# NEW ZEALAND SMART GRID FORUM

*Architecting a future electricity system for all New Zealanders*

*A catalogue of smart grid standards, publications, trials, case studies and activities in New Zealand*

*November 2014*

# CONTENTS

# Acronyms and Abbreviations

| | |
|---|---|
| **ADMS** | Advanced Distribution Management System |
| **AUFLS** | Automatic Under Frequency Load Shedding |
| **AMI** | Advanced Metering Infrastructure |
| **BEMS** | Building Energy Management Systems |
| **BRCT** | Blueskin Resilient Communities Trust |
| **DG** | Distributed Generation |
| **DLR** | Dynamic Line Rating |
| **DR** | Demand Response |
| **EA** | The Electricity Authority |
| **ENA** | Electricity Networks  Association |
| **EDB** | Electricity Distribution Business |
| **EMI** | Electricity market information |
| **EMS** | Energy Management Systems |
| **EV** | Electric Vehicles |
| **GPRS** | General Packet Radio Service |
| **HAN** | Home Area Network |
| **HEMS** | Home Energy Management Systems |
| **kWh** | Kilowatt hour |
| **MBIE** | Ministry of Business, Innovation, and Employment |
| **MW** | Megawatt |
| **MWh** | Megawatt hour |
| **PHEV** | Plug-in Hybrid Electric Vehicles |
| **PV** | (Solar) Photo- Voltaic |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SAIDI** | System Average Interruption Duration Index |
| **SAIFI** | System Average Interruption Frequency Index |
| **The Code** | The Electricity Industry Participation Code 2010 |
| **TOU** | Time of Use (Pricing) |
| **VLR** | Variable Line Rating |

# 1 Introduction

The 'Smart Grid', as a concept, has been embraced by engineers, policy makers and marketers the world over with different motivations and frequently quite different views about what the term means.

In New Zealand, the Ministry of Business, Innovation and Employment, with the support of the Electricity Networks Association commissioned a Smart Grid Forum in March this year. The Forum brings together relevant parties from business, scientific and academic circles, along with policy makers, regulators and consumers.

The New Zealand Forum's objective is to advance the development of smart electricity networks in New Zealand through information sharing and dialogue, supported by analysis and by focussed work-streams where these are considered to be appropriate.

Even in New Zealand, many groups and individuals are exploring smart grids for their own purposes. A priority for the Forum was to carry out a stocktake summary of current and recent smart grid activity as a reference document to inform our workstreams as we progress.

This report is a summary of the 'state of play' of smart grid related developments within the New Zealand electricity sector. It includes existing smart grid standards, publications and New Zealand case studies and covers the regulatory, technical and consumer engagement aspects of the smart grid. The report also identifies some opportunities for further work by the Smart Grid Forum.

My thanks to the Forum members for their input to this stocktake and to MBIE for developing the final report.

**Paul Atkins**

***Chair, New Zealand Smart Grid Forum***

***November 2014***

# 2 Smart Grid – Definition and Characteristics

The Smart Grid Forum has adopted an internationally recognised definition[1] of what a 'smart grid' is: an electricity network that can intelligently integrate the actions of all users and equipment connected to it – generators, transformers, cables, switchgear and consumers – in order to efficiently deliver sustainable, economic and secure electricity supplies[2].

A smarter grid can deliver benefits, greater choice for consumers about how energy is purchased and used, energy efficiency improvements, improved asset management and deferred capital cost.

In practical terms, the definition given above describes the state of a network with the following possible characteristics:

- » Enables two way communications and more information on the performance of assets and consumer activity than in the past;
- » Enables two way electricity flows (i.e. exports back into the network from excess distributed generation or from distributed storage);
- » Where consumers have discretionary load[3], provides consumers with the ability to manage load as a result of home and building energy management systems (HEMS and BEMS) which may become economic with the development of innovative tariffs[4] and appliances that can communicate effectively with HEMS;
- » Greater opportunity for load to be managed remotely, including traditional and new forms of load control;
- » Effective accommodation of plug in electric vehicles once they have reached a level of penetration that impacts on network operations;
- » Effective control of distributed generation and energy storage to allow a greater penetration of renewable resources than would otherwise be possible; and
- » The ability to take advantage of technology that provides for better network operations, more effective asset management, greater automation and more responsive demand.

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1 www.med.govt.nz/sectors-industries/energy/electricity/new-zealand-smart-grid-forum/

2 Darby, S. J. (2013) Load *management at home: advantages and drawbacks of some 'active demand side' options*. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 227(1), 9-17.

3 Ford, R., Stephenson, J., Brown, N., & Stiehler, W. (2014). . *Energy Transitions: Home Energy Management Systems (HEMS)*. Centre for Sustainability, University of Otago. Retrieved from http://hdl.handle.net/10523/4788

4 Miller, A. and Wood, A. (2013) *Smart Grids: Fact or Fiction?* GREEN Grid. Retrieved from www.epecentre.ac.nz/docs/media/Smart%20Grid%20White%20Paper-r11.pdf

# 3 Smart Metering and Advanced Metering Infrastructure

Advance Metering Infrastructure (AMI) is one of the developing technologies intended to enable the more efficient operation of an electricity network or 'grid'.

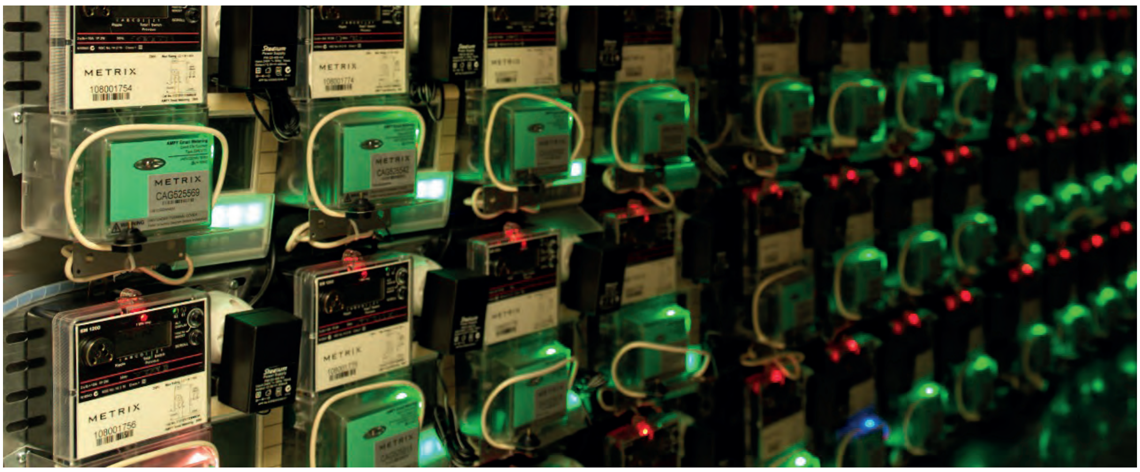
AMI is a system that comprises smart meters, communications infrastructure, and back office processes to manage the data collected by the smart meters and make information available to users. AMI provides information, where smart meters only provide data.

AMI includes the capabilities of a smart meter, but provides additional functionality such as the monitoring of meter operations and communications management (including encryption). AMI carries out the reading (interrogation) of smart meters, and enables the remote re-configuration of metering installations for alternative tariff arrangements (for example, when a consumer changes retailer).

Smart meters are devices installed on consumer's premises to measure electricity. A smart meter is typically an electronic meter that measures and records electricity consumption within programmable time periods (for example, the amount of absolute electricity consumed in each half hour, rather than just an accumulating total register of consumption over a month). It may operate as a standalone electronic meter in a similar manner to legacy (analogue) meters, and it may be read locally or, where communications are available, it may be read remotely.

Smart meters enable consumers to more accurately monitor their electricity consumption, and enable more innovative time-of-use (TOU) or dynamic pricing tariffs than have been possible in the past.

This then requires consumers to adjust their behaviour in response to a (price) signal to deliver a more efficient usage or investment outcome. Most HEMS currently available offer demand management strategies in the form of energy feedback and behaviour prompts, user initiated remote control and automation of appliances, as well as demand response and scheduling of appliances by the utility or grid operator.



Compared to the average smart phone, smart meters are not very sophisticated. They can transfer data in real time, and provide accurate and transparent billing, but useful information must be derived from the data externally (i.e. the meter only captures and provides ‘raw’ data).

Many reports confuse smart grids with smart meters and advanced metering infrastructure (AMI), and convey the concept that smart meters are fundamental to the operation of a smart grid. Smart meters only measure data about a customer’s installation, and these are at the end points of a network. Smart grids deal with significantly more than end point measurement using real-time information and monitoring from the network’s own Supervisory Control and Data Acquisition (SCADA) system.

### Interoperability

Developing technology such as smart grids and AMI will continue to evolve. It is essential that any systems implemented are interoperable. Although these systems must operate within a closed mode to ensure protection from cyber attacks, connection points between systems should have standardised interoperability requirements. Such requirements already exist in the NZ electricity market with interfaces between participants and market systems, and business-to-business exchanges between distributors and retailers.

# 4 Regulation of AMI in New Zealand

AMI is relevant to smart grids as it can facilitate the offer of services between consumers and retailers and distribution companies. The tariff capability of AMI enables indirect load control that can encourage demand reduction as well as better coordinated exports of electricity back into the network.

There are now approximately 1.1 million smart meters installed in New Zealand, and estimates are that there will be up to 1.25 million by April 2015[5]

New Zealand's AMI rollout has been market-led, which is rare internationally as large-scale rollouts are typically mandated. This has happened because:

- regulation and guidelines have facilitated innovation by retailers and distributors;
- AMI provides retailers with a platform for new product/service offerings in a competitive retail market; and
- interim certified category 1 meters[6] are due for re-certification under the Electricity Industry Participation Code by April 2015 and it has been economic to replace some legacy meters with new certified meters due to cost savings in retailer back office processes.
- AMI metering installations must meet electricity safety standards, and comply with the accuracy and infrastructure requirements and obligations in Part 10 of the Code. However, there is no requirement to install smart meters, and no standard requirements on the type of smart meter or communications technology utilised.

The advantages of this approach are that businesses can choose their own technology solution and that consumers are not directly charged for installation. The perceived disadvantages are the potential for incompatible technologies to be used and different levels of 'smartness' being installed.

