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Urban Development Smart Grid Roadmap – Christchurch Recovery Project

APEC Energy Working Group

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About Sapere Research Group

Sapere Research Group is one of the largest expert services firms in Australasia. Sapere provides independent expert testimony, strategic advisory services, data analytics and other advice to Australasia's private sector corporate clients, major law firms, government agencies, and regulatory bodies.

For the purpose of this report Sapere brought together a highly experienced project team with significant expertise in the key areas required to deliver the Roadmap for Achieving a Smarter Grid through the Christchurch Recovery.

About this report

This report is titled Urban Development Smart Grid Roadmap- Christchurch recovery project. It is requested and funded by the Asia-Pacific Economic Cooperation (APEC) Energy Working Group. The project is managed by the Energy Efficiency and Conservation Authority of New Zealand (EECA) and a Steering Group of key stakeholders has overseen the project.

The project report follows the process of identifying what is meant by the term smart grid and the discrete features of a smart grid that can be measured. A model was developed to measure the individual benefits to determine where the key value areas lie.

The same approach could be applied to any other city seeking to understand the smart grid potential from a consumers' benefit perspective. There is no single blue-print for a smart grid and we have drawn on international experiences to identify the meaning of smart grid and the application to the Christchurch circumstance.

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Executive summary

This *project* set out to develop a roadmap for a smart grid in the context of the Christchurch rebuild following the devastation caused by the 2011 earthquakes. The project arose from the idea that the rebuild offers an opportunity to establish a smart grid and a roadmap would set out how this could be achieved. This report:

- Sets out an understanding of what constitutes a "smart grid";
- Examines smart grid opportunities in the context of the Christchurch rebuild;
- Quantifies smart grid benefits for Christchurch, using an approach that could be applied in any community; and
- Identifies implications for Christchurch, other networks in New Zealand and other disaster prone communities.

Smart grid

A "smart grid" approach to electricity service delivery includes network operations, consumer engagement and accounts for all forms of future consumer demand for delivery of electricity.

Adopting a smart grid approach to system delivery implies a combination of conventional solutions, smart solutions and smart enablers.

The term smart grid covers the system wide utilisation of emerging technology to meet the future demands consumers will make on the network. Some of these demands will reduce load (e.g. heat pumps), some will change load patterns (e.g. small scale distributed generation) and some will increase load e.g. electric vehicles.

Infrastructure supporting the electricity industry is made up of long-life assets. Capability building for smart grid is a system wide issue and has to begin before it is required. It is also the product of decisions made by many stakeholders with a variety of interests. Relevant stakeholders include regulators and government agencies responsible for delivering public policy outcomes.

Christchurch

The findings with respect to Christchurch were unexpected. The opportunities of a smart grid approach are relevant in networks seeking greater efficiencies driven by technology changes in electricity system delivery. However following a disaster like the Christchurch earthquakes, everyone's top priority is to re-establish buildings and infrastructure so the disrupted population can restore their lives to a new form of normalcy.

Rebuilding is a multi-year project requiring coordination across many organisations and the whole community.

Leadership and coordination amongst providers of all aspects of energy delivery (including energy efficiency) is the pressing issue for Christchurch. Christchurch may benefit by convening a forum for the exchange of ideas and coordination of a sustainable energy strategy for Christchurch. This would help business rebuilding the city to take the opportunity to build for better energy performance and take changing energy demands into account.

In the context of the Christchurch recovery the biggest and most accessible benefits are to be found by incorporating energy efficiency measures in domestic and commercial buildings during the rebuild.

This project estimated the gross benefits[1] of a smarter grid based on a future view of consumers' requirements in a rebuilt Christchurch and current technology trends in network operations. Real data from Orion and other domestic sources plus a variety of international studies on consumer requirements were taken into account and these were converted into the Christchurch context.

This project identified that based on conservative assumptions there are significant economic benefits from a smarter grid for Christchurch.[2] The present value of the full potential gross benefit of smart grids for Christchurch is assessed as: $161 million by 2023 and $690 million by 2033. If the benefit of energy efficient buildings is included the benefits are $291 million by 2023 and $1,016 million by 2033.

Similar benefits are achievable in other communities that have not suffered a disaster.

Smart grid in disaster prone areas

A network built with a smart grid approach will be a more resilient network as a result of more distributed generation and storage (especially in the form of plug-in-electric-vehicles). This has particular relevance for communities that may face disasters such as an earthquake in the future. A more resilient electricity system will have less disruption than a traditional network following a major disaster. Following a disaster priorities change and the focus shifts to regaining some sort of normalcy. The conclusion from this work is that is the advantage of smart grid would be evident when disaster strikes but a smart grid road map is of not so relevant after the event.

Lessons for New Zealand

The method used to calculate benefits for Christchurch consumers can be repeated for any other network in New Zealand. Based on the findings for Christchurch it appears likely that all New Zealand consumers will benefit from a smart grid approach.

To the extent that there are barriers to achieving gains from a smart grid approach these tend to be matters of commercial and regulatory arrangements and the incentives on service providers (distributors, retailers and other service providers) to meet consumer demand. Those barriers are best addressed at a national level and with involvement from the market and economic regulators.

A national smart grid implementation group (along the lines of the Great Britain (GB) smart grid forum) would usefully clarify the future needs of New Zealand consumers nationally and provide support to addressing barriers to delivering the benefits of a smart grid approach

[1] We have focused on gross benefits as there are various possible paths, and by implication a range of possible costs, to realise these benefits. The gross benefit approach provides an estimate of the possible returns (or prize) that could be secured from smarter grids, within which stakeholders can then consider the cost effectiveness of various paths to secure those benefits.

