, introduce remote reading and switching or simplify the billing procedures.

The country leading investments in smart meters is Italy, where a national roll-out, called the Telegestore project, has already been achieved [20]. This project is the largest AMI system in the world. Figure 18 shows an example of the system architecture. The main features of the Telegestore project are [21];

- Remote reading of energy consumption and power
- Elimination of estimated billing thanks to bimonthly readings
- Multi-tariff structure programmability with possibility of daily, weekly, monthly and seasonal modulation
- Remote change of contractual parameters (i.e. subscribed power demand)
- Remote disconnection and remote "authorisation" of circuit-breaker manual reclosing (by the Customer)
- Monitoring of supply service quality per each individual customer (number and duration of interruptions)
- Fraud detection and prevention
- Active and reactive energy measurement
- Load profiles for active and reactive energy with 1 to 60 minutes sampling time; storage capability of 38 days @ 15 min sampling time
- Balance per each MV/LV transformer for network planning and to detect fraud areas
- Detecting of illegal tie-in or unauthorised access to the meter (tamper)
- Transmission of messages to customers about energy consumption and technical-commercial information
- Real time broadcasting of data to the customer in order to support load management algorithms and multi-tariffs, curtailment global or targeted

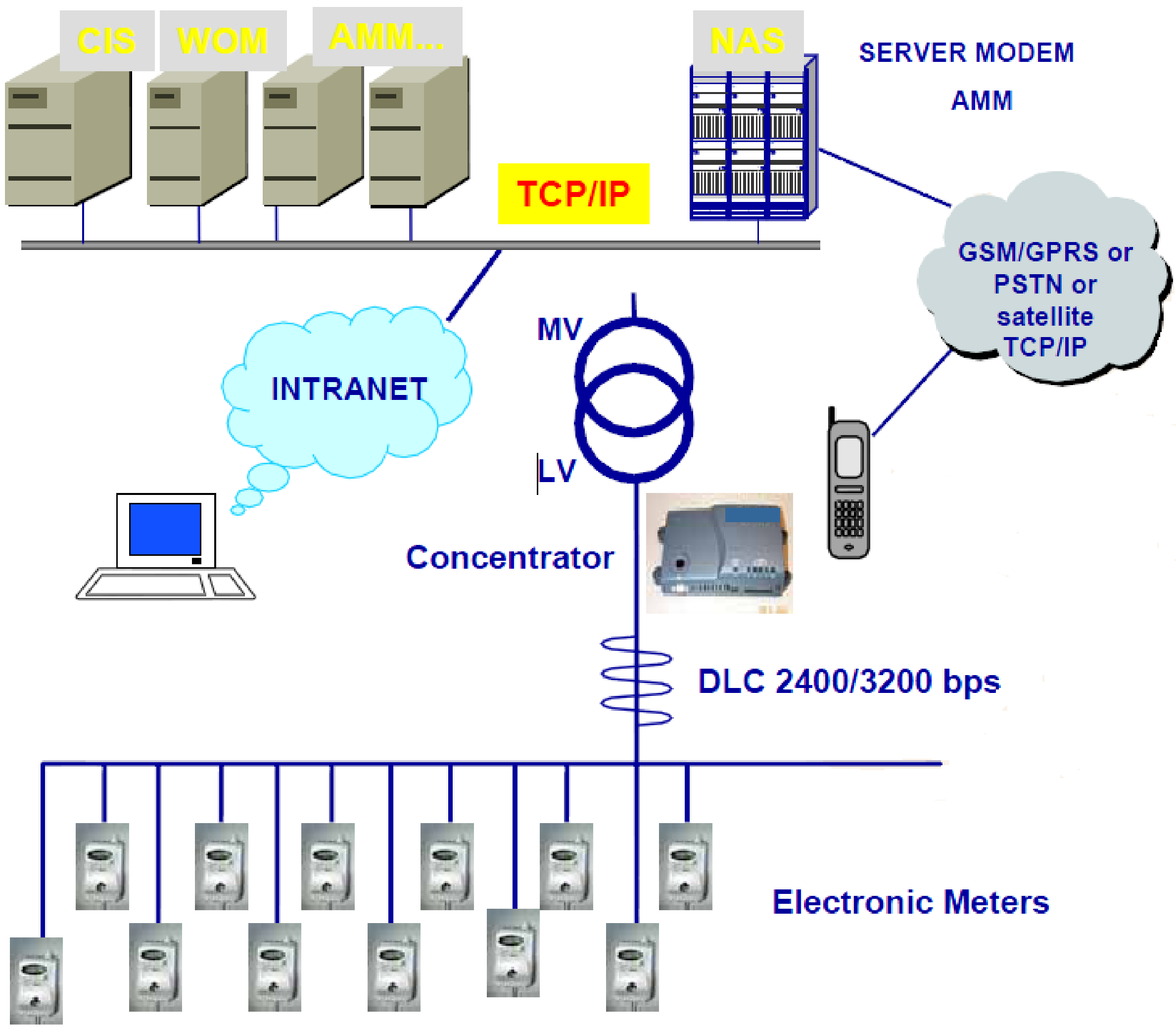


FIGURE 19: SYSTEM ARCHITECTURE FOR THE TELEGESTORE AMI PROJECT [21]

The roll out included 30 million meters, 350000 concentrators, and more than 15000 people over 3 continents. 650 local firms were used to replace the meters, with 5 meter assemblers, and more than 50 suppliers of meter components. The confirmed savings in the operational costs justify the amount of the investment (2 billion of €).

In two other countries, France and Finland, the great majority of the budget is also attributable to smart meter projects. In France the demonstration project Pilot Linky accounts for about 75% of the total spending, while in Finland the Smart Meters roll-out project by Fortum accounts for over 80% of the whole budget.

The French government has formally approved the deployment of 35 million electricity meters, starting in 2013 with completion by 2018. Deploying the Linky meter to customers across France will cost an estimated €4.3 million. The government also confirmed that the cost of the rollout is expected to be borne by Électricité Réseau Distribution France (ERDF), which manages the low and medium voltage distribution system, and recouped through new network efficiencies.

The major challenge in France will be to ensure consumer acceptance. There is a perception amongst consumer groups that the meters are primarily for the benefit of the electricity industry (dominated in France by nationwide utility EDF and its subsidiaries) and that in the end consumers will be bear the price of the meters. Only minimal support for consumer energy efficiency is required in the basic rollout and energy retailers can charge more for additional information services. A lot more work will need to be done if the meter is to play a role in reducing household costs and improving energy efficiency.

As for the Integrated System category, Figure 17 shows that in almost all countries, a significant amount of investments has been devoted to projects, which address the integration of different Smart Grid technologies and applications. Integrated System projects represent about 34% of the projects and about 15% of the total budget.

JRA-IE Catalogue

An example of some of the projects on the JRC-IE catalogue are given below.

Address

Organization: Enel Distribuzione (IT)
Period: Jun 2008 - Jun 2012
Project category: Integrated System, Home application - Customer Behaviour
Project Website: http://www.addressfp7.org
Project Description: The project aims at delivering a comprehensive commercial and technical framework for the development of "Active Demand" in the smart grids of the future. ADDRESS investigates how to effectively activate participation of domestic and small commercial customers in power system markets and in the provision of services to the different power system participants.

AFTER - A Framework for electrical power sysTems vulnerability identification, dEfense and Restoration

Organization: RSE – Ricerca sul Sistema Energetico (IT)
Period: 2011 - 2014
Project category: Grid Automation Transmission
Project Website: http://www.rse-web.it
Project Description: AFTER addresses vulnerability evaluation and contingency planning of the energy grids and energy plants considering also the ICT systems used in protection and control. Main addressed problems concern high impact, wide spread, multiple contingencies and cascading.

DLC+VIT4IP

Organization: Kema Nederland BV (NL)
Period: Jan 2010 - Jan 2013
Project category: Other
Project Website: http://www.dlc-vit4ip.org
Project Description: DLC+VIT4IP will develop, verify and test a high-speed narrow-band power line communications infrastructure using the Internet Protocol (IP) which is capable of supporting existing and extending new and multiple communication applications. These shall include the existing power distribution network for novel services in smart electricity distribution networks such as demand side management, control of distributed generation and customer integration.

E-PRICE

Organization: Eindhoven University of Technology (NL)
Period: Feb 2010 - Feb 2013
Project category: Grid Automation Transmission, Grid Automation Distribution
Project Website: http://www.e-price-project.eu
Project Description: This project proposes an advanced ICT and control framework for ancillary services (reserve capacity) which allows a more intelligent solution by giving consumers and producers clear, real-time financial incentives to adapt their consumption/production according to the actual needs of the power system. This demand-side management is being made possible by the large scale introduction of Smart meters.

EU-DEEP

Organization: GDF Suez (FR)
Period: Jan 2004 - Jun 2009
Project category: Integrated System
Project Website: www.eudeep.com
Project Description: The project brings together eight European energy utilities and aims at removing most of the technical and non-technical barriers that prevent a massive deployment of distributed energy resources (DER) in Europe. In partnership with manufacturers, research organizations, professionals, national agencies and a bank, they implemented a demand-pull rather than technology-push approach. This new approach provided three tentative "fast-tracks options" to speed up the large-scale implementation of DER in Europe, by defining three client portfolios in various market segments which could benefit from DER solutions, and by fostering the R&D required to adapt DER technologies to the demands of these segments.

EWIS - European wind integration study

Organization: Elia System Operator SA (BE)
Period: Jun 2007-Oct 2009
Project category: Other
Project Website: www.wind-integration.eu
Project Description: The project aims to work with all the relevant stakeholders especially representatives of wind generation developers. The study will use results from detailed network and market models of the European transmission system for scenarios representing immediate and longer-term needs. The recommendations will be aimed at developing, where possible and appropriate, common European solutions to wind integration challenges.

G4V - Grid for Vehicles

Organization: RWE Rheinland Westfalen Netz AG (DE)
Period: Jan 2010 - Jun 2011
Project category: Other
Project Website: www.g4v.eu
Project Description: The project of the G4V consortium will generate fast and openly available results: an analytical framework to evaluate the impact of a large scale introduction on the grid infrastructure and a visionary "road map" for the year 2020 and beyond.

Grid4EU

Organization: ERDF (FR)
Period: Apr 2011 - Apr 15
Project category: Integrated System
Project Description: Grid4EU is led by a group of European DSOs and aims at testing in real size some innovative system concepts and technologies in order to highlight and help to remove some of the barriers to the smart grids deployment (technical, economic, societal, environmental or regulatory). It focuses on how DSOs can dynamically manage electricity supply and demand, which is crucial for integration of large amounts of renewable energy, and empowers consumers to become active participants in their energy choices.

GROW-DERS Demonstration of Grid Connected Electricity Systems

Organization: KEMA (NL)
Period: Jul 2009 - Jul 2011
Project category: Specific Storage Technology Demonstration
Project Description: The GROW-DERS project (Grid Reliability and Operability with Distributed Generation using Flexible Storage) investigates the implementation of (transportable) distributed storage systems in the networks.

ICOEUR

Organization: TECHNISCHE UNIVERSITAET DORTMUND (DE)
Period: Jan 2009-Dec 2011
Project category: Grid Automation Transmission
Project Website: www.icoeur.eu
Project Description: The development and prototypically implementation of new methods and tools is the major goal of the ICOEUR project. New technologies like Wide Area Monitoring, Control and Protection as well as advanced network controllers (FACTS) and HVDC systems will be considered. The project will investigate smart interconnection between continental Europe and Russian systems.

IMPROSUME - The Impact of Prosumers in a Smart Grid based Energy Market

Organization: Inkubator Halden, Norwegian Center of Expertise for Energy and Emission Trading (NO)
Period: Oct 2010 - Oct 2011
Project category: Other, Integrated System
Project Website: http://www.forskningsparken.no
Project Description: IMPROSUME will establish a better understanding of the prosumer's role in the future power market supported by a Smart Grid and associated technologies. The project will address stimuli that are likely to motion consumers to take an active role in the market also as suppliers.

INTEGRAL

Organization: ECN, Energy research Centre of the Netherlands (NL)
Period: 2009-2010
Project category: Integrated System
Project Website: http://www.powermatchingcity.nl
Project Description: The INTEGRAL project aims to build and demonstrate an industry-quality reference solution for DER aggregation-level control and coordination, based on commonly available ICT components, standards, and platforms.

Internet of Energy

Organization: SINTEF (NO)
Project category: Integrated System
Project Description: The objective of Internet of Energy (IoE) is to develop hardware, software and middleware for seamless, secure connectivity and interoperability achieved by connecting the Internet with the energy grids. The project will evaluate and develop the needed ICT for the efficient implementation in future smart grid structures.

LASTBEG - Large Scale Tool for Power Balancing in Electric Grid

Organization: Nanotech Sas Aix En Provence (FR)
Period: Jan 2009-Oct 2009
Project category: Integrated System
Project Description: This project will demonstrate an optimization of renewable energy supplies (RES), primarily wind energy sourced onshore and offshore, with an existing pumped storage power plant (PSPP). It will integrate smart meters with power demand and supply forecasting to enable consistency of power supply in a small European country (Lithuania). The lessons learnt from this demonstration project will be disseminate directly to the participants in this project and indirectly through them to major global Transmission System Operators (TSOs), ensuring a two way exchange of best practice. This work will therefore enable a greater penetration of RES as part of the drive to meet the EC's 20:20:20 objectives.

MERGE - Mobile Energy Resources in Grids of Electricity

Organization: PUBLIC POWER CORPORATION S.A. (EL)
Period: Jan 2010 - Dec 2011
Project category: Integrated System
Project Website: www.ev-merge.eu/
Project Description: Electric power systems are facing a major new challenge: future massive integration in the electric grid of electric plug-in vehicles (EV). The project will address comprehensively the impact of electric plug-in vehicles (EV) presence regarding steady state operation, intermittent RES integration, system stability and dynamic behavior, system restoration, regulatory aspects and market arrangements.

Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution (MIRACLE)

Organization: SAP AG (DE)
Period: Jan 2010 - Jan 2013
Project category: Integrated System
Project Description: The project's main goal is to develop a concept for flex-offers that specify electricity demand and supply which is flexible in time and amount and an infrastructural approach to process lots of these flex-offers issued by small consumers and producers in near real-time. The possibility to shift demand within the mass of households developed within the MIRACLE project will allow for a higher share of fluctuating renewable energy sources in the energy mix on the grid and reduce the peak demand. We expect that the share of RES can be increased by 5% and that the peak demand can be reduced by 8-9% (but at least by 5%) for the total grid. We will furthermore reduce the mean time between transactions, which will result in more stability of the energy grid but also in reduction of costs of BRPs, by reducing the difference between their planned and actual electricity schedules.

MORE MICROGRIDS

Organization: ICCS/National Technical University of Athens (EL)
Period: Jan 2006 - Dec 2009
Project category: Integrated System, Smart Meter and AMI, Grid Automation Distribution, Home application - Customer Behavior
Project Website: http://www.microgrids.eu/index.php
Project Description: The aims of this Test Facility is to:

- Test centralized and decentralized control strategies in grid interconnected mode;
- Test communication protocols and components including aspects related to energy trading;
- A control and monitoring system built around IEC 61850 standard designed and prototyped;
- Control strategies resulting from agent software to make use of these control and monitoring functions;
- Development of intelligent modules embedding the required functions to allow a full integration of each generating/load unit into the system.

NIGHT WIND

Organization: Nederlandse Organisatie Voor Toegepast Natuurwetenschhappelijk Onderzoek (NL)
Period: Jul 2006-Jun 2008
Project category: Other
Project Website: cordis.europa.eu
Project Description: The Night Wind project proposes to design grid architectures for Wind Power Production combined with Energy Storage means of load management of Refrigerated Warehouses (Cold Stores), Refrigerated Warehouses are constant power users, day and night.

OPEN METER

Organization: Iberdrola (ES)
Period: Jan 2009 - Jun 2011
Project category: Smart Meter and AMI
Project Website: www.openmeter.com
Project Description: The main objective of the OPEN meter project is to specify a comprehensive set of open and public standards for Advanced Metering Infrastructure (AMI) supporting multi commodities (Electricity, Gas, Water and Heat), based on the agreement of the most relevant stakeholders in the area.

OPEN NODE

Organization: Atos Origin Sae (ES)
Period: Jan 2010 - Jun 2012
Project category: Integrated System
Project Website: www.opennode.eu
Project Description: OpenNode project is focused on the electrical distribution grid operation and explores answers on the three challenges introduced:

- How to improve the distribution grid monitoring to cope with volatile states in the grid
- How to integrate the “smart” substation automation devices to increase the efficiency of the distribution grid
- How to interoperate with the different roles e.g. operation of the smart meters, power and grid operation

OPTIMATE

Organization: TECHNOFI – (FR)
Period: 2009-2012
Project category: Integrated System
Project Website: http://www.optimate-platform.eu
Project Description: The project aims at developing a numerical test platform to analyze and to validate new market designs which may allow integrating massive flexible generation dispersed in several regional power markets.

PEGASE - PAN EUROPEAN GRID ADVANCED SIMULATION AND STATE ESTIMATION

Organization: Tractebel Engineering S.A. (BE)
Period: Jul 2008-Jun 2012
Project category: Other
Project Website: fp7-pegase.eu
Project Description: PEGASE is a four year project dealing with the High and Extra High Voltage transmission and sub-transmission networks in Europe (designated as ETN) and implemented by a Consortium composed of 20 Partners including TSOs, expert companies and leading research centre’s in power system analysis and applied mathematics. Its overall objectives are to define the most appropriate state estimation, optimization and simulation frameworks, their performance and dataflow requirements to achieve an integrated security analysis and control of the ETN.

REALISEGRID

Organization: RSE (IT)
Period: Sept 2008 - May 2011
Project category: Other
Project Website: www.realisegrid.rse-web.it
Project Description: The objective of REALISEGRID is to develop a set of criteria, metrics, methods and tools to assess how the transmission infrastructure should be optimally developed to support the achievement of a reliable, competitive and sustainable electricity supply in the European Union (EU).

SAFEWIND

Organization: RTE, (FR)
Period: Sept 2008 - Aug 2012
Project category: Other
Project Website: www.safewind.eu
Project Description: The project will develop: New forecasting methods for wind generation focusing on uncertainty and challenging situations/extremes. - Models for "alarming": providing information for the level of predictability in the (very) short-term. - Models for "warning": providing information for the level of predictability in the medium-term (next day(s)).

SMARTGEN

Organization: Sweco Norge AS, (NO)
Period: Oct 2010-Sept 2013
Project category: Integrated System
Project Description: Demonstrate and quantify the benefits of combining SGT with DG and LM and share this knowledge with stakeholders and decision makers in private and public sector. Develop the “SmartGen Models” which illustrates both energy resources and grid information visually by combining SGT scenarios with input from GIS and NIS.

SMARTHOUSE/SMART GRID

Organization: SAP Research (DE)
Project category: Home application - Customer Behaviour
Project Description: The SmartHouse/Smart Grid project sets out to validate and test how ICT-enabled collaborative technical-commercial aggregations of Smart Houses provide an essential step to achieve the needed radically higher levels of energy efficiency in Europe.

SUSPLAN

Organization: SINTEF ENERGIFORSKNING A/S (NO)
Period: Sept 2008-Sept 2011
Project category: Other
Project Website: www.susplan.eu
Project Description: The overall impact from SUSPLAN is contribution to a substantially increased share of renewable energy sources (RES) in Europe at an acceptable level of cost, thereby increasing security of supply and competitiveness of RES industry. The main objective is to develop guidelines for more efficient integration of RES into future infrastructures as a support for decision makers at regional as well as Pan-European level. The guidelines shall consist of strategies, recommendations, criteria and benchmarks for political, infrastructure and network decision makers and power distributors with a time perspective 2030-2050.

TWENTIES

Organization: Red Eléctrica de España (REE)
Period: 2010-2013
Project category: Grid Automation Transmission
Project Website: http://www.twenties-project.eu
Project Description: TWENTIES Project aims to demonstrate through real-life, large-scale demonstrations, the benefits and impact of several critical types of technology required to improve the European transmission network, thus giving Europe the ability to increase the share of renewables in its energy mix by 2020 and beyond, while keeping its present reliability.

WEB2ENERGY

Organization: HSE AG (DE)
Period: Jan 2010-Dec 2012
Project category: Smart Meter and AMI, Grid Automation Transmission
Project Website: www.web2energy.com
Project Description: The project Web2Energy is directed to implement and approve all three pillars of "Smart Distribution". Smart Metering – the consumer participates in the energy market Smart Energy Management – Clustering of small power producers. Smart Distribution Automation – higher reliability of supply.

ASIA

CHINA

The State Grid Corporation of China (SGCC) is the driving force behind China's effort to build a nationwide Smart Grid. SGCC has divided the development of a Smart Grid into three phases, and plans to invest in the period 2009-2020 a total of $601 billion USD into a nationwide transmission network with $101 billion USD of these funds to be dedicated to developing Smart Grid technology [22].

The first phase, which ended in 2010, focused on planning Smart Grid construction by outlining technical standards, developing technology and equipment, and implementing pilot projects. The total investment of this phase was $77.8 billion USD including a $9.2 billion USD investment into Smart Grid technology. The second phase will last until 2015 and will see the construction of a reliable nationwide transmission grid, including operational Smart Grid management systems, wide spread deployment of smart meters, and enough EV charging stations to accommodate the use of EVs. This phase will invest $282.9 billion USD with $45.8 billion USD of these funds dedicated to Smart Grid technology. The final phase will last from 2016 to 2020 and complete China's nationwide grid by connecting all planned coal, hydroelectric, nuclear and wind power generation facilities to areas of high demand in a reliable, intelligently managed transmission network. The last phase will invest $240.5 billion USD into building this transmission grid with $45.8 billion USD of these funds dedicated to Smart Grid technology

During the first phase, SGCC implemented 228 Smart Grid pilot projects to solve technical issues, test designs, and develop management systems. These projects covered the entire gamut of Smart Grid implementation, ranging from connecting wind power plants to automating distribution networks to metering households. The projects were implemented across different regions of China, including a highly publicized Smart Grid demonstration project at the Shanghai World Expo. Using the experience gained from these projects, SGCC released a set of industry rules, standards, and favoured technologies for 22 criteria of Smart Grid technology in June 2010. For both domestic and international manufacturers of Smart Grid equipment, these standards and favoured technologies have enormous impact on the products offered by their businesses. The standardization of components for such a massive project yields an economy of scale that at least initially dwarfs any other source of demand for Smart Grid equipment. Chinese manufacturers, who already make the bulk of Smart Grid equipment for the world, will shift their focus to equipment that meets SGCC‟s standardization, making it cheaper and more readily available than other Smart Grid equipment.

The Smart Grid will also play a key role in China's efforts to build infrastructure to support electric vehicles (EVs). In June 2010, SGCC announced plans to fully develop an electric vehicle charging network, intending to establish 75 public charging stations, 6,209 AC charging spots, and a handful of battery replacement stations in Shanghai, Beijing, Tianjin and other cities that will serve as pilot projects. This announcement follows a string of projects launched by SGCC aimed at introducing EVs to China. Since 2006 the SGCC has procured 101 electric vehicles, constructed 30 pilot charging stations and collaborated with Beijing's municipal government to design 7 electric bus lines for 58 electric buses. In 2008, SGCC built the infrastructure to charge 55 electric buses and over 400 electric vehicles to move athletes and staff during Beijing's Olympic Games. China's other large transmission company, China Southern Power Grid Company (CSG), is also facilitating the spread of EVs by establishing charging stations in Shenzhen, Nanning and Guilin. CSG recently signed an agreement with BYD Co. to build an energy storage station with 3 megawatts of capacity in Shenzhen.

Presently, Chinese Smart Grid efforts are focusing on the creation of a large capacity interconnected transmission backbone to transfer bulk power and to accommodate fast growing electricity demand. The distribution grid in China is less mature than in most developed countries and the penetration of small-scale renewables is limited at the moment.

On May 4, 2012, the Chinese Ministry of Science and Technology (MOST) released the Special Planning of 12th Five-Year Plan (2011-2015) on Smart Grid Major Science and Technology Industrialization Projects [23]. This plan clarifies the overall objectives for smart grid construction during the period 2011-2015, as well as the industries that China will focus on supporting.

China's smart grid perspective includes: large-scale renewable energy grid connection technology, large-scale energy storage technology, large-scale grid interconnection, long-distance transmission control technology, distribution automation, microgrids, smart meters and demand response technology. The following six industries have been identified in the 5 year plan for China's smart grid layout:

- Clean energy generation manufacturing industry such as wind power generation, solar power generation, etc.
- New materials industry such as photoelectric conversion materials, energy storage materials, insulation materials, superconducting materials and nanomaterials.
- Infrastructure manufacturing industry such as new electrical and electronic devices, transformers, etc.
- Information and communication, instrumentation, sensors, software, etc.
- Alternative energy automotive industry
- Home appliances and the consumer electronics industry

In 2012, SGCC has accelerated smart grid construction, especially Ultra High Voltage (UHV) projects. The Huainan-Shanghai UHV AC (Alternating Current) project has started the invitation to tender in Q1 2012. The Hami-Zhengzhou ±800 UHV DC (Direct Current) project has received permission to deploy from the National Development and Reform Commission (NDRC). The Ningdong-Zhejiang UHV DC project has received approval by the National Energy Administration (NEA) for preliminary work.

The grid upgrade projects for rural areas are at a crucial stage this year. Based on the previous deployment from NDRC, the State Grid investment of $7.74 billion USD for rural grid upgrading works will end by 2012. China still has a problem of 96,000 households with a population of 400,000 without electricity which need to be addressed with the rural grid upgrade, illustrating the large amount of work required in this area.

In 2011, SGCC deployed 51.62 million smart meters. SGCC plans to finish 37 million smart meter installations this year, resulting in a drop in the amount of smart meter installations by 28.32 percent from the same period last year. However, according to a report by Innovation Observatory [24], China is set to roll-out 360 million smart meters by 2030 and is still dominating world smart meter shipments as shown in Figure 19.

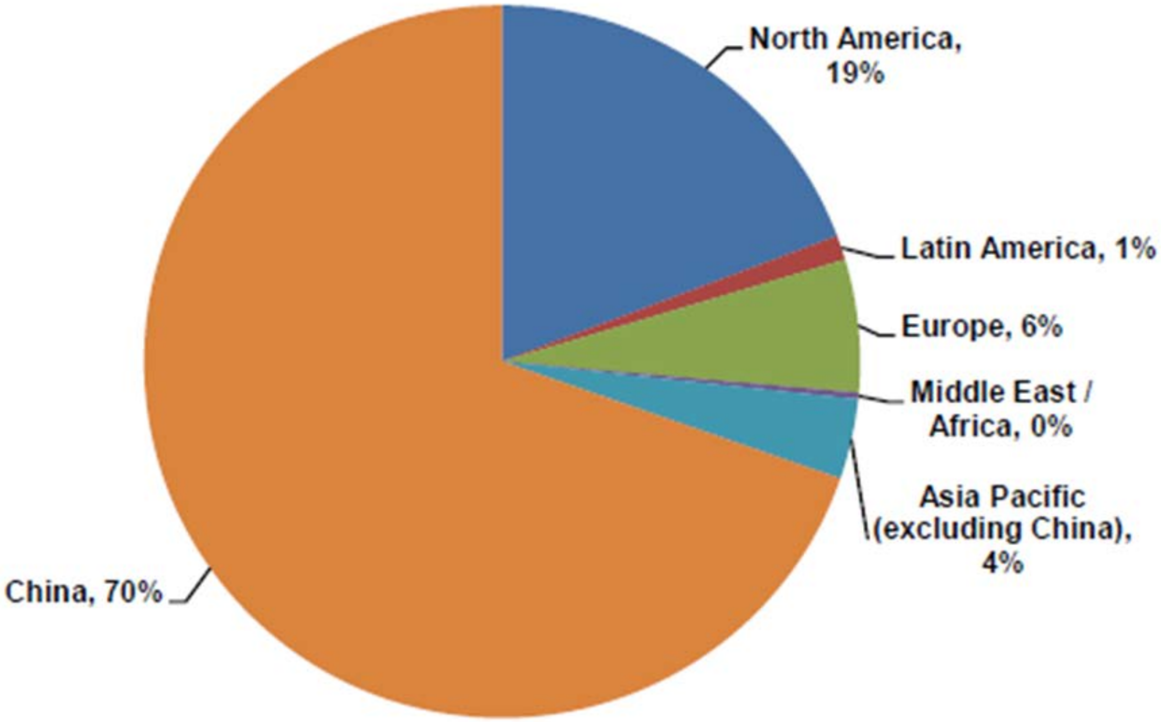


FIGURE 20: SMART METER SHIPMENTS BY REGION, WORLD MARKETS: 1Q 2012 [24]

At present, China is at a stage of rapid development of industrialization and urbanization. China's electricity demand is expected to continue to grow rapidly at a rate of 8.5 percent annually over the next two years. However, increasing demand and stagnant growth in new power plants is expected to push the limits of the power supply again this year. The maximum load of the State Grid region is expected to reach 635 million kilowatts and the power shortage during the summer peak period will reach 49 million kilowatts. The maximum shortages from North China, East China and Central China Power Grid respectively are 10 million, 25 million and 14 million kilowatts. Jiangsu Province and Zhejiang Province account for 17% of the maximum load with shortages of 13.4 million and 9.3 million kilowatts.

China's push to increase renewable generation capacity is based on on sending power generated from wind farms, hydroelectric dams, and solar power plants to cities along the east coast. However, approximately 30 percent of wind turbines in China are not currently connected to a transmission network; highlighting the limited reach and poor design of China's electricity grid (it's important to note that according to a report by AMSC on January 11, 2011 China has now installed more wind power capacity than any other nation).4 Despite completing the first phase of a 10 GW wind farm located near the city of Jiuquan in November 2010, the wind farm's remote location and China's poor transmission infrastructure has limited actual grid connected generation to 1.15 GW out of 5.16 GW of total installed capacity.5 A Smart Grid will not only increase renewable energy capacity but also help manage electricity demand in dense urban centres that are expected to grow with workers continuing to migrate to eastern cities and improving living standards, thus increasing their thirst for electricity. The advantages of Smart Grid technology will help China meet the government's two environmental goals and in turn provide security against swings in global energy prices and help to avoid power shortages and overloads [22].

While developing a reliable, countrywide Smart Grid is an enormous challenge, China's size and regulatory system provide inherent advantages that will help it achieve its goals. The massive size of China's nationwide Smart Grid provides an economy of scale that is unmatched anywhere in the world, helping to reduce costs and spark domestic manufacturing of Smart Grid equipment. While utilities in the United States are updating infrastructure and trying to upgrade old equipment, China has the advantage of building Smart Grid technology into transmission infrastructure from the outset. Also, unlike the United States where improving electricity grids is initiated on a regional level, China's enormous state-owned transmission companies and streamlined regulatory processes facilitate rapid construction without barriers that are characteristic in more developed countries. These factors have made China the largest, most important market for Smart Grid development in the world.

JAPAN

Japan is the world's third largest economy, after the U.S. and China with economic growth over the next 5 years is expected to be about 2%. Japan is also the third largest energy producer in the world generating just under 1 TWh in 2009. However, electricity generation in Japan is projected to only grow at 1.2% a year over the next five years, reaching 1,090 billion KWhs in 2016.

In contrast to the U.S., Japan's investment in electricity infrastructure declined between 1990-2001, due to a decrease in electricity demand, from roughly $40 billion to $20 billion per annum. Japan's "gold-plated" electromechanical grid and transmission infrastructure has far fewer reliability issues than its U.S. counterpart, so Japan's focus has been on enhancing its electricity distribution networks. In 2002 through 2010, Japan began investing large amounts of capital, resulting in advanced capabilities of its transmission infrastructure and power delivery service. In fact, Japan's electric grid is among the most efficient in the world, averaging distribution losses of 4.9% from 2000 to 2010, compared to 6.5% for the U.S.

Now, creating power networks that are more intelligent is a pressing need in Japan. Recently Japan has suffered sporadic blackouts after the powerful earthquake, tsunami and the attendant Fukishimi nuclear accident, which caused meltdowns at a key nuclear power plant. Central Japan, which includes Tokyo, is still facing tight supply without the plant. This 2011 sequence of tragic events has begun to redefine not only Japan's Smart Grid planning, but also the direction of its entire utility industry.

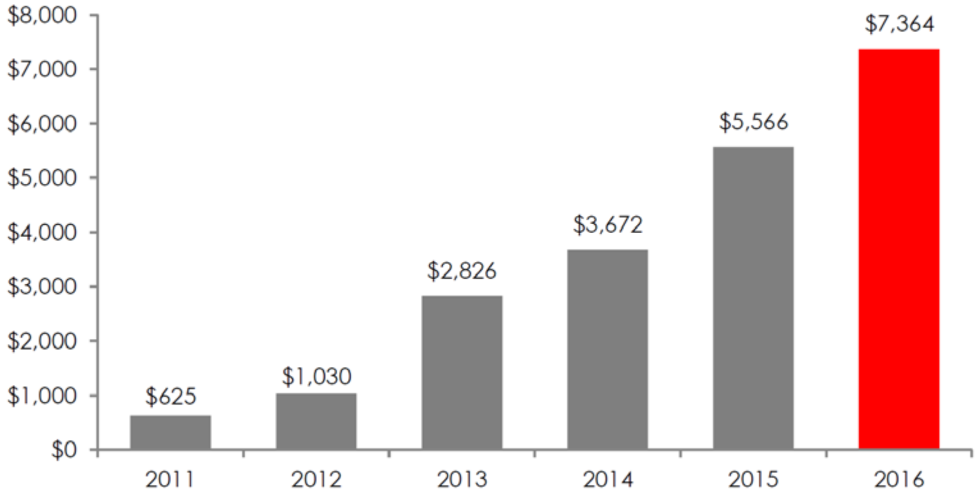


FIGURE 21: JAPAN'S SMART GRID MARKET VALUE FORECAST IN USD MILLIONS [25]

To remain a world leader, the Japanese Smart Grid technology market is projected to reach $7.4 billion USD in 2016, see Figure 20, and to have $1.7 trillion USD invested in its energy sector over the next 18 years. For example, Japan's 2010 strategic energy plan contains the following initiatives on the supply side [25]:

- Build the world's most advanced next-generation interactive grid network as early as possible in the 2020s.
- Consider specific measures to double the electricity wholesale market in three years. These are reflective of the importance the country places on remaining on the cutting-edge.

The following measures are specified on the demand side [25]:

- 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.

With these goals in mind, the Japanese government developed an initial standards roadmap for Smart Grids, several years back. Then, in 2009, the Ministry of Energy, Trade and Industry (METI) announced a massive $1.1 billion Smart Grid technology trial in four cities and towns (Yokohama, Toyota in Aichi Prefecture, Kitakyushu in Fukuoka Prefecture, and Kansai Science City – including parts of Kyoto, Osaka and Nara Prefectures). The trials will include about 5,000 households and 4,000-5,000 plug-in-hybrid electric vehicles.

The New Energy and Industrial Technology Development Organization (NEDO) and METI have launched smart homes, smart city and smart community consortiums and experiments in several target cities in 2010. Some of the best known examples are the Kashiwa Smart City, which includes a new campus at the University of Tokyo, and the Yokohama Smart City Project, in which the city is working in cooperation with five major private companies, including Accenture from the U.S.

Kashiwa-no-ha Smart City

The Kashiwanoha Smart City, located in Chiba Prefecture of Japan about 35km north of Tokyo, is a joint venture founded in September 2009 between Smart City Planning, Inc and Mitsui Fudosan Co., Ltd. The Kashiwanoha Model proposes a solution involving the creation of Kashiwanoha Smart City as an environmentally friendly city. The model is designed to enable creation of a problem-solving city that makes maximum use of nature's power through coexistence with the environment, equipping the city with state-of-the-art technologies, and proposing a new way of life to the community.

An Area Energy Management System (AEMS), shown in Figure 21, will be used to optimize energy operations in the region and maximize their efficiency, providing a platform for Kashiwanoha Smart City to grow alongside development of the entire region. By connecting together various facilities such as homes, offices, commercial buildings, solar panels, and secondary batteries, AEMS systematically allows residents and companies to see their energy consumption, encouraging them to conserve energy. In this way, AEMS would enable energy conservation to be promoted throughout the entire region. In addition to peak-cutoff and peak-shift measures already underway, more advanced and intelligent functions will be added in the future, with the goal of forecasting demand based on energy information analysis and enabling autonomous energy consumption optimization for the entire city.

A number of Energy Creation Measures will be implemented in the project to be incorporated into the AEMS including;

- Solar power generation
- Wind power generation
- Use of geothermal energy (from a hot spring)
- Biogas power generation by the use of organic waste
- Use of waste heat/compound cogeneration systems
- Use of solar heat

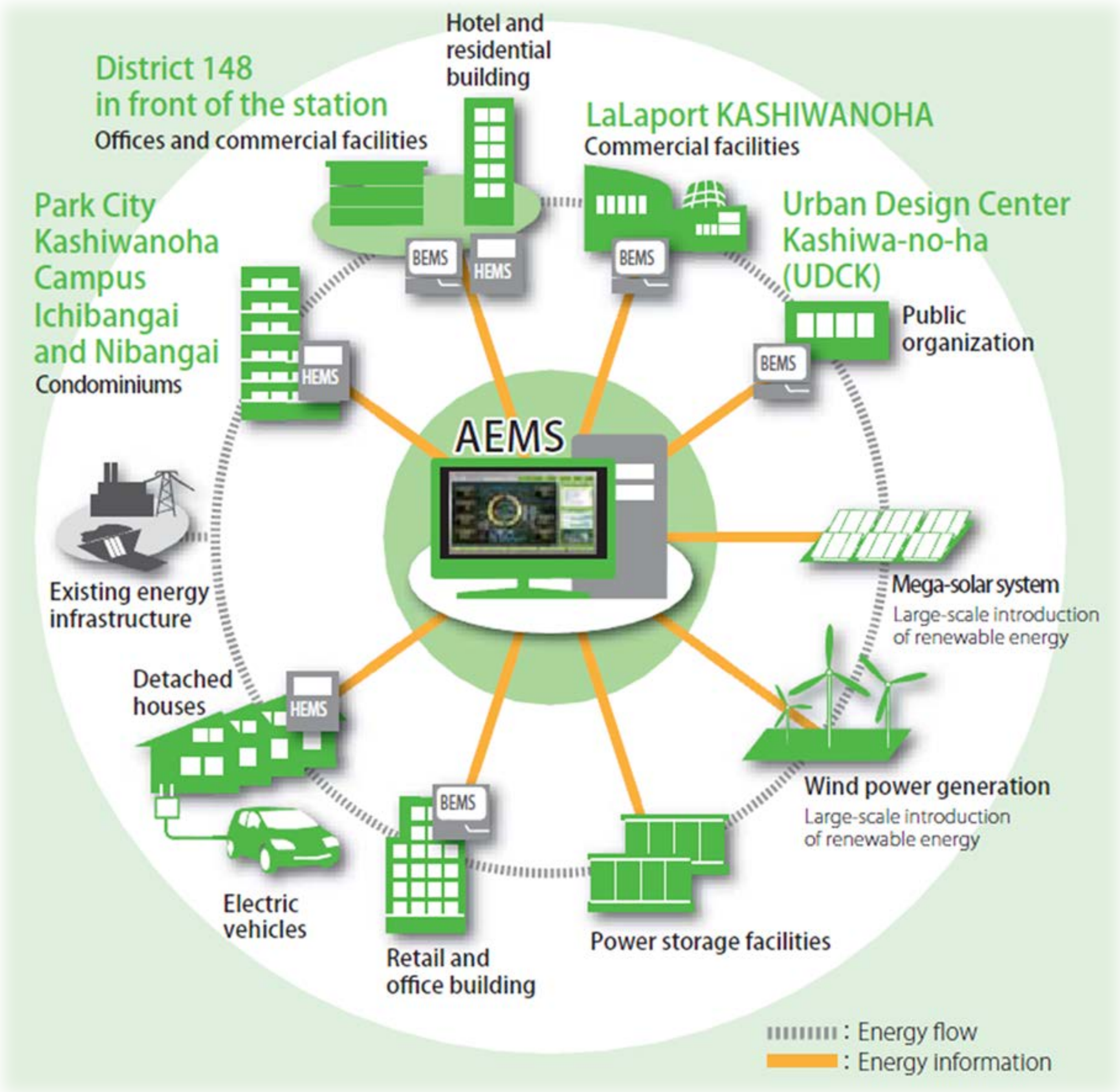


FIGURE 22: DIAGRAM OF THE KASHIWANOHA AEMS [26]

As well as the above energy creation measures, an number od energy saving measures will be implemented including;

- Installation of the CO2 emission reduction navigation system ECO LINCo for the visualization of the household use of power, gas and water
- Introduction of LED lighting and other highly efficient devices
- Task & ambient lighting and air conditioning to reduce power use

Finally the following energy storage measures will also be implemented;

- An electric vehicle sharing system that also functions as a storage battery for the entire community
- A 2,000 kW NAS storage battery that shifts and reduces peak electricity consumption
- Ice thermal storage equipment that reduces peak air-conditioning loads.