In 2009, the Parliamentary Commissioner for the Environment argued that New Zealand's market-led rollout had resulted in a missed opportunity to deliver benefits to households and the environment at a small cost, and that retrofitting additional features was likely to be much more expensive.[7]

However, others argue that the current approach has worked well because:

- metering providers are not 'locked-in' to one particular technology solution or functionality which is not subsequently used, avoiding the risks and costs of stranded assets should it not be the right solution;
- there is no agreement internationally on smart appliance or 'smart house' protocols. It is likely that different manufacturers will adopt different capabilities and communication methods;

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5 Electricity Authority estimate at July 2014

6 Used by domestic consumers and small businesses

7 www.pce.parliament.nz/publications/all-publications/smart-electricity-meters-how-households-and-the-environment-can-benefit

» AMI installations rolled out since 2008 either have a communications port for the plugin of a Home Area Networks (HAN) transmitter, or have a HAN transmitter fitted.

» AMI installations can be owned by distributors, retailers, or independent third parties who are free to contract the delivery of services to any party.

» It is unlikely that an AMI installation would become the control for a consumer’s installation, so requiring the AMI installation to act as the co-ordinator for a customer could drive unnecessary cost into the provision of metering.  Such functionality could be replaced by competitive Home Energy Management Systems (HEMS) as these become available.

The Electricity Authority (EA) has produced guidelines that set out minimum expectations relating to the functionality of new technology for AMI, and of industry participants when installing smart meters.  The EA considers the minimum capability of smart meters to be the provision of both load control and two-way remote communications, along with the normal measurement function.

The EA has also set out the strategic drivers and policy areas it sees as being critically important to the successful introduction of smart metering in the document “Advanced Metering Policy”.

| Function | EA Guideline / Policy | Benefit | Issues | Current State |
|---|---|---|---|---|
| Remote read | Should have remote communications | Reduces costs, provides regular and accurate meter readings, eliminates estimated bills and provides flexible billing options | Potential issue for gas retail as fewer physical electricity meter reads can increase the cost per gas meter read | Two retailers noted this issue in the Gas Industry Company's recent contract assessment[8] |
| Remote disconnect | Must be done in accordance with the Guideline on arrangements to assist low income and vulnerable consumers [9]<br><br>No remote reconnections for safety reasons | Reduces costs | Potential for consumer issues if used inappropriately<br><br>Guidelines provide some protection for medically dependent and vulnerable consumers | No evidence of any issue particular to smart meters |
| Last gasp[10] and other network information | No specific requirement, but meter data should be available to users of the meter installation (as agreed) | Improves management and reliability of network | The guidelines do not require any specific functionality, such as last gasp, which would benefit network companies, on the basis that additional functionality can be provided via commercial arrangements. | Some network companies are investing in the technology themselves, as evidenced by WEL Networks $30m plus project to install 'smart boxes' in the Waikato[11] |
| Enable demand response | Should have two way communications, direct load control capability (including existing hot water control), and provision for a suitable Home Area Network (HAN)<br><br>In-house customer displays are desirable | Can reduce peak demand by load shifting or reducing overall use<br><br>Can potentially reduce emissions, depending on the generation profile<br><br>Supports more efficient use of electricity | There is already considerable demand response through ripple control (maybe not used as much now), and high level of renewables mean that the benefit is less than in most OECD countries<br><br>Some contend that the un-regulated (and therefore uncoordinated) approach to the rollout may have resulted in missed opportunities | *Refer to EA 2013 year in review Pg. 30*[12] |

8 www.gasindustry.co.nz/sites/default/files/u303/second_assessment_report_- may_2014.pdf
9 Available at: www.ea.govt.nz/dmsdocument/947
10 A function that enables the meter to transmit a signal to the back-office server to indicate that it has lost power
11 www.wel.co.nz/Smart-Network/Smartbox/Smartbox-QAndA/
12 Electricity Authority 2013 Year in Review (Pg. 30) www.ea.govt.nz/dmsdocument/14676

| Function | EA Guideline / Policy | Benefit | Issues | Current State |
|---|---|---|---|---|
| Data provision | Should be processes to ensure the robustness and integrity of all data, including secure storage<br><br>Should provide ability to meter both import and export power (where appropriate) | Richer data enables better monitoring and analysis, improved accuracy and transparency<br><br>Can assist electricity users to use electricity more efficiently and inform choice on conservation efforts | There are potential issues with the ownership of / payment for data, and privacy (noting that retailers and other parties with access to data are obliged by the Privacy Act 1993 to prevent the unauthorised or unintended use or disclosure of that information) | Part 10 of the Code governs management of metering data<br><br>The EA reviewed access to meter data in 2012 and decided to monitor participants behaviours and actions and will consider providing third parties certain rights of access if necessary<br><br>The EA is currently consulting on proposals to make metering data readily available to consumers |
| Platform for new product/ services | Should be open access, and information should be available to consumers and other users of the meter installation (as agreed) | Provides for innovation and could increase demand-side participation | New products and services need to be able to deliver real benefits and need to be carefully designed and tested | Several retailers are providing their customers online access to time of use metering data and offer some analytics (e.g. Powershop's smartphone app and Mercury's GEM). GLO-BUG uses smart meter functionality to provide pre-payment plans<br><br>Some distributors and retailers are trialling or offering time of use tariffs such as Genesis energy in the Orion and WEL network regions<br><br>Smart meter data was used to monitor restoration efforts after the Canterbury earthquakes |

## Summary of Current State of New Zealand Smart Meter Rollout

Electricity meters are owned by either the retailer or a third party.  If a retailer does not own a meter, they will have a service contract with the meter provider.

There are currently four main meter equipment and service providers in New Zealand:

- Advanced Metering Services Limited (AMS) (subsidiary of Vector)
- Metrix Limited (subsidiary of Mighty River Power)
- Arc innovations Limited (subsidiary of Meridian Energy)
- SmartCo (a joint venture between several lines companies)

The following table sets out the proportion of smart meters in each region based on EA data by network area as at May 2014[13].

*Table 2: Proportion of Smart Meters by Region*

| Region | % ICPs with AMI |
|---|---|
| Canterbury | 83% |
| Auckland (greater) | 83% |
| Wellington (greater) | 58% |
| Waikato (greater) | 53% |
| Central Hawkes Bay | 47% |
| Thames/Coromandel/Tauranga/Taranaki/Wanganui/Manawatu | 43% |
| Central North Island | 31% |
| Otago | 25% |
| Northland | 18% |
| East Cape | 12% |
| Upper South Island | 3% |
| West Coast | 2% |
| Southland | 0.5% |
| Other (various other small networks) | 21% |
| New Zealand Total | 52% |

(Source: Electricity Authority)


13 Electricity Authority meter data (2014)

# 5 Energy Management Systems

Energy Management Systems (EMS) enable consumers to become more than passive participants in the electricity system.

EMS utilise information from two-way communications with the local network, grid and generation to provide some degree of control over appliances and equipment in homes and small businesses[14]. The control can either be automatic (based on service offers that a customer has selected), or through direct engagement in appliance control by the consumer.[15 16]

The provision of energy feedback and/or enabling remote control of appliances allows users to take a more active role in managing their demand. The use of Demand Response Enabling Devices (DREDs) that respond to demand response events, enable retailers or third parties to regulate their use, and/or to offer incentives to households to engage in demand-side management.

There are many different types of systems on the market. Most fall into two categories,

- *Monitoring and targeting systems* which are specifically designed to monitor energy use and target areas for improvement; and
- *Continuous commissioning systems* adjust heating ventilation and air-conditioning and other services continuously to meet changing demand

The physical operation of EMS differs depending on the specific characteristics and categorisation of the system, but most systems incorporate:

- a home control unit to act as a gateway into the network of connected appliances (which might or might not be the smart meter);
- smart appliances, smart plugs, the smart meter, environmental sensors, micro-generation and battery storage;
- a physical or web-based display to provide information or control capabilities to consumers; and
- communications capabilities between each node of the network (which may be wired or wireless).

While the existing smart meter services in New Zealand typically provide consumers or retailers with accurate energy consumption information split into absolute 30-minute time periods, many home energy management technologies provide data that is highly granular in time (e.g. a one second basis) and end use (i.e. by individual home appliances).

14 Darby, S. J. (2013) Load *management at home: advantages and drawbacks of some 'active demand side' options*. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 227(1), 9-17.

15 Ford, R., Stephenson, J., Brown, N., & Stiehler, W. (2014). . *Energy Transitions: Home Energy Management Systems (HEMS)*. Centre for Sustainability, University of Otago. Retrieved from http://hdl.handle.net/10523/4788

16 Miller, A. and Wood, A. (2013) *Smart Grids: Fact or Fiction?* GREEN Grid. Retrieved from www.epecentre.ac.nz/docs/media/Smart%20Grid%20White%20Paper-r11.pdf

Additionally, some EMS technologies enable users to remotely control connected appliances, and they may provide information direct to the consumer (compared to AMI, which send data to the utility where it is processed before being provided to the consumer).[17]

### Energy Management Systems in New Zealand

The New Zealand EMS market is still relatively immature. There are a variety of products on the market such as *ZigBee* and *Nest*, which are falling in price, however, uptake by consumers has been slow. This may be due to other home energy matters, for example, insulating and effective heating being higher on the priority list of New Zealand consumers. The rollout of smart meters and rapid development of wireless EMS systems is expected to play an important role in supporting demand-side management in households.

*Museum Slashes Energy Bill by 43%*

The fine-tuning and adjustment of building systems to ensure optimal energy use was the cornerstone of an energy upgrade at The Dowse Art Museum in 2012. Along with re-wiring parts of the Building Management System, replacing old boilers and other system improvements, the project has cut the museum's energy use by more than 40%. Reducing monthly energy bills by an average of $3,400

(Source: EECA)

While EMS technology uptake may be slow, several electricity retailers now offer smart phone apps, which enable consumers to track their energy consumption in 30-minute intervals in kWh, energy units or dollars, simplifying billing with real time data on consumption. With smart phone apps, notifications are sent automatically for promotions, when a payment is due or when meter readers will make their next visit.

Some electricity retailers have undertaken trials aimed at increasing the user's ability to control their consumption in real-time. Genesis' *Tomorrow Street* project trialled different technologies and pricing rates with consumers to understand how consumers would engage with new technologies and tariffs. The trials by Genesis provided 15 households with a mix of time of use pricing plans, Wi-Fi enabled HEMS system, solar PV panels, solar hot water systems, heat pump hot water cylinders and smartphone apps to manage home energy use. Genesis enlisted participants in coaching programmes to educate customers about energy saving and variable 'time of use' tariffs.