[2] For the purpose of this report "Christchurch" corresponds to the Orion network area

1 Background and approach to this report

1.1 Introduction

The objective of this project was to prepare a Roadmap for Achieving a Smarter Grid through the Christchurch recovery. The goals for the roadmap were to:

- Set out a practical course of action to cost effectively maximise the social, environmental and economic benefits of a smarter grid system in Christchurch;
- Provide a guide for smarter grid development during the Christchurch rebuild; and
- Provide findings that are of value for New Zealand and a case study that is relevant to the APEC community.

As a first step, we have identified and calculated the benefits possible to Christchurch consumers through the development of a smart grid. This is contained in chapter 2. An understanding of the benefits is vital in order to achieve the other goals of this report. The same approach could be applied to any other city seeking to understand the smart grid potential from a consumers' benefit perspective.

Chapter 3 sets out the findings of the project team, and a recommended way forward – based on the benefits modelling and other information gathered during the course of the project, including interview data.

1.2 Smart grid – definition and characteristics

The project team found many definitions of smart grid in publications and reports from different countries prepared for many different purposes. The definition below captures the project team's best understanding of what is meant by "smart grid":

A Smart Grid 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.[3]

A smarter grid is a transformation in the way electricity is generated, distributed, retailed and consumed. A smart grid delivers network benefits, greater choices for consumers about how energy is purchased and used, and energy efficiency improvements. Some of the choices consumers will want in the future are not necessarily economic today such as small scale distributed generation and electric vehicles. The electricity infrastructure to support these choices is made up of long-life assets under conventional systems. Therefore the adoption of smart grid techniques is a current issue as a move to a smart grid approach needs to be aligned with the investment cycle rather than the demand cycle. The rebuild of Christchurch may be an opportunity to take account of how future demands from consumers might be met more efficiently by addressing current planning.

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

[3] European Technology Platform Smart Grids, Strategic Deployment Document for Europe's Electricity Networks of the Future, September 2008

- Enablers such as two way communications and a great deal more information on the performance of assets and consumer activity than in the past;
- Two way electricity flows i.e. exports back into the network from excess distributed generation or from distributed storage;
- Greater ability for consumers to manage load as a result of in-home and building energy management systems (HEMS and BMS) driving off smart meters, more diverse product offerings notably innovative tariffs and, where applicable, distributed generation (DG) and energy storage;
- Greater opportunity for load to be managed remotely. This includes traditional and new forms of load control;
- Effective accommodation of plug in electric vehicles (PIEVs) once they have reached a level of penetration that impacts on network operations; and
- Takes advantage of technology that provides for better network operations, more effective asset management, greater automation and more responsive demand.

1.2 The Christchurch earthquakes and the recovery task

Orion owns and operates the electricity distribution network servicing the Christchurch and central Canterbury region. Its network prices and network quality standards are regulated by the economic regulator the Commerce Commission (the Commission) under Part 4 of the Act.
Orion has applied for a customised price path(CPP) because its post-earthquake circumstances are no longer able to be accommodated within its current Default Price-Quality Path (DPP) settings. This is because of the significant impacts of the catastrophic earthquakes on its business. This extract from Orion's application to the Commission for a CPP summarises what occurred:[4]

> *On 4 September 2010 Canterbury was hit by a 7.1 magnitude earthquake. The earthquake had an epicentre about 40km west of Christchurch City. There were no fatalities as a result of this earthquake but there was widespread damage to local infrastructure and buildings. The eastern suburbs of Christchurch and the Kaiapoi township were seriously affected by liquefaction and lateral ground movement.*
>
> *An aftershock sequence of more than 12,000 aftershocks of varying magnitude began that day and the sequence is ongoing. All of the earthquakes experienced since are the result of ruptures on faults not known to be active prior to September 2010. Major earthquakes followed, the most notable being the deadly and devastating 6.3 magnitude earthquake on 22 February 2011 that struck near Lyttelton on the Port Hills, the 5.7 and 6.3 magnitude earthquakes of 13 June 2011, and the 5.8 and 6.0 magnitude earthquakes of 23 December 2011.*
>
> *The event on 22 February 2011 was by far the most serious, resulting in 185 deaths.*
>
> *In the worst-affected suburbs, houses and businesses were without power, water and sewerage for some time, and roads were damaged and unsafe. The Government declared a State of National Emergency in New Zealand on 23 February 2011, which remained in place for almost nine weeks. This is the first State of National Emergency in New Zealand's history*

[4] Orion Proposal for a customised price-quality path 19 February 2013

> *declared in response to a civil defence emergency, illustrating the unique circumstances that arose in Canterbury.*
>
> *In the months following the earthquake, the Canterbury Earthquake Recovery Authority (CERA) was created as an arm of Government to lead the region's recovery and rebuild, led by former Orion Chief Executive Officer (CEO) Roger Sutton. Orion's leadership and highly effective earthquake responses were recognised with this appointment.*
>
> *As a result of the earthquakes, the Christchurch central business district (CBD) was altered irrevocably. By mid-2012, the CERA estimated that more than 650 buildings had been demolished in the CBD. CERA estimates that there will be over 1,100 CBD building demolitions. This widespread destruction not only has a severe economic impact on Canterbury, it has also imposed significant social and cultural costs to our region and its people.*

All things considered the electricity grid performed relatively well in the earthquakes. Temporary repairs were quickly implemented, and long-term repairs are ongoing. However, the scale of built and municipal infrastructure replacement that will occur in Christchurch over the coming years means that investment choices made now for will have long lasting effects.