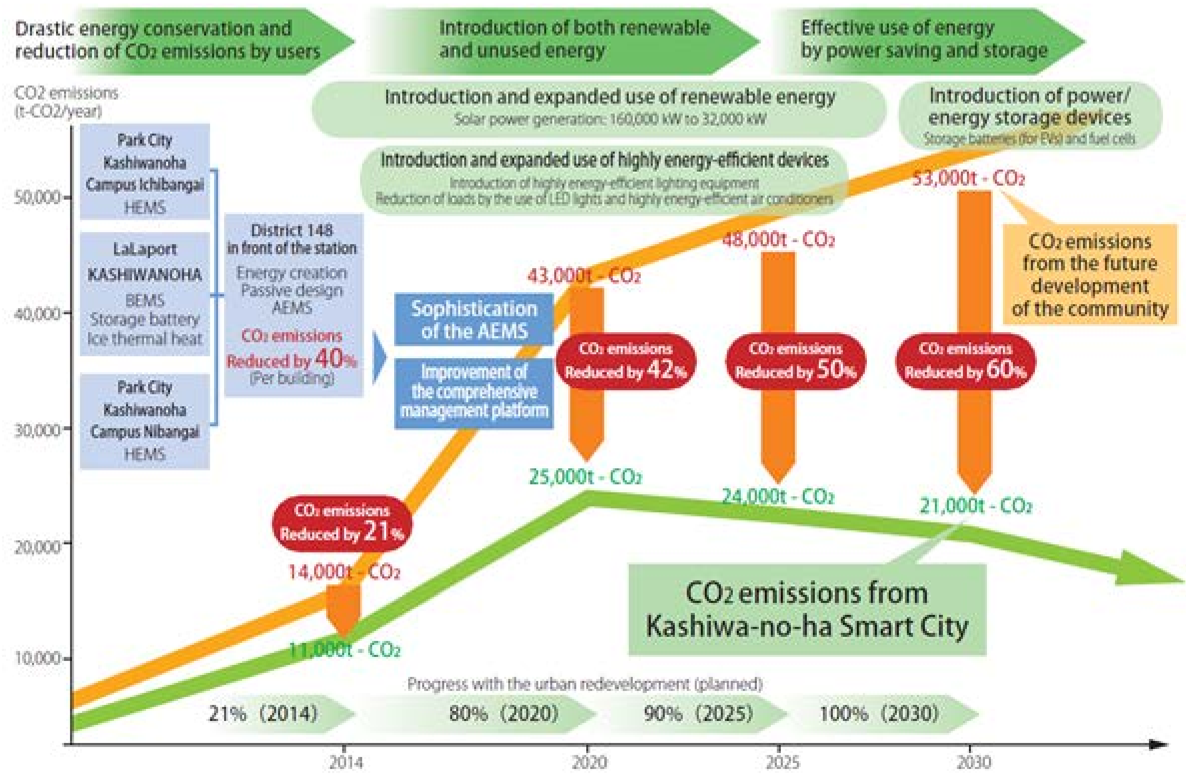


FIGURE 23: LONGTERM ROADMAP FOR CO2 EMISSIONS FOR THE KASHIWA-NO-HA SMART CITY PROJECT[3] [26]

The goal of the Smart City Project is to solve the environmental and energy issues facing the world in the future, as well as other social issues such as maintaining urban functions following disasters, with Kashiwanoha Smart City pioneering these solutions. Figure 22 shows the expected savings of CO2 emissions due the energy saving measures used in the Kashiwanoha Smart City project. The next step is to offer a model of what the world could look like in the future to cities within Japan as well as overseas.

YOKOHAMA SMART CITY PROJECT

In 2009 Yokohama launched a small-scale environmental experiment, encouraging residents to install solar panels on their roofs and buy pricey equipment to track how much energy they use, see Figure 23. Yokohama's goal was simple: to save power and cut carbon emissions in the metropolis. But since the Fukushima nuclear disaster transformed the way the country thinks about energy and power companies, Yokohama's "smart city" project has taken on added importance. What began as a modest environmental plan is now seen as a controversial blueprint for a system in which the monopolistic utilities would lose absolute control of the power grid.

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[3] CO2 emission reductions: Calculated for offices and households (excluding emissions from the industrial sector, transportation sector, etc.)

FIGURE 24: SOLAR POWER PANELS COVER HOUSE ROOFS IN A NEIGHBOURHOOD OF YOKOHAMA

The Yokohama Smart City Project (YSCP) is implemented by a collaboration of the private enterprises and the City of Yokohama and aims for creation of a new urban Japanese-model smart grid system, to significantly reduce CO_2 emissions and to achieve a dramatic introduction of renewable energy. The project has been selected as one of the "*Next-Generation Energy and Social Systems Demonstration Areas*" by METI.

The incentives and targets of YSCP are to introduce large quantities of renewables such as 27MW of PV and solar heating, a Home Energy Management System (HEMS) in 5000 homes, Building Energy Management Systems (BEMS), over 2000 EV with Charge and Discharge stations, district heating projects from factory waste heat and river water heat, and Community Energy Management System (CEMS) in three areas (refer to Figure 24).

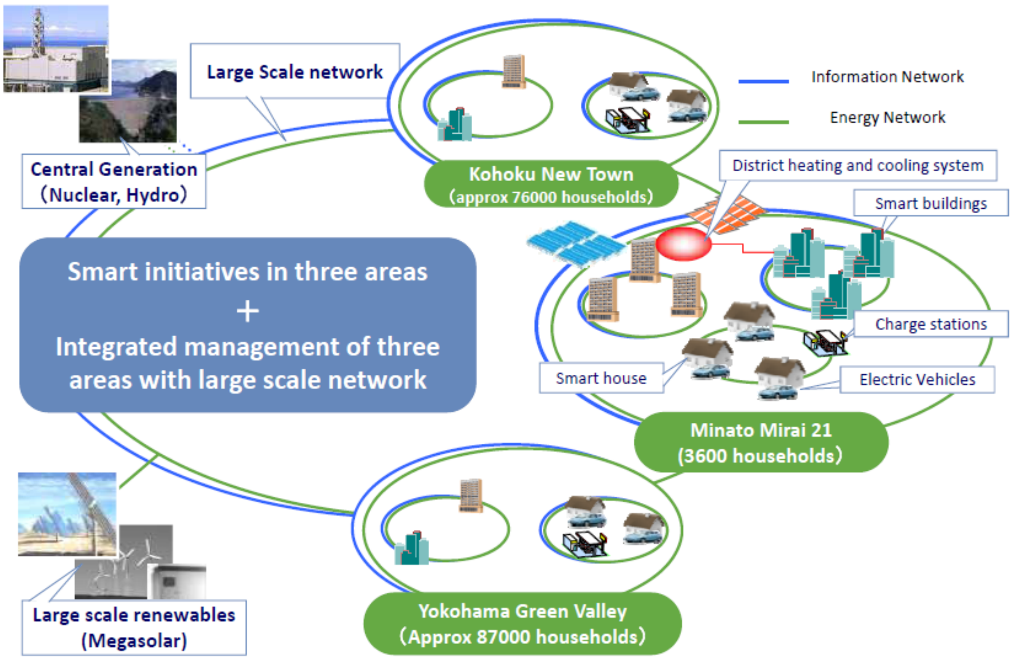

FIGURE 25: OVERVIEW OF THE YOKOHAMA SMART CITY PROJECT

Three major highlights of the YSCP are;

- **Community Energy Management System** Absorbs fluctuation power output from renewables by integrating stationary battery with Home Energy Management Systems and Building Energy Management Systems
- **Energy Management with Charge and Discharge Enabled EV** Increase usage of solar power and lower well to wheel EV CO2 footprint by developing Charge and Discharge enabled EVs that can be leveraged as clean energy storage in the three areas
- **Home Energy Management System** Introduces combined patterns of multiple PV and energy saving equipment to houses and buildings. Examines to minimize the costs by combining with reforming and expansion of efficiency by insulating materials

The goal of the Yokohama Smart City was simple: to save power and cut carbon emissions in the metropolis. But since the Fukushima nuclear disaster transformed the way the country thinks about energy and power companies, Yokohama's Smart City Project has taken on added importance. What began as a modest environmental plan is now seen as a controversial blueprint for a system in which the monopolistic utilities would lose absolute control of the power grid.

Japan partially deregulated its energy industry 16 years ago, but the changes were insignificant and the 10 regional power utilities still control 98 percent of the market, with exclusive rights to supply households and responsibility for generating and transmitting power. They also control the grid itself, which upstarts can access only by paying a tax of 15 to 25 percent on all electricity they distribute.

Facing energy shortages due to idled nuclear reactors, the government this summer encouraged people to cut their consumption by 15 percent. Television monitors in subway cars and shopping malls displayed real-time data about regional energy usage. The central government has stopped well short of proposing changes to the grid, but in the summer it passed a bill designed to encourage the growth of renewable energy. The feed-in-tariff bill, which took effect in July, requires utilities to purchase a certain amount of energy from renewable energy providers.

The Yokohama model represents a more drastic option, turning the electricity companies into bystanders rather than buyers. But the pilot project is still far too small to pose a threat. Municipal officials say that by 2014, 9,000 homes in the city will have solar panels, up from the current 5,000. The panels will be capable of generating a combined 27 megawatts of electricity — one-fortieth of a standard nuclear reactor's capacity [27].

SOUTH KOREA

The South Korean Government has laid out plans to establish a national Smart Grid. In August 2009 the Korea Smart Grid Institute (KSGI) was formed as the secretariat of Smart Grid Initiative and projects in Korea. The mandate of KSGI is to comprehensively manage the government's Smart Grid roadmap; operate a Smart Grid test-bed, pilot city; and extend other policy support for Smart Grid related issues.

State-run electricity monopoly Korea Electric Power Corp (KEPCO) plans to install 500,000 smart meters in 2010, 750,000 in 2011 and complete roll-out by 2020 with a total of 24 million smart meters installed. The company is expected to cover all metering costs and retrieve them through regular power bills [51]. South Korea plans to spend $24 billion USD over the next two decades on Smart Grids to make electricity distribution more efficient, cut greenhouse gas emissions and save $26 billion USD in energy imports. To do this KSGI has developed a Smart Grid roadmap to be implemented in three stages over five sectors by 2030. The roadmap implementation of the five sectors is as follows;

- **Smart Power Grid** - Open power grids will be built to allow various kinds of interconnections between consumption and supply sources. The roll-out of such networks will pave the way for new business models, and the building of a power grid malfunction and automatic recovery system that will ensure a reliable and high quality power supply.
- **Smart Consumer** - It aims to encourage consumers to save energy by using real-time information and producing smart home appliances that operate in response to electric utility rates.
- **Smart Transportation** - It aims to build a nationwide charging infrastructure that will allow electric vehicles to be charged anywhere. It also establishes a V2G (Vehicle to Grid) system where the batteries of electric vehicles are charged during off-peak times while the resale of surplus electricity takes place during peak times.
- **Smart Renewable -** It aims to build a smart renewable energy power generation complex across the nation by rolling out microgrids. This will ultimately lead to the emergence of houses, buildings, and villages which can achieve energy self-sufficiency through the deployment of small-scale renewable energy generation units in every end-user premise.
- **Smart Electricity Service -** With the launch of a variety of energy-saving electricity rate plans, this service aims to improve consumers' right-to-choose by satisfying their different needs. In addition, it wants to deliver a wide array of added electricity services through the marriage of electricity and ICT, and to put in place real-time electricity trading system for the transactions of electricity and derivatives.

The roadmap is split into three phases. The first phase, "Construction and operation of the Smart Grid Test-bed", is due to be completed in 2012. The second phase, "Expansion into metropolitan areas", is due to be completed in 2020. The third and final stage, "Completion of a nationwide power grid", is due to be completed by 2030. More specific information on each phase for the five sectors is given in Figure 25.

Implementation Directions by Phase	First Stage (2010~2012) 'Construction and operation of the Smart Grid Test-bed' (Technical validation)	Second Stage (2012~2020) 'Expansion into metropolitan areas' (Intelligent consumers)	Third Stage (2021~2030) 'Completion of a nationwide power grid' (Intelligent power grid)
Smart Power Grid	- Real-time power grid monitoring - Digital power transmission - Operate optimal distribution system	- Predict possible failures in power grids - Connect the power system with that 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 Consumer	- Power management of intelligent homes - Various choices for consumers including rates	- Smart power management of buildings/factories - Encourage consumers' power production	- Zero energy homes/buildings
Smart Transportation	- Build & test electric vehicle charging facilities - Operate electric vehicles as a pilot project	- Expand electric vehicle charging facilities across the nation - Effective maintenance and management of electric vehicles	- Make the presence of charging facilities commonly available - Diversify charging methods - Utilize portable power storage devices
Smart Renewable	- Operate microgrids by connecting distributed generation, power storage devices and electric vehicles - Expanded utilization of power storage devices and distributed generation	- Optimal operation of the power system with microgrids - Expand the application of power storage devices	- Make renewable energy universally available
Smart Electricity Service	- Consumers' choice of electricity rates - Consumers' selling of renewable energy	- Promote transactions of electrical power derivatives - Implement real-time pricing system nationwide - Emergence of voluntary market participants	- Promote various types of electrical power transactions - Promote convergence for the market of electricity-based sectors - Lead the power market in Northeast Asia

FIGURE 26: THE THREE STAGES OF THE SMART GRID ROADMAP FOR SOUTH KOREA [28]

JEJU SMART GRID TEST-BED

The first phase in Korea's Smart Grid roadmap is the construction of a Smart Grid Test-bed on Jeju Island. The Korean government selected Jeju, in June 2009, as the Smart Grid Test-bed, and broke ground in August 2009. This project demonstrates Korea's aspiration for a low carbon, green growth strategy. The Jeju Smart Grid Test-bed will become the world's largest Smart Grid community that allows the testing of the most advanced Smart Grid technologies and R&D results, as well as the development of business models. This Test-bed will also serve as the foundation for the commercialization and industrial export of Smart Grid technologies.

The project is conducted with the participation of the Korean government, KSGI, KEPCO, the Jeju Special Autonomous Province, companies joining the complex, Korea Smart Grid Association, research institutes, and academia. A total of $240 million USD will be injected between 2009 and 2013 with $171 million coming from industry. About 10 consortiums in five areas will participate in testing technologies and developing business models.

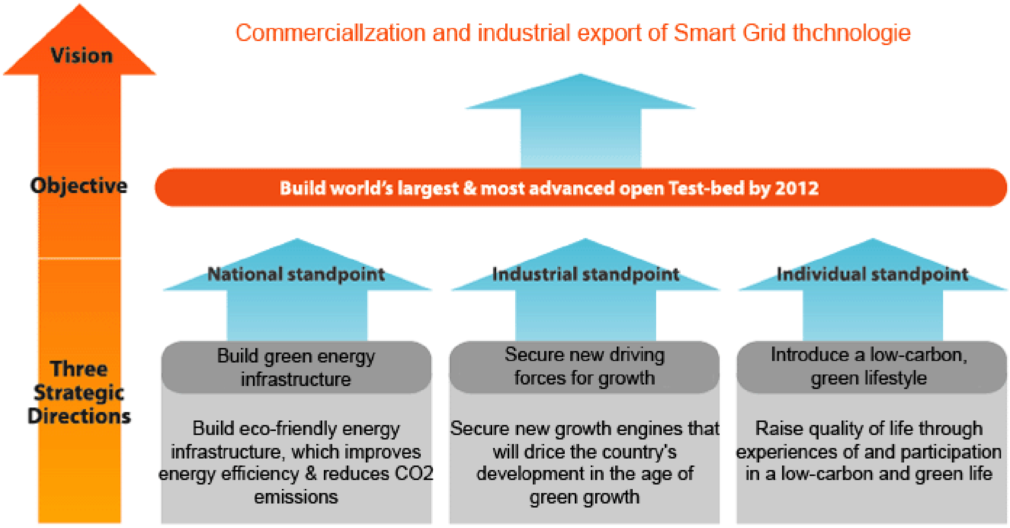

FIGURE 27: JEJU TEST-BED VISION [28]

As can be seen in Figure 26, From the **national standpoint**, this project aims to raise energy efficiency and implement green-energy infrastructure by building eco-friendly infrastructure that reduces CO_2 emissions. From the **industrial standpoint**, this project seeks to secure a new growth engine that will drive Korea in the age of green growth. And from an **individual standpoint**, this project is headed for low carbon and green life by enhancing quality of life through experiences of and participation in a low carbon, green life.

The Smart Grid test bed in Jeju is not a single facility. It is composed of five main showrooms and test facilities, owned and run by LG, GS Caltex, SK, POSCO and KEPCO and includes a fully-functioning total operating centre (TOC). The show-rooms and test facilities are scattered along the Northeastern corridor of Jeju Island.

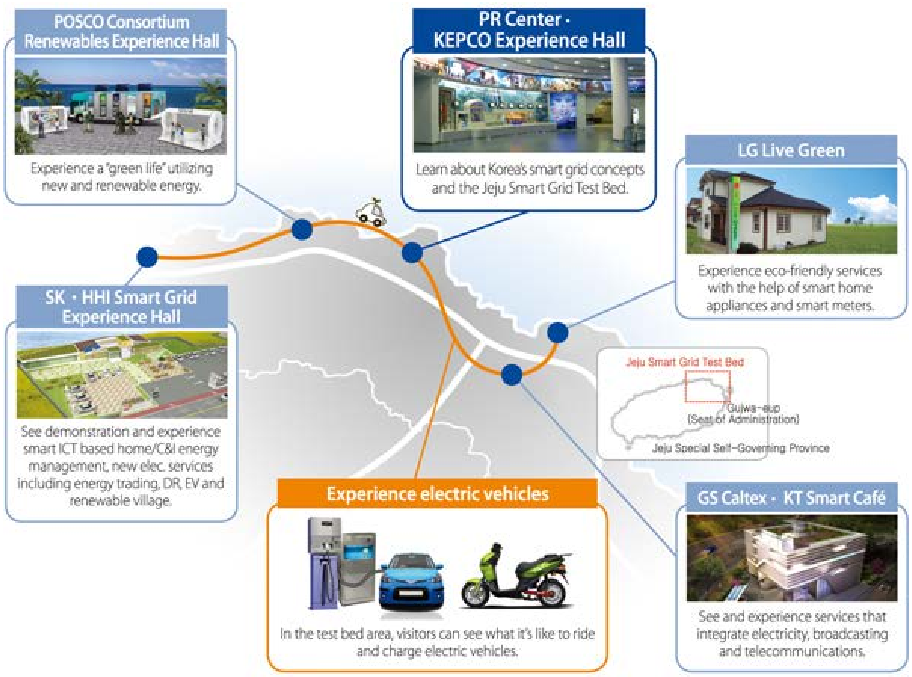

FIGURE 28: THE JEJU SMART GRID TEST-BED

10 Power IT Projects

Power IT refers to a technology that enables electric power devices and systems to become digital, environmentally-friendly, and intelligent through the convergence of electric power technology and information and communication technology (ICT). It also creates high added value for electric power services. The Power IT National Program aims to develop Power IT into a driving force behind the nation's economic growth by advancing the Korean electric power and electrical industries. The program also seeks to bring innovation and higher added value to electric power services. To achieve these goals, Korea embarked on a strategic technology development program in 2005 and selected 10 projects, which have since been systematically implemented. In Feb. 2009, the implementation of these projects was connected with the Smart Grid Initiative, a core element of Seoul's Green Growth Strategy [29].

The Power IT Program is expected to develop the electric power and electrical industries. Thus, once these 10 projects are completed, these two industries will play a critical role in propelling national economic growth and delivering innovative and high value-added electric power services. The 10 IT power projects are: [29].

- **Development of Korean Energy Management System -** This project is designed to develop integrated IT solutions for the operation of electric power systems, and to merge these systems for the purpose of localizing and commercializing the energy management system. The completion of this project will allow Korea to secure the technology needed to establish the energy management system, a central part of the infrastructure of the power system's operation. Korea will also be able to break away from its heavy dependence on Power IT source technologies of foreign countries, and raise the global competitiveness of the Korean Power IT industry.
    - *Organizers:* Korea Power Exchange (KPX), Korea Electric Power Data Network (KDN), Korea Electrotechnology Research Institute (KERI), LS Industrial Systems
    - *Participants:* Bitek Information & Communication, Two A System, IYC&C, Korea Electric Power Research Institute (KEPRI), Power21
- **Development of Intelligent Transmission Network Monitoring and Operation System -** This project seeks to use IT to maximize the full potential of power transmission facilities. In preparation for power system malfunctions or natural disasters, it also focuses on improving the efficiency of the power network by building a risk management system which uses satellite networks.
    - *Organizers:* Korea Electrotechnology Research Institute (KERI), Korea Electric Power Research Institute (KEPRI)
    - *Participants:* Korea Electric Power Data Network (KDN), Vitzro Sys, Taegwang E&C, Korea Power Exchange (KPX), Korea Midland Power (KOMIPO), Korea Sothern Power (KOSPO), Procom System, PSKEY Systems

- **IT Based Control System for Bulk Power Transmission -** The purpose of this project is to develop an Optimal Flexible Alternating Current Transmission System (FACTS) by developing IT-based 100MVA STATCOM with local technology and incorporating it into the power system. Korea also seeks to enhance its competitive position in attaining technology for cross-border power system interconnections through 20MVA BTB STATCOM.
    - *Organizer:* Korea Electric Power Research Institute (KEPRI)
    - *Participant:* Hyosung Heavy Industries
- **Development of Prototype for Advanced Substation Automation System based on the Digital Control Technology -** This project aims to develop integrated IT solutions for the operation of digital substations, and integrate electric power devices and systems. This ultimately will lead to the construction of digital substation automation systems combined with individual Intelligent Electronic Devices (IED).
    - **Organizers:** Korea Electric Power Research Institute (KEPRI), Korea Electric Power Data Network (KDN)
    - **Participants:** LS Industrial Systems, Hyosung, Hyundai Heavy Industries, Vitzro Tech, NeoOffice, Sanion, A-Zero Solution, Yousung Instruments & Electric, CR System, Songam Syscom, Taegwang E&C, Hankook IED, ITNade, Vitzro Sys
- **The Development of Power Equipment Monitoring System using Active Telemetrics -** There are three main objectives for this particular project. First, is to build an active telemetric system for remote monitoring and diagnosis of power systems. Second is to develop measuring technology and sensor equipment to comprehensively monitor the condition of power facilities; and finally, to develop communication technology that transmits information on monitoring and diagnostic results to a Regional Control Center (RCC) and National Control Center (NCC).
    - *Organizers:* Korea Electric Power Data Network (KDN), Hyundai Heavy Industries
    - *Participants:* Korea Electrical Safety Corporation (KESCO), Zenith Tech, Sanion, SML Electronics, Nexmore Systems, Hyosung, Taekwang E&C, NIDS, Neo Telecom, PSD Tech, KDNet, KMData, Bitswiz, Hyundai Heavy Industries
- **Development of Intelligent Distribution Management System** This project pursues the goal of developing an intelligent distribution system equipped with remote monitoring and control and a facility management function over all electric facilities ranging from substations to those on the premises of customers.
    - *Organizers:* Korea Electric Power Research Institute (KEPRI), Korea Electric Power Data Network (KDN)
    - *Participants*: AnyGate, P&C Tech, KDT Systems, Sanion, Shin Sung Industrial Electric, Kwang Myung Electric Engineering, Entec Electric & Electronic, Vitzro Tech, PSD Tech, Kukje Electric, Hanbit EDS, LS Industrial Systems

- **Development of Power Line Communication (PLC) Ubiquitous Technology -** This project aspires to roll out an integrated broadband network suited for electric power facilities, and to develop application technology. The expected effects of this project are as follows: enhanced technological competitiveness of Korea's heavy electric manufacturers; new export markets; a first mover's advantage in the standardization of PLC and intelligent power facility technologies; prevention of facility operation failures and provision of high-quality power services through smart and digital power facilities; and reductions in the cost of building and leasing communication facilities by harnessing the electric power infrastructure.
    - *Organizers:* Korea Electric Power Research Institute (KEPRI), Korea Electrotechnology Research Institute (KERI)
    - *Participants:* Korea Electric Power Data Network (KDN), Intercon Systems, Xeline, Iljin Electric, Media Devices, Mun Tech, Shin Sung Industrial Electric, ADT, Planet INT, KNHC
- **Power Semiconductor for Dispersed Generation and Industrial Inverter Application -** This project is to design and manufacture an Insulated Gate Bipolar Transistor (IGBT), a power semiconductor module, for its application to devices that switch renewable energy to electric sources as well as in industrial inverters used at home and industrial sites.
    - *Organizers:* Consortium of Semiconductor Advanced Research (COSAR), Fairchild Semiconductor, LS Industrial Systems
    - *Participants:* Hex Power System, Intech-faa
- **Development of integration EMS for the microgrid and application technology to real site -** In a bid to develop micro-technology that enables a future-oriented power energy supply, this project aims to develop modulated and standardized component devices such as the Power Converter System (PCS), Sub-cycle Transfer Switch (STS), Intelligent Electronic Device (IED), and Power Quality Control Center (PQCC). It also develops the design, interpretation tools, and EMS of microgrids. A Test-bed will be built to conduct performance evaluation and standardization. By doing so, Korea seeks to develop a practical and commercial microgrid technology through the convergence of renewable energy technology, distributed generation technology, electric power technology, and ICT.
    - *Organizers:* Korea Electrical Industry Technology Research Association
    - *Participants:* LS industrial systems, Korea Electric Power Research Institute (KEPRI), Korea Electrotechnology Research Institute (KERI)

- **Consumer Portal System for ITBased Energy Services Business -** The purpose of this project is to develop and realize a consumer portal system that will be the multi-service platform for the convergence of electric power technology and ICT. Doing so will allow large consumers to optimize the operation of electric resources and pursue diverse profitable businesses. The completion of this project will entail the building of a converged power infrastructure of electric power and communications, the innovation of an energy value chain and electric power service paradigm, and the facilitation of the energy supply structure.
  - *Organizers:* Kyungwon University, LS Industrial Systems, KD Power, Korea Electric Power Research Institute (KEPRI)
  - *Participants:* KESCO, Korea Society of Innovation (KSOI), Samsung C&T Corporation, Iljin Electric, Daesung (Daegu City Gas), JungBu CityGas, Korea National Housing Corporation (KNHC), Voceweb, KDT Systems, Acogito, Sanion, Wise Tech, KDN, Nao Digital

INDIA

According to the Ministry of Power (MoP), India's transmission and distribution losses are among the highest in the world, averaging 26% of total electricity production, with some States as high as 62%. When nontechnical losses such as energy theft are included in the total, average losses are as high as 50%. The need to decrease losses and energy theft, together with the new trend towards increasing energy efficiency and the share of renewables in electricity generation, are all important drivers for the development of a smarter grid [30].

FIGURE 29: AN EXAMPLE OF THE LV NETWORK CONDITIONS IN INDIA

INDIA SMART GRID TASK FORCE

In 2010 the government of India formed the India Smart Grid Task Force (ISGTF). This is an Inter-Ministerial Group and will serve as Government's focal point for activities related to smart grid and to evolve the road map for implementation of smart grids in India. Members of ISGTF have been selected from concerned Ministries, Home, Defence, Communications & IT, New and Renewable Energy, Environment and Forest and Finance, and organizations Planning Commission, Department of Science and Technology, Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA), Central Power Research Institute (CPRI), Bureau of Energy Efficiency (BEE), NTPC, PGCIL, BIS, Power Finance Corporation Ltd. (PFC) & REC.

The main functions of the ISGTF is to ensure awareness, co-ordination and integration of the diverse activities related to Smart Grid technologies, practices and services for Smart Grid Research and Development; Co-ordinate and integrate other relevant inter-governmental activities, Collaborate on interoperability frame work, Review and validate the recommendations from Smart Grid Forum. Five Working groups have been constituted to take up the different tasks related to Smart Grid activities. These Working groups are;

- WG1 – Trials/Pilot on new technologies.
- WG2 – Loss reduction and theft, data gathering and analysis.
- WG3 – Power to rural areas and reliability & quality of power to urban areas.
- WG4 – Dist Generation & renewable.
- WG5 – Physical cyber security, Standards and Spectrum.

In addition to ISGTF, the India Smart Grid Forum (ISGF) has been launched in 2010. It is a non-profit voluntary consortium of public and private stakeholders, research institutes and selected utilities with the prime objective of accelerating development of Smart Grid technologies in India Power Sector. The goal of the Forum is to help the Indian power sector to deploy Smart Grid technologies in an efficient, cost-effective, innovative and scalable manner by bringing together all the key stakeholders and enabling technologies. The ISGF will coordinate and cooperate with relevant global and Indian bodies to leverage global experience and standards where ever available or helpful, and will highlight any gaps in the same from an Indian perspective.

As of April 2012, the ISGF has 59 member organisations. This comprises of the six founding members, MoP, CEA, CERC, CPRI, BEE, and PFC, six Utilities and 47 industry members including companies such as ABB, Areva T & D, CISCO, GE Energy, HP, Hitachi, IBM, Microsoft, Schneider Electric, and Siemens to name a few.

Under the Smart Grid Forum, the following Eight Working Groups have been formed [31];

- **WG1 - Advanced Transmission**
  Objectives: Study and analyze the critical issues related to Indian transmission systems and recommend appropriate system enhancements/upgradations and technologies and standards, by creating a suitable platform within the ecosystem for the sustainable success of Smart grid deployment in India.
  Scope:
    - Reduction of transmission losses at state level (many STUs have technical losses in excess of 3-5%; the target should be about half).
    - Efficiency improvement: technical and behavioural
    - Better coordination between transmission and distribution
    - Improvement in system availability, grid discipline
    - Transmission needs for enhanced renewables
    - Planning for advanced transmission systems, e.g., FACTS, and WAMS (with PMUs)
    - Transparent and improved models for transmission pricing, which capture marginal costs and incentives (e.g., LMP) and ancillary services
    - Introduction of advanced tecnologies such as Robotics and use of helicopters for both commissioning and operations, including live line insulator cleaning, and thermo-scanning.
    - AMI at transmission levels to enable same day settlement at power exchanges
    - Introduction of day-ahead and hour-ahead trading
    - Trials on high temperature super conductivity (HTS) systems.
    - Techno-economic feasibility studies for conversion and modernization of EHV (400/220/132/110 kV) sub-stations in urban areas with GIS, unlocking the value of the real-estate.
- **WG2 - Advanced Distribution**
  Objectives: WG2 would identify and develop standards specifications for smart grids (advanced distribution) in India, encompassing measures to reduce losses, achieve interoperability, reliability and security in the distribution grids. The standards would be based on existing and/or emerging standards from organizations such as IEC, IEEE, NIST, CIGRE or others. Within these, WG2 would select suitable and relevant standards for India pertaining to advanced distribution and provide a guide (manual) on their adoption.
  Scope: The major focus areas of WG2 are
    - Advanced Distribution Operations
    - Integration with R-APDRP systems
    - Advanced Asset Management
    - Self Healing Networks
    - Integration of Distributed Energy Resources

  The WG would identify standards, use cases and provide mentoring support to the utilities in the above areas.

- **WG3 – Communications**
  Objectives: To study and recommend most suitable, sustainable and scalable communication technologies that can be adopted in India for all building blocks of smart grid in a continuum fashion. The WG focuses on analysing various communication technologies with due consideration to the total cost of ownership (TCO) in the Indian context.
  Scope:
    - **Facilitation** - By conducting on ground assessment of varied communication technologies and options in the Indian context to suggest the optimal choices for the success of the envisaged SG projects
    - **Benchmarking** - Study, analyze and recommend global technologies and their feasibility in the Indian context, and identify gaps that necessitate solution updating/adaptations or even new solutions.
    - Best practice creation and recommendation
    - **Ecosystem Management** - Coordination with other WGs, policy advocacy groups and awareness building for the best technological aspects in the relevant arena
- **WG4 – Metering**
  Objective: The WG4 aims to asses the metering scenario in India, identify the goals and requirements. The WG4 can also focus on available technologies and best practices as well as identifying gaps in existing solutions from an Indian perspective. It is worth mentioning that for R-APDRP metering applications the IEC 62056 (DLMS/COSEM) is chosen as the standard metering protocol. CPRI has the test facility for carrying out conformance test for this protocol standard. The WG4 can extend the additional design and standards requirements.
  Scope:
    - Study of country wide metering and billing practices
    - Birds eye view of AMR projects:
        - Merits & Demerits
        - Understanding of current technology
    - Regulatory provisions and Electricity act (EA)
    - Requirements for AMI infrastructures:
        - Smart meters, with differentiation as required
            - Low-cost for single-phase consumers
            - DR ready for 3-phase consumers.
        - Communications technology, including specific needs such as spectrum
        - Information requirements
        - Interface requirements
        - Throughput sizing
        - Meter Data Management Systems (MDMS)
    - Standardisation needs:
        - Meters
        - Interoperability standards and options
        - Accessories

        - Tamper simulation methodology
        - Testing needs
    - New metering philosophies :
        - KVAH metering
        - Interoperability standards and options
        - Cluster meters
        - Load Limiters
    - R&D needs:
        - TestBed(s)
- **WG5 - Consumption and Load Control**
  *Objective:*WG-5 would recommend technologies and solutions which can be adopted in India for load control and consumption to enable peak load management and overall energy management.
  Scope:
    - To recommend technologies (appliances, storage, electric vehicles etc) and regulatory/policy options viable in Indian conditions with a focus on demand side management, demand response management and TOU/variable pricing as key processes for peak load shaving and energy efficiency.
    - To focus on energy controlling and measurement systems and devices with an objective of understanding real time energy consumption information leading to smarter energy consumption with a focus on sectors such as Industries, Commercial buildings (including data centres), Infrastructure and residential sector.
    - To coordinatee with key institutions/groups like BIS, IEC, IEEE, BEE, BIS, state designated agencies and Utilities etc. to adopt appropriate standards for DR in India.
    - To work with BEE to formulate standards for appliances that are Smart Grid ready
- **WG6 - Policy and Regulations**
  Objectives: To identify and recommend appropriate regulatory policy initiatives to the Government, both central and state, and to suggest regulations to facilitate implementation of smart grid through inter-state regulations of CERC and facilitate implementation of smart grid through SERCs and the intra-state system through the forum of regulators (FoR), by demonstrating or otherwise conveying feasible and sustainable business cases and societal level cost-benefit analyses.
  Scope:
    - Suggest Innovative business and operating models in smart grids and overall, through discussion by engaging and considering perspective of all the stake holders
    - Identify, the parameters of smart grid implementation, such as, economy, design and technology options, reliability, quality , pay-back period
    - Special regulatory enablement of smart grid: Feed-in-tariff for renewables by generators including from individuals, technical requirements for connectivity,

network planning, making regulations for integration of renewables into the grid from the point of view of system operation, differential tariff for reliable supply (retail and bulk), transmission pricing models including LMP, pricing models for ancillary services, more granular and updated rate cases.
    - Policies for advanced metering infrastructure (AMI) and demand response (DR), including virtual power plants (VPPs)
- **WG7- Architecture and Design**
  Objective: The primary objective of WG7 is to define the architecture and design standards (or guidelines) to support smart grid applications and evolution. While there are other WGs under ISGF to cover aspects like advanced transmission, distribution, load control, metering, communication etc., the WG7 shall lay the technical and functional guidelines to support smart grid applications keeping in view factors like interoperability, scalability, security and, more importantly, the Indian power sector centric requirements.
  Scope:
    - Identify and define smart grid layered architecture specific to Indian power sector, and the applications involved within (conceptual architecture, system architecture, communication architecture and application architecture). The smart grid architecture shall consider the on-going implementations of IT and OT systems under R-APDRP program
    - Define the smart grid conceptual architecture, which consists of :
        - Application integration architecture: this shall include the data attributes which need to be exposed by individual systems of a smart grid, different interface types to be supported by smart grid applications (web services, XML etc.), integration interfaces with and without use of middleware technologies, interfaces considering integration with utility's legacy applications, interoperability standards to be supported by smart grid applications (e.g. IEC 61969, IEC 61400, IEC 61970, IEEE C37.118 etc.), harmonization of standards. Interoperability standards shall take into account Adaptive data infrastructure (to give room to evolution of data exchange models)
        - Architecture and design shall consider incorporation of innovative information technologies (IT) such as cloud computing - Public or Private, Internet of Things etc and also consider ease of user interface design which will help adoption of IT/smart grid systems by Indian Utilities and enable faster capacity building of Utility operators and officials
        - Communication architecture: WG7 shall work in close co-ordination with WG3 to develop the communications network architecture, which shall cover different communication network technologies needed to support smart grid applications

        - Functional architecture (technical architecture mapped with business requirements and operational improvement related expectations from smart grid)
        - Security architecture: WG7 shall work in close co-ordination with WG10 (Security) to develop a security architectur, which covers the security related aspects to be considered within smart grid applications as well as inter application integration. The security architecture shall also be covering communication network security, data security and application security related aspects.
    - Identify focus areas for and define use cases for each smart grid application.
    - Identify and define test cases for inter smart grid application integration: These test cases shall include select scenarios of a smart grid demonstrated based on architectural standards and guidelines laid out by WG7. These scenarios shall showcase the capabilities of smart grid applications corresponding to the specified scenarios and shall also cover select business processes which need inter application integration. The test cases shall demonstrate use of common language/interoperability standards to exchange information with distributed resources from various OEMs
    - Stakeholder information needs and regulatory policies are expected to evolve in future in parallel with adoption and evolution of affordable and appropriate SG technologies. WG7 would identify collaboration, communication, flexibility, portability, and extendibility and boundaries of the SG architectures to allow these changes
    - Adoption of disruptive innovations in power technologies / policies / environment (example: power delivery mechanisms like storage batteries, WAMS, bulk energy storage, heavy prosumers; green technologies like carbon sequestration, distributed bulk renewable, electric vehicles, etc.) may result in newer / radically different IS/IT needs. These cannot be anticipated / predicted with certainty as on date. WG7 will project the currently visible evolutions which are in this segment and endeavor to define Architecture needs for these.
    - Technology adoption roadmap for utilities, including plotting on SG maturity levels and covering technology lifecycle management.
    - Attempt to balance the architecture needs from perspectives of interoperability versus design/purchase freedom and stability versus innovation
    - Architecture governance mechanism
- **WG8 - Smart Grid Business Model**
  Objective: The primary objectives of WG8 are:
    - Observe and study the list of smart grid technology pilots that will be undertaken in India and recommend the most appropriate options and models for the distribution companies, including recommendations on appropriate timeframe for investments
    - To evaluate different business models for different technology pilots and recommend the most appropriate model(s).