Genesis considers that through understanding energy usage alone, consumers can save 10% on their electricity bills and that consumers will adjust their behaviour if they take control of their usage. From the Genesis Tomorrow St trials, the participating households saw an 18% reduction in energy consumption overall. One family managed to save 59% using an installed PV system whilst another family reduced their energy consumption by 37% over the entire year.

17 Ford, R. et . al. (2014). *Energy Transitions: Home Energy Management Systems*, Centre for Sustainability, University of Otago. Retrieved from http://hdl.handle.net/10523/4788

## GridSpy

GridSpy Limited specialises in energy monitoring solutions. GridSpy's products can measure circuits, in existing buildings or new builds.

GridSpy is operated via a wireless network, connected to the home internet and stores the data online via a secure website where software turns it into graphs and easily comprehensible information.[18]

18 Retrieved from www.gridspy.com/

# 6 Standards for Smart Products

The smart grid represents a technical challenge that goes way beyond the simple addition of information technology infrastructure on top of electro technical infrastructure.

### Smart grid, meter & appliance standards

The electricity network is composed of a high number of distributed nodes that are tightly coupled and operating in real time. Since all the parts of this network have organically grown over many years, even decades, figuring out where upgrades are required can be difficult. The differing time frames of the technologies involved – 40 plus years for lines, cables, and transformers compared to three to five years for consumer electronics and telecommunications makes implementing standards for intelligence a complex task.

The smart grid represents a technical challenge that goes way beyond the simple addition of information technology infrastructure on top of electro technical infrastructure. Each device that is connected to a smart grid is, at the same time, an electro technical device and an intelligent node. Interoperability or connection standards are important, and need to address both aspects concurrently. Interoperability standards allow utilities and consumers to buy pieces of equipment or appliances from any vendor knowing that they will work with each other and with existing equipment at every level. Consumers know that equipment or appliances they purchase will function and not be tied to a specific network connection or limited standard.[19]

### Current New Zealand Standards

#### *Metering Connections*

Although there is no regulatory requirement for parties to install or use smart meters in New Zealand, there are standards that cover the connection of intermittent electrical systems and some standards for metering systems.

The Electricity Industry Participation Code requires household electricity metering installations to be certified to accurately measure electricity consumption. Part 10 of the Code regulates standards, installation, testing, maintenance and certification of components and meter installations. The integrity of meter-reading information must also comply with Parts 10 and 15 of the Code. Additionally, meter providers can only give access to raw meter data to a person that has entered into a contract with a consumer.

#### *Solar PV and Other Electrical Connections*

Network companies have connection standards for Solar PV equipment that must be adhered to. This includes the need for inverters that ensure exported energy is synchronous with the grid and does not interfere with grid energy, and is capable of isolation for safety purposes when there is a fault or the network needs to be worked on.

19 International Electrcotechnical Commission Retrieved from http://www.iec.ch/smartgrid/challenges/

Qualified installers need to complete a network's 'distributed generation' application which requires details of the solar PV system, as well the installing electrician's Certification of Compliance document. Part 6 of the Code requires DG system owners to have a meter that is capable of separately measuring the quantities of electricity that flow (a) from the network (import) and (b) back into the network (export). There are no obligations requiring the retailer to purchase the energy exported at any specific buy-back rate.

Section 110 of the Electricity Act 1992 permits limited work on domestic electricity premises by occupiers. The exact nature of this work is governed by regulations made under the Act and by wiring rules or standards such as AS/NZS 3000:2007, which specify who can wire up and connect equipment within a domestic house and the standards for that connection. Solar PV systems are generally classified as a high hazard activity and therefore require a qualified installer and fixed wiring. The Code states: "The method of connection of a grid-connected inverter system shall be in accordance with the AS 4777 series of Standards in conjunction with the requirements of the electricity distributor".[20] A joint Australian and New Zealand standard that covers distributed generation inverters (and therefore covers PV) is currently being drafted (namely Draft AS/NZ 4777.2).

### *Electrical Products and Appliances*

New Zealand works closely with Australia in developing standards that govern electrical appliances and shares many joint standards. One current standard is AS/NZS 3823.2:2013 which requires air conditioner or heat pump registrations to include information about demand response capability – that is, whether it is capable or potentially capable. Registration information is available publicly online.[21]

Another relevant standard is AS 4755 which sets a framework for demand response capabilities and supporting technologies for electrical products. This standard is expected to be superseded in late 2014 by AS/NZS 4755.1. This standard is an open rather than a proprietary standard, and specifies minimum physical, functional and electrical requirements for an interface. It is analogous to the Universal Serial Bus (USB) standard, which establishes communications between personal computers and the devices they control. The standard is likely to be mandated in Australia. The New Zealand government is not consulting on the mandatory adoption of AS/NZS 4755 interfaces at this time.

Related standards to 4755.1 for the interaction of demand response enabling devices and electrical products are:

» AS/NZS 4755.3.1 Operational instructions and connections for air conditioners;

» AS/NZS 4755.3.2 Operational instructions and connections for swimming pool pump-unit controllers;

» AS/NZS 4755.3.3 Operational instructions and connections for electric and electric-boosted water heaters; and

» AS/NZS 4755.3.4 Operational instructions and connections for charge/discharge controllers for electric vehicles.

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20 Electricity Industry Participation Code 2010 retrieved from: www.ea.govt.nz/code-and-compliance/the-code/

21 See www.energyrating.gov.au

Finally, AS/NZS 61000.3.2 deals with electromagnetic compatibility of appliances and harmonic current limits.  This is very important as more appliances move to electronic power supplies that draw substantial harmonics, which may result in degradation of voltage quality. For example, more modern-heat pumps are inverter controlled, and compact fluorescent lights have power electronic power supplies, as do LED lights.  Electric vehicle chargers also use power electronics and generate harmonics. While electric vehicles are few in number at present, they are large in load, and will potentially have a large impact on power quality as they grow in number.  Modern fridges and freezers also now have inverter power supplies, and make up a reasonable size load.

### *International Smart Grid Standards*

There are a considerable number of overseas standards that can be identified through simple searches.  Many countries have undertaken considerable research work to identify applicable standards and to initiate the development of roadmaps and new standards (as required) or the improvement or updating of existing standards. For example:

- The IEEE has identified over 100 standards[22] relating to smart grids and more in development from the diverse fields of digital information and controls technology, networking, security, reliability, assessment, interconnection of distributed resources including renewable energy sources to the grid, sensors, electric metering, broadband over power line, and systems engineering.
- The IEC identifies over 100 standards as currently relevant to the smart grids. Their web page has links to these standards grouped as:
    - IEC/TR 62357: Service Orientated Architecture
    - IEC 61970: Common Information Model (CIM) Energy Management
    - IEC 61970: Power Utility Automation
    - IEC 61968: Common Information Model (CIM) Distribution Management
    - IEC 62351: Security
    - IEC 62056: Data exchange for meter reading, tariff and load control
    - IEC 61508: Functional safety of electronic /programmable electronic safety – related systems
- The IEC has an interactive map of smart grid standards.[23]  Its Smart Grid Architecture View provides a pictorial overview of the grid.  It includes clusters that form the generic Smart Grid landscape.  Components of the grid are located in topological communities grouped into systems, or so-called "functional clusters".  Clicking on a component inside a cluster provides a list of standards that apply to that component.
- In the US, the National Institute of Standards and Technology Framework and Roadmap for Smart Grid Interoperability Standards Release 2.0 (NIST Special Publication 1108R2)[24] lists relevant standards on smart grids.  The document identifies 37 Smart Grid-relevant standards, and an additional 61 standards for further review.

22 IEEE Standards http://smartgrid.ieee.org/standards
23 See interactive map at http://smartgridstandardsmap.com/
24 U.S. National Institute of Standards and Technology http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf

- In Australia, the regulatory process is proceeding with standards for smart networks and appliances, such as the recently proposed 'Smart Appliance' interfaces for air conditioners, water heaters and other appliances.

### *Voluntary Cyber Security Standards*

Voluntary standards for cyber security have been developed and agreed by operators of critical power infrastructure in New Zealand. The NZ standards, based on standards developed by the North America Electric Reliability Corporation (NERC), provide a framework to help relevant organisations recognise and address cyber security risks.

The standards have been developed by the National Cyber Security Centre, which is part of the Government Communications Security Bureau (GCSB), and New Zealand Control Systems Security Information Exchange forum (CSSIE). The CSSIE forum was established to facilitate exchange of information, in a confidential and trusted environment, concerning threats, vulnerabilities and incidents of electronic attack on control systems. Membership includes electricity generation and network companies.[25]

25 For more information see www.ncsc.govt.nz/newsroom/ncsc-voluntary-cyber-security-standards-for-infrastructure-operators/

# 7 Distributed Generation

New Zealand's electricity is mostly generated in large centralised power stations, which can be a long way from where the electricity is used.

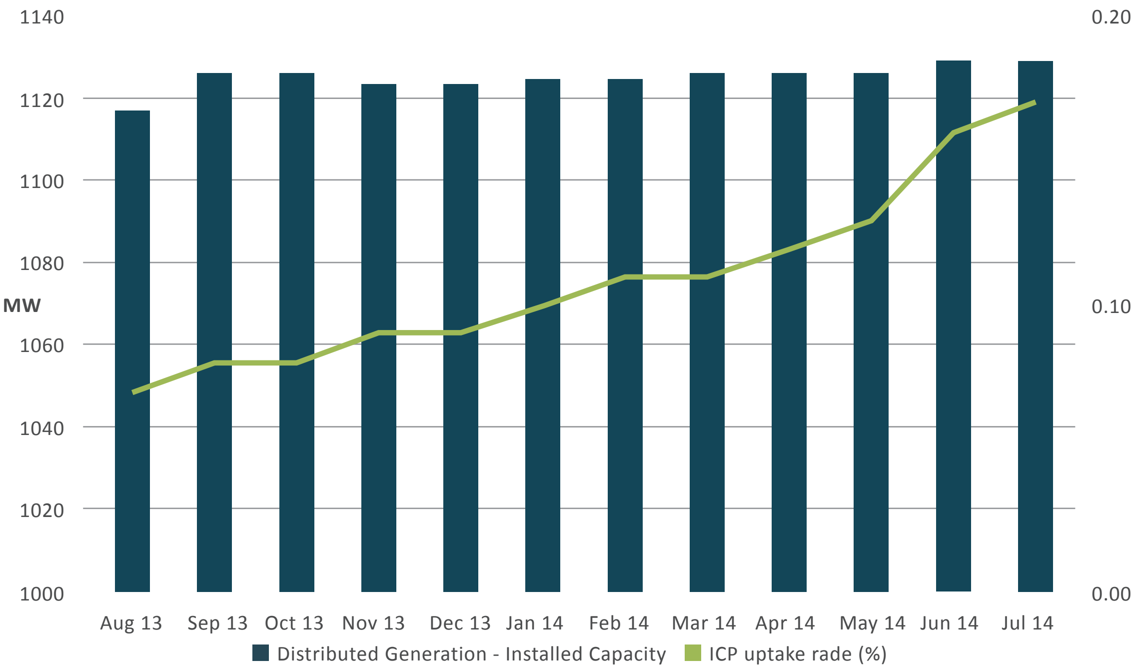
It is then moved around the country through the national grid and then to local distribution networks. Small-scale distributed generation (DG) works differently – electricity is generated from small-scale systems such as photovoltaic modules, small wind turbines, and micro-hydro schemes.