The rebuild of Christchurch presents an opportunity to take account of how future demands from consumers might be met more efficiently by addressing current planning. In reality, following a disaster such as the earthquakes in Christchurch, emphasis for the whole community becomes about getting people's lives back into some sort of new normalcy. This takes many years and, as a result of the disaster, people's priorities are different than they would have been otherwise. For example, individuals face many costs across a broader front so building to least cost becomes more of a focus than would normally be the case. Another example in Christchurch is that seismic strengthening has become a higher priority than energy efficiency which wouldn't have been the case before the earthquakes. The upshot is that restoration is more urgent than future thinking in many instances.

1.3 An APEC Perspective

The APEC Smart Grid Initiative (ASGI) has been established to evaluate the potential of smart grids to support the integration of intermittent renewable energies and energy management approaches in buildings and industry.

The APEC Energy Working Group notes:[5]

> *APEC members are in various states of smart grid development, ranging from no activity, conducting demonstrations, and engaging in joint projects with other economies. Each member economy has unique attributes that influence the benefits of smart grid capabilities and affect the priorities given to deployment strategies*

The findings from this study into the value of benefits of smart grid are relevant in all networks in the APEC member economies. However, an additional benefit of smart grid relevant to disaster prone areas in APEC comes from setting up smart grids in a way such that sub grids or "micro grids" are established so areas islanded following a disaster can still function.

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[5] APEC Energy Working Group *Using Smart Grids to Enhance the Use of Energy Efficiency and Renewable Energy Technologies* May 2011

1.4 A New Zealand wide perspective

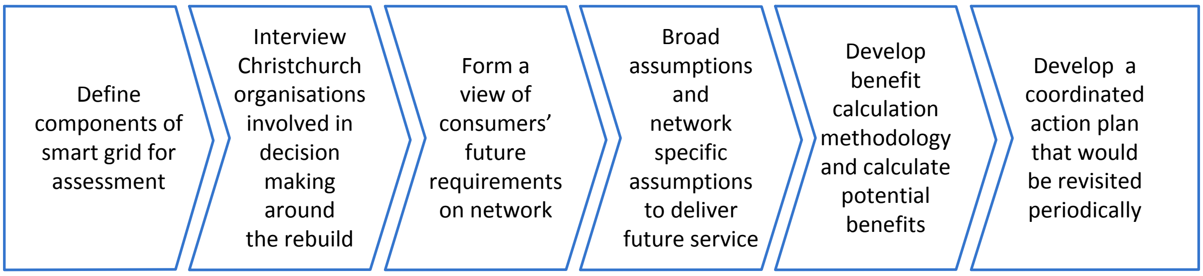
The potential gains from smart grid are not just a Christchurch issue and are not confined to communities suffering from a disaster. The definitions and methodology used in this report are applicable to all networks and relevant to a national approach. Decision making in the electricity sector has evolved over the past century and some of the smart grid opportunities may be inhibited by nationwide institutional arrangements – which is considered in more detail later in this report.

2 Calculating the benefits of adopting a smart grid in Christchurch during the recovery

2.1 High-level Approach

The steps taken to calculate the benefits of a smart grid for Christchurch and to subsequently develop an action plan to realise these benefits are shown in Figure 1 below:

Figure 1 work programme to determine benefits of a smart grid for Christchurch



The brief for the project included measuring the benefits of achieving a high level of energy efficiency amongst newly built houses and commercial buildings – in order to form a complete picture of the potential benefits of modern electricity supply and use to consumers (i.e. not because efficient buildings are a prerequisite for a smart grid). This element has therefore been included in the following methodology and analysis.

2.2 Future consumer demands in Christchurch

The concept of smarter delivery and use of electricity in Christchurch following the recovery is the same as it would be in any city. The difference is in the level of possible benefits to consumers. Benefits may come from three sources:

- A smart grid approach in the sense of network investment and operations;
- Coordination amongst stakeholders responsible for delivering the service to consumers; and
- The energy efficiency gains achievable through the rebuild.

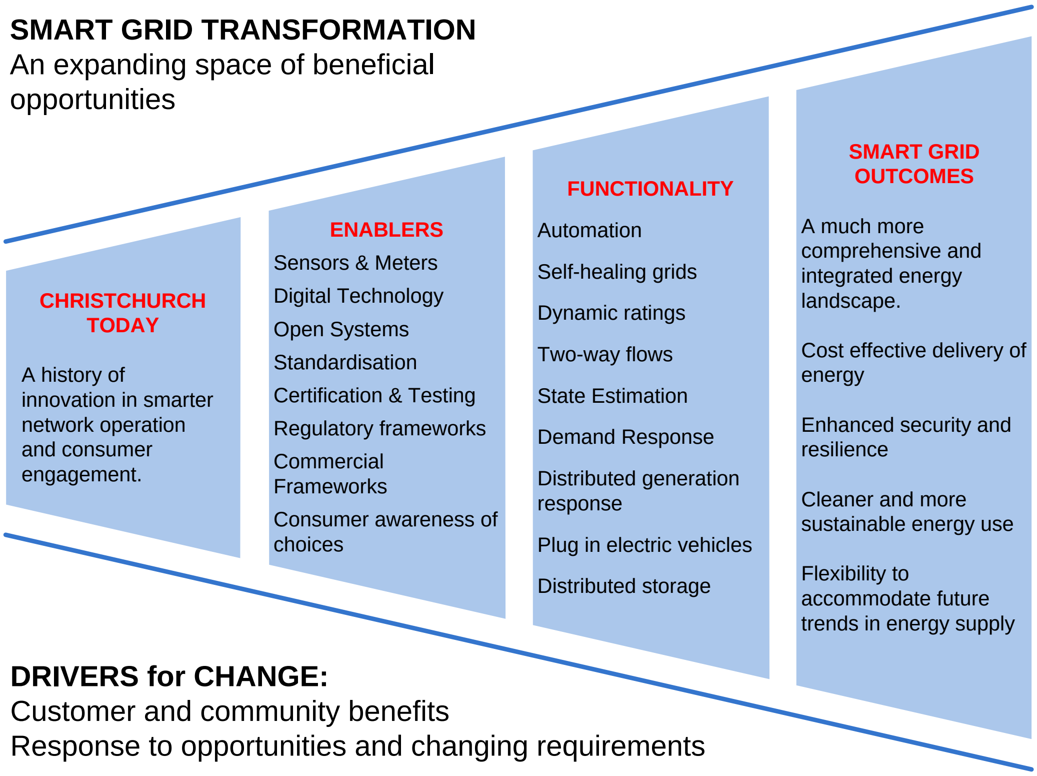
The development of a smart grid is a function of:

- Synchronisation between the objectives of the providers of the separate parts of the service to consumers – notably distributors and retailers;
- Legislation and regulation applying to both retailers and distributors;
- State of all of the technologies available to distributors and retailers;
- Data, principle data from meters and sensors; and
- Application development.

2.1 Identifying the benefit landscape

The objectives of a smart grid approach were arrived at by working back from consumer orientated outcomes, through the functionality required to deliver these, and then the enablers for this functionality. This progression is illustrated in Figure 2 below. By working back from consumer outcomes it is easy to think about what has to be done and the interdependencies to achieving the outcomes. It also assists in identifying the diversity of the stakeholders involved in delivering the benefits.

Figure 2 smart grid outcomes and the elements of the transformation



The elements of the smart grid transformation diagram were expanded into 17 distinct features of smart grid deployment made up of a mix of enablers and functional features. (See Appendix 1 for detailed descriptions of features.) The features were aggregated into 6 benefit categories which would lend themselves to forecasting and modelling to determine potential benefits (and later costs).

Figure 3 smart grid features and benefit categories

<table>
<tr><th>Smart Grid Features</th><th>Smart Grid Benefits Categories</th></tr>
<tr><td>Asset Condition</td><td rowspan="7">Electricity network benefits</td></tr>
<tr><td>Asset Capacity</td></tr>
<tr><td>Security & Resilience</td></tr>
<tr><td>System Operation</td></tr>
<tr><td>Supply Quality</td></tr>
<tr><td>Asset Utilisation</td></tr>
<tr><td>New Connections</td></tr>
<tr><td>Distributed Generation</td><td rowspan="3">Small scale DG, heat integration and storage</td></tr>
<tr><td>Heat Integration</td></tr>
<tr><td>Electricity Storage</td></tr>
<tr><td>AMI</td><td rowspan="4">In house information and tariff signals</td></tr>
<tr><td>Smart Retail Tariffs</td></tr>
<tr><td>Consumer energy data</td></tr>
<tr><td>Building Energy Management Systems</td></tr>
<tr><td>Electric Vehicles</td><td>Battery powered electric vehicles</td></tr>
<tr><td>Heat pumps</td><td>Heat Pumps</td></tr>
<tr><td>Energy Efficient Buildings</td><td>Energy Efficient Buildings</td></tr>
</table>

2.2 Methodology and assumptions

This section describes, in more detail, the methodology, assumptions and sources we have used to quantify the benefits of smart grid in Christchurch. Key aspects of the approach taken include:

- The method has been created in a way that makes it possible to apply the same approach in other cities;
- The Orion network has been particularly successful in flattening load with a combination of load management, aggressive price signals to its 400 biggest customers and the use of DG;
- Other networks that have not been as diligent and successful as Orion may have more potential for benefits from smarter network operation;
- We have used current prices for carbon so the carbon reduction benefits are small however the CO_2 savings are shown in our workings;
- We have used current oil prices with electric vehicles but we note that a step up (or a step down) has a significant bearing on the EV benefits;
- We have not assigned an option value to smart grid. Even where the immediate benefits are minimal any progress that accommodates these initiatives has value for development in the future. EV re-charging architecture and EV charging tariffs are examples;

- We have not included costs. This work quantifies benefits so that the opportunity can be identified. This summary details how we calculated the possible benefits arising from the commitment of consumers and industry players to a smart grid – the coalition of the willing;
- Even though we have not calculated costs we have had to make some assumptions about increases in costs e.g. network reinforcement required to accommodate EVs and heat pumps, and taken the reduction in those incremental costs as benefits;
- To calculate the present benefits we have used 4% real discount rate; and
- We have not determined an explicit value for incorporating microgrids (discrete areas that have the potential to link localised forms of generation and storage and be islanded from the grid) into the smart grid. Following a disaster micro grids offer greater resilience than traditional forms of electricity generation and distribution:[6]

  > *once infrastructure is broken, the time required to repair it greatly compounds a lack of safety, comfort, and efficiency. Even considering highly evolved processes—utility crews from around the nation converging on affected areas—the days and weeks that follow are very costly to cities and communities.*

  This exercise looks at smart grid benefits from a consumer's perspective. The benefit of having micro grid will depend on the nature of a disaster and the specific disruption that ensues. Our exercise is confined to the business as usual benefits of adopting a smart grid approach today.

The basis for analysing each benefit category (identified in Figure 4) and arriving at the potential benefits is set out below. What we call primary effects are those effects which are tangible and can be quantified more easily. The secondary effects, though arguably tangible to those experiencing them, are not so readily quantifiable. For that reason we will provide qualitative explanations of those benefits.

2.2.1 Network operation

Two influences will drive the investment and style of investment networks make in future

Firstly, demand growth combined with the availability of new technologies will allow the lines company to perform its traditional role more efficiently and cost effectively. Examples of smart grid applications that network companies may adopt include:

- On line condition monitoring - lowers costs through better asset management:
- Enhanced/improve fault location - lowers the SAIDI cost: and
- Dynamic rating - lowers cost by reducing the capital investment required in the network.