- To identify metrics for respective pilots and assist in their validation/monitoring.
- Examine end-to-end planning and models, with a focus on capacity building for the success of projects and programs; identify any gaps in capacity building with recommendations to overcome these.
- Based on the above, facilitate the evolution of appropriate business models for achieving goals of smart grids.

Scope:

- Study various smart grid pilot initiatives across the globe (developed as well as emerging economies) and list out the ones that are most relevant to Indian context.
- Review the draft RFP circulated by ISGTF and come up with additional points / ideas on smart grid pilot initiatives
- Prioritize the smart grid initiatives that give best returns / benefits for all stakeholders (utilities, consumers and solution providers)
- Study various business models for different smart grid pilot initiatives, which shall include:
  - funding and benefits sharing options
  - comparison of various models (pros and cons)
  - recommendation of the most appropriate business model for each smart grid pilot initiative
- Examine human and other resource capacity requirements for successful pilot and broader deployments.
- Work with other ISGF WGs wherever necessary, for understanding the costs involved and technology details of executing pilots
- Work with consumers/consumer forums and other stakeholders to articulate SG benefits
- Work for assessing and developing training and capacity building initiatives for smart grids.

Re-structured Accelerated Power Development and Reform Programme

The Accelerated Power Development and Reform Programme (APDRP) was first contemplated by the Government of India during the year 2002-2003. The main objectives of the APDRP scheme is to improve the financial viability of the state power utilities/boards, reduce Transmission and Distribution (T&D) losses, improve reliability, quality and availability of power supply, introduce systems approach with MIS. The APDRP also aims at bringing transparency in operations of the power utilities through IT implementation and thereby improve consumer satisfaction.

The scheme was further modified during the XI Plan as "Re-structured Accelerated Power Development and Reform Programme (R-APDRP)" with the aim of restoring the commercial viability of the distribution sector by putting in place appropriate mechanism so as to substantially reduce the Aggregate Technical and Commercial (AT&C) losses. In the first instance, the R-APDRP seeks to address the issue of building the baseline data including meter data acquisition. After ascertaining the AT&C losses, the issue of power system upgradation and modernisation is taken up.

The focus of the programme is on actual, demonstrable performance in terms of sustained loss reduction. Establishment of reliable and automated systems for sustained collection of accurate base line data and adoption of IT in the areas of energy accounting are necessary preconditions for the sanction of projects. The programme will cover all urban areas, cities and towns with a population of more than 30,000 (10,000 in case of special category states)

The projects under the programme will be executed in two parts as below:

Part-A: Preparation of Base-Line 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 SCADA/DMS system (only in the project area having more than 400,000 population and annual input energy of the order of 350 Million Units). It would include Asset Mapping of the entire distribution network at and below the 11 KV Transformers and include the distribution transformers and feeders, L.T lines, poles and other distribution Network equipment. It will also include adoption of Information Technology application for meter reading, billing and collection; energy accounting and auditing; MIS; redressal of consumer grievances, establishment of Information Technology enabled consumer service centres etc. The base line data and required system shall be verified by an independent agency appointed by Ministry of Power.

Part-B: Renovation, Modernization and strengthening of 11 KV level Sub-Stations, Transformers/Transformer centres, Re-conductoring of lines at 11 KV level and below, load bifurcation, feeder separation, load balancing, HVDS (11KV), Aerial Bunched conductoring in dense areas, replacement of electro-magnetic energy meters with tamper proof electronics meters, installation of capacitor banks and mobile service centers etc. In exceptional cases, where Sub-Transmission system is weak, strengthening at 33 KV or 66 KV levels may also be considered.

For projects undertaken under Part-A, 100% funding will be provided for the approved projects through loan from the Government of India. The loan shall be converted into grant once the establishment of the required system is completed within three years from the date of sanctioning and verified by an independent agency. For projects sanctioned under Part-B, conversion of the loan into grant will take place yearly based on the AT&C losses of the project area duly verified by the Independent agency appointed by the Ministry of Power.

In addition to R-APDRP, India is beginning to partake in a number of Smart Grid projects including smart meter roll outs for Puducherry [32] and Bangalore [33]. This is part of the ISGTF recommendation that the Smart Grid Project be implemented on a pilot basis in eight cities in the country of which Puducherry and Bangalore are the first. The cost for each city is around 13 million USD.

The Puducherry project primarily involves the installation of advance metering infrastructure in sync with a Central Data Control Centre. This enables the customers to ascertain the exact billing amount at any point of time and accordingly manage their power usage. The EB would be able to monitor the customers' energy usage pattern and detect malpractice or power theft, online.

According to officials, the project, which would cover 87,000 houses in the town, would be completed in four months.

The advance metering will facilitate the online billing of power tariffs and collection of dues. The efficiency in tariff collection (90 per cent at present) could also be improved to 98 per cent. Through this scheme, the EB is expected to generate an inflow to the tune of around 2 million USD per annum, without any investment.

The Bangalore project considered five potential sites for Smart Grid Pilot Studied based on the consumer spread; Domestic, Commercial, Agriculture, Industrial, Public Water works, HT Industrial are the various consumer categories. These sites were Electronic City, EPIP –Whitefield, Peenya Industrial Area, MG and Brigade Road Area, and Rajaji Nagar Industrial Area. Eventually Electronic City, shown in Figure 29 was chosen as the best among the studied sites based on the assessment of consumer participation.

FIGURE 30: THE PILOT AREA FOR THE BANGALORE SMART METER ROLL OUT [34]

Bangalore Electricity Supply Company (BESCOM) is in the process of introducing two types of smart meters, one with pre-paid capabilities and other, the usual post-paid meter. One of the biggest advantages of smart meters compared to the regular static ones is the option of 'prepaid mode of payment', thus, consumers will be able to pay their bills and even post messages through this device. Smart meters can limit consumption and, when used effectively, can put an end to load shedding. Each meter will have the maximum limit automatically and when the load exceeds, the meter will shut down. When the consumer reduces the load, the meter starts running automatically. At present, BESCOM have also access to the geographic information system (GIS) of the consumers. Besides assisting the BESCOM in bringing down its load, these smart meters will also help BESCOM to continue its efforts on bringing the smart grid, which is still in the pre-mature stages [34].

BESCOM is also providing a consumer interface unit (CIU), which can be effectively used by the consumer to monitor each one of the appliances for power consumption. The CIU displays power consumed in real time. If a TV is switched on, you will get to know the additional load. Consumers become conscious of their consumption. A study of IIT Bombay researchers have shown that smart meters can help consumers to reduce their bills by 18 to 22 percent [34].

AUSTRALIA

As in most countries, smart grid policy in Australia is part of a larger energy policy framework. In particular smart grid policy is an integral part of Australia's larger efforts at increasing renewable energy sources in the countries overall energy strategy in order to reduce CO2 emissions. In 2009, the Australian government announced a Mandatory Renewable Energy Target (MRET) of 45,000 MW or 20% of Australia’s electricity supply will come from renewable energy sources by 2020.

Additionally, under the National Framework for Energy Efficiency (NFEE) formulated by the MCE, Australia has established a national strategy for energy efficiency that includes developing energy efficiency standards, educating the public and industry about ways to reduce energy usage, and tackling regulatory hurdles that impede the adoption of smart grid technologies. In conjunction with the above mentioned renewable energy efforts as well as broader initiatives to integrate energy policymaking and regulation amongst Australia’s states and national government, the NFEE is a further platform of support for smart grid policy in Australia.

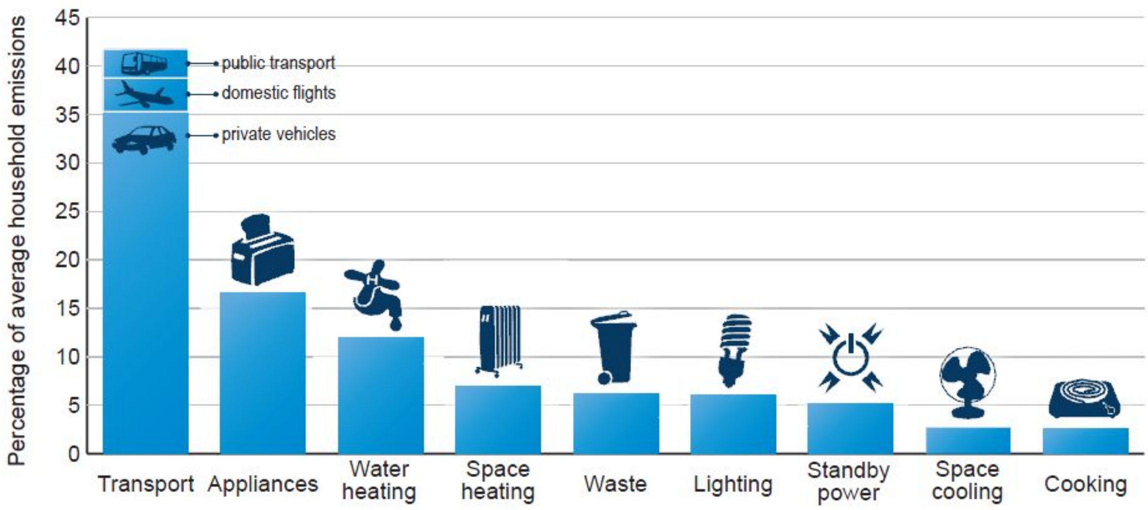

FIGURE 31: AUSTRALIAN HOUSEHOLD EMISSIONS

Photovoltaics in Australia

The Australian government has introduced a number of photovoltaic (PV) support programs as a means to the CO2 targets mentioned above. These support programs impacted significantly on the PV market in 2011. The key programs are described below [35].

The Renewable Energy Target

The 45 000 GWh Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). The RET will be reviewed in 2012 and then every two years.

- **Large-scale Renewable Energy Target** (LRET) - The LRET, covering large-scale renewable energy projects like wind farms, commercial-scale solar and geothermal, will deliver the majority of the 2020 target.
- **Small-scale Renewable Energy Scheme** (SRES) - The SRES covers small generation units (small-scale solar photovoltaic, small wind turbines and micro hydroelectric systems) and solar water heaters, which can create small-scale technology certificates (STCs). The Clean Energy Regulator has established a voluntary 'clearing house' as a central point for the transfer of STCs at $40 AUD, and liable entities are required to surrender STCs four times a year. There is no cap on the number of STCs that can be created. Because of the large numbers of small-scale PV systems that were installed during 2010 and especially during 2011 (due to rapidly decreasing PV prices, the 5X solar credit multiplier (see below) and generous Feed in Tariffs (FITs) in some States), there was a significant oversupply of STCs, with the result that the secondary market price dropped to lower than $20 AUD and the Solar Credit multiplier was therefore reduced faster than planned in 2011.
- **Solar Credits -** Solar Credits work by multiplying the number of renewable energy certificates that these systems would generally be eligible to create under the standard deeming arrangements. They apply to the first 1.5 kilowatts (kW) of capacity for systems connected to a main electricity grid and up to the first 20 kW of capacity for off-grid systems. Output from capacity above 1.5kWp is eligible for only 1 STC per MWh.

Solar Homes and Communities Plan (SHCP)

The SHCP provided upfront rebates for small-scale PV systems, and although the program ended on 9 June 2009, a very large number of pre-approval applications were received in the closing days, and installations under the program occurred through to 2011. A total of 155620 MW of PV had been installed under this program, with only 200 kW installed during 2011. The vast majority of this was for grid-connected installations, with only 4946 MW off-grid installations (none in 2011).

SOLAR CITIES

Solar Cities is an innovative $7 million AUD demonstration programme designed to promote solar power, smart meters, energy conservation and new approaches to electricity pricing to provide a sustainable energy future in urban locations throughout Australia. Adelaide, Alice Springs, Blacktown, Central Victoria and Townsville were nominated to be the first Solar Cities of Australia, in the 2007 election campaign the Labor government committed to expanding the programme to include Coburg and Perth.

Key goals of the program are to demonstrate the possibilities for solar power, smart meters, energy conservation, new approaches to electricity pricing and sustainable living in urban locations. It is a partnership approach that involves all levels of Government, the private sector and the local community. Consumers will be able to purchase solar photovoltaic panels using discounted loans. The project also plans to help low-income and rental households in the community share in the benefits of the project through other cost-saving initiatives.

FIGURE 32: A SMART METER IN-HOME DISPLAY USED IN THE ALICE SPRINGS SOLAR CITY

All seven Solar Cities are entering the final reporting and analysis phase of their projects. The Department of Climate Change and Energy Efficiency is collating energy use data from the various trials and will be publishing the results of that analysis during the next 12 months. One key finding has been the benefit of community engagement campaigns that promote behavioural change. Through this, the financial and environmental benefits derived through the use of renewable energy can be maximised.

Magnetic Island residents have installed over 675kW of solar photovoltaic (PV) across the island and saved more than AUD 900,000 on electricity bills since the Townsville Solar City project began. Consumption levels are now 12 percent below the peak annual usage, having returned to 2007 levels. This means the project has bettered one of its key project aims of deferring the installation of a third undersea cable. Initially due to be installed in six years at the beginning of the project, it has now been deferred until 2017.

Perth Solar City has continued to pursue the installation of residential solar PV as part of their trial. Significantly they have now completed a total of five iconic solar PV projects. These projects have resulted in the installation of 465 kW of solar PV which is realising an estimated AUD 205 000 per year in savings on energy bills for the facility owners.

FIGURE 33: 49KW SOLAR PV INSTALLATION AT THE CENTRAL INSTITUTE OF TECHNOLOGY IN PERTH

Endeavour Energy (formerly Integral Energy) commercialised its Thermoswitch pool timer as part of the Blacktown Solar City project. The pool pump operations trial reduced peak demand by over 20% by using a pool timer that switches off pool pumps early in the morning and/or at night.

Central Victoria Solar City (CVSC) established two 300kW Solar Parks in Bendigo and Ballarat. In 2010/11 the parks produced a total of 450 MWh of accredited GreenPower each year. CVSC is currently developing an offer to transfer ownership of the park to the community at the end of the program in 2013.

In June 2011, the 4^{th} Alice Springs Solar City iconic project, the Uterne (pronounced ‘u-turn-ay’) Solar Power Station, was commissioned. It is the largest tracking solar power station in Australia at just under 1 MW capacity, enough to supply the electricity needs of 288 average Alice Springs homes.

Adelaide Solar City has commissioned 'Tindo', the world's first solar-powered electric bus, ferries passengers around the city each day, and advertises its energy, cost and greenhouse gas savings on a real-time display erected in a prominent position at the central ticket office.

FIGURE 34: UTURNE, THE 1MW TRACKING SOLAR POWER STATION IN ALICE SPRINGS

NATIONAL SOLAR SCHOOLS PROGRAM

The Australian Government's National Solar Schools Program (NSSP) offers eligible primary and secondary schools the opportunity to apply for grants of up to $50000 AUD to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of energy efficiency measures. Funding is capped in each financial year and annual funding rounds are held. Applications are assessed against three criteria – value for money, environmental benefit and educational benefit. Additionally, to allow funding to be directed to schools in most need, applications from schools located in remote or low socio-economic areas receive additional weighting.

Schools across Australia have responded with great enthusiasm to the NSSP. Since the program commenced on 1 July 2008, over 8000 schools have registered their interest to participate. By April 2012, more than $190 million AUD in funding had been awarded by the Australian Government to over 4600 schools for PV and other measures. Several State Governments provide additional funding.

Around 90 per cent of approved schools have chosen to install a PV system with their NSSP funding. In the 2011-12 funding round, 784 schools have shared in over $25 million AUD. Almost 2000 applications were received in the 2011-12 funding round. In 2012 approximately $25 million AUD in funding will be available under the program for the final round, which closed on 4 May 2012. By the end of the program it is expected that approximately 60% of all eligible primary and secondary schools in Australia will have received an NSSP grant.

SOLAR FLAGSHIPS

In May 2009 the Australian Government announced a call for 1 GW of solar generation via 4 solar power stations (solar thermal and PV). The Solar Flagships program is split over two funding rounds with the first round to target 400MW of electricity generation. From the 52 proposals for funding in Round 1 of the program, 2 were selected in June 2011: the 150 MW Moree Solar Farm (PV) and the 250 MW Solar Dawn (solar thermal) projects.

The projects were given until 15 December to meet financial close but were unable to do so. Solar Dawn’s financial close deadline was extended until 30 June 2012. The four shortlisted Round 1 PV applicants (AGL, BP Solar, Infigen-Suntech and TRUenergy) were asked to submit updated applications by 7 February 2012, and all did so. There is no indication yet as to which project will be selected or when construction will begin.

RENEWABLE REMOTE POWER GENERATION PROGRAM (RRPGP)

The RRPGP closed in 2009 but some large-scale projects are completing construction and expect to be finished by the end of 2012. The program provided rebates of up to 50% of the capital cost of renewable energy and related components used for diesel displacement in stand-alone power systems. Typical applications included off-grid households, indigenous communities, community organisations, retail/roadhouses, tourism sites, pastoral stations and other off-grid business and government facilities.

Components eligible for the rebate included renewable generation equipment, inverters, battery banks, enclosures, other supporting equipment and installations costs. For water pumping, only the renewable energy components were eligible (not pumps, pipe, concrete footings etc). Stand-alone power systems varied from 100% renewable to less than 50% renewable, with the diesel generator providing the majority of the load. Some systems included both PV and wind. System upgrades were also funded.

Program achievements include:

- $300 million committed to renewable energy generation in remote and regional areas
- more than 9000 residential and medium-scale projects up to 20 kilowatts in size
- residential and medium-scale projects plus renewable energy water pumps with a total power capacity of more than 10,600 kilowatts of solar, wind and micro-hydro that are estimated to save more than 24 million litres of diesel fuel each year
- 31 major projects with AUD 52 million in funding, saving more than seven million litres of diesel fuel each year as well as other fossil fuels
- installation of more than 170 renewable generation systems for Indigenous communities under the Bushlight scheme (see below), and
- support for industry training, accreditation, inspections, testing and standards development.

Bushlight

Bushlight is an Australian Government-funded national, non-profit project that installs renewable energy systems in remote Indigenous communities (known as homelands) throughout central and northern Australia. Each system installation is preceded by, and carried out in conjunction with, a comprehensive program of community Government. It also receives funding from a range of other sources, including fee-for service work for discrete projects.

In 2011, Bushlight installed 5 new renewable energy systems, with a combined total output of 91.2 kWp of PV. Bushlight upgraded 4 systems with an additional 9.51 kWp. The total installed capacity was 100.71 kWp. Bushlight's Maintenance program provided scheduled servicing and ongoing support to 265 renewable energy systems located in 220 communities.

State and Territory Feed-in Tariffs

A range of State based feed-in tariffs applied across Australia in 2011. Note that these show the status of feed-in tariffs in 2011 and that some States have announced changes for 2012. (all prices are in AUD)

The changes that occurred in 2011 were:

- The Victorian feed-in tariff (called the Premium Feed-in Tariff) closed from 30 Sept 2011 as it had reached its cap. It will be replaced by the Transitional Feed-in Tariff as of 1 Jan 2012, which will guarantee a minimum of $0.25/kWh for systems up to 5kW. Net metering (called the Standard Feed-in Tariff) continued to be available for systems up to 100kW.
- The South Australian Feed-in Tariff was reduced from $0.44/kWh to $0.16/kWh as of 1 Oct 2011 (which is less than the retail tariffs), and eligible systems receive the payment only until 30 Sept 2013. As of 27 Jan 2012, systems will also be eligible to receive what has been called the Premium Feed-in Tariff, which is meant to represent the value of the exported electricity to the retailer. This is set at $0.071/kWh for 2011-12, rising each year to $0.112 by 2013-14, when it will be reviewed.
- In the ACT, systems up to 30 kW were eligible for an $0.457/kWh feed-in tariff until 31 May 2011. Systems from 30 kW up to 200 kW were eligible for a feed-in tariff of $0.3427/kWh from April 2011. It was capped at 15MW. From 12 July 2011, both size categories became eligible for the $0.3427/kWh feed-in tariff, and so the 15MW cap was reached by 13 July 2011 and the scheme was closed for all systems. For systems up to 30kW that are not receiving any feed-in tariff, the electricity retailer ActewAGL provides net metering.
- The New South Wales $0.20/kWh gross feed-in tariff was closed to new applications as of midnight 28 April 2011. After that date new installations may receive payments from retailers that are meant to reflect the value of the exported electricity to the retailer.

- The Western Australian $0.40/kWh net feed-in tariff was reduced to $0.20/kWh from 30 June 2011, then closed to new applications from 1 Aug 2011. System owners are paid between AUD 0,07/kWh and AUD 0,61/kWh (depending on location, retailer and if is residential or commercial) by retailers under the Renewable Energy Buyback Scheme.

NATIONAL SMART METERING PROGRAM

The National Smart Metering Program (NSMP) was established by the Ministerial Council on Energy (MCE) to develop a framework for an efficient, flexible and open-access smart metering infrastructure across the national electricity market (NEM). Since the commencement of the program in mid-2008, the MCE worked extensively with industry stakeholders (including electricity retailers, distribution businesses, metering providers, consumer organisations, market operators and jurisdictions) to deliver the following:

- The Smart Metering Infrastructure (SMI) Minimum Functionality Specification
- Proposed changes to the National Electricity Rules to support a mandated rollout of smart metering
- Draft issue change forms for changes to the NEM Procedures to support the provision of smart metering services
- An evaluation of home area network (HAN) interface standards
- Advice to the MCE in relation to in home displays guidelines and direct load control in priority appliance guidelines
- Pilots and trials status reports for 2008, 2009,2010
- Business, consumer and technology reporting frameworks to support the consistent reporting and sharing of information from pilots and trials
- The smart metering future pilots and trials report
- A national testing framework for the testing of changes to NEM systems to support smart metering services

FIGURE 35: A NEWLY INSTALLED SMART METER IN MELBOURNE

A number of pilots and trial projects were planned as part of NSMP by a variety of Australian utilities including Country Energy, EnergyAustralia, Western Power, ETSA Utilities and Actew/AGL. Both Western Power and EnergyAustralia will run an extensive technology trial on most of the smart meter functions in the SMI Functionality Specification. Country Energy and ActewAGL will run trials that test both the technology and provide better costs and benefits data to support revised cost benefits analysis. ETSA Distribution has been conducting extensive direct load control trials for air conditioning testing technology and consumer responses. A summary of each of the projects is given below [36].

COUNTRYENERGY
Start Date: Q1 2009 - End Date: Dec 2011

- Installation of smart meters within 2 representative communities of approx 6000 meters each. Mainly residential customers. Aims to test all components of the current MCE functional specification and gather cost and benefit information
- Assess application and performance of selected technologies on CountryEnergy's network in accordance with min functional specification and service level requirements and the interaction with broader Intelligent Network program

ENERGYAUSTRALIA - Newington Smart Village Trial

Start Date: March 2009 - End Date: March 2011

- Covering 1000 homes by end of 2010 Aim is to provide customers with the ability to further reduce their environmental footprint and their energy bills and pilot smart meter applications and provide information on benefits of those applications
- Majority of functions in the current MCE functional specification will be tested in lab trails and/or in the field pilot Assessing end-to-end replacement of existing hot water load control technology costs and benefits Testing end-to-end security against AMISec Requirements and NIST Smart Grid Security process Utilise fourth generation wireless technology Testing of different HAN technologies Trial remote support IT framework for smart metering

WESTERN POWER
Start Date: July 2008 - End Date: Dec 2011

- 8500 smart meters in the Eastern Region of Perth with 2000 smart meters at edge of grid location to test communications capabilities
- Trial a variety of technologies to test the functionality required by various customer densities and geographic factors
- Smart meter infrastructure and minimum smart meter functionality performance to be tested to DPI spec or NSSC working group draft performance standards

ETSA DISTRIBUTION
Start Date: January 2005 - End Date: April 2010

- Direct Load Control – air conditioner
- Source or develop demand response enabling devices for use with air conditioning equipment within Australia.
- Assess FM communication systems.

ACTEWAGL
Start Date: February 2008 - End Date: December 2010

- Communications test, test change management capability, test skill set fit for work required, test customer acceptance.
- Fibre-to-the-Premise and 3G
- Test preferences for in-home display versus website Test customer acceptance of end-to-end technology solution Test customer management practices required

In April 2011, the National Stakeholder Steering Committee (NSSC) for the National Smart Metering Program confirmed completion of the majority of agreed NSMP deliverables, handover of remaining deliverables to responsible parties, and the appropriateness of formally closing the NSSC.

While the federal government in Australia has put on hold its smart meter program, the individual state governments have actively pursued smart meter programs for several years now. Most notably is the state of Victoria, which mandated in November 2008 that smart meters be installed in all homes and small businesses. The project, which aims to roll out 2.5 million smart meters by 2013, will provide utilities and consumers with meter data every 30 minutes and will eventually lead to dynamic electricity pricing based on time of use. The states of Western Australia and New South Wales have also launched much smaller pilot projects.

SMART GRID, SMART CITY

In June 2010, a consortium led by Energy Australia (now Ausgrid), a national utility, the state of New South Wales and the cities of Newcastle and Sydney successfully won a A$100 million contract from the Australian government for Smart Grid Smart City (SGSC). SGSC creates a testing ground for new energy supply technologies. At least 30,000 households will participate in the project over three years.

The demonstration project gathers information about the benefits and costs of different smart grid technologies in an Australian setting. It includes smart sensors, new back-end IT systems, smart meters and a communications network. These systems provide instant information about the electricity network to make it more efficient and help reduce interruptions, support more renewable energy, and gives households greater control over their energy use.

TECHNOLOGY IN THE HOME

A number of different technologies being tested have the potential to give households better control over their power use and a more reliable and efficient supply of electricity. These include [37]:

- A web portal that allows users to actively monitor their energy use online, calculate their energy costs and green house gas emissions
- A variety of household energy monitoring systems, including a wireless control system that allows you to switch appliances on and off remotely from your computer or smart phone
- Better monitoring and measuring devices to improve the reliability and efficiency of the electricity network
- Distributed storage and generation devices, including fuel cells and battery storage
- Electric cars.

FIGURE 36: TWO POSSIBLE IN-HOME DISPLAYS FOR THE SGSC PROJECT [37]

Selected households in the Smart Grid, Smart City trial areas are being offered a range of cutting edge technologies and tools to help them manage and monitor their electricity use. Many of these new technologies are designed to make the most of next generation smart meters being installed as part of the program. In addition, the smart meters come with advanced security features and allow for remote trouble-shooting and meter reading.

Figure 35 shows two in home displays being trialled in this project. The left display has a target for unit cost to be below $50, resulting in limited functionality. It has one-way integration with the smart meter and displays data in five minute intervals "Always on". The utility has no visibility of level of engagement. The display shown on the right assumes customer acquires device, not the utility (due to cost). It gets data both locally (meter) and from the web (utility). This has the advantage of reducing the load on the utility communications network. It displays data in five minute intervals, "Always on", and the utility has some visibility of engagement.

Alternatively, some customers will get the use of a Home Monitor System (HMS) accessed through a web portal to monitor their energy use. This online tool lets the customer see detailed information about their energy and water use in real time. You can also track your greenhouse gas emissions and estimated energy costs. Figure 36 and Figure 37 show an example of the basic and advanced versions of these web interfaces.

FIGURE 37: BASIC SMART GIRD WEB PORTAL [37]

FIGURE 38: ADVANCED CUSTOMER PORTAL [37]

Some households will be given to a Home control system, see Figure 38. They will be able to track the energy use of up to ten appliances in their home with the home control system. It also allows them to switch their appliances on and off from anywhere with internet access. The online tool works with a HMS to give greater control over power costs.

FIGURE 39: HOME AREA NETWORK INTERFACE [37]

Other systems being trailed include:

- **Demand response control** - Selected households will have the opportunity to join a trial of air conditioner and pool pump cycling, called demand response control. With their consent, Ausgrid will remotely put these high-energy appliances in a low power mode at peak times. For example, the air conditioner compressor would be switched off automatically whilst the fan continues to run, reducing the electricity cost with little change in comfort. Giving households options like this may help networks even out the peaks in electricity use, reducing the need for costly infrastructure in the future.
- **Hot water load control -** This is done by standard ripple control technology. Also being tested is a wireless, more reliable way to control off peak hot water using a smart meters' load control switch.
- **Online Water Management** - Using wireless communications, the water meter can 'communicate' with a smart meter. This makes the smart meter a hub for information on power and water use, which can be accessed online through the home monitor system. Hunter Water and Sydney Water will install these smart water meters at a number of households.
- **New pricing and energy efficiency workshops** - Ausgrid and its retail partner will test new time-based pricing and incentives for households to reduce power use in peak times. These pricing trials will be voluntary.

Electric Vehicle Trial

Another aspect of the SGSC project involves studying the impact of electric vehicles on the grid. Ausgrid has introduced 20 Mitsubishi iMiev electric cars to its fleet in Sydney, Newcastle and the Central Coast. Each car is fitted with an electronic logbook that tracks how the cars are driven and recharged. The trial aims to answer questions, such as:

- What are the benefits of electric cars?
- What impact will electric cars have on our energy network and the environment?
- When and where do drivers charge their cars, and for how long?
- What will be the impact of charging electric cars during times of peak electricity demand?
- How does the community respond to electric cars?

The EV trial is being conducted in three parallel streams. The first stream is looking at installing electric vehicle charge points in and around Sydney and Newcastle. The standard charge point, pictured on the left in Figure 39, is capable of charging the iMiev's battery to 100% within six hours. There plans for 50 standard charge points be installed in the Sydney and Newcastle areas. The quick charger, pictured on the right in Figure 39, is capable of charging the iMiev's battery to 80% within 20 minutes. There plans for eight quick charger points to be installed in Sydney and Newcastle and along the F3 freeway to facilitate travel between these cities. Both units can be installed and commissioned in a few hours [38].

FIGURE 40: THE STANDARD (LEFT) AND QUICK (RIGHT) ELECTRIC VEHICLE CHARGERS USED IN SGSC [38]

The second stream is focused on conducting a road trial. Twenty Mitsubishi iMiEVs fully electric vehicles will be used in the trial, as shown in Figure 40. These cars have a 16kWh battery, a top speed of 130km/h and a real world driving range of approximately 90km. Eight cars will be used in a fleet scenario and the other twelve have been loaned to staff for full private use.

FIGURE 41: THE MITSUBISHI IMIEV USED IN THE SGSC PROJECT [38]

The road trial hopes to answer the following questions:

- How far are electric cars driven each day?
- What time of day are electric cars charged?
- Where are electric cars charged?
- How much energy do electric cars require from the grid?
- What trips are electric cars unsuitable for?

The final stream assesses the impact of electric vehicles to the electricity grid. As part of this stream, SGSC will attempt to answer questions on the possible uptake of electric vehicles and their likely usage. Questions like;

- Who will buy electric cars?
- When do they travel?
- How far do they travel?

will need to be answered. From the answers to these questions a geo-spatial model of the uptake and usage of electric cars such as seen in Figure 41 will be able to be generated. There will be several factors influencing electric car uptake such as technology breakthroughs, government incentives, cost of petrol, and other green benefits.

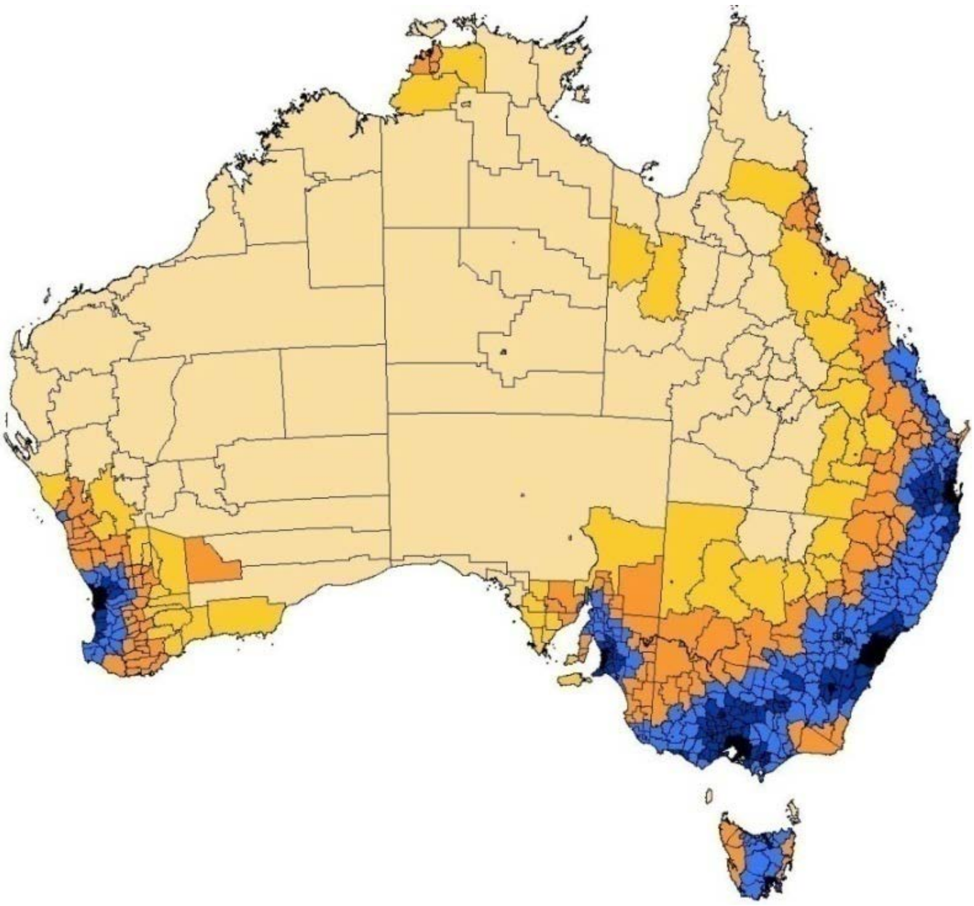

FIGURE 42: GEO-SPATIAL MODEL OF ELECTRIC VEHICLE UPTAKE IN AUSTRALIA [38]

Another important aspect for the effect of electric vehicles on the grid is commuter travel distance. The distance travelled is geographically sensitive, with rural commuters expected to travel further than city commuters. When it comes to recharging the EV, the maximum load remains the same and the recharge time increases with distance travelled. Also, the load profiles are expected to be different depending on the use of the EV, whether it's a commuter car, a fleet car or a family runabout. This will have an effect on the total added load as shown in Figure 42.

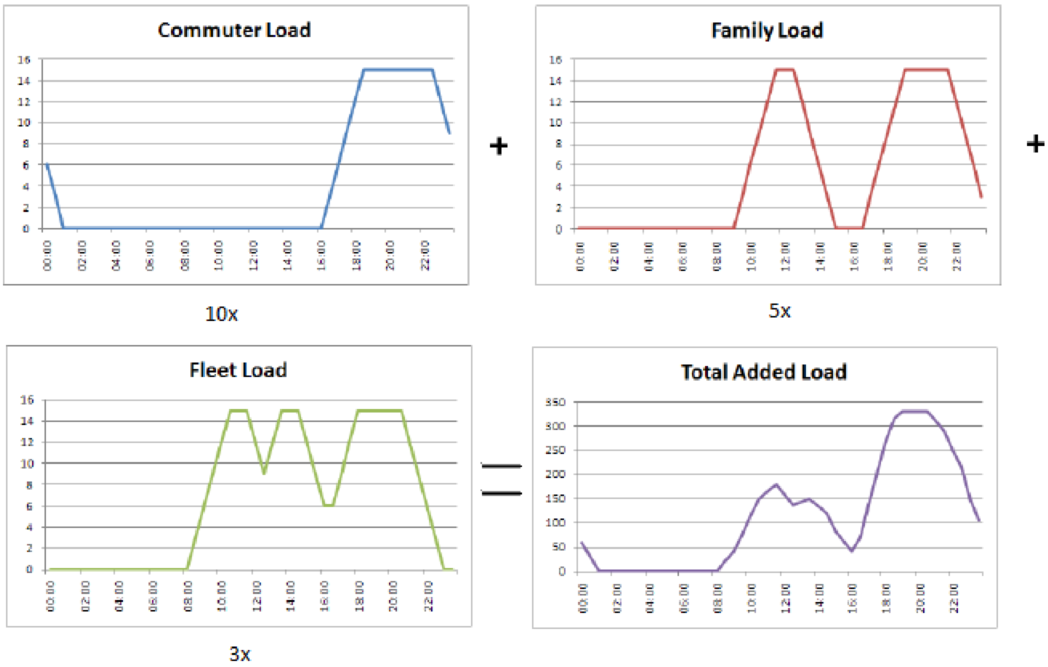

FIGURE 43: EXAMPLE OF POSSIBLE LOAD PROFILES BASED ON EV USAGE [38]

Finally, the analysis will be used to model the increased load with the existing network. Different charging schemes will be investigated to determine if there enough spare capacity on the grid to support EV charging. Figure 43 illustrates the effect of different charging schemes on the load of a distribution substation.