These generation sources may be used, for example, as electricity sources for businesses, homes or farms. DG systems are commonly smaller than 10kW and are often only capable of supplying part of a household's needs.[26]

The New Zealand grid is likely to experience increased DG as commercial options continue to reduce in price and installers make more of a marketing push. In urban areas, DG is most likely to be domestic and commercial solar PV with rural areas developing a mix of micro-wind generators and Solar PV.[27]

Installation of DG is expected to continue to increase as the costs of smaller scale and new renewable technologies decline, although the overall generation contribution will remain relatively small.[28] This is shown in Figure 1 below which compares the total installed capacity of distributed generation with the rate of uptake over the last year. Uptake has doubled, but it has had only a small effect on total capacity.

*Figure 1: Installed Distributed Generation – Capacity and Uptake*




(Source: Electricity Authority EMI data)

26 Electricity Authority, (2013). Small-scale distributed generation. Retrieved from www.powersmartsolar.co.nz/vdb/document/97

27 Behrens, P. (2013). *Monitoring mechanisms for tracking the progress towards a smarter grid in New Zealand*, National Energy Research Institute

28 About 10-15% of installed PV generation capacity can only supply about 2-3% of energy generation

Power quality may become an issue with large amounts of DG, as consumer-owned installations may not always meet quality standards.  Power quality issues are beginning to be seen across some networks.  As the penetration of consumer-installed DG increases, these problems will become more critical, with networks supporting increased maintenance and servicing requirements.[29]

Importantly, smart technologies such as AMI will allow distributors to analyse historical information and understand the changes to their networks better.  Companies with access to AMI information are generally confident they will be able to monitor changes to their networks.

29 Behrens, P. (2013). Monitoring mechanisms for tracking the progress towards a smarter grid in New Zealand, National Energy Research Institute

## Growth in Solar Photovoltaics

The Sustainable Energy Association of New Zealand (SEANZ) reported that over the last three years, prices for PV have dropped around 65 percent and installations have risen to around 40 homes a month. New Zealand's rapid uptake of PV is unique, considering the lack of specific incentives. According to the EA's Electricity Market Information data, total installed PV generation capacity in August 2014 was estimated at 13 MW (see Figure 2). The Canterbury University EPECentre recently published a paper suggesting that solar PV has the potential to increase to more than 30 MW, possibly as high as 750MW, within the next five years. However, researchers have stated it is too early to make detailed predictions and that further research is needed.[30]

If PV in New Zealand grows to 1GW, this would represent about 10% of today's installed generation capacity. However, even with a capacity factor of about 15%, PV would only generate 2-3% of NZ's electrical energy needs. It would also increase the variability of electricity supply as the sun shines, or is shaded by clouds. The EPECentre GREEN Grid project is working to understand the potential variability and to determine ways to deal with it. The GREEN Grid project is also looking at ways of modelling PV, and other distributed renewable generation, in the low and medium voltage networks.

Currently PV-induced voltage fluctuations are generally not an issue. However, in future with high-connection densities of PVs in the distribution low-voltage grid, the short-time solar irradiance fluctuations could lead to unpredictable variations in voltage levels at consumer premises.

It is not possible to say with certainty what parts of the distribution network will be affected the most. The GREEN Grid is developing modelling techniques to study this. These voltage fluctuations due to the inconsistencies in PV output may be mitigated to a certain extent by the provision of backup from energy storage systems.[31]

### *Solar Lights up Museum*

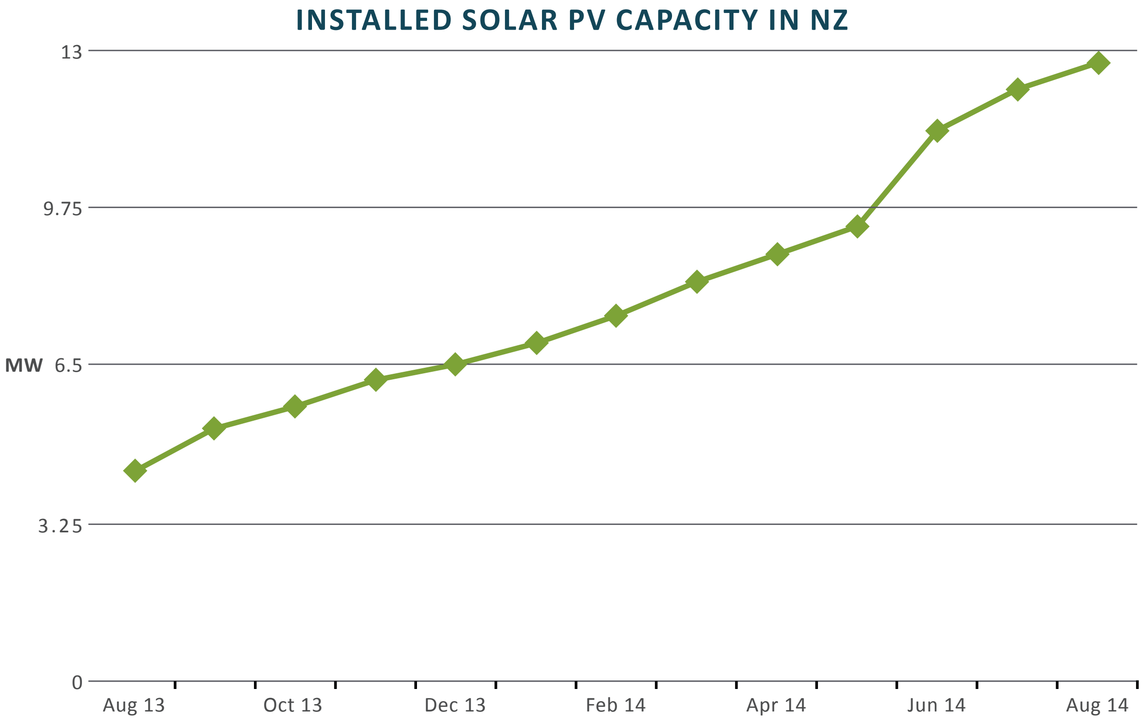
Auckland War Memorial Museum has one of the largest arrays of micro-inverter solar panels in the country. There are 189 solar panels housed on the Museum roof, generating enough power each day to light the exterior of the building by night thanks to a partnership with Meridian Energy. The solar panel system is connected to the grid, but all the energy generated from the sun's rays will be used onsite, reducing the Museum's electricity bill. The amount of renewable energy generated by the solar panels will be equivalent to the power consumed by around eight average households, or approximately 60,000 kWh per annum.

(Source: Meridian Energy)

30 Wood, A. Miller, A. Claridge, N. Moving to the Sunny Side of the Street: Growing Residential Solar Electricity in New Zealand

31 Nair, N.K.C., Zhang, L., (2009) S*martGrid: future networks for New Zealand power systems incorporating distributed generation*. Energy Policy 37

*Figure 2: Installed Solar PV Capacity in Mega Watts in New Zealand 2013-2014*




(Source: Electricity EMI data)

### *Exporting Electricity from Distributed Generation- Net Metering*

Net metering provides for excess generation in one period (e.g. midday) to be offset against demand in another period, (e.g. midnight). It effectively allows customers to receive retail prices for the excess electricity they generate at any given time. Net metering is common in parts of Europe, and allowed by at least one utility in the UK. However, in New Zealand no form of subsidies or price support mechanisms are mandated.

### *Solar Buyback Rates*

Large daytime consumers such as schools and in particular commercial buildings that operate all year round have the most to gain from PV installations through reductions in their electricity bills.[32] In New Zealand, many retailers will pay for excess electricity generated by solar PV as summarized in Table 3 below.

In New Zealand, retailers are not required to offer a set buy-back rate for electricity exported into the distribution network by small-scale DG, or to offer a fixed term contract. Without subsidies, the buy-back rate will naturally trend towards wholesale electricity prices, which is evident in New Zealand. The greatest return on any DG investment will therefore be from reduced demand for imported electricity rather than from the sale of surplus electricity.

32 Wood, A. Miller, A. Claridge, N. Moving to the Sunny Side of the Street: Growing Residential Solar Electricity in New Zealand

*Table 3: Current buy back rates applying to Distributed Generation*

| RETAILER | SYSTEM SIZE | EXPORT POWER RATE |
|---|---|---|
| Contact | Up to 10kW | 8¢ / kWh, + GST |
| Mercury Energy | - | 3.5c / kWh (Auckland & Christchurch only). |
| Trust Power | Up to 10kW | 7.0¢ / kWh, + GST |
| Nova | - | 7.2 c / kWh + GST |
| Genesis | - | 4 - 7¢ / kWh (North Island Only) |
| Meridian | Up to 10kW | 7c /kWh in the summer and 10c /kWh in the winter |

(Source: powersmartsolar.co.nz)

Part 6 of the Code regulates the processes for connecting generation to distribution networks, including default contract terms and conditions. It also provides pricing principles and a dispute resolution framework. The EA is currently reviewing the operational aspects of Part 6.

In general, each distributor specifies any technical interconnection requirements for DG connected to its network, to ensure the DG causes no harm to people or other electrical equipment, or adversely impacts the quality of supply provided by the local network.

Australia and New Zealand have adopted AS 4777–2005 as the primary standard for inverter-based small DG systems.[33] This standard is commonly referenced by distributors, and the EA has recently proposed a streamlined connection process for small-scale DG systems that are certified to be compliant with the standard and with other electrical regulations. A major review is underway to develop a new joint standard with Australia – AS/NZS 4777.

33 Inverters convert DC to AC at the required frequency and voltage, and may also perform other safety and power quality functions.

# 8 Electricity Distribution Business

The distribution sector is likely to see the largest change in the progression to a smarter network.