Secondly, the change to a smart grid orientation for a network company is a response to a transformation in the way consumers want to use energy and interact with the network physically (i.e. the primary relationship for most consumers is with the retailer). We have taken into account the growing trend in many countries for consumers to become more engaged in the supply of electricity, its use and a greater interaction between consumer use and the constraints of supply. These consumers are responding to technology changes, an awareness of the potential for energy efficiency, greener power sources, and a more local sustainability agenda. Changes include the

[6] US National Electrical manufacturers Association *The Power of Microgrids* 2014

adoption of distributed generation such as rooftop photovoltaic cells, a much higher penetration of heat pumps for space heating, the possibility of electric vehicle charging, in-home energy systems that allow consumers greater monitoring with possible modulation of load, demand management as a service that earns rewards, and retailers exploring ways that they can engage consumers more closely. These changes, and the changes that network companies will make in response, are what are collectively known as smart grids or smart networks.

To calculate the benefits consumers might expect from a smart grid approach to network operation we have based our understanding of the Orion network on its Asset Management plan[7] and a smart grid survey that explores intentions and progress on the adoption or need to adopt innovative technologies. (See Appendix). In particular we have:

- Calculated the estimated current disruption to Christchurch consumers based on existing SAIDI and SAIFI figures[8] and calculated the value of reducing those disruptions using a value of lost load (VoLL) figure of $8167/MWh;[9]
- Estimated the possible reduction in those SAIDI and SAIFI figures increasing to 5%[10] in 2023 as a benefit from smart grid;
- Applied a reduction in operational expenses[11] of 5% per annum from smart grid operation based on international research;[12] and
- Assumed a reduction in reinforcement costs of 25% of current network costs.[13] Network costs are assumed to increase to allow for reinforcement to accommodate EVs and heat pumps. This cost-saving is of the order confirmed by the detailed GB cost/benefit model.

The comparable network spending paths for Orion with and without smart grid is shown in Figure 4.

[7] See http://www.oriongroup.co.nz/publications-and-disclosures/asset-management-plan.aspx

[8] **System Average Interruption Frequency Index (SAIFI)** and **System Average Interruption Duration Index (SAIDI) are** reliability indicators commonly used by electric power utilities and economic regulators.

[9] EA *investigation in the VOLL in NZ summary of findings* January 2012 – load weighted average for all consumers

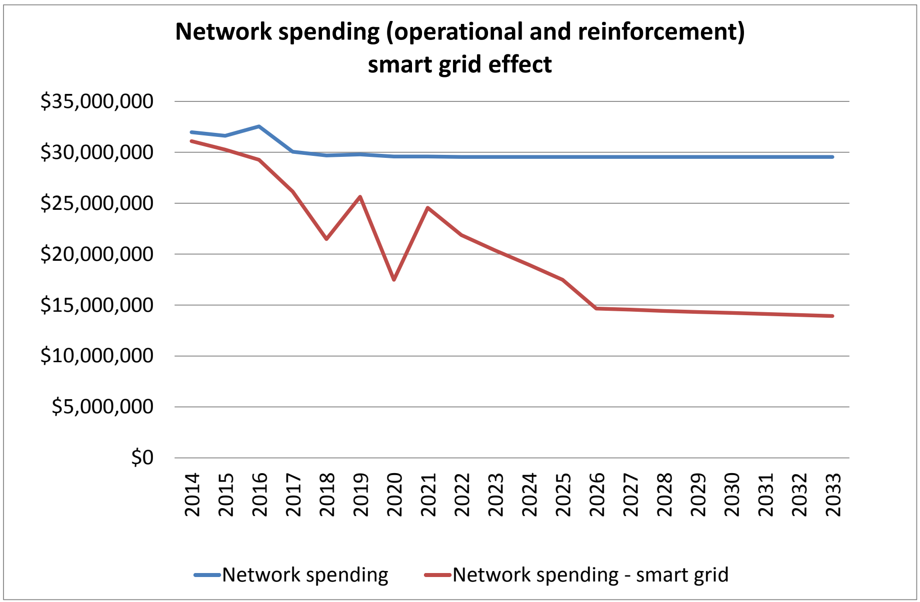
[10] EPRI E*stimated costs and benefits of smart grid technical report* 2011 uses a figure of 20% savings in the US

[11] Orion *AMP* April 2013

[12] Gridwise Alliance *Realising the Value of an Optimized Electrics Grid* February 2012

[13] Orion *AMP* April 2013

Figure 4 estimating the smart grid network benefits in Christchurch



2.2.2 In-home and in-building information and tariff signals

Many vendors now offer home energy management systems (HEMS). The purpose of this report is not to identify the cheapest or the best but to account for the effect that will take place if they become widespread amongst New Zealand consumers' homes and buildings. There is no mistaking the market is large and growing internationally:[14]

> *The current Home Energy Management Systems (HEMS) market is valued at $1.5 billion in 2013, and includes utility residential demand response (DR), connected home subscriptions, software services, and associated hardware. While the market is still in its infancy, the top two leading home automation companies combined already have over 2 million customers paying monthly subscription fees of between $20 and $60, demonstrating the HEMS market's remarkable potential. New companies have entered the arena, hungry for the next set of opportunities revolving around software and bundled service solutions, and the market has shifted in its scope and product offerings.*

The design and focus of HEMS have changed since the first wave of HEMS came onto the market in 2008 and 2009.