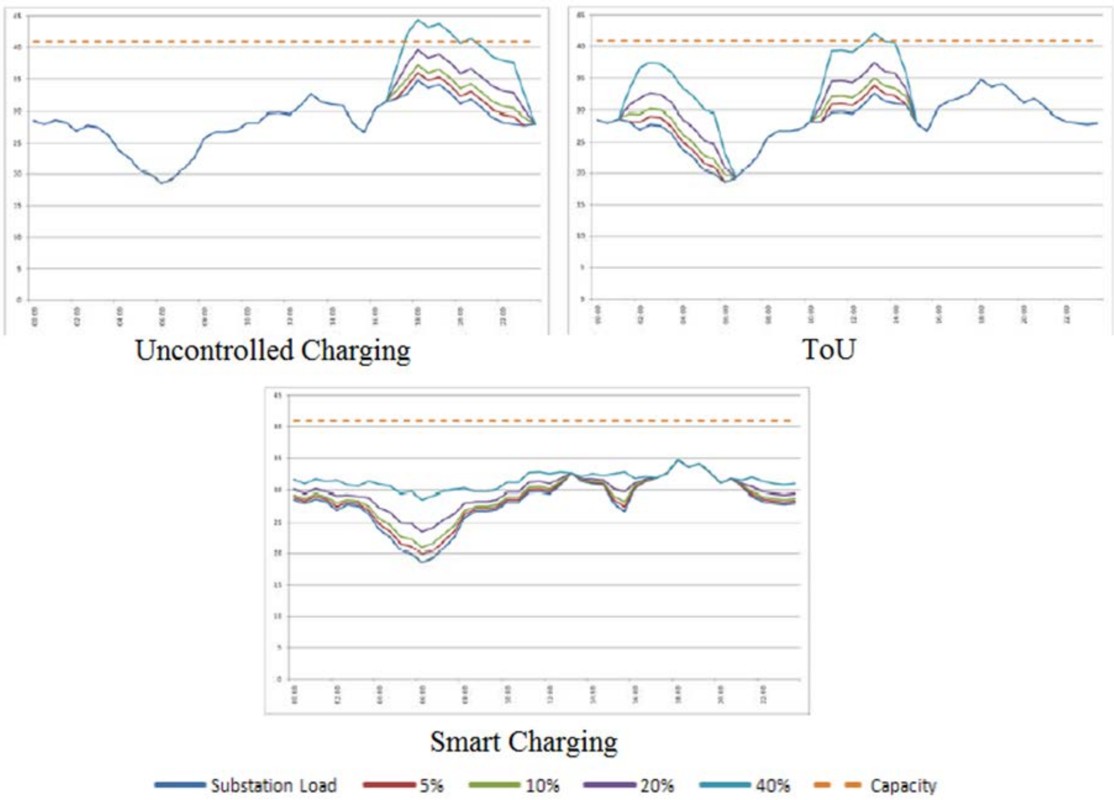

FIGURE 44: TOTAL LOAD ON A DISTRIBUTION SUB FOR VARIOUS EV UPTAKE AND CHARGING SCHEMES [38]

GRID SIDE APPLICATIONS

As well as the customer side applications mentioned above, the SGSC project is also investigating a number of Grid side applications, namely:

- Active Volt-VAr Control (AVVC)
- Substation and Feeder Monitoring (SFM)
- Fault Detection, Isolation and Restoration (FDIR)
- Wide Area Measurement (WAM)

Most of these trials will be conducted in Nelson Bay due the large number of customers, its favourable feeder layout, good customer densities, varied demographics, and strong communications coverage. [39]

ACTIVE VOLT-VAR CONTROL

The aim of the AVVC system is to "*leverage the Smart Grid platform to measure voltage delivery across the distribution network to enable more efficient management*". The system employs the following controllable devices shown in Figure 44;

- 3 x Transformers
- 1 x 6MVAr 33 KV Caps
- 2 x 2MVAr 11 KV Caps
- 6 x 11 KV Pole-top Caps
- 6 x Existing Reclosers
- 20 x New Reclosers
- 1 x New Voltage Regulator

And the following monitoring devices

- Pole-top Cap Controllers
- Reclosers
- DM&C Devices in DCs
- Smart Meters

The Active Volt-VAr Control (AVVC) Platform project includes Conservative Voltage Reduction (CVR), DMS & measurement based IVVC algorithms, optimal capacitor placement, and a STATCOM investigation. The objectives of this investigation are reducing real power flow, reducing reactive power flow, voltage profile flattening, and reducing tap changer operations while maintaining line-drop compensation. The current status is;

- CVR: Business engaged and modelling in progress
- IVVC: DMS and D400 entering testing phase
- Cap placement identified & remediation underway
- STATCOM: Singleton 66kV ring group engaged (Project Brief delivered) and modelling underway

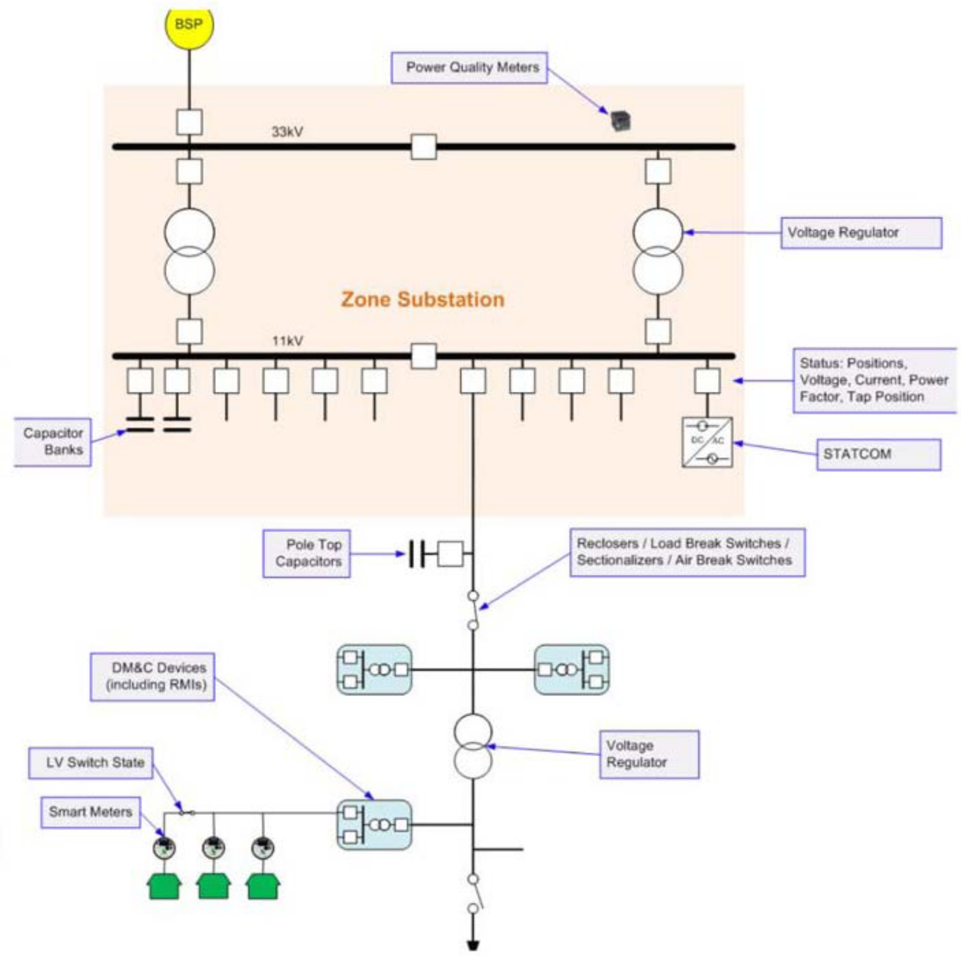

FIGURE 45: THE SGSC ACTIVE VOLT-VAR CONTROL SYSTEM [39]

SUBSTATION AND FEEDER MONITORING

The Substation and Feeder Monitoring (SFM) system aims to significantly reduce the incremental cost of delivering vital asset information to the business by leveraging common IT and Communications platforms. The types of data used in the SFM system include;

- Transformer monitoring
- Video monitoring
- Distributed Temperature Sensing (DTS)
- Dynamic Feeder Ratings Platform
- Partial discharge analysis
- Replacement oil filled cable pressure monitoring
- Environmental DM&C transformer monitoring

The current state of distribution monitoring is very limited. For example, current Earth Fault Indication, shown on the left in Figure 45, has a mechanical flag which drops with the presence of an earth fault. This device is manually used to restore supply and requires to be manually reset. Another example shown on the right of Figure 45, is a maximum demand indicator. This device measures only single phase current to +/-20% at the transformer, and needs to be manually read every 6 months.

FIGURE 46: SOME OF THE EXISTING DISTRIBUTION MONITORING EQUIPMENT [39]

By replacing the old monitoring systems with modern systems and communications remote, real-time measurements, of distribution voltages and currents will be possible, see Figure 45. This will enable several benefits in asset lifetime, asset maintenance and systems including;

- **Asset lifetime**
    - Identify overloaded distribution substations
    - Gain increased ability to track transformer life
    - Real Time Dynamic Cable Rating
        - Reduce assumptions used in short time cable rating calculation
        - Identify and track hot spots along cables
- **Asset Maintenance**
    - Enable real time visual inspection of critical assets
    - Enable prediction of maintenance requirements ahead of time
        - Oil filled cable pressure monitoring and profiling
        - Monitor partial discharge activity on cables, sealing ends and joints
        - Transformer environment condition monitoring
- **Systems**
    - Identify and develop standard for localised weather monitoring systems
    - Standardise substation design for secondary systems including supporting systems
    - Report experiences & benefits of deploying smart grid infrastructure
    - Feed fault and health information into existing maintenance processes

FIGURE 47: NEW SYSTEMS BEING IMPLEMENTED INCLUDING 3 PHASE CURRENT AND ANGLE MEASUREMENTS ON THE LEFT AND COMMUNICATIONS EQUIPMENT INCLUDING 3G AND WIMAX ON THE RIGHT [39]

The current status of the project is in the detailed design and implementation planning stage. Design DBs have been issued and the first online DGA is undergoing bench testing and about to be installed. Also, collocating several initiatives to perform comparative studies has begun (Soil Thermal Resistivity)

FAULT DETECTION ISOLATION & RESTORATION

The aim of the fault detection isolation and restoration (FDIR) scheme is for improving reliability through advanced DMS Functions and adding actuation points. Also, to make use of better network data to determine probability of a fault occurring (pre-fault)

Devices used in the FDIR scheme include:

- Intellirupters
- Loadbreak switches
- Reclosers
- 11kV Network Sensors
- Smart Meters

Pre-fault analysis will be achieved using:

- Soil Thermal Resistivity
- Insulator leakage
- Earth Potential Rise (EPR) Monitor
- Transmission Sag monitor
- Relay Statistics

The current status of the project includes:

- Intellirupter deployment -October
- Soil Thermal Resistivity monitor installed, more to be collocated with DTS
- Collaborating with DTS Dynamic Ratings
- Insulator leakage monitoring installed

WIDE AREA MEASUREMENT

The purpose of this project is to better predict system state and possibly prevent large scale blackouts using Phasor Measurements in a Wide Area Measurement (WAM) system, see Figure 47. The implementation of the WAM scheme involves collaboration between Ausgrid and TransGrid including real time sharing of Synchrophasor data as well as Wide Area Control simulation of proactive and reactive measures.

Included in the project is an investigation into 11kV paralleling. This investigation plans to study the cause and impact of circulating currents and arcing during paralleling with the aim to increase safety of related switching operations

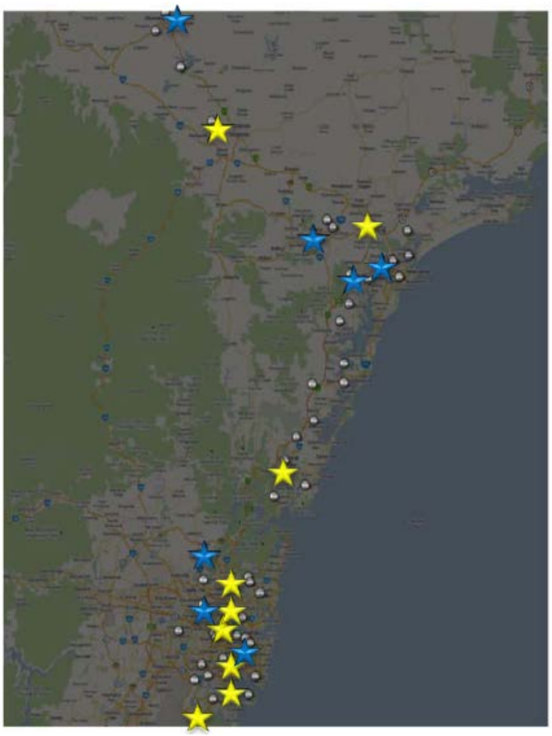

FIGURE 48: SHOWS THE LOCATION OF SOME OF THE PHASOR MEASURING EQUIPMENT IN AND AROUND SYDNEY AND NEWCASTLE [39]

The benefits of the WAM system include enhanced system planning with the ability to provide additional data to operators and planners of both networks, to be able to review system faults and an increased ability to transfer power. Other benefits include increased network monitoring and modelling with:

- Extend monitoring to include lower level generation sources
- Improve models of load response & small signal oscillations
- Model validation

The WAM system will also enhance system protection and system stability by being leveraged by control and protection schemes, being able to identify stability problems through variations in phasors across transmission lines and post-contingency load control.

SMART GRID STANDARDS DEVELOPMENT

It is apparent that to achieve a fully functioning Smart Grid will require a large investment in a variety of devices and systems throughout the entire electricity system. A key element to interconnecting these devices and systems is interoperability. Standards development will play a key role in ensuring interoperability and assisting the uptake of new technologies by the various users of the electricity network such as utilities and consumers.

In New Zealand, standards are produced by Standards New Zealand the operating arm of the Standards Council, an autonomous Crown entity operating under the Standards Act 1988. The majority of standards are developed in partnership with Standards Australia and are joint Australian/New Zealand standards. Standards New Zealand is New Zealand's national representative for both the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Because of this, a lot of ISO and IEC standards become A/NZ standards.

The IEC is based in Europe and produces a large amount of standards and technical reports related to the electric power industry. The IEC is aware of the role standards have on Smart Grid development and have already identified a number of IEC standards relevant to Smart Grids.

In the United States, the Energy Independence and Security Act of 2007 (EISA) made it the policy of the United States to modernize the nation's electricity transmission and distribution system to create a smart electric grid. EISA assigns to the National Institute of Standards and Technology (NIST) the "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems" [40].

In the context of a New Zealand Smart Grid, the work carried out by the IEC and the NIST will play a significant role in how the grid will develop. The work from these two organisations related to smart grids are summarised here over the next few pages.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

In 2008 the IEC Standardization Management Board (SMB) approved the creation of a Smart Grid Strategic Group, SG3, tasked with developing a framework for Smart Grid Standardisation. The framework includes protocols and model standards to achieve interoperability of smart grid devices and systems and to develop a long term strategic plan for the IEC where future new standards work is needed.

A Smart Grid web portal on the IEC website was developed and is maintained by the SG 3 secretariat. The portal provides information for industry including ready-to-use standards and guidance documents, background information on some of the drivers for Smart Grid, the challenges in developing a Smart Grid, and information on the current developments at the IEC [41].

CORE SMART GRID STANDARDS

SG3 has highlighted five existing IEC standards that are considered core Smart Grid standards. These are;

- IEC/TR 62357 – Framework of power automation standards and description of the SOA (Service Oriented Architecture) concept.
- IEC 61850 – Substation automation and beyond
- IEC 61970 – Energy Management System – CIM and GID definitions
- IEC 61968 – Distribution Management System – CIM and CIS definitions
- IEC 62351 – Security

IEC/TR 62357 - POWER SYSTEM CONTROL AND ASSOCIATED COMMUNICATIONS – REFERENCE ARCHITECTURE FOR OBJECT MODELS, SERVICES AND PROTOCOLS

This is a technical report describing all the existing object models, services, and protocols developed in technical committee (TC) 57 and showing how they relate to each other. TC 57 (Power Systems Management and Associated Information Exchange) develops standards for electric power system control and associated telecommunications in the areas of generation, transmission and distribution, real-time operations and planning. A second objective of 62357 is to develop a strategy to combine and harmonize the work of these various activities to help facilitate a single, comprehensive plan for deployment of these standards in product development and system implementations [42].

In today's utility enterprise where information exchange between the various generation, transmission and distribution management systems and other IT systems is not only desirable but necessary in most cases, each system plays the role of either supplier or consumer of information, or more typically both. That means that both data semantics and syntax need to be preserved across system boundaries, where system boundaries in this context are interfaces where data is made publicly accessible to other systems or where requests for data residing in other systems are initiated. In other words, the ***what*** of the information exchange is actually much more important for system integration purposes than ***how*** the data is transported between systems. [42]

Most previous efforts to define system architectures have dealt primarily with the ***how*** (i.e., definition of protocols for transporting the data), with a focus on utilizing as many existing ISO or TCP/IP standards to provide the various layers in the ISO OSI seven-layer reference model for protocol profiles. However, the increasing use of object modelling techniques to define the data for information exchange within the different standards initiatives has appropriately shifted the focus away from the ***how*** to the ***what***. This is the good news. The bad news is that each initiative has chosen its own modelling language/notation and more importantly generated its own object model definitions. This was not done intentionally, and in fact each initiative had perfectly good reasons for their choices, given the limited scope of their domain of application. But the consequence is that instead of one object model for each physical entity in the generation, transmission and distribution operations domain being standardized, at least two or more object models exist in most cases with different definitions for classes, attributes, data types, and relationships between classes. Furthermore, in most cases different modelling languages have also been used. [42]

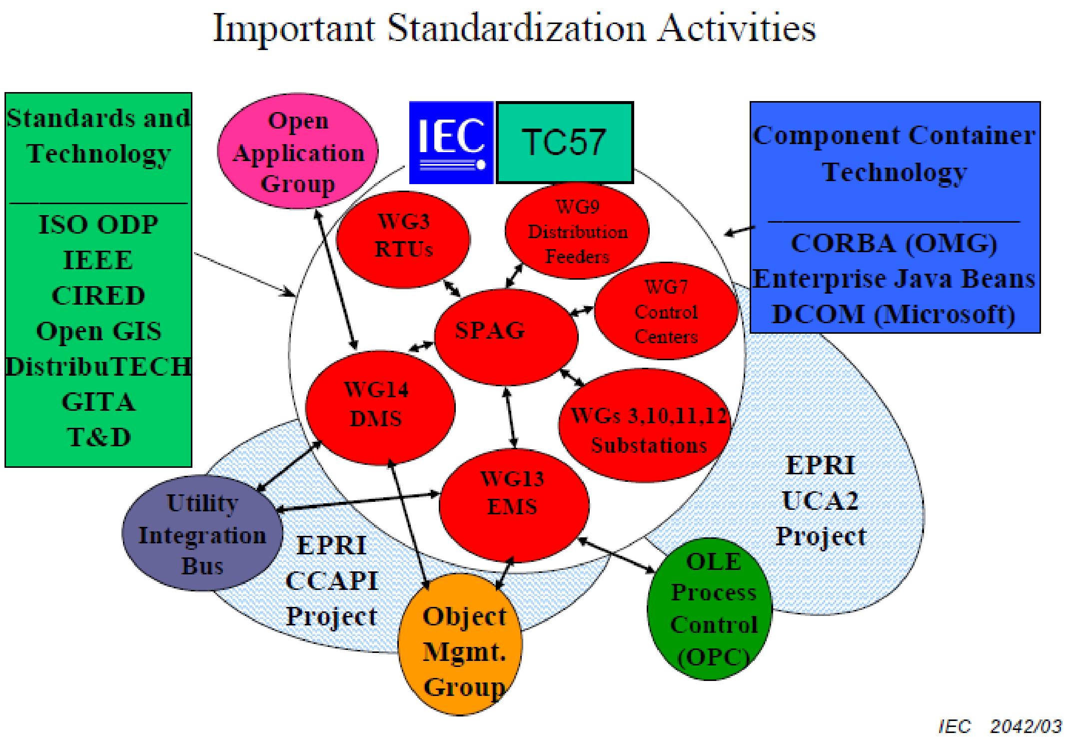

FIGURE 49: COORDINATION AMONG STANDARDS ACTIVITIES [42]

The first objective of the reference architecture is to describe all the existing object models, services, and protocols and how they relate to each other. A strategy can then be developed to show where common models are needed, and if possible, recommend how to achieve a common model. Where changes cannot be made due to maturity of standards, then recommendations for adapters to make the necessary transformations between models are made. Figure 1 is a graphical representation of the scope of IEC 62357.

IEC 61850 - COMMUNICATION NETWORKS AND SYSTEMS IN SUBSTATIONS

This standard is for the design of electrical substation automation systems and is part of IEC 62357 discussed above. It defines the communication between various intelligent electronic devices (IED) in the substation and the related system requirements [43]. The abstract data models defined in IEC 61850 can be mapped to a number of protocols, such as Manufacturing Message Specification (MMS), Generic Object Oriented Substation Events (GOOSE), and soon to Web Services. These protocols can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying. Figure 50 shows A possible layout of an IEC 61850 enabled substation.

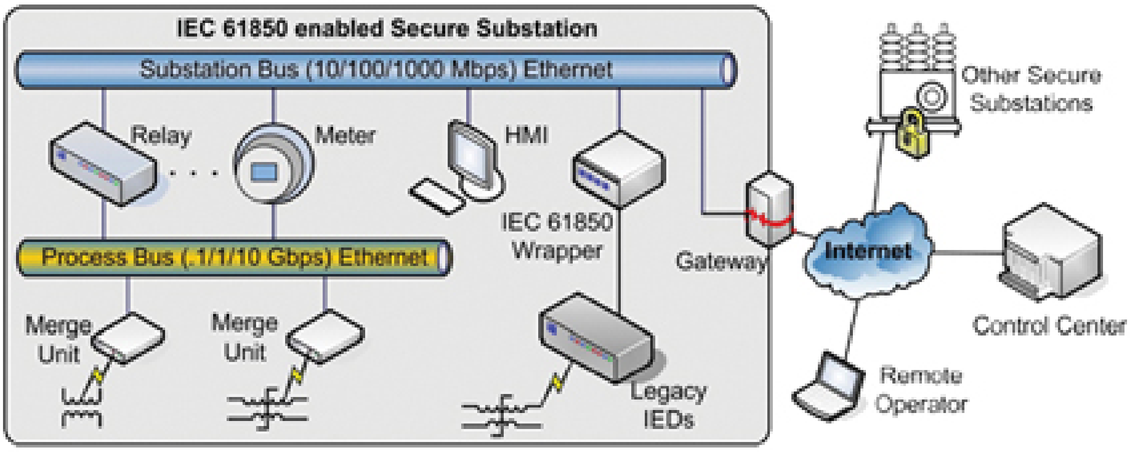

FIGURE 50: POSSIBLE LAYOUT OF AN IEC 61850 SUBSTATION

There are 10 parts to the standard available in separate standard documents;

- Part 1: Introduction and overview
- Part 2: Glossary
- Part 3: General requirements
- Part 4: System and project management
- Part 5: Communication requirements for functions and device models
- Part 6: Configuration description language for communication in electrical substations related to IEDs
- Part 7: Basic communication structure for substation and feeder equipment
    - 7-1: Principles and models
    - 7-2: communication service interface (ACSI;)
    - 7-3: Common Data Classes
    - 7-4: Compatible logical node classes and data classes
    - 7-10: Communication networks and systems in power utility automation - Requirements for web-based and structured access to the IEC 61850 information models [Approved new work]
- Part 8: Specific communication service mapping (SCSM)
    - 8-1: Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2)
- Part 9: Specific communication service mapping (SCSM)
    - 9-1: Sampled values over serial unidirectional multidrop point to point link
    - 9-2: Sampled values over ISO/IEC 8802-3
- Part 10: Conformance testing

IEC 61970 – ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE

This standard defines application program interfaces (APIs) for an Energy Management System (EMS). It is largely based upon work of the Electric Power Research Institute (EPRI)

Control Center API (CCAPI) research project (RP-3654-1). The principle objectives of the EPRI CCAPI project are to:

- reduce the cost and time needed to add new applications to an EMS or other system
- protect the investment in existing applications that are working effectively
- improve the capability to exchange information between disparate systems both within and external to the control center environment.

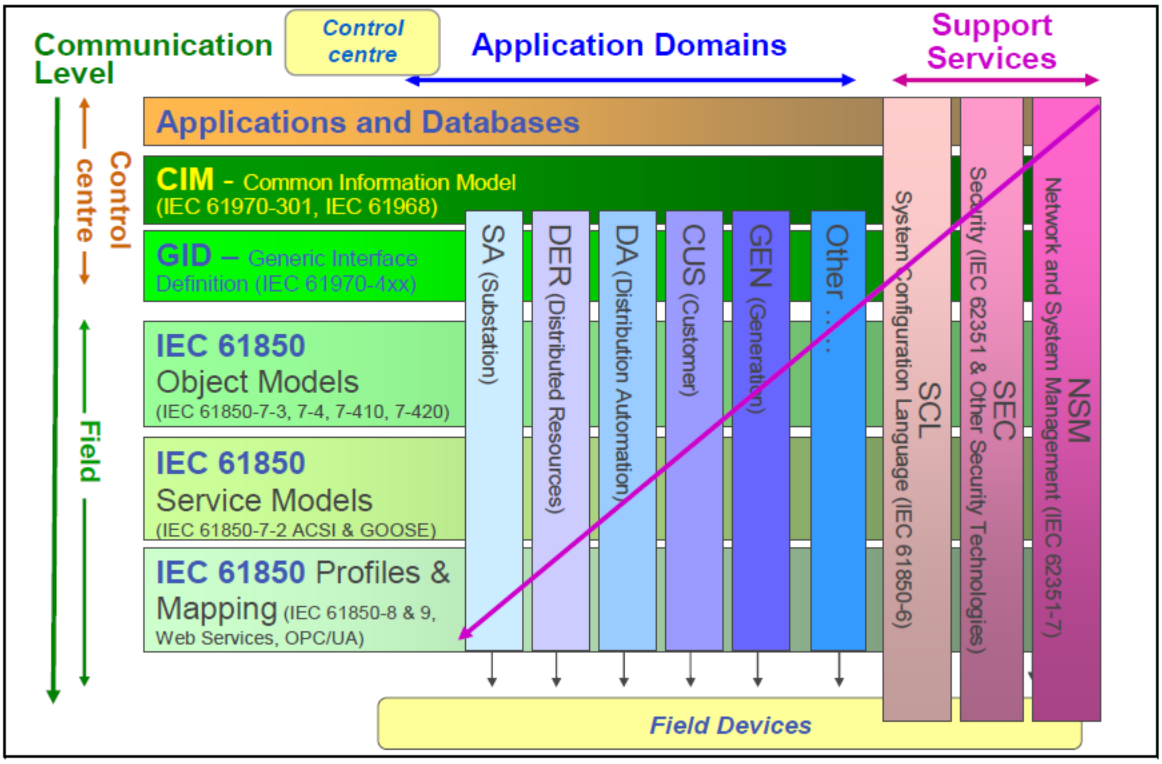

FIGURE 51: IEC 61850 MODELS AND THE COMMON INFORMATION MODEL (CIM) [44]

The objective of 61970 is to develop a set of guidelines and standards to facilitate the integration of applications developed by different suppliers in the control center environment and the exchange of information to systems external to the control center environment. The scope of these specifications includes other transmission systems as well as distribution and generation systems external to the control center that need to exchange real-time operational data with the control center. Therefore, another related goal of these standards is to enable the integration of existing legacy systems as well as new systems built to conform to these standards in these application domains [45].

The complete set of standards includes the following parts:

- Part 1: Guidelines and general requirements
- Part 2: Glossary
- Part 3XX: Common Information Model (CIM)
- Part 4XX: Component Interface Specification (CIS)
- Part 5XX: CIS Technology Mappings

IEC 61968 – APPLICATION INTEGRATION AT ELECTRIC UTILITIES – SYSTEM INTERFACES FOR DISTRIBUTION MANAGEMENT

The 61968 series of standards is intended to facilitate inter-application integration, as opposed to intra-application integration, of the various distributed software application systems supporting the management of utility electrical distribution networks. Intra-application integration is aimed at programs in the same application system, usually communicating with each other using middleware that is embedded in their underlying runtime environment, and tends to be optimized for close, real-time, synchronous connections and interactive request/reply or conversation communication models.

IEC 61968, by contrast, is intended to support the inter-application integration of a utility enterprise that needs to connect disparate applications that are already built or new (legacy or purchased applications), each supported by dissimilar runtime environments. Therefore, IEC 61968 is relevant to loosely coupled applications with more heterogeneity in languages, operating systems, protocols and management tools. IEC 61968 is intended to support applications that need to exchange data on an event driven basis. IEC 61968 is intended to be implemented with middleware services that broker messages among applications, and will complement, but not replace utility data warehouses, database gateways, and operational stores [46].

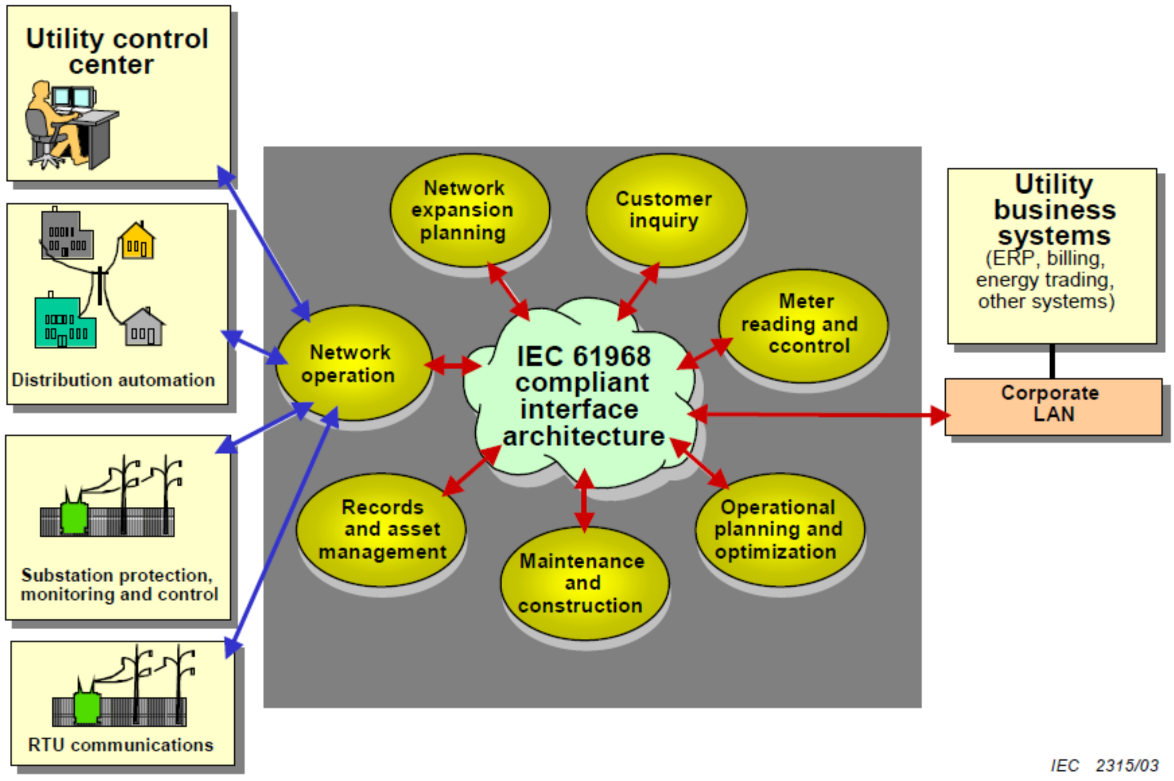

FIGURE 52: DISTRIBUTION MANAGEMENT SYSTEM WITH IEC 61968 COMPLIANT INTERFACE ARCHITECTURE

61968 is currently still under development although several parts are available now. The following list details the different parts of IEC 61968 and their current status.

- Part 1 – Interface architecture and general requirements
- Part 2 – Glossary
- Part 3 – Interface for Network Operations
- Part 4 – Interfaces for Records and Asset Management
- Part 5 – Interfaces for Operational planning & optimization [Under Development]
- Part 6 – Interfaces for Maintenance & Construction [Under Development]
- Part 7 – Interfaces for Network Extension Planning [Under Development]
- Part 8 – Interfaces for Customer Support [Under Development]
- Part 9 – Interface Standard for Meter Reading & Control
- Part 10 – Interfaces for Business functions external to distribution management [Under Development]. This includes *Energy management & trading, Retail, Supply Chain & Logistics, Customer Account Management, Financial, Premises & Human Resources*
- Part 11 – CIM Extensions for Distribution [Under Development]
- Part 12 – CIM Use Cases for 61968 [Under Development]
- Part 13 – CIM RDF Model exchange format for distribution
- Part 14-1-3 to 14-1-10 – Proposed IEC Standards to Map IEC61968 and MultiSpeak Standards [Under Development]
- Part 14-2-3 to 14-2-10 – Proposed IEC Standards to Create a CIM Profile to Implement MultiSpeak Functionality [Under Development]

IEC 62351 – SECURITY

IEC 62351 is a standard developed by WG15 of IEC TC57. This is developed for handling the security of TC 57 series of protocols including IEC 60870-5 series, IEC 60870-6 series, IEC 61850 series, IEC 61970 series & IEC 61968 series. The different security objectives include authentication of data transfer through digital signatures, ensuring only authenticated access, prevention of eavesdropping, prevention of playback and spoofing, and intrusion detection.

Specific objectives include:

- IEC 62351-1 provides an introduction to the remaining parts of the standard, primarily to introduce the reader to various aspects of information security as applied to power system operations.
- IEC 62351-3 to IEC 62351-6 specify security standards for the IEC TC 57 communication protocols. These can be used to provide various levels of protocol security, depending upon the protocol and the parameters selected for a specific implementation. They have also been design for backward compatibility and phased implementations.

- IEC 62351-7 addresses one area among many possible areas of end-to-end information security, namely the enhancement of overall management of the communications networks supporting power system operations.
- Other parts are expected to follow to address more areas of information security.

The justification for developing these information security standards is that safety, security, and reliability have always been important issues in the design and operation of systems in the power industry, and information security is becoming increasingly important in this industry as it relies more and more on an information infrastructure. The deregulated market has imposed new threats as knowledge of assets of a competitor and the operation of his system can be beneficial and acquisition of such information is a possible reality. In addition, inadvertent actions (e.g. carelessness and natural disasters) can be as damaging as deliberate actions. Recently, the additional threat of terrorism has become more visible.

Although many definitions of "end-to-end" security exist, one (multi-statement) standard definition is "*1. Safeguarding information in a secure telecommunication system by cryptographic or protected distribution system means from point of origin to point of destination. 2. Safeguarding information in an information system from point of origin to point of destination*"[4]. Using this definition as a basis, the first four standards address the security enhancements for IEC TC 57 communication profiles, since these were identified as the obvious first steps in securing power system control operations. However, these security enhancements can only address the security requirements between two systems, but does not address true "end-to-end" security that covers internal security requirements, including security policies, security enforcement, intrusion detection, internal system and application health, and all the broader security needs.

Therefore, the final sentence in the scope/purpose statement is very important: it is recognized that the addition of firewalls or just the simple use of encryption in protocols, for instance by adding "bump-in-the-wire" encryption boxes or even virtual private network (VPN) technologies would not be adequate for many situations. Security truly is an "end-to-end" requirement to ensure authenticated access to sensitive power system equipment, authorized access to sensitive market data, reliable and timely information on equipment functioning and failures, backup of critical systems, and audit capabilities that permit detection and reconstruction of crucial events [47].

IMMERGING SMART GRID STANDARDS

In addition to the "core" Smart Grid standards discussed above, SG3 has identified a number of additional immerging standards that will become core Smart Grid standards when completed. The main focuses for these new activities are advanced meter infrastructure (AMI), distributed energy resources (DER) and electric vehicles (EV).

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[4] ATIS: an expansion of FS-1037C which is the US Federal Government standard glossary for telecommunications terms.

IEC Smart Grid Standardization Roadmap

IEC SG3 has produced a Smart Grid Standardization Roadmap [44] covering general topics such as communication, security, and planning as well more specific applications including smart transmission systems, renewable energy generation, distributed automation, demand response, and electric storage, as well as many additional topics. In each case, a description of the topic's requirements is given including any existing standards present, the gaps are identified and recommendations are given. A brief overview of the roadmap findings are given below.

General

Communication

A secure, reliable and economic power supply is closely linked to a fast, efficient and dependable communications infrastructure. The planning and implementation of communications networks requires the same care as the installation of the power supply systems themselves. In a smart grid context this means the efficient integration of all components and stakeholders for a common concept. For this purpose syntactic and semantic interoperability is the challenge to be met. Figure 52 describes the basic systems and their interconnection in the power utility domain.

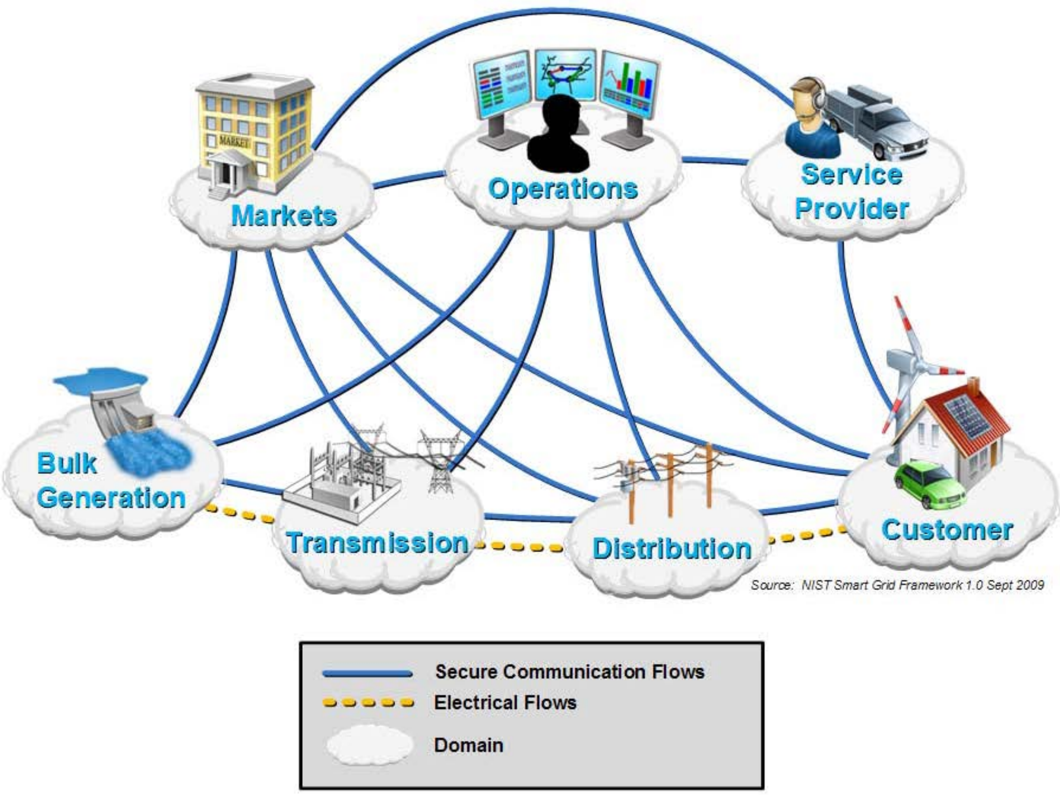

Figure 53: Conceptual Model

From a communication point of view, each system plays the role of either supplier or consumer of information, or more typically both. In addition to this intersystem communication, these systems consist of subsystems with specific internal communications.