Moving from a unidirectional system of distributing electricity, to a bidirectional one whereby the consumer can input into the grid could result in power quality issues. Smart meters, HEMs and smart SCADA[34] will provide part of the data needed to develop mechanisms for bidirectional transmission.

In this more dynamic environment, the main challenge for distributors will be to develop and operate their network in a reliable, affordable and sustainable way, while neutrally facilitating the market and customer needs.[35]

The Electricity Networks Association (ENA) has concluded that distributors could make welfare-enhancing smart grid investments, but have little incentive to do so because they would not receive a sufficient share of the benefits under existing market arrangements. The ENA believes aligning distributors' commercial interests with the public interest requires new business models, or perhaps modified regulatory provisions governing investment risk and returns.[36]

### Smart Grid Developments and trials by EDBs: Vector, Unison, Powerco and Orion.

#### *Vector*

Vector owns the electricity distribution network in the greater Auckland region. In addition to being the largest gas and electricity and distributor in New Zealand, 40 per cent of Vector's business is in related technology products.

Vector sees significant opportunities in renewable distributed generation and is currently investigating a number of initiatives including testing new renewable and energy management technologies for the home and businesses, many of which are being delivered through Vector's involvement in new technology developments.[37]

Vector has launched an installation of solar PV panels combined with battery storage for domestic customers. The installation includes a 12.3 kWh lithium ion battery pack, inverter, and control unit with a choice of three, four, or five kW capacity PV panels. The potential problems of increasing PV penetration into the network are described as over/under-voltage and un-intended islanding. Further the addition of battery storage mitigates these issues. Further, the addition of battery storage enhances the benefits of Solar PV including supply security, power quality management, mitigating the potential charging impact of electric vehicles on the network, and operation as a peak power supply.[38]

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34 Supervisory Control and Data Acquisition – a term to describe computer-based systems that monitor and control industrial processes, such as electricity distribution and transmission networks

35 Behrens, P. (2013). *Monitoring mechanisms for tracking the progress towards a smarter grid in New Zealand*, National Energy Research Institute

36 ibid

37 Behrens, P. (2013). *Monitoring mechanisms for tracking the progress towards a smarter grid in New Zealand*, National Energy Research Institute

38 Miller, A. Strahan, M. Tahu, Q. (2014) Systems to Implement Demand Response in New Zealand retrieved from www.epecentre.co.nz

Vector's programmes are an example of market innovation within the distribution sector. Other networks are also investigating this business model, with WEL Networks trialling a PV/ micro-wind mix.[39]

### *Unison Networks Ltd*

Unison Networks views smart grid applications as aligning to three areas: EMS technologies, smart metering, and load control (including systems and communications). Unison has developed a strategy for a more aggressive implementation of smart grid applications through the deferment of low risk asset refurbishment that, in turn, releases capital to be spent on the application of smart grid technologies. For example, if a substation transformer is in need of low-risk refurbishment, Unison may defer the refurbishment and fast switching technology will be installed. This results in the same or improved risk profile, as the fast switching allows load to be lifted several times faster avoiding additional transformer degradation.[40]

Unison bases decisions on a return on investment (ROI) calculation. This ROI is computed by capturing available information on costs and benefits using a New Zealand-customised smart grid benefit tool. This tool drives the Unison 5-year asset management plan, with technology trials as part of the approach. However, even with this developed ROI process it is still difficult to understand some aspects of cost, for example the value of lost load in commercial and residential settings. The EA has estimated the value of lost load at about $0.5 million for each region based on a nation-wide assessment. The EA is looking to produce regional estimates using 2010 survey data for from the Automatic Under-Frequency Load Shedding (AUFLS) implementation.

39 Miller, A. Strahan, M. Tahu, Q. (2014) Systems to Implement Demand Response in New Zealand retrieved from www.epecentre.co.nz

40 Behrens, P. (2013) *Monitoring mechanisms for tracking the progress towards a smarter grid in New Zealand* National Energy Research Institute

*Table 4: Smart Grid Technologies Deployed by Unison Networks Ltd*[41]

| Technology | Description | Benefits |
|---|---|---|
| Distributed Temperature Sensing (DTS) | This technology is being used by Unison to monitor critical high voltage circuits. DTS is able to locate hot spots on the cable route helping to identify issues which could become major problems in the future. DTS also aids in calculating the real-time dynamic rating of the circuit. | » Extend asset life<br>» Enhance asset capacity<br>» Improve network reliability (reduced SAIDI SAIFI)<br>» Improve utilisation of existing asset base<br>» Avoidance of faults<br>» Improve asset condition assessment through real time monitoring<br>» Enhanced knowledge of asset base<br>» Improved planning and network design |
| Thermal Sensors | This sensor technology measures soil thermal resistivity. Thermal resistivity of soil is the biggest unknown factor when it comes to calculating the rating of a circuit. By accurately determining the soil's thermal resistivity, the current carrying capacity of the cables can be accurately calculated. | » Extend asset life<br>» Enhance asset capacity<br>» Improve network reliability (reduced SAIDI SAIFI)<br>» Improve utilisation of existing asset base<br>» Avoidance of faults<br>» Improve asset condition assessment through real time monitoring<br>» Enhanced knowledge of asset base<br>» Improved planning and network design |
| Power Transformer Management System | This technology is used for managing the most important and expensive individual assets in the power distribution industry, the power transformer. By installing different types of monitoring equipment such as winding and oil temperature sensors and combining this with annual moisture and DGA tests, the condition and rating of transformers can be accurately determined. | » Extend asset life<br>» Enhance asset capacity<br>» Improve network reliability<br>» Improve utilisation of existing asset base<br>» Avoidance of faults<br>» Improve asset condition assessment through real time monitoring<br>» Enhanced knowledge of asset base<br>» Improved planning and network design<br>» Optimisation of control room operations |

41 Smart grid technologies deployed by Unison- response to NZ Smart Grid Forum Stocktake survey

| Technology | Description | Benefits |
|---|---|---|
| Self-healing network | A self-healing network is a system comprised of sensors, automated controls, and advanced software that utilizes real-time distribution data to detect and isolate faults and to reconfigure the distribution network to minimize the customers impacted. | » Improve network reliability (reduced SAIDI SAIFI)<br>» Improve power quality<br>» Enhanced knowledge of asset base by utilisation of inherent network sensors<br>» Intelligently reconfigures and sectionalises feeders<br>» Expedites fault detection and fault location<br>» Faster restoration of supply due to self-healing functionality, utilisation of inherent fault passage indicators and ability to operate switches remotely<br>» Improved planning and network design facilitated by inherent network sensors including ability to validate network modelling<br>» Optimisation of control room operations |
| Installation of automated switches | Allows real time monitoring and control of the distribution network. It automates decision making while enabling optimised load shifting that manages network constraints, alleviates overloading conditions, reduces outage occurrence and duration, and creates a more efficient electricity distribution system. | » Centralises remote monitoring of electrical distribution infrastructure;<br>» Expedites fault detection, fault location and service restoration;<br>» Intelligently reconfigures and sectionalises feeders;<br>» Analyses distribution load flow;<br>» Increases infrastructure reliability;<br>» Optimises decision making;<br>» Reduces operating and maintenance costs;<br>» Improves customer satisfaction. |
| Advanced Distribution Management System | Advanced Distribution Management System (ADMS) is a system that combines SCADA, Outage Management and Network Management functions together into one system. Network Management functions include engineering and network analysis tools. | » Enables self- healing network;<br>» Enhanced operational efficiency;<br>» Instantaneous load shifting;<br>» Enables resource planning for major events<br>» Improved customer satisfaction with the outage management function |

### *Powerco*

Powerco is New Zealand's second largest electricity and gas network utility connected to networks in Taranaki, Wanganui, Rangitikei, Manawatu, Wairarapa and Wellington. Powerco has identified the opportunity for smart grid technology in major asset replacement projects in the medium term. Currently, the company has focused on exploiting smart grid technologies on a small-scale through creating business plans for individual projects. Underlying the whole approach is a focus on improving network reliability.

Powerco views New Zealand as fulfilling a 'fast follower' role when it comes to the incorporation of smart grid technologies for distributed generation and electric vehicles. In becoming a fast follower, Powerco is conducting small-scale trials on home management systems and network automation to keep experience and capability within the company for when large-scale investment will be necessary.

As networks often do not consider themselves in a competitive environment, there is a strong history of data sharing between Unison and Powerco. To some extent, this broadens both companies' knowledge base and helps prepare for future changes. Powerco will also continue to work closely with the University of Christchurch Green Grid project.

### *Powerco's Research Projects*

Powerco is currently undertaking two smart networks research projects: Demand Side Management Technology & Behaviour and Distribution Transformer Monitoring.

### *Project One: Demand Side Management Technology & Behaviour*

The objective is to bring global research and into the New Zealand context and demonstrate different pricing and technology opportunities to reduce peaks whilst giving consumers better choices. Powerco's project will research consumer and supply chain behavioural factors that influence success of retailers or other parties rolling out new products and services. The project conducts in depth analysis of three homes with very different energy consumption patterns- energy efficient, average and extravagant. The homes have different family compositions and are located in different climates with different sunshine aspects.

Trial participants record their experiences in a diary, helping Powerco assess engineering and behavioural characteristics. The company will monitor electricity, gas and water use, temperatures and moisture levels in the homes.

The two-year trial will also be looking at solar panels and energy storage as a possible back-up supply during power cuts. Powerco and the Wellington City Council are working together to see if homes can generate their own power when disasters strike.[42]

### *Project Two: Distribution Transformer Monitoring*

This trial assesses the business case of intelligent monitoring or information collection across the distribution network using 250 distribution transformer monitoring units. The project's focus is on the value of information for network monitoring.

The benefits to assess include consumer service benefits, network planning, design and asset management benefits, and network operations benefits (outage management, restoration) from granular, time series network information (on differing scales of urgency).