Based on interviews conducted for the GTM research report Bojanczk defines HEMS as:

> *Encompassing any product or service that monitors, controls, or analyzes energy in the home. This definition includes residential utility demand response programs, home automation services, personal energy management, data analysis and visualization, auditing, and related security services.*

Bojanczk distinguishes between solutions targeted at the utility and non-utility sectors:

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[14] Kamil Bojanczyk GTM research **Home Energy Management Systems: Vendors, Technologies and Opportunities, 2013-2017** August 29, 2013

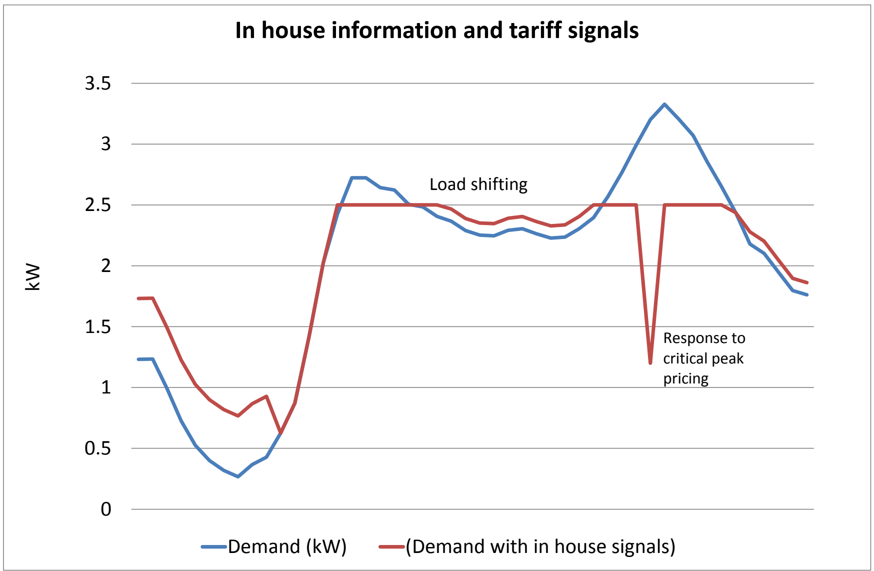
> *Utility solutions include both the utility and the thousands of homes enrolled in the HEMS program. These solutions require a detailed economic analysis custom-tailored to each utility, and typically boil down to a single-load-per-home demand response program or an energy efficiency and customer engagement initiative.*
>
> *Non-utility solutions focus solely on the home customer and integrate various smart-home services, which fall under the broad definition of HEMS proposed above. The detailed economic analysis used for utility customers is replaced with a smart marketing campaign targeting the needs of homeowners - vendors often enter the home with a security solution and then offer HEMS as an add-on sale.*

For this benefit category in the New Zealand context we are capturing activity managed by a household or business. The building occupier may have a building management system, smart meter and DG. Whether it manages the energy use automatically or in a much more manual way there is at the very least more information available on consumption patterns and tariff signals (from both the distributor and the retail energy supplier) that encourage more efficient energy consumption.

With improved information it is expected that consumers will switch consumption away from peak pricing periods and reduce energy consumption overall. Smart meters have been rolled out to over half of the domestic consumers in New Zealand and tariffs are starting to be split into time periods to reflect a day and night differences in costs.

The benefit is up to 30% savings in the average per kWh cost.[15] We also calculate the value of deferred generation and deferred transmission.[16] We have assessed an average 0.25kW of load can be shifted over and above current load management patterns for residential.

Figure 5 illustration of the approach taken to estimating the benefits of in house information and tariff signals



[15] Gridwise Alliance *Realising the Value of an Optimized Electricity Grid* February 2012 and observed wholesale prices in the NZ electricity market

[16] Transpower Annual Reports on historical spending on transmission augmentation and IEA *Energy Technology System Analysis programme Technology brief* April 2010 estimated costs of constructing a combined cycle gas plant

2.2.3 Plug in electric vehicles (PIEVs)

For this category of smart grid benefits we have taken a conservative view of when the growth in uptake of electric vehicles accelerates. In reality we will follow the rest of the world in terms of technology used, especially in storage medium and in terms of the vehicles that sell well.

Electric vehicles form part of smart grid even though they are not established as part of the system by the usual infrastructure providers. The decision to have PIEVs on the road and connected to the network will be made by consumers. Those consumers will expect the benefits that they bring and will also expect the infrastructure to be in place to support them. The infrastructure provided will both support PIEVs and integrate their potential for network management. In that vein Smart Grid News features and articles by Jesse Berst, [17] focus on the delivery of the enablers rather than the issue of when their use will expand:

> *Eight states representing nearly 1/4 of America's auto market have pledged to adopt measures to make it easier to own an EV, including changing building codes and encouraging more charging stations. For instance,* according to the New York Times*, they will simplify rules for installing chargers; develop charging stations that take the same form of payment; and require charging stations at workplaces, multifamily residences and other places.*
>
> *The pact includes California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont. The eight states have set a six-month deadline for drafting an implementation plan.*
>
> *California already issues rebates for EV buyers and requires automakers to sell zero-emission vehicles in the state. As a result, 29% of the plug-in cars sold in the United States reside in California, according to the Union of Concerned Scientists. Even so, overall numbers aren't big, according to SF Gate. Americans have bought just 140,000 of them in the past three years. Still, some forecasters believe the EV market is poised for a takeoff, even before the news of the eight-state pledge.*
>
> *Utilities should be forewarned that the governors of all eight states have pledged to promote time-of-use rates to encourage off-peak charging by EV owners. The governors are also promising to buy EVs for their own fleets and urge cities to do the same.*

As customers purchase PIEVs, consumption of petrol decreases and consumption of electricity increases. By making the assumption that PEVs will be charged outside of peak periods, and that the storage can be used to back flow into the local grid, we can obtain several benefits. (For the purpose of this exercise we have not allowed for charging during work hours. The actual pattern of charging that emerges will depend on the response from retailers and distributors when PIEV's become more widespread.)