SG3 investigated the existing IEC standards and found there a large amount of standards related to communications including;

- IEC 62357 Power system control and associated communications - Reference architecture for object models, services and protocols
- IEC 61968 Application integration at electric utilities - System interfaces for distribution management
- IEC 61970 Energy management system application program interface (EMS-API)
- IEC 61850 Communication networks and systems in substations
- IEC 60870-5 Telecontrol equipment and systems – Part 5 – Transmission protocols

As well as the standards mentioned above, key standards were identified which cover the intersystem and subsystem communication of Bulk Generation, Transmission, Distribution, Operation, Markets, Service, and Prosumers. These standards are highlighted in several tables in the roadmap [44].

The analysis also uncovered some gaps in the current standards spectrum, namely;

- In case of multi-utility support the data models for gas and water supply domains are not yet considered in IEC 61970 and IEC 61850.
- Currently no complete mapping exists between IEC 61850 and IEC 61970.
- A seamless smart grid communication requires a mapping of intersystem-to-subsystem communication. Currently standardized mappings of established domain standards (e.g. from IEC 61850 to Home and Building Automation domain) are not yet specified.
- The integration and migration of technology standard IP v6 to existing communication standards is necessary.
- Seamless wireless communication standards for AMI applications are not yet defined. These could include WiFi, Mobile WiMAX, GPRS etc.

Six key recommendations were suggested by SG3 related to communications standards work. They are;

1. Although the focus of CIM and Service Oriented Architecture (SOA) is on the electric energy domain, the CIM and SOA concept is open and flexible to being adapted to non-electric domains. In the Distribution System Operation the gas and water supply is also managed. For a common concept of multi-utility management an integration of non-electric extensions of CIM and SOA shall be considered.
   Investigate multi-utility effects on the further development of IEC 61970 and IEC 61850.

2. A seamless smart grid communication requires mappings between intersystem and subsystem communication. Investigate existing profiles for mapping between established core standards. Develop profiles in case of missing profiles.
3. Users require future-proof communication standards in order to safeguard their investment in communication infrastructures. A future-proof communication standard is expected to be independent from communication technologies. Therefore the communication standards shall be open so that state-of-the-art communication technologies can be applied.
4. For AMI communication different mappings on physical communication technologies are required. Include Wireless Transport protocols.
5. In a Smart Grid concept technical and business processes along the energy chain grow together. CIM and SOA provide a common concept for the integration of technical and business processes. The underlying IEC 61970 SOA structure allows the flexible implementation of new applications. Promote and inform other stakeholders about the capabilities, benefits and limits of the CIM and SOA structure of power automation.
6. There is a lot of confusion among stakeholders about the application of IP-based communication to Smart Grid. There is a perception that the existing power automation framework of TC 57 standards (e.g. IEC 61850 and IEC 61970) is somewhat in contradiction with a widespread usage of IP-protocols and communication. However IEC 61850 and IEC 61970 clearly offer the possibilities to use IP and TCP/IP for non-time-critical Smart Grid applications. This misperception should be actively fought by the IEC, in order to avoid reinventing the wheel.
   Evangelize / inform stakeholders about the close connection of power automation standards to TCP/IP.

Security

Cyber Security is an important success criterion for a secure, efficient and reliable operation of the Smart Grid. The most important goal of Cyber Security is the protection of all relevant assets in the scope of the Smart Grid from any type of hazards such as deliberate cyber security attacks, inadvertent mistakes, equipment failures, information theft and natural disasters. These hazards predominantly concern the IT and telecommunication infrastructure. In order to achieve an adequate level of protection, classical security objectives such as confidentiality, integrity, availability, non-repudiation and privacy must be assured by the implementation of security controls.

Because of the nature of the Smart Grid as a huge network of interconnected sub-networks and its inherent complexity, the aforementioned risks could quickly be increased. More precisely, the risks can be stated as:

- The architecture of the Smart Grid will be complex with a very high number of endpoints, participants, interfaces and communication channels and with different levels of protection in the underlying systems. In general, it is always a challenge and requires effort to achieve an adequate level of protection for such a complex system.

- The introduction of Smart Metering systems and processes will increase the number of endpoints dramatically and will move them to private households. Physical security is hard to achieve in these scenarios and time and motivation to penetrate the systems are in plentiful supply.
- Many components of the Smart Grid can be characterized as legacy where security has never been an important requirement.
- The majority of network connections and communications paths in the scope of the Smart Grid will be based on Internet-technologies / IP-networks. This infrastructure comes along with high flexibility and many existing systems but also introduces a higher vulnerability because of the mal-ware (e.g.: worms, viruses) which already exists in this ecosystem and the potential risk of this spreading quickly, which could have fatal consequences.
- A higher number of attack scenarios based on very different objectives, ranking from industrial espionage and terrorism to privacy breaches can be anticipated.

Investigating the existing standards framework, cyber security requirements already exist for specific applications and domains. They differ in granularity and scope, ranking from process oriented to technical standards. Some standards address the operator, while others contain very detailed implementation requirements. A list of relevant documents is given below:

- *IEC 62351-1 to 6, Power systems management and associated information exchange - Data and communications security.* Security for protocols, network and system management, role-based access control; NWIPs are in planning.
- *NERC CIP-002* and *CIP-003* to *CIP-009*. The North American Electric Reliability Corporation (NERC) has issued the Critical Infrastructure Protection (CIP) Cyber Security Standards to protect electrical systems. The CIP Cyber Security Standards are mandatory and enforceable across all users, owners and operators of the bulk-power system. *CIP-002* specifies the means by which critical cyber assets are identified. *CIP-003* through *CIP-009* cover security management controls, personnel and training, electronic security perimeters, physical security of cyber assets, systems security management, incident handling and recovery planning.
- *IEEE 1686-2007, IEEE Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities, Institute of Electrical and Electronics Engineers* Specifies functionality of IEDs in order to address critical infrastructure protection programmes.
- *ISO/IEC 27001, Information technology - Security techniques - Information security management systems – Requirements*
- *ANSI/ISA-99, Security for Industrial Automation and Control Systems* Covers the process for establishing an industrial automation and control systems security programme based on risk analysis, establishing awareness and countermeasures, and monitoring and Cyber Security management systems.
- *NIST Special Publication 800-82* Guide to Industrial Control Systems (ICS) Security; Current status is draft.

Missing standards and recommendations will be identified as a result of the risk assessment and the Cyber Security requirements which stem from that. There is a high probability that existing standards are not sufficient to cover the complex architecture and the manifold use cases of the Smart Grid. Not all protocols have a "security" extension. As an example, IEEE 1588 has no security mechanism at all while being crucial for protection applications. In addition to domain- and application-specific standards, common and application-spanning aspects need to be addressed. This is especially true for the requirements covering the aspects of end-to-end security. Furthermore, technical requirements will not be sufficient to address the complexity of the Smart Grid, especially towards growth and change. Operational aspects such as policies and training as well an ongoing cycle of risk assessments needs to be developed and introduced.

In order to capture the complexity of the Smart Grid, an Overall Security Architecture needs to be addressed by standardization efforts. It should contain the following aspects, either as integral parts or as references to separate standards.

1. A specification of a dedicated set of security controls (e.g. perimeter security, access control) to protect the Smart Grid needs to be comprehensively developed. As an example, a specification of granular access controls for the discrete boundaries derived from compartmentalization needs to be determined.
2. A compartmentalization of Smart Grid applications (domains) based on clear network segmentation and functional zones needs to be developed.
3. A specification comprising identity establishment (based on trust levels) and identity management in the Smart Grid as a large network connecting a high number of entities and end points needs to be developed. It should cover the aspect of credential management (distribution, validation, revocation) as an essential part.
4. Moreover, existing standards must be reviewed, adapted and enhanced to support general and ubiquitous security across wired and wireless connections.
5. IEC 62443 should confirm the standards architecture and the implementation methods, harmonize the constitution of standards with ISA and other organizations, speed up the standardization process, and be compatible with the contents of the Smart Grid. The goal is to realize the unification and standardization of any industrial control systems.
6. Security of the legacy components in the Smart Grid was not fully considered in the initial design, thus the security performance was poor and difficult to upgrade. Standardization of the physical protection and network protection should be enhanced for the legacy.

Planning for the Smart Grid

Planning for the Smart Grid includes transmission system planning and distribution network planning. In general the planning standards are enacted by a country or an organization individually. However, some standards related to power system planning, such as large-scale wind farm and PV system connection into transmission systems and interconnection of distributed generation into power networks should be released by international standard organizations. Here the two types of standards are analysed and some suggestions are put forward.

To provide the favourable conditions for renewable power or connection of distributed generation is one of the goals of Smart Grid development. The 'IEC Standard for connecting MicroGrids with electric power systems' may include the following contents:

1. Design standard of MicroGrid. This includes equipment, protection schemes, and information system inside MicroGrid, etc.
2. Standard for MicroGrid operating in island mode. This includes power management, voltage and frequency control, stability, protection, cold load pickup, monitoring and communication, power quality, installation and testing, etc.
3. Standard for connecting MicroGrids with grid:
   Grid connection mode and conditions. This includes access mode (single PCC or multiple PCC), isolation mode, interconnection transformer, grounding mode, prevention of electromagnetic interference, withstanding voltage and current surge capacity, etc. Connection methods have major effects on the planning and operating of transmission system. Some organizations have their own standards for connection of wind power but up to now there has been no international standard for this. There are some national or international standards for PV connection, but they concern only distributed connection of small PV system.

With the development of distributed generation, standards for interconnection of distribution generation and distribution network planning standards with distribution generation incorporated in them are needed. On the other hand, as an effective way to utilize distribution generation, MicroGrid will play an important role in the Smart Grid. Therefore, standards for MicroGrid interconnection with power networks or distribution system planning standards with MicroGrid incorporated are required.

IEC SG3 has again identified a number of existing standards that address Smart Grid planning. These are;

- *IEC 61727:2004, Photovoltaic (PV) systems – Characteristics of the utility interface*. This is suitable for PV system smaller than 10 kVA, connected with LV distribution system.

The *IEEE 1547* series is a set of standards concerning *Interconnecting Distributed Resources with Electric Power Systems*. Since 2003, three standards in the IEEE 1547

Series have been released by the IEEE and another three are still in the draft phase. The IEEE 1547 Serial Standards are currently the most widely accepted standards in the field of distributed resources interconnection and have been formally affirmed as one of the first batch of the USA Smart Grid construction standards. The IEEE 1547 series are outlined as follows:

- *IEEE 1547.1:2005, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems*. Published in 2005, this standard further describes the testing of the interconnection in order to determine whether or not it conforms to standards.
- *IEEE 1547.2:2008, Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems*. This provides a technical background on the standard.
- *IEEE 1547.3:2007, Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems.* Published in 2007, this standard details techniques for monitoring of distributed systems.
- *IEEE 1547.4: Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems (draft).* This is a guide for design, operation, and integration of conforming systems.
- *IEEE P1547.5: Draft Technical Guidelines for Interconnection of Electric Power Sources Greater than 10MVA to the Power Transmission Grid (draft).* Designed for distributed sources larger than 10 MVA
- *IEEE P1547.6: Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks (draft).* This describes practices for secondary network interconnections.

Although some corporations and organizations have enacted their own wind turbine connection code, there is no universal international standard. For example, in the Nordic Wind Turbine Connection Code, there are detailed performance requirements in relation to voltage and frequency, as shown in Figure 53. Is it necessary to give such detailed and strict standards? An IEC standard for wind turbine connections is needed to give the fundamental requirements.

Existing international standards for PV systems connection, such as *IEC 61727, Photovoltaic (PV) systems – Characteristics of the utility interface* and *IEEE 929-2000, Recommended practice for utility interface of photovoltaic (PV) systems,* are only suitable for PV system connection into the distribution network. They are focused on requirements concerning power quality, security and protection. There are no international standards for large-scale PV system connections into transmission systems.

In the IEEE 1547 series, IEEE 1547.4 is the only standard worldwide that deals with MicroGrid interconnection, and it is still currently a draft standard. It is suggested that an IEC standard dealing with MicroGrid interconnection should be drawn up.

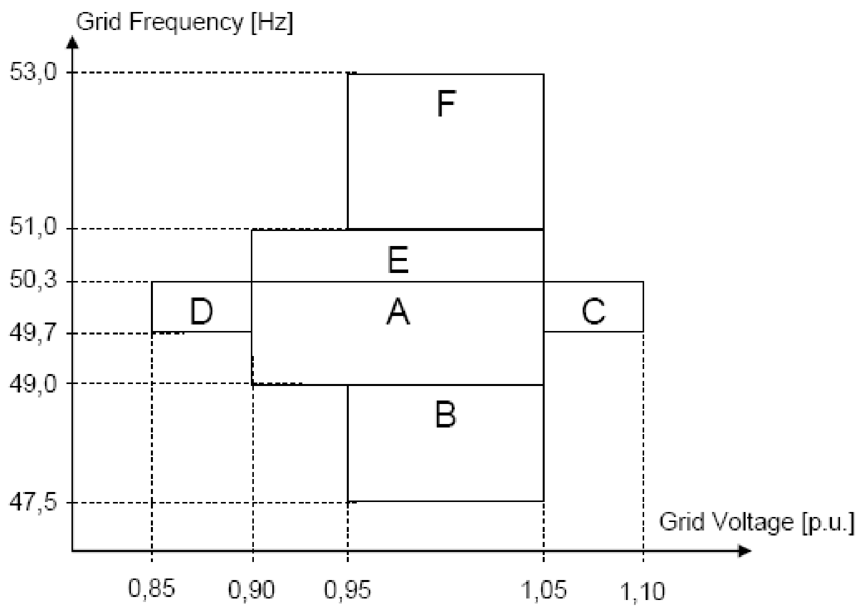

FIGURE 54: GRID FREQUENCY AND VOLTAGE

SG3 has suggested a number of recommendations for Smart Grid planning standards namely;

1. The 'IEC Standard for wind turbine connection' may include the basic requirements concerning active power control, reactive power control, reactive power capacity, dimensioning voltage and frequency and operating characteristics under grid disturbances.
2. The 'IEC Standard for PV station connection' may include the basic requirements concerning effects on power quality, active power control, reactive power control, dimensioning voltage and frequency and operating characteristics under grid disturbances.
3. The development of an IEC standard for connecting microgrids with electrical Power Systems. This new standard should include the contents mentioned under requirements in Clause 4.2.3.2.

SPECIFIC APPLICATIONS

As well as the above mentioned general topics of communication, security, and planning, the Smart Grid Roadmap developed by IEC SG3 also covered the following specific applications;

- Smart transmission systems, Transmission Level Applications
- Blackout Prevention / EMS
- Advanced Distribution Management
- Distribution Automation
- Smart Substation Automation – Process bus
- Distributed Energy Resources
- Advanced Metering for Billing and Network Management
- Smart Metering
- Smart Home and Building Automation
- Electric Storage
- E-mobility
- Condition Monitoring
- Renewable Energy Generation

For each of the above topics, a description is given outlining what the specific application is covering, some of the requirements that should be met in order to meet that description. This is followed by an analysis of the existing standards framework to see which standards are applicable and where there are gaps in the framework. Finally, some recommendations are given for future work. More detail on this work can be found in the roadmap [44].

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

In the United States, the Energy Independence and Security Act of 2007 (EISA) made it the policy of the United States to modernize the nation's electricity transmission and distribution system to create a smart electric grid. EISA assigned the National Institute of Standards and Technology (NIST) the task of developing a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems.

In response to the urgent need to establish interoperability standards and protocols for the Smart Grid, NIST developed a three-phase plan:

1. To accelerate the identification and consensus on Smart Grid standards
2. To establish a robust Smart Grid Interoperability Panel (SGIP) that sustains the development of the many additional standards that will be needed
3. To create a conformity testing and certification infrastructure.

Work began on the three phase plan in 2008 with workshops and meetings with various experts from a diverse group of stakeholders. By January 2010 the publication of the *NIST*

Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 represented part of Phase 1 of the NIST plan. In Release 1.0, 75 existing standards were identified that were applicable to Smart Grid development. In addition, there were 15 high-priority gaps identified which required new or revised standards. The SGIP was established in November 2009 to further the development of consensus-based Smart Grid interoperability standards.

Since 2010 progress had been made on Phases 2 and 3 of the NIST plan leading to the publication of *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0* [40] in 2012. This document contains eight chapters covering the following topics Purpose and Scope, Smart Grid Visions, Conceptual Architectural Framework, Standards Identified for Implementation, Smart Grid Interoperability Panel, Cybersecurity Strategy, Testing and Certification, and Next Steps. A summary of each chapter is given below.

Chapter 1 - Purpose and Scope outlines the role of NIST with respect to the Smart Grid, defines key concepts and priorities discussed in the document, identifies potential uses of the document, and describes the basic content of the document.

The role of NIST with respect to the Smart Grid began in 2007 with the Energy Independence and Security Act of 2007. It was quickly realised that there was an urgent need to establish Smart Grid standards and protocols. NIST was tasked with coordinating development of a standards and protocols framework. Figure 54 depicts a history of NIST and the Smart Grid.

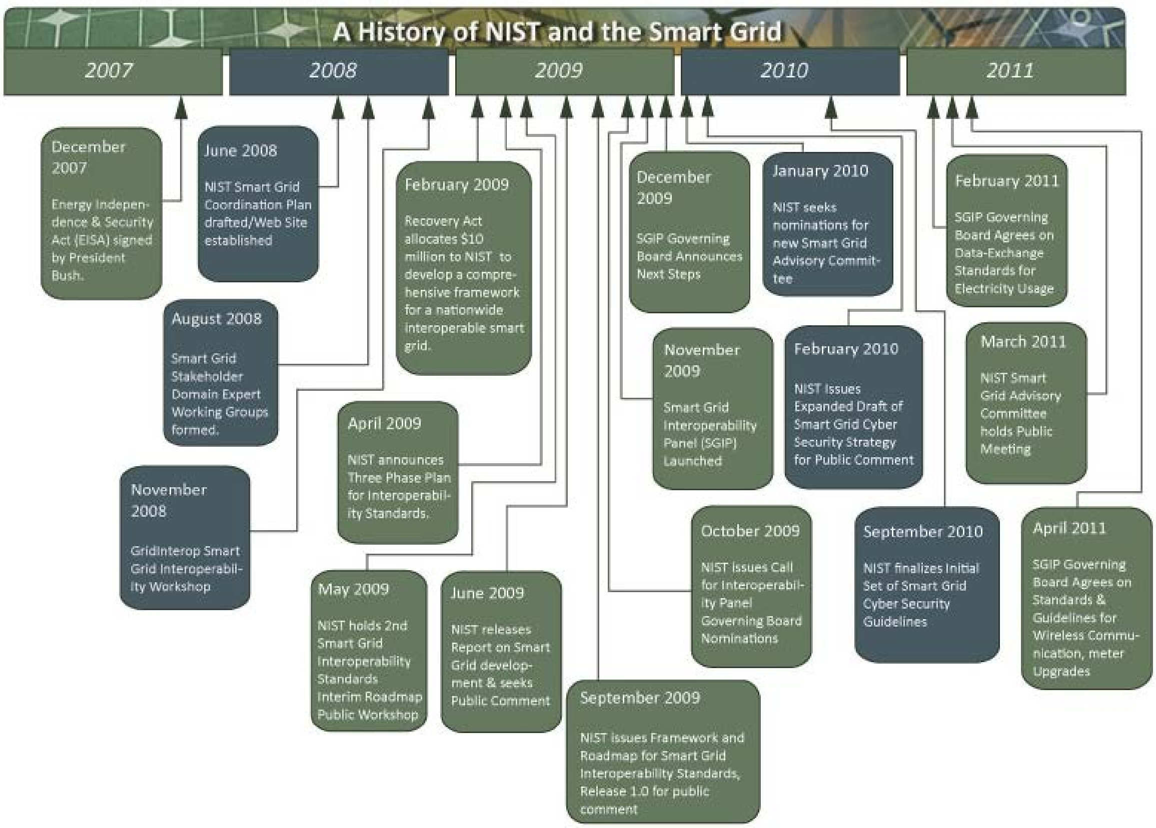

FIGURE 55: A HISTORY OF NIST AND THE SMART GRID [40]

The Key Concepts of NIST involvement is to expedite development of an interoperability framework and a roadmap for underpinning standards. To facilitate broad and balanced input from all Smart Grid stakeholders, the SGIP was established to:

- To create a forum with balanced stakeholder governance that would bring together stakeholders with expertise in the many various areas necessary for the Smart Grid, including areas such as power engineering, communications, information technology (IT), and systems engineering.
- To support development of consensus for Smart Grid interoperability standards.
- To provide a source of expert input for the interoperability standards framework and roadmap.

The Smart Grid will ultimately require hundreds of standards. Some are more urgently needed than others. To prioritize its work, NIST chose to focus on eight key functionalities especially critical to ongoing and near-term deployments of Smart Grid technologies and services. The eight priority areas are:

- Demand response and consumer energy efficiency
- Wide-area situational awareness
- Energy storage
- Electric transportation
- Network communications
- Advanced metering infrastructure (AMI)
- Distribution grid management
- Cybersecurity

Chapter 2 - Smart Grid Visions provides a high-level description of the envisioned Smart Grid and describes major organizational drivers, opportunities, challenges, and anticipated benefits. These concepts have been discussed in Chapter 1 of this document.

Chapter 3 - Conceptual Architectural Framework presents a set of views (diagrams) and descriptions that are the basis for discussing the characteristics, uses, behaviour, interfaces, requirements, and standards of the Smart Grid. Because the Smart Grid is an evolving networked system of systems, the high-level model provides guidance for standards-setting organisations (SSOs) developing more detailed views of Smart Grid architecture.

Fundamental goals of architectures for the Smart Grid include

- **Options** – Architectures should support a broad range of technology options—both legacy and new.
- **Interoperability** – Architectures must support interfacing with other systems.
- **Maintainability** – Architectures should support the ability of systems to be safely, securely, and reliably maintained throughout their life cycle.
- **Upgradeability** – Architectures should support the ability of systems to be enhanced without difficulty and to remain operational during periods of partial system upgrades.

- **Innovation –** Architectures should enable and foster innovation.
- **Scalability –**The architectures must support development of massively scaled, well-managed, and secure systems with life spans appropriate for the type of system, which range from 5 to 30 years.
- **Legacy –** Architectures should support legacy system integration and migration.
- **Security –** Architectures should support the capability to resist unwanted intrusion, both physical and cyber.
- **Flexibility –** Architectures should allow an implementer to choose the type and order of implementation and to choose which parts of the architecture to implement without incurring penalties for selecting a different implementation.
- **Governance –** Architectures should promote a well-managed system of systems that will be enabled through consistent policies over its continuing design and operation for its entire life cycle.
- **Affordability –** Should enable multivendor procurement of interoperable Smart Grid equipment through the development of mature national and international markets.

The conceptual model presented by NIST supports planning, requirements development, documentation, and organization of the diverse, expanding collection of interconnected networks and equipment that will compose the Smart Grid. The model is divided into seven domains, Markets, Operations, Service Providers, Bulk Generation, Transmission, Distribution, and Customer.

Each domain—and its sub-domains—encompass Smart Grid actors and applications. Actors include devices, systems, programs, and stakeholders that make decisions and exchange information and applications are tasks performed by one or more actors within a domain. To enable Smart Grid functionality, the actors in a particular domain often interact with actors in other domains, as shown in Figure 55.

The conceptual model described here provides a high-level, overarching perspective of a few major relationships that are developing across the smart grid domains. It is not only a tool for identifying actors and possible communications paths in the Smart Grid, but also a useful way for identifying potential intra- and inter-domain interactions, as well as the potential applications and capabilities enabled by these interactions.

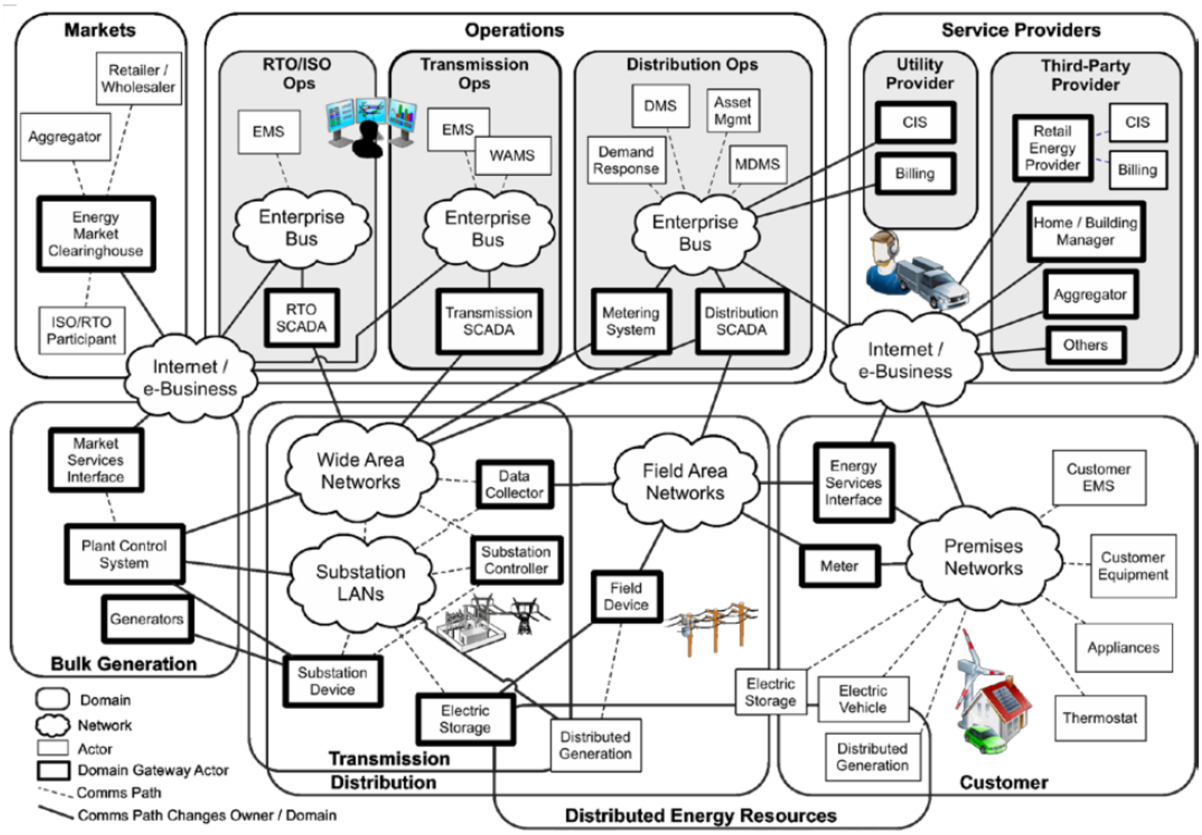

FIGURE 56: CONCEPTUAL REFERENCE DIAGRAM FOR SMART GRID INFORMATION NETWORKS [40]

Chapter 4 - Standards Identified for Implementation presents and describes existing standards and emerging specifications applicable to the Smart Grid. It includes descriptions of selection criteria and methodology, a general overview of the standards identified by stakeholders in the NIST-coordinated process, and a discussion of their relevance to Smart Grid interoperability requirements.

During the first phase of the NIST three-phase plan for Smart Grid interoperability, NIST's approach to accelerate the development of standards was to 1) identify existing standards that could be immediately applied to meet Smart Grid needs, or were expected to be available in the near future, and 2) identify gaps and establish priority action plans (PAPs) to develop additional needed standards to fill these gaps.

After the publication of *Release 1.0*, and the establishment of the SGIP, NIST transitioned the standard identification process so that it works through various SGIP venues and activities. These venues include the many SGIP committees, SGIP working groups, PAPs, and numerous face-to-face meetings in conjunction with many industry conferences relevant to the Smart Grid. The SGIP has developed a process where standards can be added to the Catalog of Standards (CoS) through either SGIP working groups or PAPs. The basic process is outlined in Figure 56.

The CoS is a compendium of standards and practices considered to be relevant for the development and deployment of a robust and interoperable Smart Grid. Though standards facilitate interoperability, they rarely, if ever, cover all levels of agreement and configuration required in practice. As a part of its work program, the SGIP is defining a testing and certification program that may be applied to the equipment, devices, and systems built to the standards listed in the CoS and that, if applied, will substantiate that implementations designed to the respective standards not only have compliance with the standards, but are also interoperable with one another.

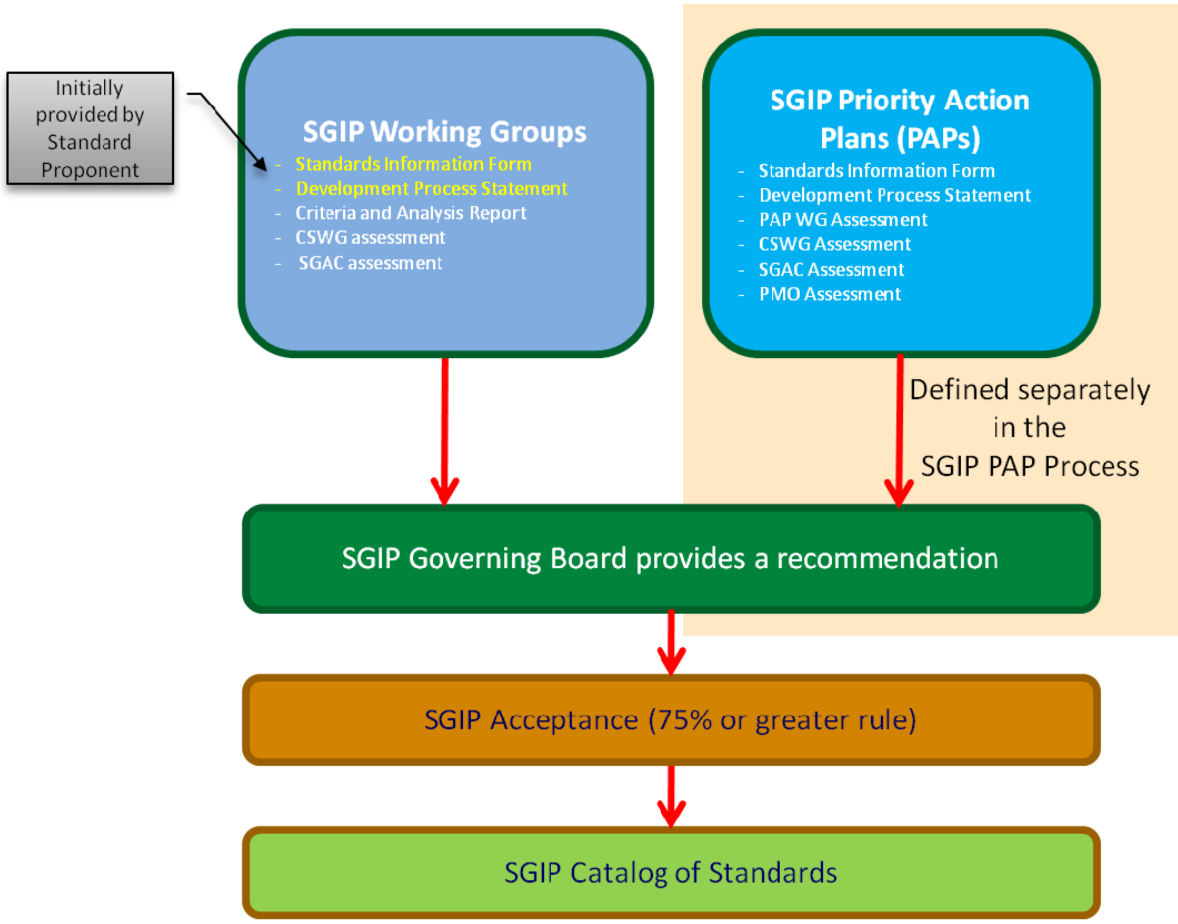

FIGURE 57: BASIC PROCESS BY WHICH STANDARDS CAN BE ADDED TO THE CATALOGUE OF STANDARDS (COS) [40]

The NIST Framework has identified 37 Smart Grid-relevant standards and an additional 61 standards for further review. Details of these identified standards can be found in Table 4-1 and 4-2 of [40].

Chapter 5 - Smart Grid Interoperability Panel presents the mission and structure of the SGIP. The SGIP is a membership-based organization established to identify, prioritize, and address new and emerging requirements for Smart Grid standards. Working as a public-private partnership, the SGIP provides an open process for stakeholders to interact with NIST in the ongoing coordination, acceleration, and harmonization of standards development for the Smart Grid. As of January, 2012, the SGIP includes over 740 member organizations and over 1,900 member representatives in 22 Smart Grid stakeholder categories; 29 of these member representatives are from Canada, with the largest foreign membership, and 58 more are from other countries, including China.

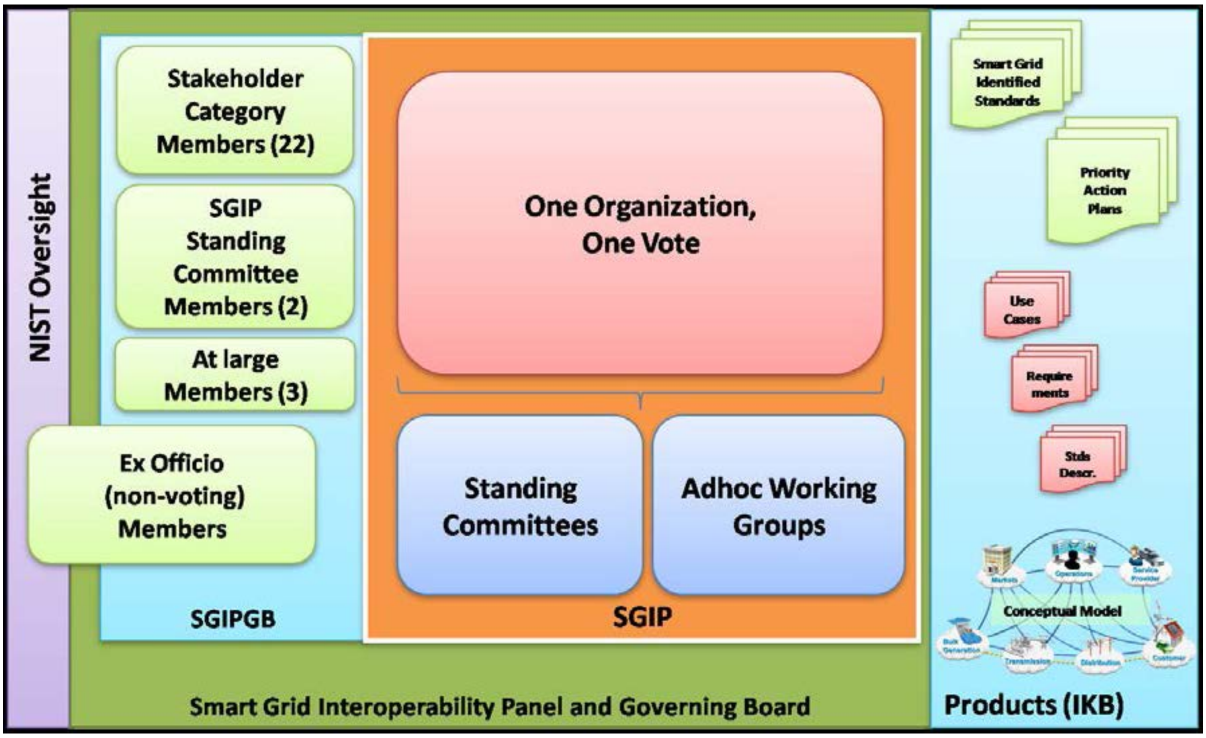

FIGURE 58: SGIP STRUCTURE [40]

The SGIP is guided by a Governing Board, elected by the participating member organizations. The Governing Board approves work programs for the SGIP to efficiently carry out its work, prioritizes objectives, and arranges for the necessary resources. The members comprise representatives from the 22 stakeholder groups plus 3 at-large members and maintain a broad perspective of the NIST Interoperability Framework and support NIST.

Much of the work of the SGIP is carried out by standing committees and permanent working groups. There are two standing committees—the Smart Grid Architecture Committee (SGAC) and the Smart Grid Testing and Certification Committee (SGTCC). At the present time, the SGIP has established one permanent working group, the Cybersecurity Working Group (CSWG). There are also a number of ad hoc working groups, including Domain Expert Working Groups (DEWGs) and Priority Action Plans (PAPs).

PAPs are a key activity of the SGIP. They arise from the analysis of the applicability of standards to Smart Grid use cases and are targeted to resolve specific critical issues. PAPs are created only when the SGIP determines there is a need for interoperability coordination on some urgent issue. Specifically, a PAP addresses one of the following situations:

- A gap exists, where a standard or standard extension is needed.
- An overlap exists, where two complementary standards address some information that is in common but different for the same scope of an application. An example of this is metering information, where the Common Information Model (CIM), 61850, the American National Standards Institute (ANSI) C12.19, Smart Energy Profile (SEP) 1.0, and SEP 2.0 all have nonequivalent methods of representing revenue meter readings.

Chapter 6 - Cybersecurity Strategy provides an overview of the content of the NIST Interagency Report 7628, *Guidelines for Smart Grid Cyber Security* [48], and outlines the go-forward strategy of the Cybersecurity Working Group (CSWG). Cybersecurity is now being expanded to address the following: combined power systems; information technology (IT) and communication systems in order to maintain the reliability of the Smart Grid; the physical security of all components; the reduced impact of coordinated cyber-physical attacks; and the privacy of consumers.

The CSWG now has more than 650 participants, comprising national and international members from 22 Smart Grid stakeholder categories including utilities, vendors, and service providers, academia, regulatory organizations, state and local government, and federal agencies. Members of the CSWG assist in defining the activities and tasks of the CSWG, attend the SGIP and SGIP Governing Board (SGIPGB) meetings, and participate in the development and review of the CSWG subgroups' projects and deliverables. Currently, there are eight subgroups, with each subgroup containing one or two leads.

- **AMI Security Subgroup** This subgroup was created in late 2010 to accelerate the standardization of a set of AMI security requirements by a formally recognized standards development organization (SDO) or a selected standards-setting organization (SSO). Additionally, the subgroup has developed a suite of eight AMI use cases and related failure scenarios that will serve as input to the SGAC and overall architecture.
- **Architecture Subgroup** This subgroup has initiated the development of a conceptual Smart Grid cybersecurity architecture based on the high-level requirements, standards analysis, overall Smart Grid architecture, and other cybersecurity information from NIST Interagency Report (NISTIR) 7628.
- **Design Principles Subgroup** This subgroup was created after publishing NISTIR 7628 to continue the work of identifying bottom-up problems and design considerations developed by the former Bottom-up, Vulnerability, and Cryptography and Key Management subgroups.
- **High-Level Requirements Subgroup** This subgroup developed an initial set of security requirements applicable to the Smart Grid, published in NISTIR 7628. The security requirements are specified for logical interface categories rather than for individual logical interfaces.
- **Privacy Subgroup** This subgroup conducted a privacy impact assessment (PIA) for the consumer-to-utility portion of the Smart Grid to include an initial set of issues and guidelines for protecting privacy within the Smart Grid environment. The Privacy subgroup continues to investigate privacy concerns including interfaces between consumers and non-utility third parties, as well as utilities and other third parties.
- **Research and Development (R&D) Subgroup** This subgroup identifies problems that arise or are expected to arise in the Smart Grid that do not yet have commercially viable solutions. The R&D subgroup identified in NISTIR 7628 an initial set of high-priority R&D challenges, as well as R&D themes that warrant further discussion. Many of the topics are now being addressed by other industry groups, by federal agencies, and by the Design Principles subgroup.