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42 Retrieved from www.powerco.co.nz/News-and-Media/Latest-News/Wellington-home-part-of-innovative-trial/

*Table 5: Powerco's Demand Side Management Technology Trials*

| What's in homes | Assessing |
|---|---|
| Remotely controlled infra-red heating | Control (load shifting), comfort and heat retention, Smart thermostat. |
| Remote controlled radiator/ "storage" | Control (load shifting), comfort and heat retention, Smart thermostat. |
| Remotely controlled heat pump | Control (load shifting), comfort (& efficiency to old heating) and heat retention. |
| Gas fire heating | Substitution, comfort and heat retention. |
| Gas central heating/water | Substitution, comfort and heat retention. Smart thermostat. |
| Insulation & down-lights | Alternate thermal envelopes. |
| Alternate PV set up | Micro inverters and array set ups (direction, tilt). |
| Solar controller | PV self use; protect, promote ripple connections. |
| Bathroom heat/fans | Timer based control to minimise peak over-run |
| Baseline testing | Multiple old heating sources to benchmark. |
| Fridge/ freezer/ laundry | White goods not available but opportunity to manage. |
| Energy storage | Peak effect on selected loads (18:00 on; 2kWh). Resilience (4kWh). Model optimal P, small ESU, demand &gas. |
| Cooking options | Efficient cooker, gas cooker, slow cooker. |

(Source: Powerco)

### *Orion Networks*

Orion uses Demand Response for the purposes of deferring capital expenditure and maintaining compliance with their security of supply standard. The use of Demand Response was an important tool in managing the restoration of supply during the 2010-2011 Canterbury earthquakes. Metering owners have installed approximately 110,000 smart meters, most of which contain inbuilt ripple receivers on the Orion network. Where appropriate, the remainder of the 190,000 network connections have standalone ripple receivers.

The use of ripple control allows a 5-10% reduction of peak demand corresponding to 30-60 MW. Customers with loads exceeding 300 kVA are subject to peak demand period pricing. This enables a further 3% reduction of peak demand. Furthermore, it is estimated that the use of day-night pricing options has encouraged approximately 10% of load to be shifted from the daytime peak into the overnight trough. Peak demand has been reduced by a total of approximately 20 per cent and this is responsible for a large part of the divergence between energy and peak demand.[43]

43 Miller, A. Strahan, R. Tahu, Q. (2014) *Systems to Implement Demand Response in New Zealand*, EEA Conference & Exhibition 2014, 18 - 20 June, Auckland

*The Blue Skin Community Energy Project*

The Blueskin Wind Development is led by Blueskin Energy Ltd, a company wholly owned by the Blueskin Resilient Communities Trust (BRCT), and is aiming to build three 850 kW wind turbines generating approximately 6.1 GWh for an 'energy community' of 2500-3000 people with a demand of 5.4 GWh annually. BRCT has agreements with OtagoNet and has received assistance from Pioneer Generation, Meridian, Trustpower, DNV-GL Energy, Russell McVeagh, Ethical Power Consulting, the Akina Foundation and Foot Law. The Blueskin Energy Project is in its fourth year of wind monitoring and is currently preparing a Resource Consent application to build the turbines at a cost of approximately $5 - $6 million.

BRCT provides energy advice, home performance assessments, climate change planning, and solar advice. The BRCT has recently installed solar PV on its office roof along with over 100 kW of solar panels installed locally in the last 18 months. BRCT is working with researchers and will soon be putting in-line data loggers into solar homes for monitoring. BRCT is currently in discussions with Oxford University to begin a trial of DIY Smart Grid initiatives. This study will be part of a wider global research with other sites also in South Africa and the UK.[44]

# Demand Response

Demand response (DR) is a generic term that encompasses a variety of responses from the demand-side including interruptible load, control of hot-water heating load by distributors, and peak period load control.[45]

DR in New Zealand enables local organisations to earn money by helping the grid manage spikes in demand and keep electricity prices low. In addition, DR can act as a valuable grid-stabilising resource for renewable energy systems like New Zealand's. The level of power generated by wind and hydro resources fluctuate throughout the day. To support changing generation capacity and security, participating companies reduce consumption or take their operations off the grid for short periods of time.[46]

*Demand Response Case study*

*Nelson-Marlborough District Health Board*

Nelson-Marlborough DHB installed powerful new generators at Nelson Hospital in 2009. The DHB must run the generators regularly to ensure the batteries are charged and diesel is turned over so participating in Transpower's security and price response programme made sense.

The DHB signed up to the Price Responsive and Security programmes, taking part in 13 of the 20 events completed during the course of the programme and were paid approximately $60,000 for participating. The additional fuel costs were around $4,500.

(Source: Transpower)

44 For more information see: www.brct.org.nz/

45 Electrcity Authority retrived from www.ea.govt.nz

46 EnerNOC Demand Response definition, Retrieved from: http://www.enernoc.com/our-resources/case-studies/demand-response-for-organisations-in-new-zealand

Uses of DR include:

A. Distribution system asset deferral and management of Transpower peak prices (referred to as load management in this document, and discussed further in Section 10)

B. Instantaneous reserve, to enhance spinning reserve held as an ancillary service to deal with the contingency of the loss of a large generating unit;

C. Management of high spot prices, either nationally or locally due to a transmission constraint for example

D. Deferral of transmission investment, in order to reduce the cost of strengthening the grid, through limiting the flow of power in Transmission assets; and

E. Management of maintenance outages

In most cases customers who provide DR, either reduce their electricity bill or receive payments for being flexible with their load.[47]

### Transpower's Demand Response Programme

Transpower's Demand Response Programme is funded by regulated transmission charges approved by the Commerce Commission and is a means of deferring further transmission investment. Transpower is currently working with the EA and the Commerce Commission to develop a protocol for the use of its DR programme.

In 2013 a total 134 MW was offered compared to a target of 100 MW. It was also offered at a lower cost than anticipated, with each event designed to answer specific questions about how DR could be used during different scenarios on the grid. Performance has been positive enough for Transpower to use DR to support the power system in times of real need.

47 Miller, A. Strahan, R. Tahu, Q. (2014) Systems to Implement Demand Response in New Zealand, EEA Conference & Exhibition 2014, 18- 20 June, Auckland

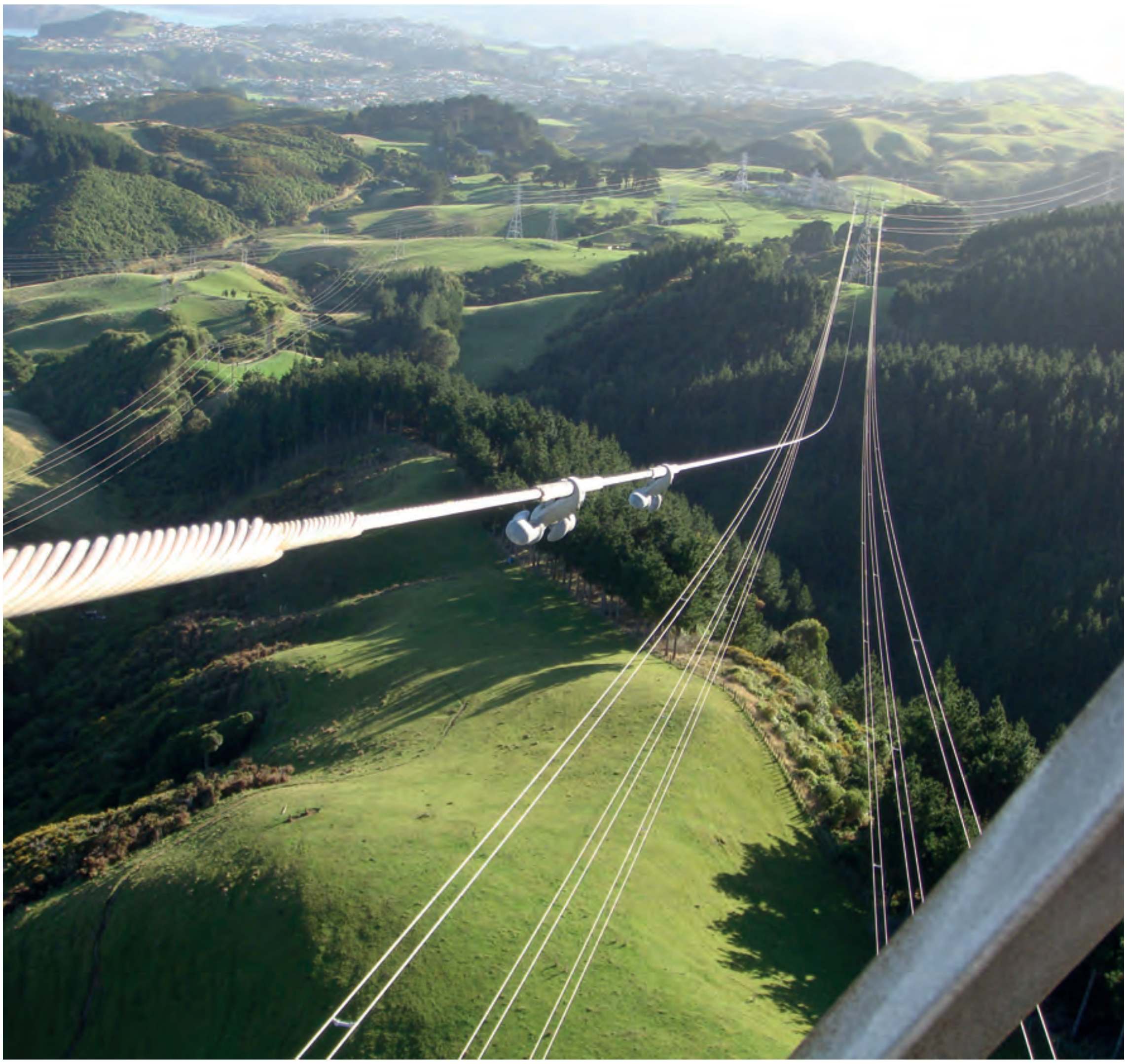
*Benefits of Demand Response*

The benefits of DR for the network and customers include:

- Lower costs to all customers – any reduction in peak demand can result in reduced grid and generation investment which means lower electricity costs; and
- Increased reliability of service – if Transpower can switch off non-essential load in response to transmission or generation failures, supply can be maintained to essential services.

*Transpower's Future Demand Response Work*

Transpower's DR programme has provided valuable learnings about the nature of a small subset of DR types and sizes. Transpower has not yet determined the potential DR capacity from new small and medium providers (20-500 kW), which make up approximately 25% of electricity consumption in New Zealand.  Transpower will consider opportunities to further grow DR capability by targeting differing DR customer types by market segment, starting with a commercial buildings programme.



### *Variable and Dynamic Line Rating*

Variable and Dynamic Line Rating (VLR and DLR) is another tool that Transpower uses to improve capacity utilisation of assets, by 'working the assets harder'. The tool changes the rating of transmission lines to reflect likely or actual operating conditions. For example, a line might be able to be rated at a higher capacity on a cold day, thereby avoiding the need for high cost resources to meet regional peaks.