The take up scenario of PIEVs for Christchurch is a function of the proportion of new vehicles that are electric. We do not assume an acceleration of new vehicle replacement. We have based our electric displacement of new vehicle rate on international research.[18]. We have used Ministry of

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[17] Jesse Berst is the founder and Chief Analyst of SGN and Chairman of the Smart Cities Council, an industry coalition.

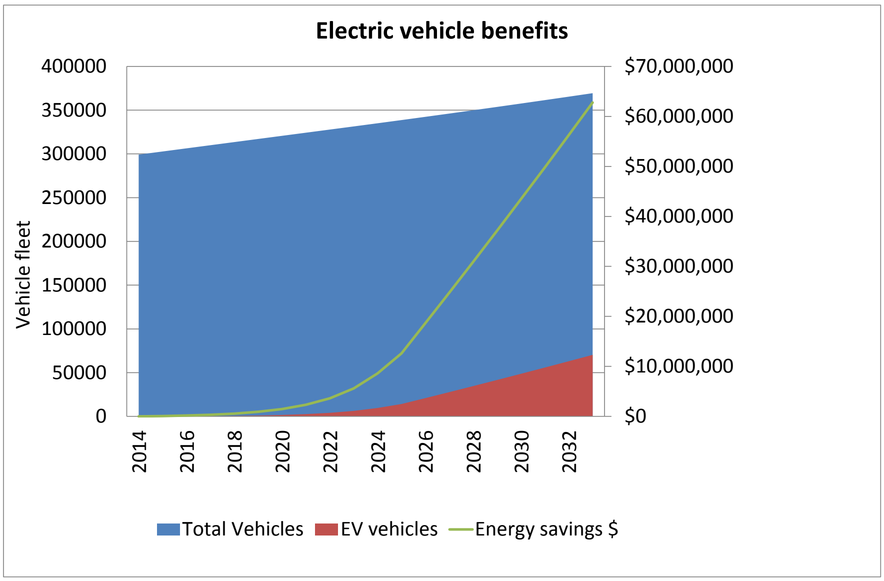
[18] ICF *Impacts of Electric Vehicles – deliverable 5. International Impact Analysis of market uptake scenarios and policy implications* April 2011

Transport data on the new vehicle replacement rate and Christchurch vehicle ownership. We have used local research for average per day distance travelled in New Zealand.[19]

We have calculated the difference between the cost to consumers of using petroleum based fuel (adjusted for road tax) and electricity recharging.[20]

For this exercise we have assigned a zero value for improved resilience on the network as a result of being able to draw saved energy back onto the network from the EV batteries.

Figure 6 increase in the EV fleet used for estimating the benefits from electricity vehicles in Christchurch



2.2.4 Distributed generation

Distributed generation is generation connected to the local distribution network or an embedded network (such as a shopping mall) rather than the national grid. It can also be characterised as small scale locally deployed generation. Often it is a generator attached and dedicated to a single household or building and solar powered photovoltaic cells are a good example of DG. The scale of DG and the variability of domestic consumption means that inevitably there will be periods of the day when the consumer is importing from the grid to make up their load and periods when they are exporting back onto the network. This creates a series of issues such as metering arrangements, commercial arrangements when the DG is exporting, safety issues when linesmen are working, two way flows on the network to be managed by the network operator, the capital cost (and economics) of installing the DG and maintenance costs.

In the context of smart grids the cost of DG is falling as the technology improves, while the cost of centrally produced electricity is rising, so DG will be installed by consumers more and more. Distributed generation can, if providing cheaper power at useful times and in the right places, reduce the cost of power, reduce net peak load and improve reliability.

[19] CAENZ *Electric Vehicles Impacts on New Zealand's Electricity System Technical report* December 2010

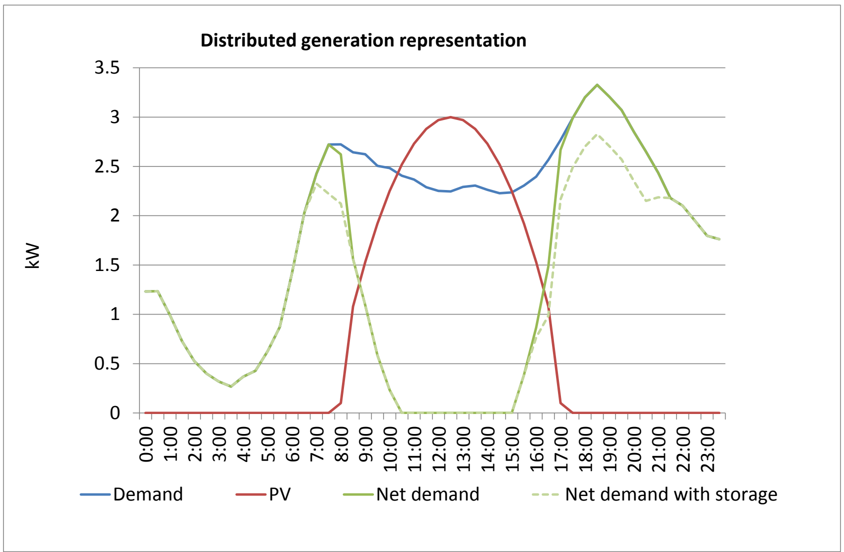
[20] MBIE Based on current average Christchurch delivered electricity charges

In calculating the smart grid benefits accompanying a wider uptake of DG technology we have assumed an aggressive uptake of DG for new buildings based on deployment of combined PV and storage. PV without storage is close to, and in some cases at, parity with bundled retail tariffs[21] where it offsets current consumption. Payment for net exports (where PV generation exceeds household consumption) tends to be less than the bundled electricity price and tends to be more variable. The cost of battery storage is also declining and we assume that combined PV and battery units will become commercially viable at a domestic level . There is already evidence that where combined PV and batteries are installed and controlled the network company can get value from this approach[22].