- **Standards Subgroup** This subgroup assesses standards and other documents with respect to the cybersecurity and privacy requirements from NISTIR 7628. These assessments are performed on the standards contained in the Framework or when PAPs are finalizing their recommendations.
- **Testing and Certification Subgroup** Created in late 2010, the Testing and Certification (TCC) subgroup establishes guidance and methodologies for cybersecurity testing of Smart Grid systems, subsystems, and components.

To date, the Standards subgroup has produced detailed reports that contain analysis and recommendations for improvements in the following standards:

- Association of Edison Illuminating Companies (AEIC) Metering Guidelines;
- American National Standards Institute (ANSI) C12.1: American National Standard for Electric Meters Code for Electricity Metering; ANSI C12.18: : American National Standard Protocol Specification for ANSI Type 2 Optical Port;
- ANSI C12.19: American National Standard For Utility Industry End Device Data Tables; ANSI C12.21: American National Standard Protocol Specification for Telephone Modem Communication;
- ANSI C12.22: American National Standard Protocol Specification For Interfacing to Data Communication Networks;
- International Electrotechnical Commission (IEC) 60870-6/ Telecontrol Application Service Element (TASE).2/ Inter-Control Centre Communications Protocol (ICCP): Control Center to Control Center Information Exchanges;
- IEC 61850: Communications Networks and Systems for Power Utility Automation;
- IEC 61968: Common Information Model (CIM) and Messaging Interfaces for Distribution Management;
- IEC 61970: Energy Management System Application Program Interface (EMS-API) (also referred to as the “Common Information Model for Wires Models”);
- IEC 62351: Power Systems Management and Associated Information Exchange - Data and Communications Security, Parts 1 through 7;
- North American Energy Standards Board (NAESB) Energy Usage Information;
- National Electrical Manufacturers Association (NEMA) Upgradeability Standard (NEMA SG AMI 1-2009);
- Organization for the Advancement of Structured Information Standards (OASIS) Web Services (WS)-Calendar;
- Role of Internet Protocol Suite (IPS) in the Smart Grid, an Internet Engineering Task Force (IETF)-proposed document;
- SAE J1772-TM: Society of Automotive Engineers (SAE Electric Vehicle and Plug in Hybrid
- Electric Vehicle Conductive Charge Coupler;
- SAE J2847/1: Communication between Plug-in Vehicles and the Utility Grid;
- SAE J2836/1: Use Cases for Communication between Plug-in Vehicles and the Utility Grid;

- Institute of Electrical and Electronic Engineers (IEEE) C37.238/D5.7, Draft Standard Profile for Use of IEEE Std. 1588 Precision Time Protocol in Power System Applications;
- International Electrotechnical Commission (IEC) 61850-90-5, Use of IEC 61850 to Transmit Synchrophasor Information According to IEEE C37.118; and
- IEEE 1588, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.

Chapter 7 - Testing and Certification provides details on an assessment of existing Smart Grid standards testing programs, and it offers high-level guidance for the development of a testing and certification framework. This chapter includes a comprehensive roadmap and operational framework for how testing and certification of the Smart Grid devices will be conducted.

Chapter 8 - Next Steps contains a high-level overview of some of the currently foreseen areas of interest to the Smart Grid community, including electromagnetic disturbance and interference, reliability and “implementability” of standards.

CURRENT NEW ZEALAND SMART GRID PROGRESS

Our national electricity system includes four basic components: generation, transmission, distribution and retailing.

New Zealand has five major generators who together provide more than 90% of the country's electricity. They own and/or operate some 168 power stations. Another 32 power stations which supply the remaining 10% of electricity are independently owned. Currently about 74% of New Zealand's electricity comes from renewable resources like hydro, geothermal, biomass, solar and wind. Government's goal is to increase this to 90% by 2025.

Transpower is the state-owned company responsible for maintaining the national grid. Its assets include 25,000 towers, 16,000 poles and 12,000 km of transmission lines.

Distribution of electricity locally is done by the electricity networks businesses (ENB's) who sit between the national grid managed by Transpower and residential, commercial and industrial consumers. These 29 companies manage some 150,000 km of local lines. They deliver the electricity consumers buy from retailers. They have a range of ownership models, from publicly listed to privately owned by local consumer trusts or local government bodies.

Most electricity consumers – whether they are residential or commercial consumers – buy their electricity from 18 retailers. Most of these retailers are owned by the five major generators. There are some 1.7 million residential consumers who purchase about 34% of the available electricity annually while 275,000 commercial, industrial and agri-business consumers use 66% of available electricity annually.

GOVERNMENT

At this stage, there is no specific policy on smart grids from the New Zealand government. However, general policy regarding the electricity sector is found in New Zealand's Energy policy, which is set by the Ministry of Economic Development. In August 2011, the government released the New Zealand Energy Strategy 2011-2021 (NZES). The NZES sets the strategic direction for the energy sector and the role energy will play in the New Zealand economy. The government's goal is for New Zealand to make the most of its abundant energy potential through the environmentally responsible development and efficient use of the country's diverse energy resources.

In the public consultation phase of the document, the government received a total of 3,844 submissions were received covering either or both strategies. Of these, 359 were 'unique' submissions: 210 from individuals and 149 from businesses and other organisations; and 3,485 from individuals based on templates supplied by either Greenpeace or the World Wide Fund for Nature – New Zealand. A wide range of perspectives were submitted. Petroleum sector submitters, along with some business organisations, were generally supportive of the areas of focus set out in the draft New Zealand Energy Strategy. However, many renewable energy companies, environmental organisations and individuals were concerned not enough emphasis was placed on climate change, energy efficiency and the promotion of renewable energy [49].

The New Zealand Energy Strategy 2011-2021 sets out four priority areas [50]:

- **Diverse Resource Development** This priority area has three main areas of focus; develop renewable energy resources, develop petroleum and mineral fuel resources, and embrace new energy technologies. As part of the renewable energy resources focus, the government has set a target that 90% of electricity generation should be from renewables by 2025, providing this does not affect security of supply.
- **Environmental Responsibility** This priority area has two main areas of focus; best practice in environmental management for energy projects, and reduce energy-related greenhouse gas emissions, see Figure 58. The Government has set a target for a 50 percent reduction in New Zealand’s greenhouse gas emissions from 1990 levels by 2050. Government policies that will reduce energy greenhouse gas emissions include:
    - The New Zealand Emissions Trading Scheme (NZ ETS).
    - Facilitating greater investment in renewable energy and in energy efficiency and conservation.
- **Efficient Use of Energy** This priority area has four main areas of focus; warm, dry, energy efficient homes, an energy efficient transport system, enhance business competitiveness through energy efficiency, and better consumer information to inform energy choices. This priority area does have a focus on AMI technology. As smart meter technology is installed by companies, the Government will ensure consumer rights are protected, and will monitor the effect on consumer energy use and electricity bills. The Government will encourage industry participants to explore the opportunities offered by smart meter, grid and appliance technologies in providing consumers with better information and options for their energy management.
- **Secure and Affordable Energy** This priority area has three main areas of focus; competitive energy markets, reliable electricity supply, oil security and transport. In 2009 and 2010, the review of the electricity market resulted in significant electricity market reforms. The reforms make it easier for more electricity retailers to operate across New Zealand, so customers will have more choice in providers. The Government has also established a three-year $15 million fund to promote customer switching. The Electricity Authority estimates that residential customers could save on average about $150 a year – or $240 million a year across all customers – by switching to the cheapest available retailer. The Government’s major electricity market review in 2009 also resulted in a broad suite of proposals to increase security of supply. New measures to promote secure electricity supply include phasing out the reserve energy scheme and ensuring that market participants have clear incentives to manage risk. These incentives include a proposed floor on spot prices and requiring companies to compensate consumers during conservation campaigns.

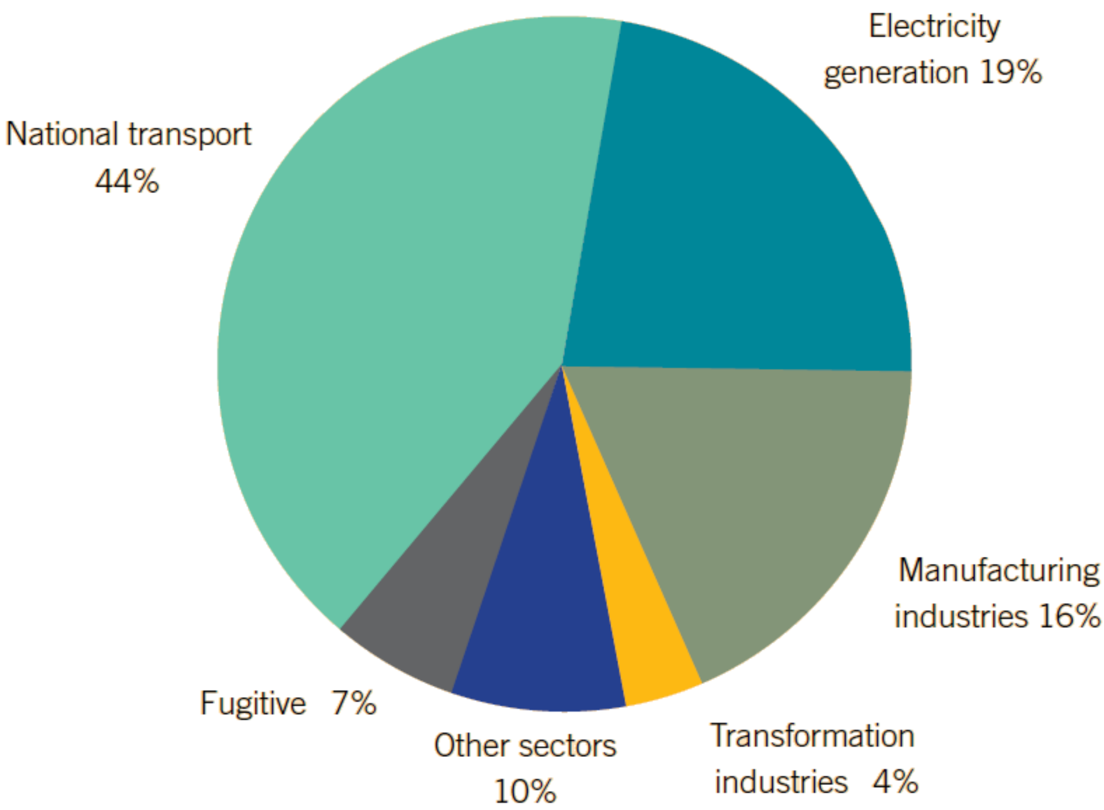

FIGURE 59: NEW ZEALAND ENERGY EMISSIONS BY SECTOR IN 2009 [50]

The New Zealand Energy Efficiency and Conservation Strategy 2011-2016 (NZEECS), a companion strategy to the NZES, is specifically focused on the promotion of energy efficiency, energy conservation and renewable energy. The NZEECS sets out six objectives for six sectors, which will contribute to the overall New Zealand Energy Strategy 2011-2021 goal:

- Transport: A more energy efficient transport system, with a greater diversity of fuels and alternative energy technologies.
- Business: Enhanced business growth and competitiveness from energy intensity improvements.
- Homes: Warm, dry and energy efficient homes with improved air quality to avoid ill-health and lost productivity.
- Products: Greater business and consumer uptake of energy efficient products.
- Electricity System: An efficient, renewable electricity system supporting New Zealand's global competitiveness.
- Public Sector: Greater value for money from the public sector through increased energy efficiency.

The policy set out in NZEECS regarding the electricity system is stated as. "The Government will continue to set the framework and incentives for a competitive electricity market to deliver the 90 percent target, including by:

- Removing unnecessary barriers to investment in large-scale renewable electricity generation, such as further improving consenting processes under the Resource Management Act and supporting the implementation of the National Policy Statement on Renewable Electricity Generation to provide clear guidance to councils.
- Incorporating the cost of greenhouse gas emissions into electricity investment decisions through the New Zealand Emissions Trading Scheme.
- Fostering the deployment of new renewable sources such as marine energy.
- Ensuring the electricity sector has an appropriate focus on electricity demand management tools.

Building on the solid framework and incentives in place for the electricity market, the Government will promote a coordinated approach to emerging electricity system technologies. The Government will further consider its role in promoting new electricity industry development and in addressing market failures and system constraints on new technologies. The scope of this work includes:

- The future role of distributed generation and barriers to its deployment.
- The impact of new renewable generation technologies on the electricity system.
- System requirements of smaller-scale generation technologies.
- Demand management opportunities, including opportunities for more efficient use of electricity.
- The risks, opportunities and growth path of smart grid infrastructure.
- Smart metering opportunities and risks.

The Government will monitor industry rollout of smart meter, smart network and smart appliance technologies, to promote consumer choice and a more efficient electricity system. The Government wishes to see a responsive and future focused electricity system taking advantage of new technology opportunities and welcoming new investors. It wants the electricity system to take advantage of new smart technologies to promote energy conservation to consumers and to improve energy efficiency.

The Electricity Industry Act 2010 provides lines companies with the option of developing smaller-scale electricity generation. This change is expected to provide new options for remote communities presently serviced by uneconomic lines. The Government expects all parties responsible to minimise lines losses and make efficiency gains in the operation of the electricity system, and plan ahead to ensure the system can securely support a greater proportion of renewable generation and integrate new technology in the future." [50]

In the last 20 years, there has been a concerted focus on developing a competitive retail electricity market, culminating in the Electricity Industry Act 2010 which established the Electricity Authority (EA) (previously the Electricity Commission). The EA is responsible for regulating the New Zealand electricity market. Its objective is to promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers.

GENERATION

The majority of electricity generation in New Zealand is split between five companies. Three of these, Meridian Energy, Genesis Power and Mighty River Power, are state-owned enterprises while Contact Energy and TrustPower are privately owned. Between them, these companies accounted for 92% of New Zealand's electricity generation in 2011 [51]. The mix of generation is split between hydro, geothermal, coal, gas, and wind, with around 77% of the generation coming from renewables. This puts New Zealand third in the world for renewable generation as a percentage of total electricity as shown in Figure 59.

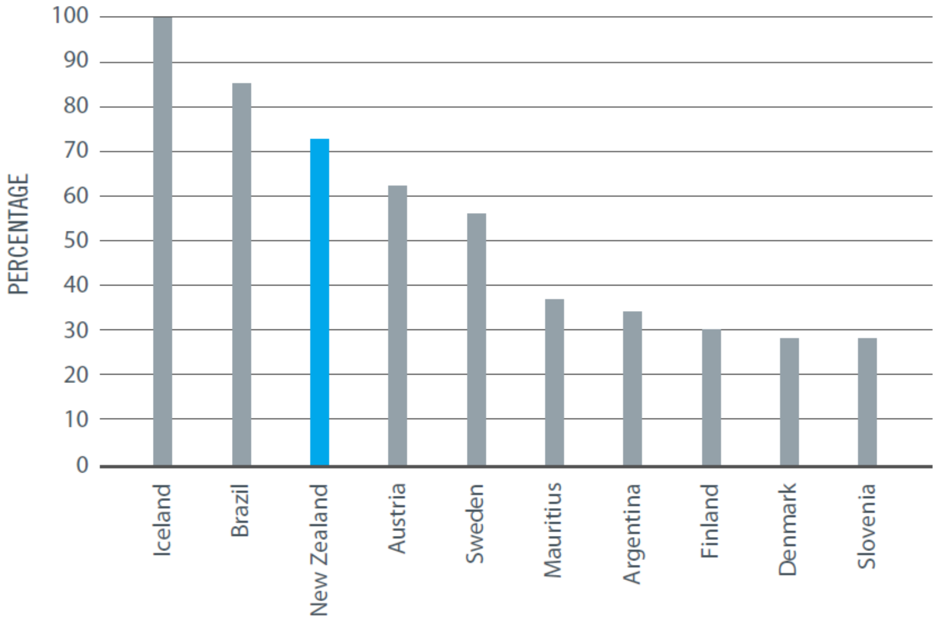

FIGURE 60: TOP 10 RENEWABLE ELECTRICITY COUNTRIES AS A % OF TOTAL ELECTRICITY [52]

The control of these generation assets quite advanced, with companies having invested in complex SCADA systems over the past couple of decades. These systems allow for remote control and monitoring of all of the generator's assets exchanging data every few seconds. This means a high level of automation is possible, for example, whole stations can be given a set point for MW and MVAr and operated automatically or control can be done at the unit level. While automation algorithms are present, the generation systems are overseen by trained human operators.

The advanced control systems available to the generators should make possible Smart Grid style operations such as enhanced frequency and voltage control algorithms, and automatic generation control and dispatch. These systems will become more important with increasing amounts of intermittent renewable energy such as wind or solar. They will also require centralised control and communications, probably from Transpower as the System Operator. However, at this stage each generator has their own communication and control systems which are not compatible with each other as highlighted by the exchange between Meridian Energy and Genesis Power of Tekapo A and B power stations which needed to be controlled by MEL while Genesis put their own systems in place.

Future Generation Scenarios

In 2011, a total of 43,138 GWh of electricity was generated in New Zealand as shown in Figure 60. Of this, 57.6% was generated from hydro, 18.4% from gas, 13.4% from geothermal, 4.7% from coal, and 4.5% from wind. The remaining generation was from bioenergy and other thermal [51]. Demand for electricity in New Zealand is expected to grow by an average of 1.5% per annum until 2040 according to the EA. It is expected to grow by an average of 1.8% per year until 2020, slowing to an average of 1.2% per year by 2040 [53].

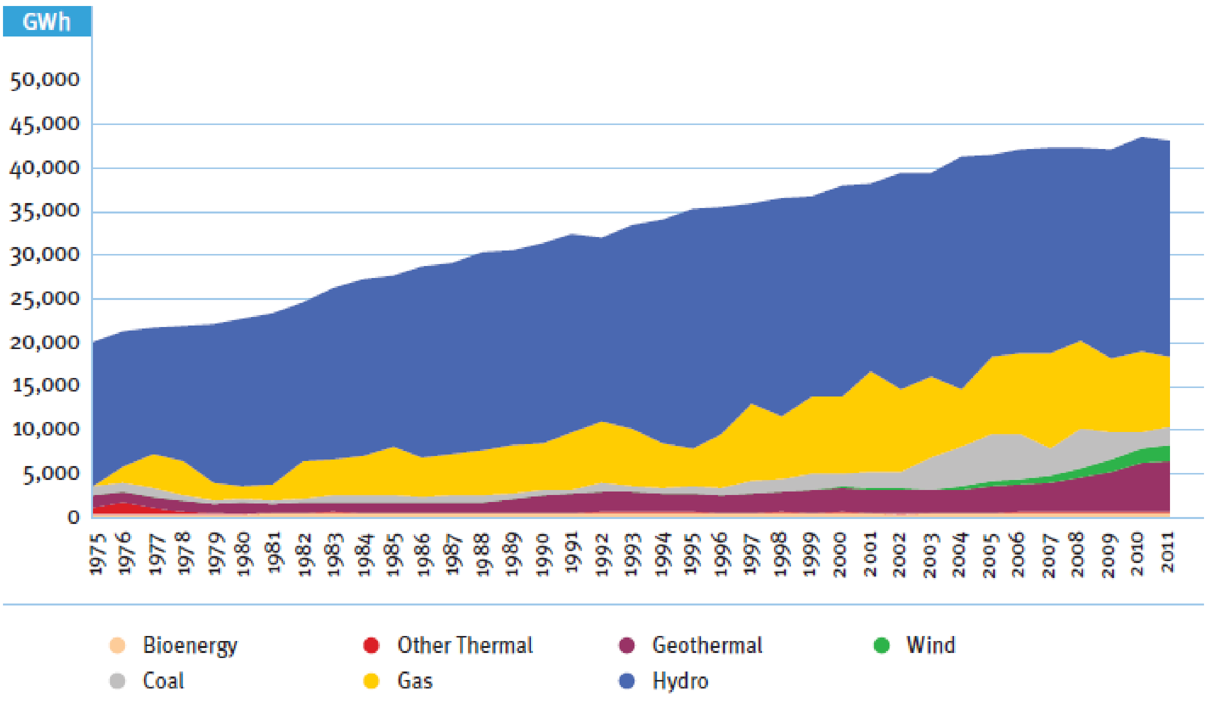

Figure 61: Annual Electricity Generation by Fuel Type [51]

To ascertain the generation mix needed to meet this demand the EA developed five different generation scenarios extending to 2040. Each of the five scenarios has been developed to represent plausible views of future possibilities, taking into account most of the uncertainties. However, none is presented as a 'most likely' future scenario and all are assigned equal weighting. The five scenarios are [53];

Sustainable path - New Zealand embarks on a path of sustainable electricity development and sector emissions reduction with a long-term average carbon charge of $60/t. In addition, no new large gas discoveries are made in the future. The resultant high gas price make gas-fired baseload generation relatively uneconomic to run and forces some to be decommissioned. Renewable generation, including hydro, wind, and geothermal, backed by thermal peakers for security of supply, are the least-cost option under this scenario. Electric vehicle uptake is high, and vehicle-to-grid technology is used to manage peaks and provide ancillary services. New energy sources are brought on stream in the late 2020s and 2030s, including biomass, marine, solar, and carbon capture and storage. Demand-side participation becomes a more important feature of the market, driven by consumer pressure.

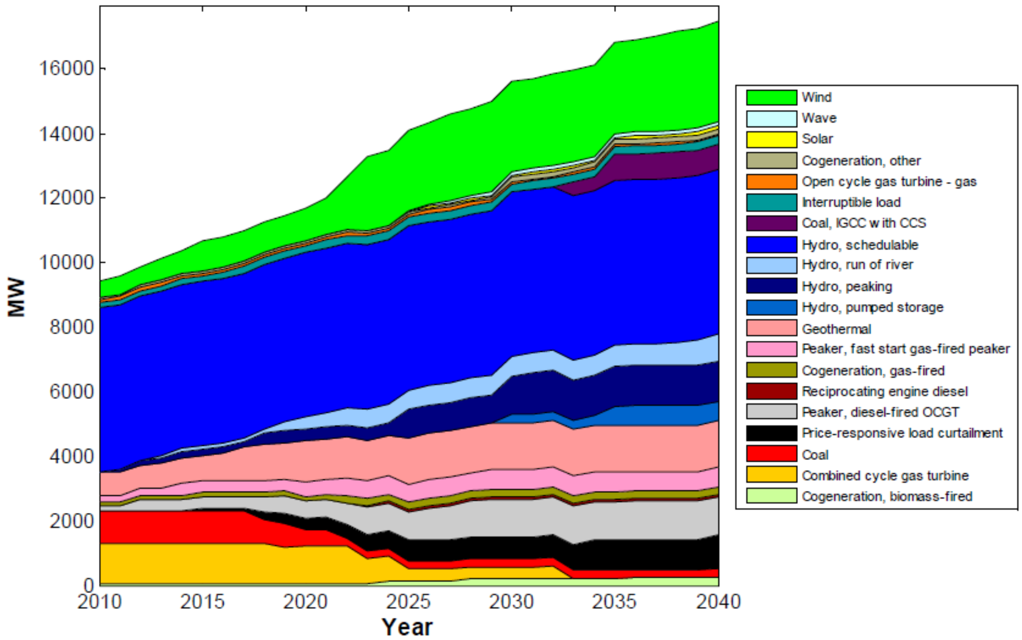

FIGURE 62: INSTALLED CAPACITY BY TECHNOLOGY BY YEAR - SUSTAINABLE PATH SCENARIO [53]

SI wind - Wind development proceeds at a slightly more rapid pace than in *Sustainable path*. The major wind farms having or currently seeking resource consent are built in the lower South Island in the early years. As with the *Sustainable path*, a high carbon charge and gas price lead to the decommissioning of some thermal plants. These plants are replaced by renewable generation. Thermal peakers supplement renewable development. New technologies are available after 2020. Less geothermal generation is available to this scenario because of resource consenting issues.

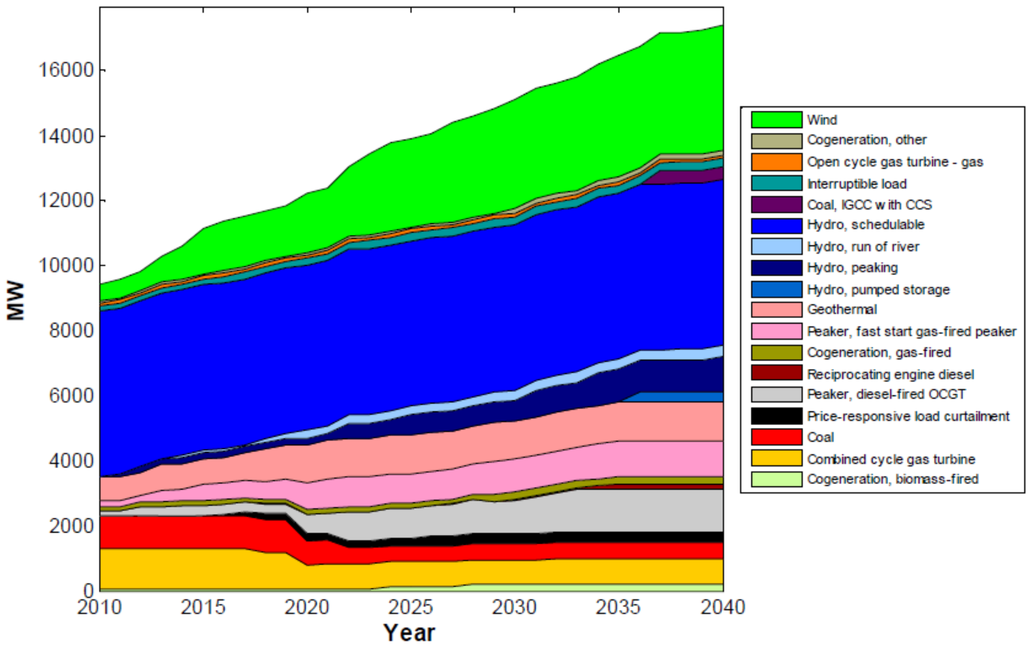

FIGURE 63: INSTALLED CAPACITY BY TECHNOLOGY BY YEAR – SOUTH ISLAND WIND SCENARIO [53]

Medium renewables - A 'middle-of-the-road' scenario. Renewables are developed in both islands, with North Island geothermal development playing an important role. The lead time between gas discovery and production leads to gas shortage between 2020 and 2030. Tiwai smelter is decommissioned in the mid-2020s.

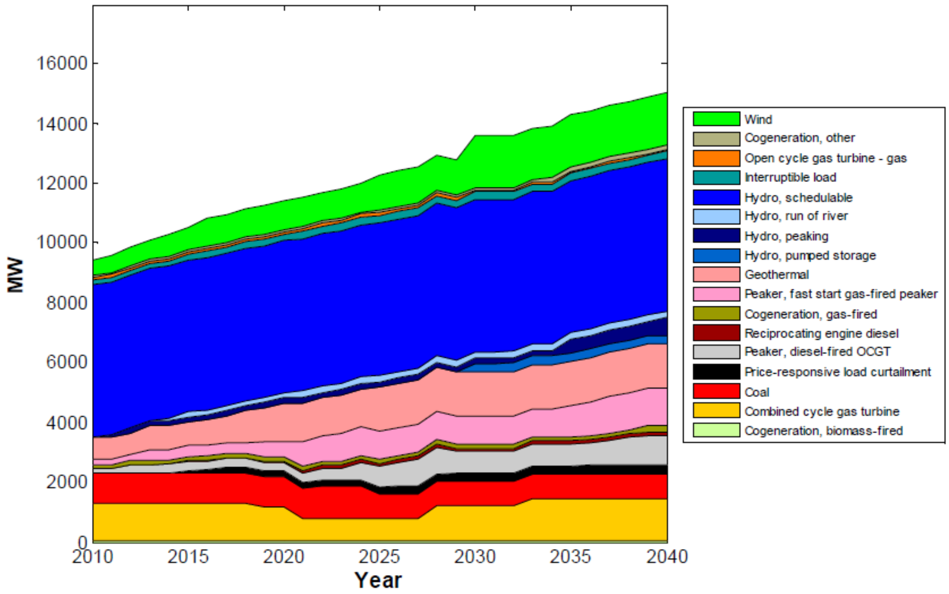

FIGURE 64: INSTALLED CAPACITY BY TECHNOLOGY BY YEAR – MEDIUM RENEWABLES SCENARIO [53]

Coal - The assumed low carbon charge and greater gas availability after 2030 make new gas-, coal-, and lignite-fired plants economic. Geothermal resources are still the least-cost option, with all the high-temperature resources developed prior to 2025. Little new hydro can be consented and some existing hydro schemes have to reduce their output, owing to difficulty in securing water rights. Electric vehicle uptake is relatively rapid after 2020.

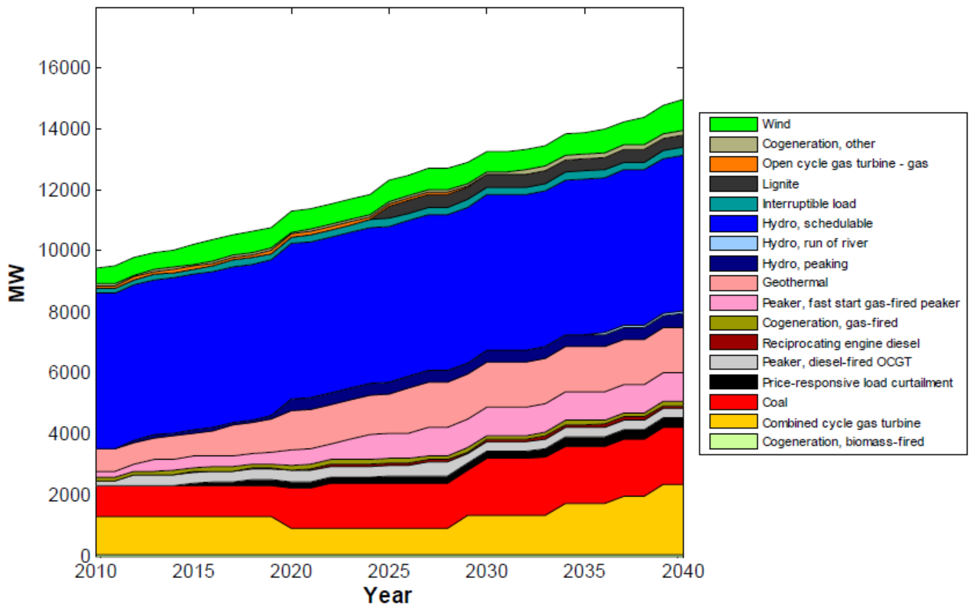

FIGURE 65: INSTALLED CAPACITY BY TECHNOLOGY BY YEAR - COAL SCENARIO [53]

High gas discovery - Major new gas discoveries keep gas prices low over the entire time horizon. Some existing thermal power stations are replaced by new, more efficient gas-fired plants. New CCGTs and gas-fired peakers are built to meet the country's power needs; the most cost-effective renewables are also developed. The demand-side remains relatively uninvolved.

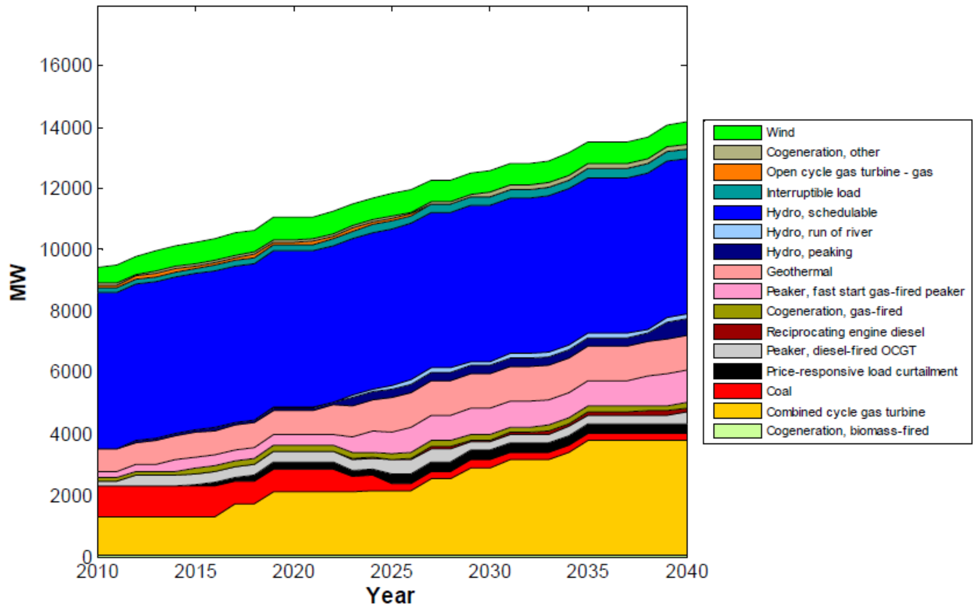

FIGURE 66: INSTALLED CAPACITY BY TECHNOLOGY BY YEAR – HIGH GAS DISCOVERY SCENARIO [53]

It should be noted that of the five scenarios presented, only the Sustainable Path scenario achieves the governments goal of 90% renewable generation by 2025 as shown in Figure 66.

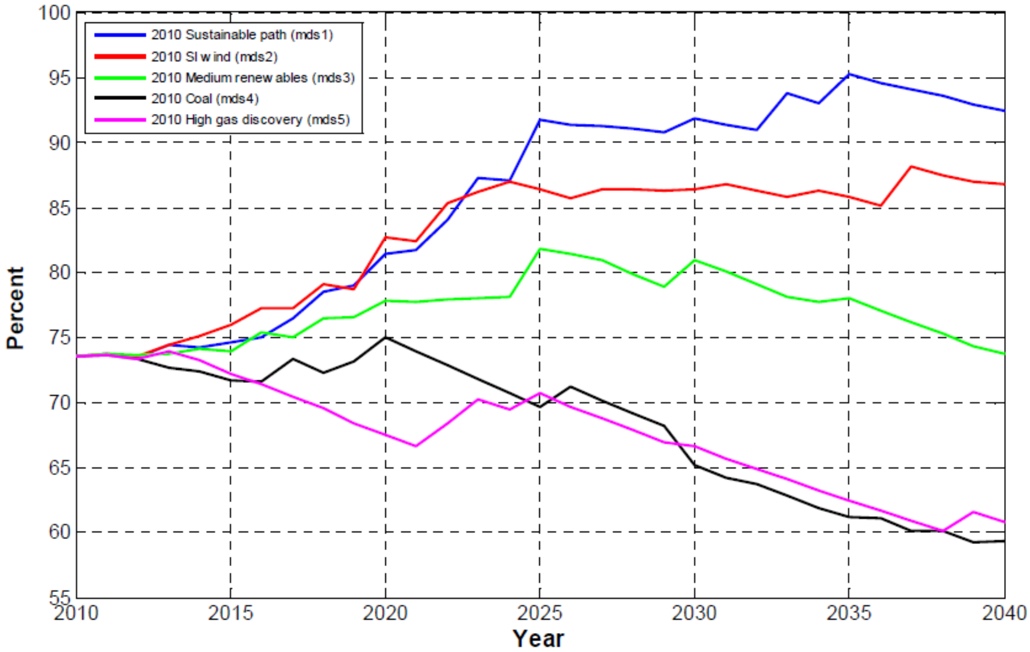

FIGURE 67: RENEWABLE ENERGY PERCENTAGE FOR EACH OF THE FIVE SCENARIOS [53]

According to the EA Statement of Opportunities 2010, there are 524MW of committed generation projects. This includes the 200MW gas open cycle peaking plant at Stratford power station which was opened 31st May 2011 and the 160MW Te Mihi geothermal station due to be completed in 2013.

From 2012, the above generation scenarios draw from a list of ‘prospective’ projects. These projects vary widely in terms of their current status. Some are consented or going through the consenting process, and are marked as either under appeal or applied for consent. Others have been proposed by generators, but are not yet in the consenting process. Some have been suggested, but are not currently known as being investigated by generators, because, for instance, they are not yet technically practical, or would not be economic under current market conditions.The list of projects includes:

- Nearly 40 possible wind projects, ranging from 10 to 540MW, located throughout New Zealand (although with the majority in the North Island) and totalling over 4300MW.
- Up to 150MW of new interruptible load, up to 1300MW of demand-side response available at peak, and up to 1000MW of vehicle-to-grid support from plug-in electric vehicles.
- 12 geothermal projects, located in the central North Island and totalling over 1000MW.
- Over 55 possible hydro projects ranging in size from 10 to 340MW, located throughout New Zealand and totalling around 3750MW.
- Six generic marine projects totalling nearly 250MW.
- Nine assorted co-generation projects totalling about 450MW.
- Eight gas-fired CCGTs totalling nearly 3000MW (Otahuhu C and Rodney stages 1 and 2), Taranaki CC 2 and Taranaki CC 3, plus three generic 400MW plants in Auckland, Taranaki and New Plymouth.
- 12 gas-fired thermal peakers, totalling about 1250MW, located in Taranaki or the Waikato.
- 24 diesel-fired thermal peakers, totalling about 1500MW, located as needed, and six 40MW diesel reciprocating engine generators.
- Six generic solar plants each of up to 50MW each.
- Seven black coal plants (generic projects in the 300 to 400MW range, nominally located at Glenbrook, Taranaki, Christchurch, Tauranga, Northland, and in the Waikato).
- Two lignite plants (400MW generic projects located in Southland and Otago).
- Seven coal, gas, or lignite plants with carbon sequestration.

These projects vary widely in consentability and economic viability. For example, some of the modelled hydro schemes may face considerable difficulty obtaining consents. The selection of projects is intended to be indicative of possible opportunities.

TRANSMISSION

The transmission network in New Zealand, known as the National Grid, is owned and operated by Transpower New Zealand Limited who is also the System Operator. In total, the national grid contains 11,803 kilometres of high-voltage lines, 178 substations and 1116 transformers.

As mentioned previously, the majority of generation in New Zealand is from renewable sources. A significant amount of this is hydro-electric generation located in the southern region of the South Island. However, the majority of the major loads are located in the North Island, particularly in the Auckland region. As a result, the grid is long and stringy and features a high voltage backbone spanning the length of the country (some 2000 kilometres) that links distant generation to major loads, see Figure 67. Connected to this backbone are a series of regional grids that serve regional loads and generation [52].