This requires either real time monitoring of the local weather along a transmission line or use of detailed historical data. This information is fed into an algorithm that calculates the new line rating. Transpower is using variable ratings based on detailed historic data on six transmission lines already and will be exploring the use of real time information to lift grid performance within the next ten years.[48]

A similar method can be applied to cables and transformers, through short-time overload of their capacity in suitable conditions. Dynamic cable rating will be applied to the new 220 kV cables through Auckland within the next five years to ensure security of supply if there is a failure of the overhead line that supplies Northland and North Auckland. This approach optimises the return on the investment in these new cables and defers the timing of additional lines and cables.

On-line condition monitoring of assets such as transformers can provide early warning of equipment failure, which in turn can deliver better supply reliability as well as optimise asset utilisation. On-line condition monitoring requires data acquisition and signal processing to acquire and sift through data produced by large numbers of devices. This technology has been researched and used in New Zealand for many years.[49]

48 Transpower NZ Limited (2011), Transmission Tomorrow *www.transpower.co.nz/sites/default/files/publications/resources/transmission-tomorrow.pdf*

49 Miller, A. & Wood, A. (2013) *Smart Grids: Fact or Fiction?* GREEN Grid www.epecentre.ac.nz/docs/media/Smart%20Grid%20White%20Paper-r11.pdf

# 10 Load Management

The ability of distribution operators to manage load variability on lines is an important aspect of smart grid.

Traditionally, load management within electricity networks has involved ripple control systems managing hard wired loads (such as domestic electric hot water services) to shift electricity demand into off-peak periods, to reduce peak transmission charges and manage distribution capacity with a financial incentive to consumers.[50]

However, the introduction of smart SCADA, AMI, smart appliances and enhanced communications, and the further development of ripple control systems have allowed many more opportunities for load management. Current tariffing and metering arrangements can already provide control for off peak heating, heat pumps, saunas, spas, swimming pools, and night-store heaters. AMI and HEMs could extend this control.

### Upper South Island Load Management System

Orion has combined with seven other lines companies to control the load on the Upper South Island networks to reduce demand during peak loading times. This reduces the need for transmission investment for growth, which puts downward pressure on costs for customers.

The System does this by using all available load-shedding capability across the Upper South Island to automatically reduce load if needed during grid outages.

This programme is estimated to have reduced load at peak times by about 30MW during the winter period – the equivalent of removing about 10,000 homes from the national grid. The System was a key factor in saving Transpower peak charges of $3m to customers in the region in 2010.

(Source: oriongroup.co.nz)

For commercial and industrial customers, the switching of irrigation, motor, heating and cooling loads is also now commonplace. At a regional level, more recent developments have used ripple control to reduce transmission peaks across multi-utility regions, and helping defer transmission investment.

However, as the adoption of these new technologies for households and businesses increases, there is a real risk that the switching of significant amounts of aggregated load has the potential to destabilize electricity supply and/or degrade power quality. This would clearly have a significant and detrimental impact on consumers.[51]

50 ENA, (2013) *Principles of Load Management*, Electricity Networks Association, Retrieved from http://www.electricity.org.nz/Site/Reports/reports/default.aspx

51 ENA, (2013) *Principles of Load Management*, Electricity Networks Association, Retrieved from http://www.electricity.org.nz/Site/Reports/reports/default.aspx

### *Ancillary Services- EnerNOC*

EnerNOC is a global leader in demand response and has over five years of experience in aggregating demand-side loads in the New Zealand and Australian electricity markets. EnerNOC's Interruptible Load (IL) programme is one of the most sophisticated demand response programmes in the world.

Operating in the Instantaneous Reserves market, EnerNOC automatically reduces capacity across dozens of sites to adjust for the small number of major fluctuations in the balance between electricity generation and demand. In 2012, EnerNOC built a 20MW diversified DR portfolio in the Lower North Island for Genesis Energy to manage exposure to high wholesale prices in Wellington. This is likely to be superseded by the use of Financial Transmission Rights, which are now available as a new market product in offering the generator/retailers the basis risk management that they require.[52]

### *Benefits of Load Management*

As noted above, there are potential benefits to effective and efficient load management for electricity customers in New Zealand, with resulting improvements to the price, quality, security and reliability of their electricity supply. There are also potential market benefits where participants can provide offerings to their customers through demand-side participation which manages the cost of their consumption as well as driving a greater level of competitiveness.

The ENA "Smart Networks Working Group" defined some of the benefits as a range of deferred investments at the generation, transmission and distribution levels with a commensurate improvement in system utilisation. There is also an expectation that AMI would provide for greater communication and information flows which can assist with power quality recording and enhance engagement with customers. Load management is clearly only one element in a complex arrangement of elements to deliver benefits to consumers.

### *Risks of Load Management*

Poorly coordinated load management is a significant risk to customers and the industry. Whilst networks are designed to facilitate and cater for the variations in load that we see today, significant changes in the quantities switched and synchronized switching (either planned or unplanned) of aggregated customer load in and out of service has the potential to destabilize the distribution network which may result in significant risks to customer supply.

It is also important to realise that new technology is not costless and takes time to implement. This will be weighed up against an investment window and return period. There is often a lag between getting data and turning this into information on which to make decisions. In the case of smart appliances that are responsive to load or tariff control, effective adoption could take longer than 10 years unless there is an overarching financial requirement to do so.

There may be further load management opportunites for distribution companies to undertake similar cooperative ventures to reduce load in other regions through the load management of EV charging points, heat pumps and HEMS.[53]

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52 Retrieved from EnerNOC www.enernoc.com/our-resources/brochures-faq/faq-new-zealand-interruptible-load

53 ENA, (2013) *Principles of Load Management*, Electricity Networks Association, Retrieved from http://www.electricity.org.nz/Site/Reports/reports/default.aspx

There has been concern expressed over the potential loss of historically available controlled hot water heating load due to increasing penetration of gas and LPG hot water systems which in turn lowers the load management resource from homes. This concern reflects a view that the system value of flexible controllable load in aggregate may exceed the value to consumers of alternative hot water systems, but that value is not recognised and protected by current market arrangments.

Investigation of the economic and greenhouse gas impacts of gas hot water system penetration is a potential research topic of the GREEN Grid project.

# Market Development: Electricity Authority

The Electricity Authority is an independent Crown entity with the statutory objective of promoting competition in, reliable supply by, and the efficient operation of the electricity industry for the long-term benefit of consumers.

The EA's focus for market development is to develop a workably competitive electricity market by reducing barriers to entry, expansion and exit of parties facilitating consumer participation, providing efficient price signals and promoting flexibility and resilience into the market and market systems.[54]

The EA's 2014/15 work programme includes several key regulatory projects that support the development of a smart grid, particularly by facilitating consumer participation and by providing efficient price signals.[55] These projects include:

### *Distribution Pricing Review*

The EA is concerned that current arrangements may not be promoting operational and investment efficiency in the distribution sector and the broader electricity market. Distributors are expected to align their pricing methodologies with voluntary pricing principles introduced in October 2010 to promote efficient distribution pricing and retail competition. The review is examining the extent of alignment and whether the EA should take an alternative approach.[56]

### *Retail Data Project*

This project is considering options to promote retail competition by improving consumers' access to their retail data. For consumers to drive competition, they need to access information about the various offers available in the market, assess these offers in a well-reasoned way and act on this information by purchasing the good or service that offers the best value to them. Consumers actively participating in the electricity market by making

54 Electricity Authority, July 2013, Strategic directions for market development, page 2
55 Electricity Authority 2014/15 work programme, retrieved from http://www.ea.govt.nz/dmsdocument/18308
56 Electricity Authority 2014/15 work programme, retrieved from http://www.ea.govt.nz/dmsdocument/18308

decisions will drive vigorous competition and efficiency gains as firms compete to deliver what consumers want.[57]

The EA has proposed to provide consumers and their agents with access to consumption data that is currently recorded by meters. Consumers with smart meters would have access to half-hourly consumption data that could be used to make more efficient energy-related decisions.[58] This could make it easier for retailers to offer more dynamic pricing plans. Trials with two way information flows to test customer engagement and tailor products to suit customer needs will be an important step to learn about the value a smarter grid can bring to both consumers and the electricity industry.[59]

### *Research Project: Effects of Low Fixed Charges*

This project is to examine the effects on competition, reliability, and efficiency of the Electricity (low Fixed Charge Tariff Option for Domestic Consumers) Regulations 2004 (the Regulations). The EA wants to understand the market development implications of the Regulations. The EA is concerned that the duplication of tariffs may be harming retailer innovation and competition and that the Regulations establish constraints on efficient distribution pricing.[60]

### *Time-Of-Use Pricing*

Electricity usage typically peaks around the same time every day in a given area. The simplest method of discouraging electricity use during peak times is to institute a time-of-use (TOU) price schedule, under which electricity is least expensive when loads are low (typically at night) and most expensive during peak times (usually afternoons). Customers paying TOU rates may adjust loads manually or use Energy Management Systems to control their loads. TOU pricing schemes may vary with the season, but are generally set far in advance. This means TOU pricing does not help much on the few days per year when load approaches its annual peak.

Day/night and night only TOU tariffs have been available to domestic consumers since the late 1980s however, consumer uptake of these tariffs is low. Taking advantage of these types of tariffs has relied on having appliances, such as night store heaters, permanently wired to a separately controlled night meter.

### *Flick Electric*

Flick Electric launched in June in the Hamilton and Wellington markets after demonstrating to the EA it had the financial wherewithal and systems to buy electricity in the wholesale electricity market and then account for its sale to customers with smart meters.
Flick believes average New Zealand homes should save around seven per cent on their bills over the long run. Flick charges the actual spot market price and passes through all distribution and network costs without marking up any of these costs. This concept encourages consumers to change their consumption patterns and track the spot market prices.[61] Flick is hoping the advent of smart meters and HEMS will mean customers can better use the hour-by-hour price signals it sends.[62]

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57 Electricity Authority, Retail data project webpage, http://www.ea.govt.nz/development/work-programme/retail/retail-data/

58 Electricity Authority, July 2014, Retail data project: access to consumption data consultation paper, at http://www.ea.govt.nz/development/work-programme/retail/retail-data/consultations/#c12844

59 Strbac, G. et al. (2012) Smart New Zealand Energy Futures: A Feasibility Study. Summary Report

60 Electricity Authority, 2014/15 work programme, available at http://www.ea.govt.nz/dmsdocument/18308

61 Retrieved from www.flick.co.nz

62 Retrieved from www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11320201

### *Contact Energy: Peak & Off-Peak Pricing*

Contact Energy offers peak/off-peak pricing in Christchurch, effectively offering two-tier time of day pricing to residential customers, to encourage shifting load to off-peak periods. Contact's experience found that customers are only able to load-shift to the degree that their lifestyle allows.  Contact believe this may change as smart appliances become more prevalent but the main learning is that time of day pricing suits certain people with a more natural off-peak consumption profile.[63]

Contact benefits as a generator from load shifting, although a trial of this size is insignificant in the scheme of Contact's overall generation.  There is also a benefit to network businesses in load shifting "Our experience has been that network companies are unwilling to reflect a benefit like this to them in their pricing when they are not in control of the load profile (in the same way as hot water control for example)".[64]

This activity is an example of the smart grid concept as consumers take control of their consumption patterns and are able to make decisions to reduce electricity use.