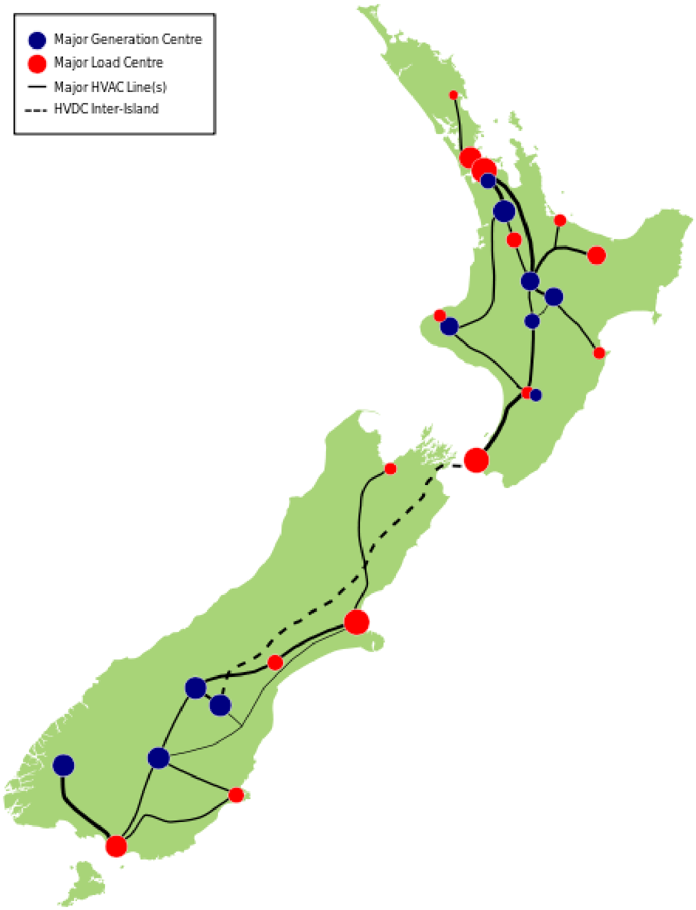

FIGURE 68: A SIMPLIFIED DIAGRAM OF THE NEW ZEALAND TRANSMISSION GRID [54]

The national grid was largely constructed throughout the 1950's with the HVDC inter island link being completed in 1965. The late 1980s and early 1990s saw the completion of the 220 kV backbone, with the last line connecting Stratford in Taranaki to Huntly in Waikato. The HVDC Inter-Island was also upgraded by increasing the operating voltage of the lines, replacing the original Cook Strait submarine cables and installing a new thyristor pole in parallel to the existing mercury arc valve converter equipment to double its capacity to 1240 MW

In 1997, Transpower adopted a strategy known internally as “the glide path”, and minimised spending on the grid and renewing assets. The rationale for this strategy was based on the expectation that there would be widespread installation of distributed generation (electricity generated close to where it is used), and that this would significantly reduce the need to expand and renew the grid. [55]

However, by 2003, it had become clear that the glide path strategy was unsustainable. Many of the grid assets were approaching the end of their useful life, and at the same time had to carry higher loads than previously experienced to meet the demands of a growing economy and population. Transpower identified that the grid backbone was nearing its capacity and that investment was needed in many other parts of the grid.

Transpower has moved from a long period of very low investment, over the last 20 years, to a concentrated period of high reinvestment in the transmission grid. Between 1995/96 and 2004/05, capital expenditure on new build and asset renewal averaged around $100 million per year. However, over the next decade Transpower expects to spend $3 to $5 billion to meet future electricity demand.

Grid Upgrade Projects

Transpower currently has committed to over 20 upgrade projects throughout New Zealand with four major projects totalling $2 billion. These projects are:

- North Island Grid Upgrade - Building a new power link between Whakamaru and Auckland.
- North Auckland and Northland Grid Upgrade Project - Reinforcing the network with a new 220kV cable link and two new substations.
- HVDC Inter-Island Link Project - Replacing Pole 1 of the inter-island HVDC link with a new pole.
- Wairakei to Whakamaru Replacement Transmission Line Project - Building a new double circuit transmission line between Wairakei and Whakamaru.

North Island Grid Upgrade

The $824 million North Island Grid Upgrade (NIGU) project involves strengthening the grid between Auckland and Taupo. There are three major components: an overhead transmission line, substations and underground cables. The 186 km, 400 kV capable overhead transmission line, a first for New Zealand, runs from a new substation at Whakamaru to a new Brownhill Road substation in South Auckland. Four underground 220 kV cable circuits will run from this new switching station - two circuits to a new substation at the existing Pakuranga site and, at a later date, two circuits to Otahuhu substation. Construction of the line started in February 2010, and the line is due to be commissioned in September 2012.

FIGURE 69: A 400KV CAPABLE STRAIN TOWER FOR THE NIGU PROJECT

The project was the subject of considerable controversy and protest during the planning and approval stages. Many individuals and communities living near the proposed route expressed concerns about the visual impact of the line, possible health effects, and the devaluation of their properties. A particular point of concern was that the proposed transmission towers were to be up to 70 metres (230 ft) in height. On 24 February 2005, protestors stormed out of a public meeting in Tirau, and effigies of the Transpower CEO Ralph Craven and Prime Minister Helen Clark were burnt in the street.

In April 2006, the Electricity Commission announced an intention to decline Transpower's investment proposal, on the grounds that it was not the most cost-effective solution. However, on 12 June 2006, the vulnerability of power supply to Auckland was revealed when a major transmission failure occurred at Otahuhu substation, leading to the 2006 Auckland Blackout. It started at 8:30 am local time, with most areas of Auckland regaining power by 2:45 pm local time. It affected some 230,000 customers had an impact on at least 700,000 people in and around the city.

North Auckland and Northland Grid Upgrade Project

The North Auckland and Northland Grid Upgrade Project involves installing a new underground 220 kV cable circuit from Pakuranga to Albany, connecting through Penrose substation and new substations at Hobson Street and Wairau Road. The new circuit will help reinforce electricity supply in North Auckland and Northland. Currently, they rely on one transmission line between Otahuhu and Henderson for their power.

The new cable will be buried primarily underneath existing roads and within designated transmission corridors. The project will also remove an overhead transmission line between Pakuranga and Penrose.

Figure 70: Trenching and Ducting in Northwood Reserve, Albany

The total estimated cost for the project is $417 million. It involves 37km of 220kV cabling and 33 overhead towers to be removed. The cable installation began in October 2011 and is due to be commissioned in 2013.

HVDC Inter-Island Link Project

On 21 September 2007, the original Pole 1 mercury-arc converter stations located at Benmore and Haywards substations were stood down "indefinitely". However, in December 2007, Transpower announced that one-half of the capacity of Pole 1 would be returned to "warm standby" service before the winter of 2008 in order to meet the demand for power in the North Island if needed. The remaining half-pole equipment of Pole 1 was to be decommissioned.

On 13 March 2008, Transpower announced that work had been completed to restore 50% of the capacity of Pole 1 to service at times when the demand for power on the North Island peaked. Several mercury arc rectifiers were salvaged from the Konti-Skan link between Denmark and Sweden for this restoration. The energy transfer on Pole 1 was strictly limited to the northbound direction, to reduce the stress and strain on the aged converter system.

The decommissioning of half of Pole 1 and the operational restrictions placed on the remaining Pole 1 capacity led to the HVDC link operating mostly in monopolar mode, using Pole 2 alone. In 2010, Transpower reported that continuous operation in monopolar mode has caused the HVDC link to act as a galvanic cell with the earth, causing Benmore's Bog Roy earth electrodes to erode as they acted as an anode, and causing the build up of magnesium and calcium hydroxide deposits on Hayward's Te Hikowhenua shore electrodes as they acted as a cathode. Additional replacement and maintenance works were required.

On 1 August 2012, Transpower decommissioned the remaining half of the Pole 1 mercury arc valve converter stations at Benmore and Haywards, after 47 years in service. The Inter Island link at the time was the last HVDC system in the world with mercury arc valve converters in operational service.

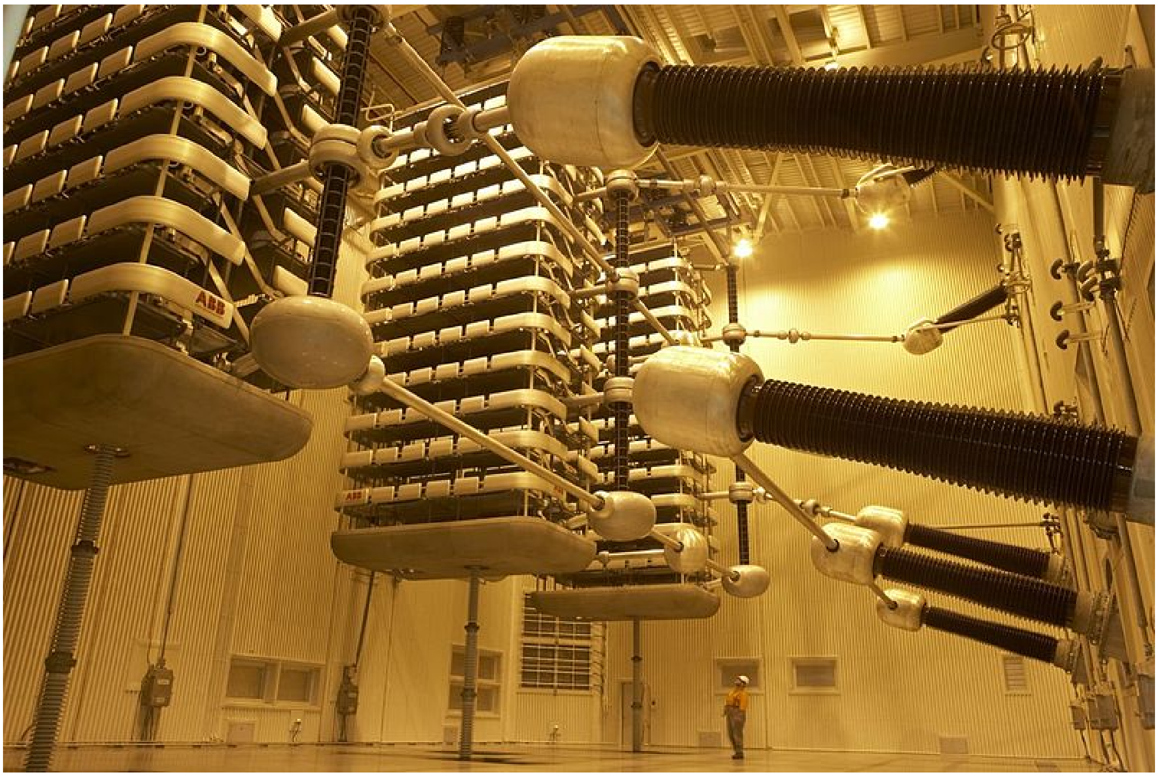

FIGURE 71: THYRISTOR VALVES USED ON THE HVDC LINK (POLE 2)

Transpower are constructing and installing new AC/DC converter equipment at Benmore and Haywards substations to increase capacity of the HVDC inter-island link. The new converter equipment, known as Pole 3, uses state-of-the-art thyristor valve units. It replaces the Pole 1 equipment at both substations. The HVDC Pole 3 project, worth up to $672 million, will be commissioned in early 2013.

Work involved in replacing Pole 1 with the new Pole 3 converter stations included:

- New valve halls adjacent to the Pole 2 valve halls at both Benmore and Haywards, each containing the thyristors converters
- New transformers connecting the valve halls to the 220 kV buses at both Benmore and Haywards
- Connecting the Pole 3 thyristors to the existing Pole 1 lines at both Benmore and Haywards
- Connecting the Pole 3 thyristors to the existing electrode lines at both Benmore and Haywards
- Switching the number 5 Cook Strait cable from Pole 2 back to the Pole 1/3.
- New 220 kV filters on the 220 kV buses at both Benmore and Haywards
- New transformers connecting the four synchronous condensers C7 to C10 to the 110 kV bus at Haywards
- New 5th and 7th harmonic filters connecting to the 110 kV bus at Haywards.
- Removal of the existing converter transformers connecting the Pole 1 mercury arc valves and two of the synchronous condensers to the 110 kV bus at Haywards.
- Removal of all remaining mercury arc valve Pole 1 equipment at both Benmore and Haywards.

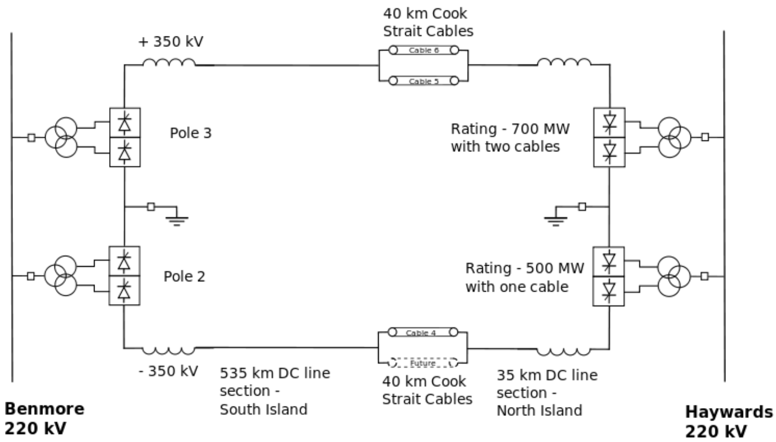

FIGURE 72: A SIMPLIFIED SCHEMATIC OF THE HVDC LINK

In addition to the work on Pole 1 and 3, Pole 2 will be taken out of service in 2013 to have the control systems replaced with new systems identical to those used in Pole 3, and to install a new bipole control system to control both poles.

WAIRAKEI TO WHAKAMARU REPLACEMENT TRANSMISSION LINE PROJECT

Transpower is carrying out a project to build a new double circuit 220 kV transmission line between Wairakei and Whakamaru to help connect more generation being built in the area. As part of this project, the existing Wairakei to Whakamaru B line (via Poihipi Rd) will be decommissioned and removed. This project will provide sufficient capacity for the foreseeable future. The expected budget for this project is $100-$300 million

TRANSMISSION TOMORROW

In 2008, Transpower began to look at the future of generation and the use of electricity in New Zealand as part of their Transmission 2040 strategy. They were aware that transmission is interlinked with a diverse range of stakeholders in the wider electricity system, including customers, landowners, distribution networks, retailers, generators and others. As such the changing face electricity sector would have a significant impact on the transmission network.

The Transmission Tomorrow document describes Transpower's views about the future needs for New Zealand's electricity transmission. They see [52];

- An economy becoming increasingly reliant on electricity, with increasing expectations of a reliable supply
- Transmission technology changing, enabling Transpower to utilise their existing assets better
- Technology enabling far more interaction with and by consumers
- Increasing amounts of remote and intermittent generation being built.

The major long-term planning concerns lie with the high voltage backbone grid. Today, the backbone grid predominantly carries energy from south to north. This often reverses overnight, as South Island hydro generators conserve water, and periodically reverses in dry winters, when the southern hydro lakes run low.

To determine the shape of tomorrow's grid, they have developed four scenarios of electricity generation and demand development in New Zealand, which look forward 30 years, see Figure 72. The scenarios are based on the two key elements that most affect the size and capacity of the grid – demand for electricity and the nature and location of generation.

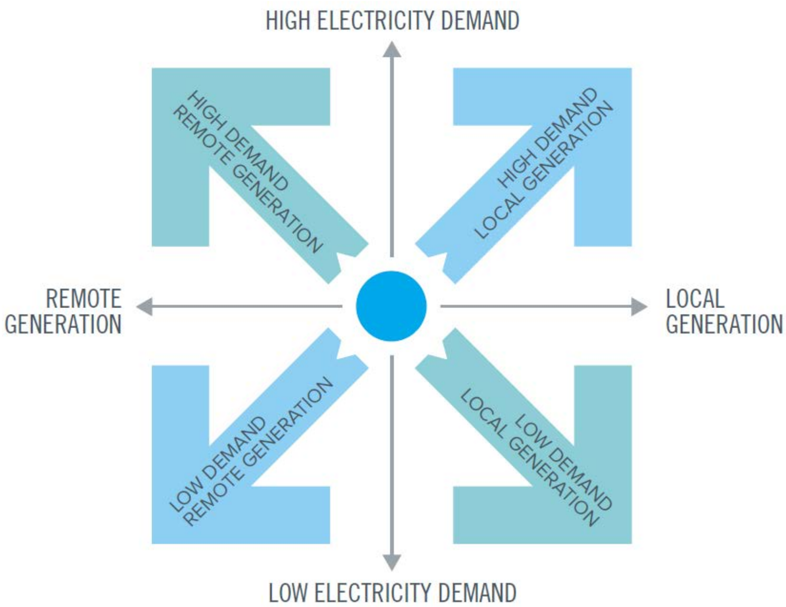

FIGURE 73: TRANSPOWER'S FOUR SCENARIOS FOR ELECTRICITY GENERATION AND DEMAND DEVELOPMENT IN NEW ZEALAND [52]

The scenarios use a range of peak demand growth as follows [52]:

- Increases from today's level by the year 2040, ranging from 30 to 80 percent in the North Island.
- Changes from today's level by the year 2040, ranging from -5 to 60 percent in the South Island. Negative growth only occurs in one scenario – where the Tiwai Point aluminium smelter closes.

These are not extreme limits – a 30 percent increase by 2040 is equivalent to an average annual growth rate of about 1 percent per year; a 100 percent increase by 2040 is equivalent to a growth rate of 2 percent per year. Actual growth could be lower or higher. New generation modelled in our scenarios is based on known and possible resources of hydro, wind, geothermal, gas or oil, coal and, to a lesser extent, marine generation. These resource areas and their spatial relationship to the major load centres will, to a large extent, dictate the future size and capacity of our grid.

Transpower has developed three strategies to deliver the grid of tomorrow. The three strategies are, Lifting Grid Performance, Lifting System Performance, and Improving Reliability and Resilience [52]. A summary of the three strategies is given below.

STRATEGY 1 – LIFTING GRID PERFORMANCE

Transpower will lift the performance of New Zealand's grid and transmission assets by:

- Completing life cycle-based asset fleet renewal and refurbishment programmes.
- Extending condition and risk-based approach to asset management.
- Operating key assets to ratings that reflect the actual conditions at the time.
- Maximising the capability of transmission routes using new approaches.

Tomorrow's grid will feature more volatile flows from intermittent renewable generation, demand response and distributed generation. This could erode grid utilisation. The challenge is to instead increase utilisation of the transmission asset fleet while optimising new capital outlay. Operating the grid will incorporate real-time asset management, with use of predictive models to provide variable and dynamic major asset ratings based on actual conditions. The utilisation of long transmission routes will be enhanced by using technology to allow the lines to be run at close to thermal limits safely, deferring the timing of new lines.

There are five initiatives to Strategy 1 as shown in Figure 73:

- **Renewal and Refurbishment** A major 30 year asset renewal programme was begun in 2008. The programme was based on a full life cycle assessment of each asset type includes comparison of the capital cost of replacement against the reduced life cycle costs of maintenance, spares, interruptions and electrical losses. These new life cycle strategies for all major asset fleets were completed in 2009/2010. The outcomes of this programme include;

  - Greater asset standardisation such as fewer AC voltage levels and fewer transformer types.
  - Better serviceability including enabling work on inservice (live) assets
- **Condition Based Asset Management** Current monitoring of conductive assets such as towers, conductors and joints, cables and busbar elements is relatively sophisticated. This includes wide use of ground and helicopter-based thermal surveying, and quick development of new monitoring techniques to address emerging issues. Maintenance of key power transforming and switching equipment is largely specification-based, modified by periodic infield condition assessment such as oil or electrical testing. With continued advances in condition monitoring to extend asset life more active monitoring will be installed on key assets.
- **Operating Assets to Ratings** In most cases, asset ratings are set to limit temperatures in key elements of the asset. Pre-calculated line ratings reflect the least favourable combination of temperature, wind and sunshine expected during that rating period. The actual load-carrying capacity of the line at any given time is often higher. Variable asset rating aims to make available this 'unused' capacity.
- **Real-Time Asset Management** Variable and dynamic asset ratings require a real-time asset management capability. At a minimum, Transpower's regional operating centres (ROCs) will become asset management centres able to use the data to initiate proactive action to prevent asset problems and provide real-time ratings at critical times. The ability to accurately estimate and monitor key temperatures within equipment in real time will greatly increase the ability to react to an asset failure without disconnecting customers. Real-time asset management will also require a more dynamic and interactive relationship between the system operator and the grid owner. Transpower's dual role is a key advantage for this, versus other regimes where the system operator is in separate ownership.
- **Maximising Capability of Transmission Routes** The carrying capacity of existing lines is being progressively lifted by thermally uprating (retensioning) existing conductors or by installing larger or duplexed conductors. A next step with long lines supplying major load centres is to allow them to operate closer to their thermal limits by extending the use of reactive compensation. Compensation can take the form of fixed capacitors, SVCs and STATCOMs. Management of many reactive support devices requires the installation of area-wide automated management systems in the form of regional reactive power controllers (RPCs) in both Christchurch and Auckland. Series compensation technology will be used to better utilise longer lines.

DATE/INITIATIVE	NEXT 5 YEARS	WITHIN 10 YEARS	WITHIN 20 YEARS	20+ YEARS
RENEWAL AND REFURBISHMENT	Strategic replacement programme for major plant continued	Asset performance comparable to that of our international peers	Complete strategic replacement programme	Assets designed to maximise availability – little offline maintenance required over lifetime of asset
CONDITION-BASED ASSET MANAGEMENT	Extend monitoring on key or at-risk assets	Roll out of SMS to deliver rich asset data (see Part 4)	Major substation equipment only serviced if identified by condition-based information	
OPERATING ASSETS TO RATINGS	Variable line ratings across New Zealand Dynamic line rating for specific lines	Dynamic cable rating for Auckland upgrades Dynamic transformer rating and cycling		Asset capability dynamically optimised in dispatch of the electricity system
REAL-TIME ASSET MANAGEMENT	Introduce real-time asset management in grid operation	Proactive maintenance and outage scheduling using rich asset data		
MAXIMISING CAPABILITY OF TRANSMISSION ROUTES	Area wide RPCs in main centres Use of STATCOMS in Auckland	Use of series compensation	Major transmission routes can operate close to thermal limits	Conversion of key AC lines to higher capacity DC (due to technology advances)

COMMITTED INITIATIVE
POTENTIAL OUTCOME
POSSIBLE TECHNOLOGY TREND

FIGURE 74: TIMING DIAGRAM FOR THE LIFTING GRID PERFORMANCE STRATEGY [52]

STRATEGY 2 – LIFTING SYSTEM PERFORMANCE

Strategy 2 aims to improve the efficiency of the New Zealand electricity system and the utilisation of the grid by:

- Improving the interaction between generation and transmission.
- Increasing the ability to use consumer response.
- Developing the operational capability to dispatch a highly utilised electricity system.

Operating the electricity system will become more dynamic and complex, with more intermittent renewable generation, variable asset ratings, distributed generation, energy storage and consumer response. The transmission and distribution grids will become interactive (two-way) with a flow-on effect of more variability on the grid. Load forecasting will better reflect local conditions (such as temperature, wind and cloud cover). Dispatch of generation will be dynamic. Switching of controllable loads and demand-side response by consumers will become part of the load-balancing mix.

Electricity system operators will have sophisticated applications and displays to operate and dispatch a complex, highly utilised grid, while maintaining a strong awareness of electricity system performance. Use of wide-area controls to integrate and automate the operation of generators, grid devices and load to respond to grid contingencies will be an alternative to providing grid redundancy through new grid assets.

There are three initiatives to Strategy 2 as shown in Figure 74:

- **Integrating Transmission and Distribution** Involves two major system management technology upgrades that will combine to provide major customer benefits in the next decade.
    - *Automatic Generation Control (AGC)* Currently, one generator in each island is dedicated to load-following. Within the next few years, AGC will manage the dispatch of generation. Transpower's new market systems software can already run the generation dispatch automatically, while the network platform investment will provide the high speed communications platform to enable wide use of AGC.
    - *New control technologies on the HV DC system* The upgraded HVDC bipole control system (to be commissioned in 2013) will enable a single national frequency-keeping market. The net present value of savings from a single market to maintain frequency at a stable 50 Hz in each island is estimated at between $25 and $107 million per year.

  By combining automatic dispatch of generation using AGC with the use of variable ratings and the automated operation of the grid, the existing grid can be better utilised reducing the need for new lines on the backbone grid.
- **Enabling Consumer Response** Demand-side response such as traditional ripple controlled water heating, off-peak charging of electric cars or the direct control of appliances to cover for the loss of grid capacity from a failure of generation or grid equipment will become more relevant in the near future. The ability to reduce the peak demand will help to defer grid investment in the short term. For example, the upper South Island distribution companies have reduced the peak demand in the region by 3 percent, deferring investment of $10 million by at least two years. Upcoming opportunities include:
    - The wider ability to control non-essential consumer loads to respond to unplanned outages or near-term issues on the grid over the next 20 years.
    - The ability to secure a predictable response from many smaller consumers through control of individual appliances and devices in homes and businesses in the longer term.
- **Developing Operational Capability** LV distribution networks gradually become ‘two-way’ with the growth of demandside response and smaller scale embedded generation resulting in the actual flows across the grid becoming less predictable. This will challenge the traditional approach to managing the connection between the grid

and its consumers. A number of future trends will increase the demand on operators to be able to quickly understand the true state of the electricity system. These include

- o Variable and dynamic asset ratings.
- o Automated Dispatch
- o Wide-Area Management Control Systems

Some improvements being adopted include

- o Automated constraint design in the market systems software.
- o Constraint visualisation package that allows ready identification of discrepancies between what is happening on the actual grid and how it is represented in the market systems.
- o New controller-centric displays that complement the system management applications.

DATE/INITIATIVE	NEXT 5 YEARS	WITHIN 10 YEARS	WITHIN 20 YEARS	20+ YEARS
INTEGRATING GENERATION AND TRANSMISSION	Introduction of AGC New HVDC controls manage transmission north of Wellington	Integrated control of generation and transmission for contingencies to enable renewables	Automated dispatch of generation and transmission (self-healing grid stage 1)	
ENABLING CONSUMER RESPONSE	Secure up to 60 MW of demand-side response in upper North Island Initiatives in upper South Island and upper North Island to test use of mass consumer response	Use of wide-area response from smaller consumers defers timing of additional grid capacity		Demand-side response automatically covers short-term grid failures (self-healing grid stage 2)
DEVELOPING OPERATIONAL CAPABILITY	Automated design of dispatch constraints Operator displays to provide situational awareness	Automatic dispatch of generation integrated with dispatch of transmission		Operators able to 'pilot' a fly-by-wire self-healing grid with automated dispatch and dynamic systems to ensure stability

COMMITTED INITIATIVE
POTENTIAL OUTCOME
POSSIBLE TECHNOLOGY TREND

FIGURE 75: TIMING FOR LIFTING SYSTEM PERFORMANCE

STRATEGY 3 – IMPROVING RELIABILITY AND RESILIENCE

Strategy 3 aims to improve the resilience and reliability of the grid by:

- Maintaining key strategic spares and resource to ensure security can be restored after a major event.
- Designing and configuring substations to reduce the risk of long-duration failures.
- Ensuring the grid remains reliable and resilient against failures of key substations.
- Deploying modern grid monitoring technologies to prevent instability on a more highly utilised grid.

Reliability and resilience describe how robust the grid is to both expected and unexpected events that can cause loss of supply to end consumers. Reliability refers to the day-to-day ability of the grid to provide continuity of service. The difference between 100 percent continual service and the grid's actual performance is its reliability. Resilience refers to the ability of the grid to withstand and recover from major unplanned events.

With increasing loading on grids and wider use of automated controls, the inherent stability of traditional grids is being eroded, and exposure to sudden wide-area collapses or cascading failures due to mal-operation of automated or complex systems must be considered. Adoption of automated controllers therefore requires careful and precise engineering and exhaustive testing.

Consumers will demand increasing reliability from key electricity-powered services. In the next 10–20 years, technology will emerge to allow many consumers to 'ride through' relatively short interruptions of around one hour or two, using local storage and the ability to turn off non-essential load such as refrigeration. A number of resilience initiatives have been proposed, as shown in Figure 75. These include:

- **Maintaining Spares to Restore Security Quickly** The practice of maintaining temporary transmission towers and key cable components is ongoing and will continue into the future. This also includes key substation equipment spares. In addition the procurement of spare transformers to ensure a failed transformer can be replaced inside one month has occurred over the last few years.
- **Major Substation Diversity** High impact low probability fault reviews are being conducted at several key high risk substations. This is resulting in strategies to increase substation diversity such as the commissioning of GIS at the Otahuhu and Whakamaru Substations.
- **Key Substation Site Strategies** A programme of developing long-term site strategies for all of the major substations has begun. Currently two critical sites, Penrose in Auckland and Central Park in Wellington, have been completed. In addition, two nationwide site risk management programmes have been initiated. One is focused at eliminating high impact common cause failures (such as a transformer fire leading to failure of neighbouring transformers). The second is a review with connected customers of individual substations, to optimise resilience across the combined systems.
- **Deploying Monitoring Technology to Prevent Instability** As utilisation of the grid is increased, monitoring systems that can provide early warning of emerging stability issues will be required. These systmes will include:
    - Wide-area monitoring systems (WAMS) using a network of phasor measurement units (PMUs).
    - Due to increased dependance on wind and geothermal, over-frequency arming will be advanced to avoid electricity system failure if a large section of the grid shuts down unexpectedly .
    - Automatic under-frequency load shedding (AUFL S)

DATE/INITIATIVE	NEXT 5 YEARS	WITHIN 10 YEARS	WITHIN 20 YEARS	20+ YEARS
RESTORING SECURITY QUICKLY	Complete strategic transformer spares programme	Automatic under-frequency load shedding improvements		Automatic rerouting of power flows using power electronics
RESILIENCE OF MAJOR SUBSTATIONS	Complete HILP reviews for Bunnythorpe substation and Wellington and Christchurch	Diversity into Wellington and Christchurch	Further diversity to wider Auckland	Major substations become modular and compact
SITE RISK MANAGEMENT	Site strategies for Penrose and Central Park	Site strategies for all major sites		Greater standardisation of equipment and layouts – enables hot swapping of failed assets
MONITORING TECHNOLOGY DEPLOYMENT TO PREVENT INSTABILITY	Complete installation of systems to monitor electricity system dynamics	Improved dynamic response information extends operating envelope of existing grid	Dynamic systems used to contain and limit widespread failures	

COMMITTED INITIATIVE
POTENTIAL OUTCOME
POSSIBLE TECHNOLOGY TREND

FIGURE 76: TIMING FOR IMPROVING RELIABILITY AND RESILIENCE

DISTRIBUTION

The distribution sector in New Zealand is divided up into 29 Electricity Network Businesses (ENBs). Together the ENBs manage approximately 150,000 km of local lines, $7.35 billion in assets and are forecast to spend $7.5 billion on capital and operating expenditure in the next 10 years [56]. Most of these ENBs sell their lines services to electricity retailers, who in turn bundle them with energy and on sell them to consumers. There are a few cases where ENBs sell energy directly to consumers, mostly large commercial and industrial consumers. Most ENBs also provide additional services such as ripple control load management, some metering and field service contracting.

Figure 76 shows the geographical location of the 29 ENBs operating in New Zealand. There is quite a wide variety in the networks that different ENBs service. Some companies cover largely urban areas such as Vector and Wellington Electricity Lines, some cover mostly rural areas such as PowerCo and MainPower while others have a mix of urban and rural customers like Orion. The local distribution networks are likely to experience the most changes compared to other sectors when progressing to Smart Grid, for example, two way power flows where previously there was a top down topology. However, because of the differences between ENBs, there is likely to be large differences in the technologies deployed.

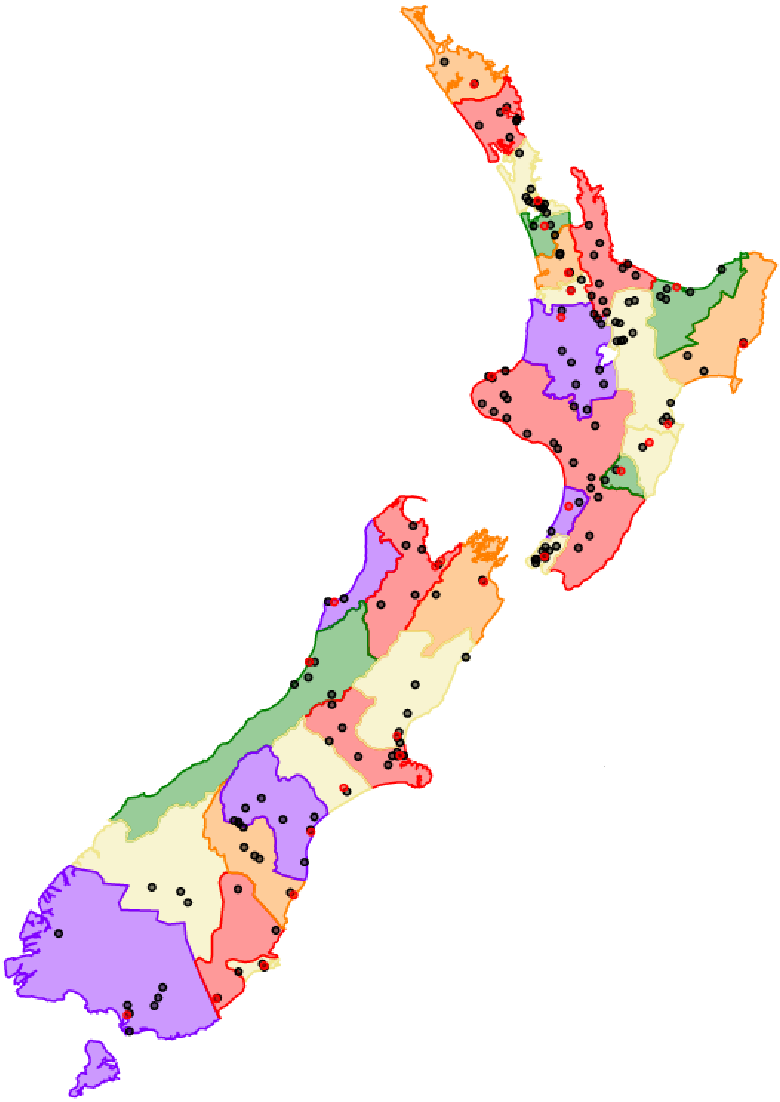

FIGURE 77: MAP OF THE 29 ENBS NETWORK AREAS IN NEW ZEALAND [57]

ELECTRICITY NETWORKS ASSOCIATION – SMART NETWORKS

The Electricity Networks Association (ENA), an organisation providing advocacy and support services to ENBs, recently released a report *"The case for deployment of smart network technologies in New Zealand"* in which a cost benefit analysis of smart technologies was presented The ENA created a Smart Network Working Group (SNWG) comprising of representatives form 10 different ENBs and chaired by Toby Stevenson, Director of Sapere Research Group. The objectives of the SNWG are to:

- Develop the business case for smart networks (in the New Zealand context) in order for Electricity Network Businesses (ENB's) to maximise the value of the technology for their customers and owners; and
- Develop industry positions with regard to the implementation of and opportunities presented by smart networks technology in line with the stated objectives of the Electricity Networks Association and its members.

The case for an individual ENB to invest in smart network technology would be based on their ability to achieve a commercial return on:

- Improved capacity utilisation;
- Deferring new conventional investments;
- Improving reliability relative to the cost;
- Providing faster and less disruptive network reinforcement (e.g. providing additional power electronics or storage to minimise roadworks); and
- Offering new services to customers.

The SNWG identified the current state of Smart Network features available to ENBs. These features are the enablers for the cost benefit analysis above, they include:

- More real time information on the status of the network.
- Two way communications, i.e. greater interaction between distribution devices such as meters, substations, switches and home area networks.
- The capability for greater simulation and analysis to support network operation, especially demand side response and distributed generation (DG).
- The possibility of more accurate load reporting.
- The possibility of more advanced diagnostics and reporting.
- Better fault notification, fault interpretation and response ability.
- Improved information on power quality, voltage functions and imbalances, and harmonics.
- Potential for automation to maximise efficiency and reliability (e.g. self healing networks).
- The possibility of minimising or eliminating bottlenecks and loop flows.
- Greater synchronisation between system operation and network operations.
- Customer information displays.
- The potential for more accessible engagement by the customer.

These developments and possibilities are potential enablers for ENBs to satisfy the business challenges they face. These include imperatives to:

- Accommodate an apparently open-ended trend towards more exacting power quality and reliability requirements.
- Defer capex at a time when a great deal of network replacement is required as well as the need for greater investment to meet rising peak demand.
- Optimise the timing of individual investments.
- Improve network utilisation (higher capacity factor and where N-1 doesn’t necessarily mean 50% utilisation of assets).
- Accommodate ongoing demand growth in the most economical way.
- Improve asset management practices.
- Maintain or improve the level of service to consumers.

- Improve network reliability in a cost effective way.
- Offer the national System Operator new types of cost-effective ancillary services, such as system balancing.

Other changes are inevitable. Electricity flows are likely to move from unidirectional to two way flows with the possibility of widespread micro DG (notably photovoltaics) and storage. Variability and intermittency of generation sources will come with increases in renewable generation and greater penetration of DG. The prospect of a significant step-up in demand from electric vehicles and the possibility that they may also provide system storage are more changes that are likely.

SMART NETWORKS – COSTS AND BENEFITS

The cost benefit analysis (CBA) presented in Table I is based on the judgement of those participating in the SNWG study. The CBA indicates that the benefits of smart networks substantially out-weigh the costs at the national level and therefore that deployment of smart networks can be expected to provide long-term benefits to consumers, provided these benefits are shared in some way with consumers. Using the best local and international data ranges that the SNWG has been able to obtain, and assembling this into 'Worst case', 'Possible outcome', and 'Optimistic case' scenarios, provides a strong message that considerable national benefits can be delivered by the deployment of smart network technologies and systems.

TABLE I: ESTIMATED PRESENT VALUE OF SMART NETWORK COSTS AND BENEFITS [56]

Benefits		**PV ($millions)**	
	Worst Case	**Possible Outcome**	**Optimistic Case**
Deferred generation capital expenditure	$200	$400	$400
Deferred transmission capital expenditure	$182	$363	$436
Reliability, PQ and customer engagement	$132	$264	$396
Deferred distribution capital expenditure	$129	$258	$310
Carbon saving from less fossil fuel base load build	$84	$168	$168
Less petroleum fuel use	$26	$27	$27
Metering	$8	$17	$25
Smart Network Benefits	**$761**	**$1496**	**$1761**

Costs	**Worst Case**	**Possible Outcome**	**Optimistic Case**
Metering	$380	$201	$201
Changes to Network planning	$220	$120	$90
Improved demand forecasting	$219	$119	$89
Demand response	$199	$78	$59
Additional Smart Network Operating Costs	**$1018**	**$518**	**$439**

Benefit Cost Ratio	**Worst Case**	**Possible Outcome**	**Optimistic Case**
All benefits / all costs	0.7	2.9	4.0

These results indicate there is a strong case, from a national perspective, for the deployment of smart network technologies. It is noted that the costs and benefits faced by each ENB from deploying smart network technologies will be unique to its situation, influenced by the age of its assets, the level of growth it is experiencing, the amount of spare capacity in its network, the extent to which consumers value improvements to service quality, and so forth.

One of the key areas of influence on an ENB's ability to extract the benefits of smart networks is the nature of metering specifications, the timeliness of access to metering information, communications infrastructure and the resulting degree of load control the ENB can access in its network. For the purpose of the cost benefit analysis, the assumption has been made that smart meters will be rolled out and ENBs would get access to information in a form that they are able to use for smart network purposes.

The following considers the benefits that might be available if ENBs all deployed smart network technologies simultaneously and pursued the incremental gains possible from doing so. [56]

Deferred new Transmission Investment

If all ENBs were to move to smart networks there would be significant potential gains for transmission investments. Total capex for transmission is $5,069.3 million over 10 years. This has been averaged to obtain a per annum value and applied in the following way:

- The net present value of half of development and enhancement/freehold purchases (excl HVDC) deferred for 5 years amounts to $312 million.
- The net present value of one fifth of refurbishment and replacement deferred for five years amounts to $50 million.

Deferred Generation Build

A distribution system that can shift load out of peaks reduces the need for peaking generation and flexibility from base load or mid merit plants. This also helps reduce the need for flexible fossil fuelled stations which is a plus for renewable generation. Added to this, the smart network will also accommodate greater DG. Together these factors could result in deferring generation investment.

The value assigned to this benefit is based on the potential to shift demand growth forward by one year, ie demand would be able to be met for an extra year by the existing generation fleet by improving load factor as a result of smart networks. This converts into a one year deferral in perpetuity of a 200MW power station (ie this generation investment is permanently deferred).

DEFERRED INVESTMENT IN BOTH REPLACEMENT AND DISTRIBUTION NETWORK UPGRADES

A key benefit of the smart network is the ability to reliably shift load and, as a result, defer investment in peak capacity. This is already common practice in New Zealand via ripple control. Smart networks will allow more to be achieved through:

- Accessing a broader pool of load control, improving the reliability of accessing existing load control and utilising load control more efficiently in network operations;
- Greater monitoring can provide real time asset condition information that would lead to more optimised asset replacement and maintenance programmes; and
- Better accommodation of DG and, in time, electric vehicles.

These effects will combine to reduce some replacement and growth related capex. The degree to which this is achieved in a specific network will depend on a variety of factors including the degree to which measuring devices (such as smart meters and sensors on the networks) are deployed to provide the necessary information and the profile of the existing load.

Deferred distribution capex is calculated as:

- Total system growth capex for ENBs is forecast to be $948 million over 5 years and an average of this has been used for annual calculations. The figure used for the benefits is the net present value of one half of this capex deferred by five years; and
- Asset replacement and renewal capex is forecast to be $1,068 million over five years. The net present value of one quarter of this capex deferred for five years is the figure used.

RELIABILITY, POWER QUALITY AND CUSTOMER ENGAGEMENT

Smart networks will be able to assist ENBs to improve reliability, power quality and customer engagement through better planning, better forecasting, greater responsiveness with consumers, and more optimisation of the network. For the purpose of quantifying this benefit a value has been put on saving system minutes (TX or DX), but this doesn't account for "improving the consumer experience" in other ways.

Benefits are calculated as the NPV of 20 system outage minutes saved (a reduction of the annual average from 150 minutes to 130 minutes) by smart networks based on a VoLL of $20,000 and a system peak of 6600 MWs with a load factor of 0.6. The 20 SAIDI minute estimated annual benefit is considered conservative, reflecting the apparent gain from – for example – the effective application of single phase reclosures at sub-station level.

Carbon Saving from Less Fossil Fuel Base Load Build

The result of more efficient distribution, more efficient use of renewables and more DG should result in deferring the need for fossil fuel fired generation to come into the stack to meet rising demand. If smart networks displace one year of demand growth, and if that capacity were to have come from a coal-fired power station, the annual saving is carbon output from 200MW x 85% load factor x carbon price of $25. This may seem implausible given the prospects of a coal-fired power station being built. However, several of Transpower's planning scenarios note coal-fired power stations as plausible options, especially in the north, given the restrictions on baseload gas fired generation or the low likelihood of new substantial scale hydro generation being built.

Less Distillate Use

A flatter load shape resulting from more efficient network operations and more load shifting would see less distillate running required to meet peaks occasionally through the average year. Benefits for this purpose are based on reduced requirement for peaking capacity (based on the former Whirinaki rate of about $470/Mwh). In addition, less occasional distillate use on peaks will reduce carbon emissions. The less distillate use figure includes carbon savings based on the reduced energy output x CO_2 x carbon price of $25.

Metering

As discussed in a previous section, smart meters are in most cases being rolled out by retailers based on a business case that reflects the operational gains retailers are able to make. For the purpose of a cost benefit assessment of smart networks, the costs and benefits attributable to smart meters are estimates of the incremental costs and benefits of utilising smart meters for delivering smart network outcomes. The estimates of smart meter benefits include:

- Reduced non-technical losses system-wide in the order of $1.9 million;
- Potential for $1.52 million reduction in reserves requirements;
- Network fault management reductions of a possible $950,000; and
- Total reduced technical inspections of $380,000.

Other Benefits

There are other possible benefits that are more difficult to quantity or are value transfers and are not included. These are:

- Possible lower energy charges as a result of reduced peaks;
- Possibly lower transmission operating costs;
- A shift towards more just-in-time maintenance if the information flows are able to provide greater confidence in the state of equipment such as transformers;
- Less field service work as a result of better diagnostics and more targeted call outs; and
- Electric vehicles and greater penetration of electric vehicles should be eased if investment has already been made in smart network technologies.

Estimating costs is difficult because the range of options and technologies that might be employed is evolving rapidly. Also, as referred to under benefits, each ENB will respond differently to the smart network opportunity and, in reality will incur costs incrementally through time. The costs identified here are those that might be incurred simultaneously if all ENBs were to adopt smart network technologies and operational practices at the same time.

METERING

The incremental metering costs applicable to smart network operations are essentially additional interface costs and associated IT system requirements. For this evaluation an assumption has been made that some networks require smart meters at every ICP and some would deploy metering for smart meter to transformer level only. This approach means that the average cost is slightly higher (as indicated in an earlier section) but that is likely to be a sensible approximation for a national cost benefit analysis. System wide, a cost of systems of $532 per meter has been applied to 500,000 meters.

CHANGES TO NETWORK PLANNING

To the extent electricity distribution networks are set up and operated as radial rather than mesh networks, their ability to provide redundant circuits and security of supply is limited. In any event, such redundancy by duplication of lines would incur substantial costs.

For larger distribution networks with a large number of zone substations, better interconnection could be achieved with the addition of inter-region switches (normally open) and remote sensing equipment to determine loss of voltage or load requiring backup.

A further enhancement to geographic supply could come from intentionally building diversity into supply zones (to the extent that it is not done already). Rather than having supplies dedicated to predominantly commercial or domestic services, the diversity of the different load characteristics could assist with load management in the sub-network (where boundaries permit).Again, this would be achieved by changes to the network topology and potential interconnection. For the purpose of this exercise, costs for changes to network investment include IT systems and extra equipment such as circuit breakers and sensors. For the CBA an estimate of an average $40,000 for 3000 feeders has been used. The worst case scenario is an additional one off IT cost of $100 million across the sector.

PREDICTION OF FUTURE DEMAND

The assumption is that better forecasting of demand, facilitated by greater information, would feed into ENB capacity planning. It is likely to be of increasing importance as distribution networks become more actively managed, necessarily assuming increasingly complex ‘system operator’ functions at a local level. To make use of the consumption data that is generated would require a mix of system/network control and analysis to correctly derive a benefit from the data.

The costs for providing improved demand forecasting are estimated to be $50 per ICP for additional meters, sensors and control systems plus up to an average of two additional full time equivalents (FTEs) per ENB. The worst case scenario includes an additional one-off IT cost of $100 million across the sector.

DEMAND RESPONSE (INCLUDING ADDITIONAL LOAD CONTROL)

While load control is used to its maximum extent during times of peak demand, it is limited to reducing controlled circuit loading to zero, exposing the underlying non-controlled demand. This reduction is further limited by control relays that fail to operate, or customers who choose the uncontrolled option.

A second aspect of load control that could be explored is trough filling. While the peak shaving process pares the demand to the non-controlled demand, by front loading the energy storage in non-peak periods, the impact and shape of controlling load might be improved. This would require some expertise and analysis, along with changes to the operation of the control systems. Costs are likely to be on average one FTE per ENB.

Demand response costs include replacing faulty relays (1/3 of all relays at $100 per relay) plus changes to load control operations of $50,000 per ENB.

ADVANCED METERING INFRASTRUCTURE

Like many countries in the world, New Zealand is currently in the process of a national roll out of smart meters and AMI, see Figure 77. However, due to a number of reasons, the roll out in New Zealand differs significantly from those overseas. The use of advanced meters in New Zealand is being driven by market forces, rather than by government or regulatory decisions. This is because New Zealand already has a centralised load management system (the ripple control system) in place since the 1950s. Therefore, load management is not a primary driver of AMI in New Zealand, although the ability to enable more controllable load does make AMI systems attractive.

According to the Electricity Commission's report on the AMI roll-out in New Zealand [58] there also appear to be several other drivers that have not been seen in other countries. These are:

a) Interim compliance deadline of 2015: The Rules provide that retailers must ensure that meters at residential and small commercial premises are fully certified by 1 April 2015.16 The deadline was set in 1999, and was agreed and voted on by industry participants under the rules of self governance that applied at the time.

   By 1 April 2015, retailers must either:

   - ensure that their existing meters are fully certified, by requiring the meter owner to fully certify their meters. That can involve statistical sampling of meter populations to the individual testing of each meter installation, the removal and testing of meters, and the replacement of meters once certified; or
   - install or acquire new, fully certified meters.

Many retailers and meter owners have taken the opportunity to install new advanced meters that deliver additional functionality, rather than certify their old meters.

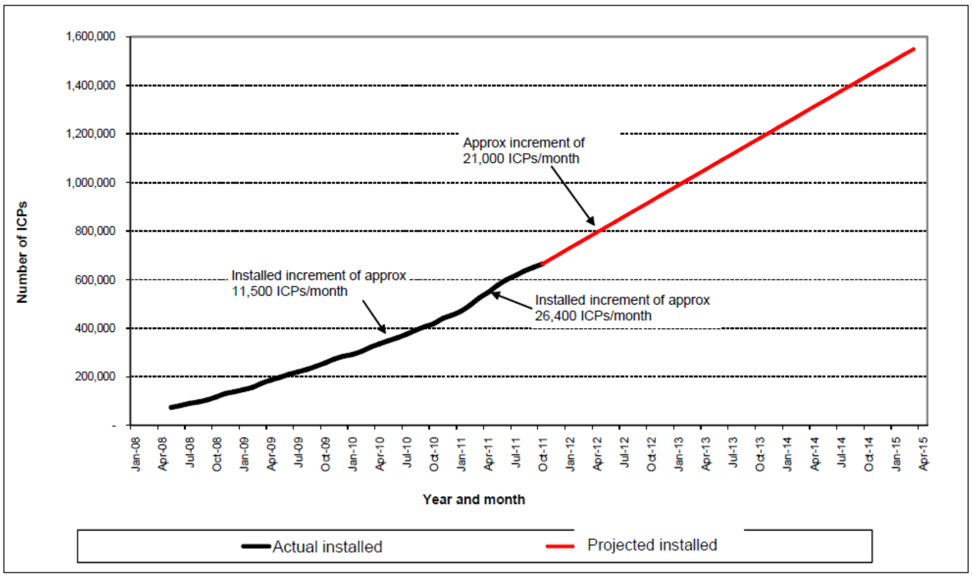

FIGURE 78: ESTIMATE OF ACTUAL AND PROJECTED AMI METER INSTALLATIONS

b) Lease costs for advanced meters have fallen: The cost of advanced meters and associated communications has fallen in recent years to a level where retailers can lease an advanced meter at a cost approaching the cost of leasing an existing 'basic' meter.
In a 2008 report [59], LECG noted that the market rate for leasing an advanced meter in New Zealand was approximately $75 per annum where a retailer was prepared to enter into a long term, high volume contract (e.g. for several hundred thousand meters). That is reasonably close to the $55-$60 p.a. cost of leasing a basic meter.

c) Operational efficiencies that reduce retailers' costs to serve: The benefits associated with obtaining accurate metering information and the corresponding reduction in invoice queries enables reasonable savings in retailer back-office and settlement processes.

d) Competitive provision of metering assets: Unlike many other countries where the provision of metering is a monopoly activity, in New Zealand, the provision and operation of meter services is a competitive market. Retailers are able to choose metering services from a range of providers, or provide those services themselves, and can replace any meter equipment owner's equipment with another meter owner's equipment.
As some of New Zealand's major electricity retailers do not own meters, they face no stranded metering asset costs if they switch from existing basic meters to advanced meters. Those retailers therefore face a lower financial hurdle to using advanced meters than retailers that own meters.

For a similar reason, meters are usually not replaced when a consumer switches retailers. Provided the meter has the attributes required by the retailer gaining the consumer, the gaining retailer will normally lease the use of the meter from the existing meter owner (which could be the outgoing retailer or a third party supplier).
A roll-out of AMR meters in Christchurch by Meridian Energy via its subsidiary Arc Innovations, appears to have acted as a catalyst for other retailers to roll out advanced meters. This indicates that competition in the deregulated electricity market is producing benefits. Therefore, the roll-out of advanced meters by one retailer appears to have placed competitive pressure on other retailers to do likewise.

The Electricity Commission was required under the Government Policy Statement on Electricity to report to the Minister on whether the roll-out of smart meters in New Zealand should be regulated, and whether the voluntary guidelines around technical aspects of smart meters were adequate. In March 2010, the Energy and Resources Minister Gerry Brownlee agreed to the recommendations set out in the Electricity Commission's report on the roll-out and requirements for smart meters in New Zealand. The Commission concluded that [58]:

- There are differences in the New Zealand electricity market compared to other countries, which mean the reasons for regulating smart meters overseas do not apply to New Zealand (including the fact New Zealand already has a functioning ripple control system to manage peak load);
- The current roll-out of smart meters is happening within an acceptable timeframe;
- Smart meter technology is not fully developed and may become obsolete;
- There is a high level of compliance with the current voluntary guidelines;
- Regulating the roll-out of smart meters could create additional costs for consumers for no additional benefit.

The Electricity Commission did not recommended extensive regulation of smart meters, because the benefits of regulation are not considered to outweigh the costs at the time. The Commission did, however, recommend regulating some technical standards, for example on information exchange protocols and data security, through electricity industry rules.

The voluntary guidelines on Advanced Metering Infrastructure, published by the Electricity Commission in 2009, set out recommendations relating to the introduction of new technology for metering and the supporting infrastructure. The guidelines also outline participants' obligations for situations where new meters are installed for new and existing consumers. According to the guidelines, advanced metering systems are electronic meters that measure electricity, record consumption and meter event information electronically, have two way communications, can be remotely read, and may have the following attributes: [60]

- Remote connection and disconnection;
- Tamper detection;
- Outage detection;
- Quality of supply monitoring;

- Demand limiting;
- Communications interface to a range of devices e.g. in-property display, direct load control equipment, link to a computer in the premises (perhaps via the internet or perhaps the communications interface enables more external communication beyond the electricity industry);
- Export metering where applicable; and/or
- Registers and meter functionality that may be reprogrammable for time period or demand limiting.

The guidelines provide specific AMI system requirements including; terms, conditions and pricing of services; metrology; consumption data recording; changes to firmware via communications system; meter reading; management of load control; data security: access, storage, and transportation; provision for HAN interface; provision for customer displays; premise disconnections and reconnections; prepayment; parameter setting; event recording; multiple load control systems; and safety.

The Electricity Authority is currently reviewing *Part 10 Metering arrangements* of the *Electricity Industry Participation Code 2010*. The motivation for this review is to:

- fix the problems with the current Code;
- update the current Code to allow for and keep pace with the adoption of new metering technology; and
- future proof the Code to enable innovation.

The review has been carried out over seven stages since August 2008 and has involved five different consultations with industry over that time. The most recent consultation was held between September and November 2011 [61]. This revised Part 10 proposal is the fifth consultation undertaken in connection with the fundamental review of part 10 of the Code. The paper presents and seeks feedback revisions to the Part 10 proposal presented in the June 2010 consultation paper relating to:

- authorisation for onsite physical access to a metering installation;
- management of the security and privacy of metering data;
- requirements for audits;
- provision of registry records for interim certified metering installations;
- control device certification;
- obligations for initial livening of an installation control point (ICP);
- metering installation certification requirements and processes; and
- timeframes.

A number of submissions were made from various stakeholders including retailers, lines companies, Transpower, and smart meter manufacturers. The feedback from the submissions was a mixture of agreement and disagreement on the points noted above. The stakeholders were able to express their views on the various topics and these were noted by the Authority. A spreadsheet of the responses is avalible on the Authorities' website [62].

Following the fifth consultation, an AMI forum was held on the 30th November 2011. The forum sought to progress work on nomination of the metering equipment provider (MEP) and AMI data access by identifying the state of play for AMI in order develop options to enable the Authority Board to make an informed decision on the way forward. The objective in relation to access to AMI data was to "ensure that access to AMI data is provided in a manner that promotes competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers." This objective is based on the Authority's statutory objective.

The May 2011 consultation paper defined the problem as follows:

- AMI is an infrastructure asset with natural monopoly characteristics; and
- this means parties who own or control an MEP have incentives to charge prices for AMI data that would likely stymie the dynamic efficiency benefits from value-added AMI services.

Most non-consumer submitters did not agree with this problem definition.

Major retailers, owners of major MEPs and one major distributor considered the AMI market is workably competitive and not a natural monopoly, and that barriers to entry to the AMI market are low. They considered this was supported by potential entry into the market by Smartco, previous findings by the High Court, Commerce Commission and Electricity Commission, the fact that obtaining AMI data was not a problem in practice, and availability of other options for distributors seeking AMI data, including duplication of infrastructure and alternative technology.

Distributors seeking functionality from AMI to enable them to implement "smart grids" and/or intending to enter the AMI market considered the problem related to impediments to co-ordinating between MEPs, retailers and distributors to obtain the functionality, inter-operability, and communications infrastructure sought by these different parties. They considered having multiple AMI providers on a distribution network would prevent distributors obtaining the data or functionality that they required.

Based on information received in submissions and subsequent discussions with industry participants, the Authority wanted to test the proposition that the AMI market may be workably competitive, taking into account:

- the first limb of the Authority's statutory objective is "to promote competition for the long-term benefit of consumers", which the Authority has interpreted as meaning workable or effective competition;
- the entry and potential entry into the metering and AMI market by a range of providers, which suggests there are no apparent or unreasonable barriers to entry;

- entrants appear to have developed business cases to support duplication of AMI rather than negotiating third party access to existing AMI;
- the range of AMI solutions and offers; and
- the degree of innovation and investment in what appears to be a dynamic AMI market.

The Authority is also testing the extent that issues around ensuring that AMI delivers the functionality that meets the requirements of some distributors and the longer-term requirements of consumers. This is to confirm whether reliance on commercial negotiations and competition is sufficient to ensure the Authority's objectives are achieved in relation to access to AMI data, or whether it is appropriate to give any one party "rights" over nomination of the MEP.

In response to the forum, SmartCo Ltd included a submission expressing their views [63]. SmartCo is a consortium of ENBs serving over 550000 customers. The members of SmartCo presently own the bulk of the meters on their networks. However there are up to a dozen retailers operating on these networks with eight serving at least 5000 customers. SmartCo members are concerned that if the responsibility for metering remains in the hands of the retailers then there will be a mix of different systems with different functionality across the network and that this will affect network automation and enhanced services for customers.

Drivers for AMI from ENBs perspective include wish to increase plant utilisation and defer capital expenditure, management of multi-directional energy flows arising from DG, servicing demand from EVs, and voltage management. Drivers from a retail perspective relate to servicing energy market purposes.

SmartCo suggests that the Authority facilitate the installation of ubiquitous and coordinated AMI on a per network basis, with specifications meeting the needs of both retailers and networks. They state the EICP provides that a retailer may only trade at an ICP if there is an MEP which has responsibility for metering at that ICP, but are concerned how the MEP is appointed. SmartCo suggests that the EIPC should provide that:

1) Subject to point 3, each network owner shall appoint the MEP for each ICP on its network or within a discrete area of its network, and may subsequently change that appointment
2) The network owner may do this only after consultation with each retailer which serves at least (5%) of the affected ICPs and shall ensure that retailers' reasonable requirements are met. Such retailers shall have access to a dispute resolution process.
3) The network owner may (irrevocably) choose not to appoint the MEP for all or part of its network, in which case retailers shall do so in respect of each affected ICP they serve, and may subsequently change that appointment.
4) The retailer may only do this after consultation with the network owner and shall ensure that the network owner's reasonable requirements are met. Networks owners shall have access to a dispute resolution process.

RETAIL

The New Zealand retail electricity market consists of 17 companies. The five major electricity generators in New Zealand own 9 of these retail companies between them and service approximately 95% of the ICPs as of 2011. These major retailers offer a range of different pricing plans to the consumer these include:

- **Anytime / 24 hour / Continuous / All Day / Uncontrolled** - This rate is for the supply of electricity at the same price 24 hours a day. Supply to this type of meter cannot be restricted or "controlled". This meter measures everything from Hot water cylinder to light switches.
- **Controlled / Economy** - This rate is for the controlled supply of electricity to selected appliances that are permanently wired to a separate meter. This means that the electricity supply for a hot water cylinder, for example, can be turned off during peak times for an allocated period determined by the Network company.
- **Composite / Economy 24 / All Inclusive / All Day Economy / Inclusive** - This rate is a combination of the Anytime and Controlled rates but electricity is supplied through a single meter. Supply to separately wired appliances, e.g. a hot water cylinder, can be turned off during peak times for an allocated period determined by the network company.
- **Day / Night** - These rates are for customers who use an above-average amount of electricity at night. Different rates apply for day (typically 7am-11pm) and night (typically 11pm-7am). There are no restrictions on which electrical appliances you use at night; you choose when you want to operate them.
- **Night Only** - This rate is for the supply of electricity to a separately metered appliance that is used only at night, e.g. a night storage heater. Typically this will be for an 8 hour period between 11pm and 7am.
- **Night Plus / Night Boost** - This rate is for the supply of electricity to a separately metered appliance that is used only at night, e.g. a night storage heater. Typically this will be for an 8 hour period between 11pm and 7am and includes a "boost" period. The appliances are permanently wired to a separate meter and the electricity supply is subject to unscheduled interruptions.
- **Triple Saver - Night / Peak / Off-Peak** - These rates are only available for electricity supply to 3-register meters. Triple Saver has different rates for night, peak and off-peak times. Typically Night rates apply between 11pm - 7am, Peak rates apply between 7am - 11am and 5pm - 9pm and Off-Peak rates apply between 11am - 5pm and 9pm - 11pm.
- **Day / Night (controlled)** - These rates are for the controlled supply of electricity to selected appliances that are permanently wired to a separate meter. Different rates apply for day (typically 8am - 12am) and night (typically 12am - 8am).

The above shows how New Zealand companies have been offering to customers Smart Grid style options such as time of use pricing and load management through hot water ripple control.

It is expected that as the technology matures, load management features could be expanded to include smart appliances such as those that have been trialled overseas or to offer “real-time” pricing options to consumers. However, the current roll-out of AMI from the retailers seems primarily concerned with remote meter reading and little emphasis has been placed on providing these options to consumers.

DISCUSSION

One of the first things that becomes apparent when looking at Smart Grid progress around the world is the scale in terms of investment and projects from both government and the private sector. As shown in Figure 78, the top ten countries invested over $18 billion USD in Smart Grid related projects and research in 2010 with China and United States the biggest investors. While the scale of this investment is beyond what a country the size of New Zealand is capable of delivering, it could be said that government investment in Smart Grid technologies and research has perhaps not been at a level it could have been relative to our trading partners. That said, there has certainly been investment from the private sector most notably around the installation of smart meters.

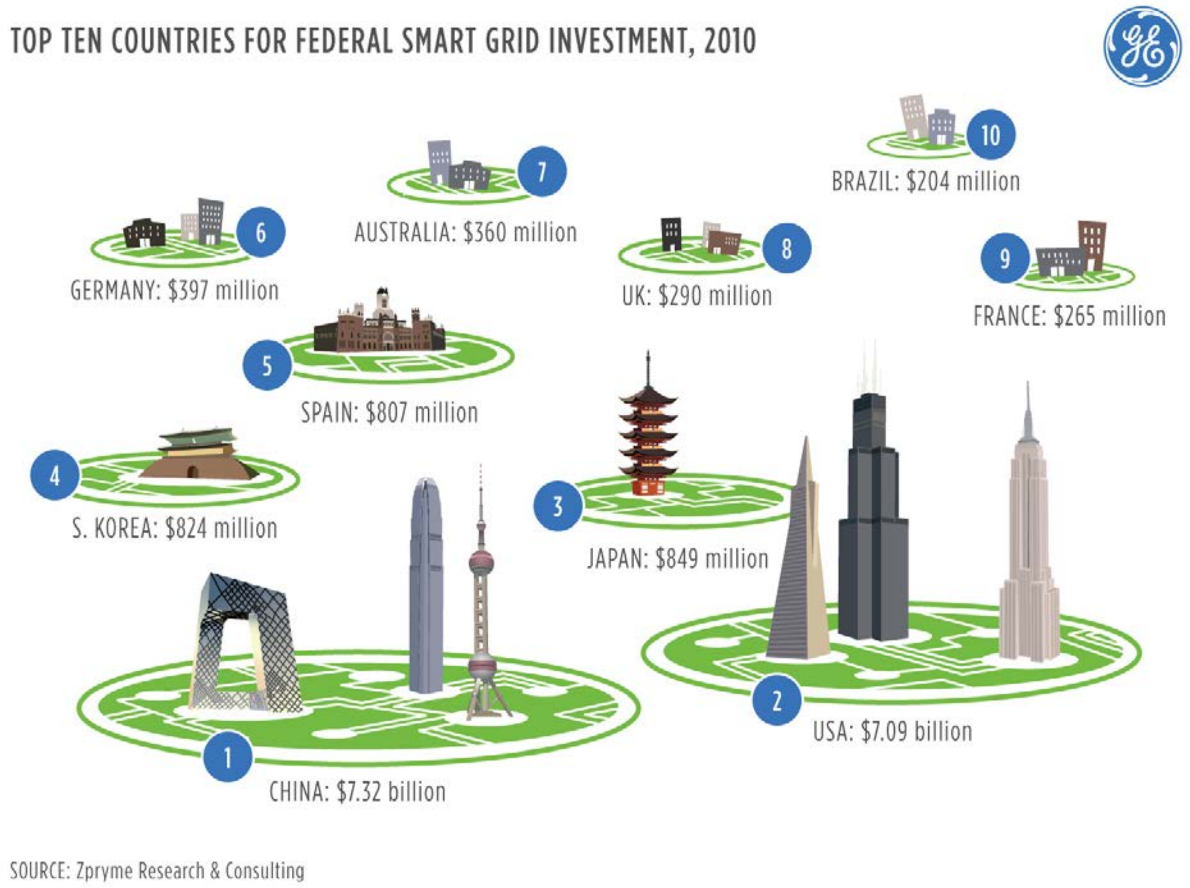

FIGURE 79: TOP TEN COUNTRIES FOR SMART GRID INVESTMENT IN 2010 [64]

The second most notable aspect of overseas Smart Grid progress is leadership. In most of the regions investigated there was some sort of forum or task force set up, usually by government, to oversee and direct Smart Grid Research and funding. Good examples of this are the Smart Grid Advisory Committee (SGAC) and Smart Grid Task Force (SGTF) setup by the United States government, the Ontario Smart Grid Forum in Canada, the European Technology Platform for Electricity Networks of the Future (ETPENF) for the European Union, and the work done by the State Grid Corporation of China (SGCC) in China. This is something that is noticeably absent from the New Zealand Smart Grid environment.

Some of the Smart Grid demonstration projects that have been undertaken around the world have produced some interesting results. For example, In the United States, peak load management is a key focus on several projects. The Olympic Peninsula Project effectively demonstrated the ability of how coordination of residential electric water heaters and thermostats, commercial building space conditioning, municipal water pump loads, and several distributed generators and electric price signals to manage the peak loading on a feeder. The Maui Smart Grid Project is using a DMS to manage increased renewable and distributed generation and reduce peak loads by 15%. The West Virginia Super Circuit and the Beach Cities Microgrid in San Diego both have a focus on reducing peak loading.

In the European Union a large focus is on increasing renewable energy and distributed generation and a lot of Smart Grid projects reflect this. Projects such as EU-DEEP, The European Wind Integration Study, Large Scale Tool for Power Balancing in Electric Grid, Night Wind, Safewind, SmartGen, and SUSPLAN are all focused on incorporating more renewable energy sources and distributed generation onto the European grid. There is also a significant amount of work and spending on AMI projects currently throughout Europe with more than half of the €5 billion being spent on smart meters. The Telegestore project in Italy, the largest AMI system in the world, illustrates the potential of a well thought out AMI system. Completed in 2005, the Telegestore project was highly unusual in the utility world because the company designed and manufactured their own meters, acted as their own system integrator, and developed their own system software. The Telegestore project is widely regarded as the first commercial scale use of smart grid technology to the home, and delivers annual savings of €500 million at a project cost of €2.1 billion.

Over in Asia, China has begun an extremely large grid upgrade project with over $100 billion USD dedicated to developing Smart Grid technology. Over 228 Smart Grid pilot projects were commissioned by State Grid Corporation of China (SGCC) to solve technical issues, test designs, and develop management systems. These projects covered the entire gamut of Smart Grid implementation, ranging from connecting wind power plants to automating distribution networks to metering households. In addition SGCC has installed over 51 million smart meters and is set to install 360 million by 2030. Japan has begun developing the Kashiwa-no-ha Smart City the Yokohama Smart City Projects which incorporate a range of Smart technologies such as solar panels, electric vehicles, AMI, Energy Management Systems, and distributed generation. A major focus of the Kashiwa-no-ha Smart City project is to solve the environmental and energy issues facing the world in the future, as well as other social issues such as maintaining urban functions following disasters. South Korea has created a Smart Grid roadmap with the first phase, the Jeju Smart Grid Test-bed, due to be completed this year. Again, the focus on this project is to promote energy efficiency and implement green-energy infrastructure. Meanwhile in India, the focus is on restoring the commercial viability of the distribution network. India has the highest transmission and distribution losses are among the highest in the world, averaging 26% of total electricity production, with some States as high as 62%. When nontechnical losses such as energy theft are included in the total, average losses are as high as 50%.

Australia has a similar strategy to New Zealand with its energy policy with a focus on increasing renewable generation, reducing CO2 emissions and energy efficiency, albeit the percentages are different. One thing that stands out in Australia is the wide spread adoption of photovoltaic systems in some areas. Several large government programs such as the Renewable Energy Target, Solar Homes and Communities Plan, Solar Cities, National Solar Schools Program, and the renewable remote power generation Program, were undertaken which promoted both large scale and small scale PV systems among other renewable generation. With such an increase in PV installations this has given rise to various power quality issues such as voltage rise and this has resulted in a sharp reduction of feed-in tariffs and network companies rejecting new installation requests in some areas.

Another area that has seen a lot of focus in Australia is the National Smart Metering Program (NSMP), a federal government led program which outlined specifications and standards for smart meters and instigated several smart meter pilot projects throughout Australia. The NSMP finished in 2011 leaving individual state governments actively pursuing their own smart meter programs. Most notably is the state of Victoria, which mandated in November 2008 that smart meters be installed in all homes and small businesses. The project, which aims to roll out 2.5 million smart meters by 2013, will provide utilities and consumers with meter data every 30 minutes and will eventually lead to dynamic electricity pricing based on time of use.

Another significant project for Australian Smart Grids is the Smart Grid, Smart City project led by Ausgrid. This project seeks to test various technologies from grid side applications through to electric vehicle use through to technology in the home such as in home displays. The results from the trials will be worth monitoring as Australia and New Zealand are similar cultures and New Zealand utilities could expect Australian behaviours to resemble those of New Zealanders especially regarding electric vehicle use and consumers reaction to smart appliances and in home displays.

The roll of standards in future Smart Grids technologies cannot be understated. Fortunately, it appears the international standards community are well aware of this importance and have made considerable progress in a lot of key areas. Both the International Electrotechnical Commission (IEC) in Europe and the National Institute of Standards and Technology (NIST) in the United States have developed a Smart Grid standard Roadmap/Framework. In it they have identified key areas of Smart Grids which require standards, what existing standards if any meet these requirements, and which areas require more work to meet the needs of industry.

Along the way a number of key Smart Grid standards have been identified, such as IEC 61850, IEC 62351, IEEE 1646, and IEEE 1547 and these standards already play an important role in current Smart Grid related projects around the world. What is promising in the current Smart Grid standards work is the level of collaboration that appears to exist between the European and United States standards organisations. Each organisation is acknowledging the work of the other and not trying to reinvent the wheel with their own versions of a standard.

Regarding the Smart Grid progress in New Zealand, one thing that is apparent is there seems to be no specific policy on Smart Grid from the government. There is an overall energy strategy for the country of which having 90% of electricity generation from renewable sources is a major part. However, there is no central plan on how this is to be achieved. This is of course due to how the electricity market is setup in New Zealand and it is believed that the market will be able to deliver the 90% renewable target. Another part of the energy strategy from the government concerns the efficient use of energy. As a part of this, there is a focus on AMI technology. As smart meter technology is installed by companies, the Government will ensure consumer rights are protected, and will monitor the effect on consumer energy use and electricity bills.

As mentioned previously, the generation, transmission and parts of the distribution sectors of the industry are already quite "smart" in a lot of the technologies that are used. There is room for improvement in the interoperability between the different communication and control systems employed by various companies as has been highlighted recently with the asset change. What will require some research, is managing the generation mix if New Zealand meets its 90% of electricity generated from renewable energy target. How will the grid manage with the intermittent nature of wind power? How much wind is feasible on the grid? Is large scale energy storage going to be necessary/viable. New hydro generation, an excellent complement to wind, is becoming increasingly harder to get resource consent for so the bulk of renewable generation in the near future is likely to be from geothermal.

Transpower has developed a strategy for the future of the transmission sector which has been called Transmission Tomorrow. The forecast demand for electricity and the type and location of generation sources will place specific demands on the transmission network. To meet these demands Transpower has developed three long term strategies, Lifting Grid Performance, Lifting System Performance, and Improving Reliability and Resilience. These strategies involve a number of Smart Grid features including real-time asset management, enabling consumer response, Automatic Generation Control and new control technologies on the HVDC link. This plan and the ability to implement it suggest that the transmission sector's transition into a Smart Grid should happen reasonably smoothly.

The distribution sector is likely to see the largest change in a progression into the Smart Grid. Traditionally, the power flow has been unidirectional from transmission to customer. However, as more distributed generation appears on the network from sources like PV, the power flow is going to become more complicated and bidirectional. This could result in power quality issues and voltage stability problems. For this reason it would make sense for the ENBs to have increased monitoring of the voltages and currents on their networks. One possible source for this information could be from the AMI networks currently been installed by various retailers and ENBs.The current state of the various AMI networks in the country is quite mixed at the moment with the different stakeholders wanting different features from their smart meters and at minimal cost. The industry could benefit from some leadership in this area, a central plan as has been seen from other regions in the world such as Italy for example.

Peak load control and demand side management is another key Smart Grid focus area overseas. This is something New Zealand already has a lot of experience with ripple control systems and contracted interruptible load. These systems have been proven to be effective throughout New Zealand for a number of years and there is no reason to think that this is going to change in the near future. The benefit from load control of smart appliances over a Home Area Network as trialled overseas is likely to smaller than the benefit seen from the current hot water cylinder control. The exception to this would be electric vehicle charging. Studies have suggested that coordination and control of electric vehicle charging is likely to have significant benefits to peak loading on feeders. This is something that should definitely be considered as electric vehicles become more prevalent in the country.

CONCLUSIONS

New Zealand already possesses an electricity system that many other countries are striving to achieve by their move to Smart Grid technology. The majority of our electricity is generated from renewable energy sources such as hydro, wind and geothermal and effective peak load management is achievable through ripple control and contracted interruptible load. These two factors are the most common reasons stated by countries for the need for a Smart Grid. Does this make New Zealand a world leader in Smart Grids? Unfortunately not, as there are a number of aspects to Smart Grid that other countries are further advanced than New Zealand. For example, responding to new consumer demands (such as HP, EV), distributed generation, and the use of distributed storage. Also, at the policy level, many countries are seeking to reduce oil and gas dependency and this is a considerable driver for smarter networks that can facilitate low carbon transport and diversification of renewable energy sources including greater use of distributed wind, wave, tidal and solar.

There is enough evidence to suggest that there will be significant economic benefits by companies investing in smart technologies through deferred capital expenditure, increased efficiencies and reliability to customers. A number of conclusions regarding the future of electricity and Smart Grids in New Zealand can be stated, these are:

- The demand for electricity in New Zealand is likely to increase in the future.
- The generation mix is going to change. There will be more emphasis on renewable energy resources with the goal of reaching 90% of electricity generation from renewables. New generation is likely to be made from a combination of wind and geothermal. Energy storage systems may become necessary.
- Also there will likely be an increase of distributed generation on low voltage networks as the price of photovoltaic cells continues to decrease. This will need to be carefully managed to avoid the voltage problems that have been seen elsewhere in the world.
- Utilities will gradually install Smart Grid solutions into their networks such as EMS and IEC 61850 based systems to improve interoperability between systems and reliability to customers.
- The ripple control system and contracted interruptible load will continue to be used to manage the peak loading of the grid.
- AMI installations will continue to be installed. This is one area which would benefit from more leadership. With the current regime of each retailer and ENB wanting to install their own systems there is the real risk that overall metering infrastructure of the country will too fragmented to facilitate future smart technologies. This could result in some serious problems in the future as the Smart Meter and associated Home Area Network could be an excellent method for controlling the charging of electric vehicles and other loads.

The introduction of new technologies (at scale rather than simply as demonstrations) will have considerable impact on network company businesses requiring attention to business processes, IT and control system architectures, planning policies, procurement policies, spares and field support, and company skills. It may require new partnerships and interactions with consumers at a much closer level than in recent years. International experience shows that the above tasks are frequently underestimated and many of the excellent demonstrations that can be seen around the world and are described in this report, remain as one-offs. The transition from innovative demonstration to *"Business as Usual"* is critical because it is only when innovation is deployed at scale are the benefits released to consumers and to wider society in the form of productivity gains, exports, and delivery of government policy goals.

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