### *Examples of Smart Consumer Participation*

Online billing, energy management systems, and apps make it easier for consumers to monitor and manage their energy use.  As deployment of smart meters spreads, two-way communications networks become capable of recording half-hourly interval electricity consumption data.  As a result, retailers are able to implement time-based rates and energy management programmes for residential and smaller commercial customers.

Several retailers now offer online billing and energy management tools giving consumers the ability to track estimated usage and access household electricity usage comparison data to identify if they are low, average, or high users compared to the average consumption range. Customers can also compare historical usage to anticipate forthcoming bills so that they can take control of their power usage and make savings.

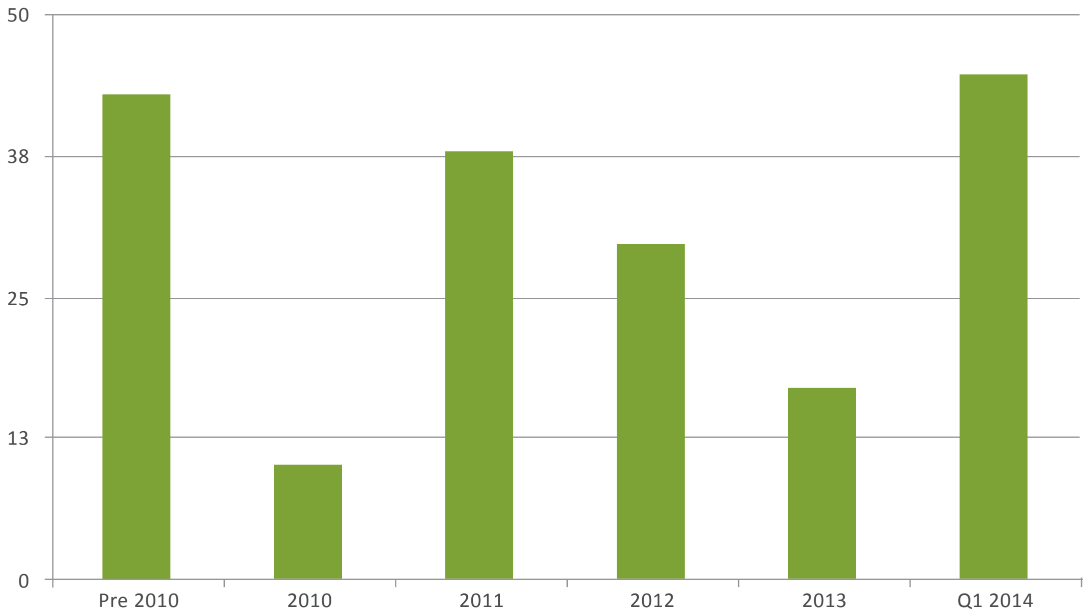
63 Correspondence with Contact Energy
64 ibid

# 12 Electric Vehicles

In March 2014, there were 183 electric and plug-in hybrid vehicles (EVs and PHEVs) registered in New Zealand[65] representing 0.01 percent of all car registrations.

There was a record number of EV registrations in the first quarter of 2014, with a total of 45, compared to a total of 47 for all of 2012 and 2013. This is represented in Figure 3 below.

*Figure 3: Plug-in hybrid and electric vehicle registrations*




(Source: Ministry of Transport vehicle registration data)

EVs are relevant to smart grids because recharging impacts on demand and grid stability, and also because EV batteries have the potential to provide useful backup and storage capacity. The greatest impact will be on local distribution networks, especially as the uptake of EVs is likely to be clustered in certain areas – potentially higher socioeconomic areas in cities.

The up-front cost, and range anxiety appear to be the obvious barriers to the uptake of EVs.[66] This is reflected in strong sales of the recently released plug-in hybrid Mitsubishi Outlander which is more versatile, overcoming the range issue.

Currently an exemption from road user charges (RUC) is the only financial incentive offered by government to encourage the uptake of EVs. All other non-petrol vehicles in New Zealand are required to pay a RUC and the average driver (driving 14,000 km a year) pays about $812.[67]

65 Ministry of Transport data, see also http://www.transport.govt.nz/assets/Uploads/Research/Documents/2013-Fleet-report-final.pdf
66 Compare uptake to that of hybrid vehicles (over 8,000 registrations), which are cheaper up-front and not reliant on charging stations
67 As at 1 July 2014, the RUC for cars is $58 per 1,000 km see- http://www.nzta.govt.nz/vehicle/registration-licensing/ruc/rates-fees.html


EVs have the potential to be an alternative source of home battery storage for PV applications. With sufficient EV batteries, smart metering could facilitate the pooling of storage capacity at a community level. Battery storage allows energy produced during off peak demand periods to be saved and used during peak demand periods.[68]

### *Northpower and EVs*

Northpower is actively promoting the use of EVs – it has made two standard chargers available to the public, and has installed a fast charger capable of providing 80 per cent charge capacity within 30 minutes (compared to the standard eight-hour full charge).[69] Three more chargers will be added later if demand increases. Northpower recently completed a study that showed its electricity network could comfortably handle tens of thousands of EV's charging overnight. It is currently importing EVs to on-sell to local businesses.

### *APEV NZ*

EVs are also promoted through New Zealand's Association for the Promotion of EVs (APEV NZ), which is the sister association to APEV Japan. APEV NZ's mission is to create financial, environmental, health and energy security benefits for all New Zealanders through facilitating innovation, education, demonstration and collaboration in the EV sector. Members include

68 The Energy Efficiency and Conservation Authority (EECA) has a guide to the regulatory and market environment "Deploying electric vehicles in New Zealand" available at: www.eeca.govt.nz/sites/all/files/deploying-electric-vehicles-feb-2012.pdf

69 www.northpower.com/news/entry/first_fast_charge_station_for_electric_vehicles_to_open_in_whangarei

auto manufacturers, electric bike, scooter and specialty vehicle companies, energy companies, charging infrastructure providers, local governments, universities and polytechnics.[70]

### *Halo IPT- inductive charging pads*

New Zealand engineering professors John Boys and Grant Covic have pioneered inductive power transfer technology (IPT). Their technology is used to charge electric vehicles. Halo IPT, the New Zealand-based start-up, sees inductive charging pads as a solution to the hassle of daily recharging of EV/PHEVs. Instead of plugging in, a charging pad the size of a bath mat in the centre of the garage floor sends electromagnetic waves to a converter in the car that does the recharging. The next frontier for the engineers is developing in-road wireless charging, eliminating the need for plug-in battery chargers, and enabling cars to recharge as they travel along highways. They aim to lower the cost and battery weight, increase the power, and make cars more efficient.[71]

### *The UltraCommuter*

Developed at the University of Waikato in partnership with HybridAuto, the UltraCommuter is a two-seat battery electric car that uses a lithiumiron-phosphate battery and is designed for long range. During testing it reached 85 kilometres per hour and a range of 180 kilometres. With a larger battery pack the UltraCommuter could achieve a range of 250 kilometres at a speed of 100 kilometres per hour. Research has showed that long-range battery electric cars are feasible with today's technology, but the cars must be designed specifically as battery electric to achieve a good performance.[72]


70 Retrieved from www.apev.org.nz/

71 Retrieved from www.pmscienceprizes.org.nz/winners-2013-the-prime-ministers-science-prize/

72 Retrieved from www.ipenz.org.nz/IPENZ/events_and_awards/Docs/MikeDuke.pdf

# 13 Discussion and Opportunities for New Zealand

The following section outlines some of the recommendations extracted from the research.

### Smart New Zealand Energy Futures Report

Meridian's Smart New Zealand Energy Futures report concluded that changes in electricity demand are expected to create a substantial economic case for smart grid opportunities in New Zealand. The benefits available from using demand side management were estimated to reduce New Zealand's required electricity system investment by up to $3.5 billion in 2030 and up to $10.6 billion in 2050.[73]

Other findings included:

- deployment of smart EV charging and HEMS technologies could bring significant benefits at a distribution network level from 2020 onwards. Similar benefits may be available at a generation level around 2030.
- the benefits of demand response may be shared among several industry participants along the energy value chain. Achieving active demand side participation is internationally considered a barrier to achieving the full economic benefits that a smarter grid could deliver. The industry has a key role to play to raise awareness, put appropriate systems and processes in place and create incentives for greater demand side participation in the energy market;[74] and
- New Zealand's market design and regulatory framework will need to evolve to provide the right investment signals to unlock flexible demand side participation and to ensure that New Zealand's existing load control resource is being fully utilized.

### *Survey Response*

Respondents to a research survey conducted in conjunction with this report suggested that New Zealand could become a world leader in areas other nations may have overlooked. In particular, asset health analytics as most of our asset replacements are driven by age, given low to moderate growth in demand. Better understanding the end of life indicators of assets gives the ability to better manage the asset lifecycle.

In addition, some respondents identified the potential for New Zealand to adapt technology in the marketplace to cater for low-density networks (for example size, price, suitability of technology), and to lead the application of asset health/dynamic ratings on smaller scale assets (for example power transformers < 20MVA).[75]

73 G. Strbac et al. (2012) Smart New Zealand Energy Futures: A Feasibility Study, Imperial College, London & Meridian Energy.

74 ibid

75 Park, J. Unison Networks Ltd (2014) NZ Smart Grid Forum Stocktake Survey

It was also suggested that within the New Zealand electricity industry, a large amount of data is already collected from power systems.  There may be opportunities for New Zealand to become a leader in the use and analysis of data to improve the efficiency of the power system operation, improve asset utilisation, and to lower capital expenditure.  This brings together information technology, signal processing, and power systems.  Research in these areas could lead to new inventions, new products and services for the industry, which could ultimately lead to new export opportunities.[76]

76 Miller, A. (2014) NZ Smart Grid Forum Stocktake Survey

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