Our representative system is 3.04kW peak producing 2651 kWh per annum based on NIWA information.[23] We assume our storage can return a kW of power when called. Our take-up rate is 50% of new buildings (mostly homes) and 2% retrofit.

With the assumed penetration of DG there is a calculable impact on dry-year risk. We have assumed dry year is a 1:10 year event and that the value of any extra generation during that period is $300 per MWh being the value to consumers of the extra security[24]. We assume the value in late autumn when the level of security is highest but the level or irradiance is lower than average.

Figure 7 Illustration of a consumer load where PV capacity is matched to peak load. Net import falls to zero as PV output increase and the site becomes an exporter during the peak of the day. The introduction of storage reduces export and extends the effect on net demand of solar PV.



[21] Electricity Authority Retail advisor Group Investigating barriers facing small scale distributed generation discussion paper February 2011

[22] See vector offering of solar plus battery back up http://www.vector.co.nz/node/5839

[23] NIWA http://www.niwa.co.nz/our-services/online-services/solarview

[24] Electricity Commission Compulsory Buy Back Consultation Paper Scarcity Pricing and Default Buy Back Technical Group August 2010

2.2.5 Heat pumps

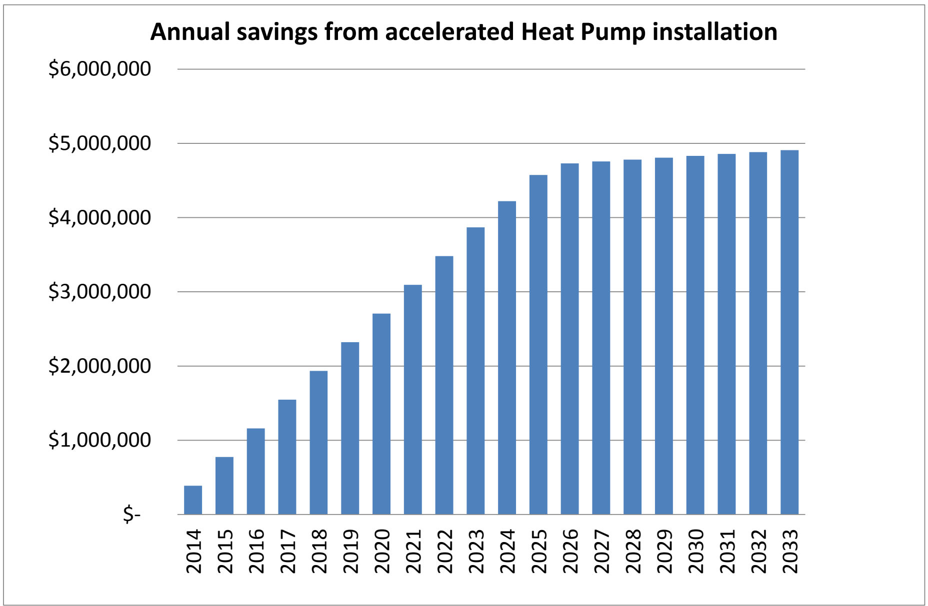
A heat pump can provide more efficient space heating than other sources of heating in the context of both fuel efficiency and cost efficiency to the consumer. Heat pumps provide benefits to consumers in the form of better health outcomes and cheaper energy.

We have included the benefits of heat pumps in the context of smart grids because adopting the technology to heat at the same level of comfort but doing so more efficiently is consistent with the other assessments included here.

We have assumed an enhanced take-up of heat pumps by an enlightened public and applied to both new builds and retrofitting. We have assumed where installed for an existing home it displaces other inefficient forms of heating such as inefficient electricity heating, coal, LPG and open fires. [25] A reduction in carbon emissions is material for this effect but at the carbon prices used for this exercise the monetary benefit is limited.

We include a modest wellbeing benefit from reduced hospital emissions.[26]

Figure 8 estimation of annual savings resulting from uptake of heat pumps to displace other heating methods.



2.2.6 Efficient buildings

Efficient buildings consume less energy overall as a result of good design, good insulation and fit out of energy efficient equipment. A smart grid approach to network operation or consumer engagement can go ahead whether the building stock is set up as energy efficient of not. However an aspiration to provide electricity supply at least cost to consumers using smart grid approach

[25] Otago University http://www.physics.otago.ac.nz/eman/hew/ and BRANZ : http://www.branz.co.nz/cms_show_download.php?id=e3fb50e5420bf7132a8512e6247bc33a8e5dd6d4

[26] Ministry of Economic Development *Cost benefit Analysis of the Warm Up New Zealand; Heat smart Programme* June 2012

should include a calculation of the benefits of energy efficiency using the same approach as calculating the benefits from smart grid so a complete picture of the potential benefits of modern supply to consumers can be made.

We have calculated the estimated commercial[27] and residential[28] rebuild for Christchurch in square meters, and the estimated annual spend on energy per square meter. We have assumed an estimated 30% savings in energy consumption for new buildings built to higher standards than the minimum building code.[29]

For the purpose of our benefit calculation we have taken into account the energy savings to consumers and benefits in the form of deferral of transmission benefits.

Figure 9 approach to energy savings possible through adopting an energy efficiency approach with rebuilding.

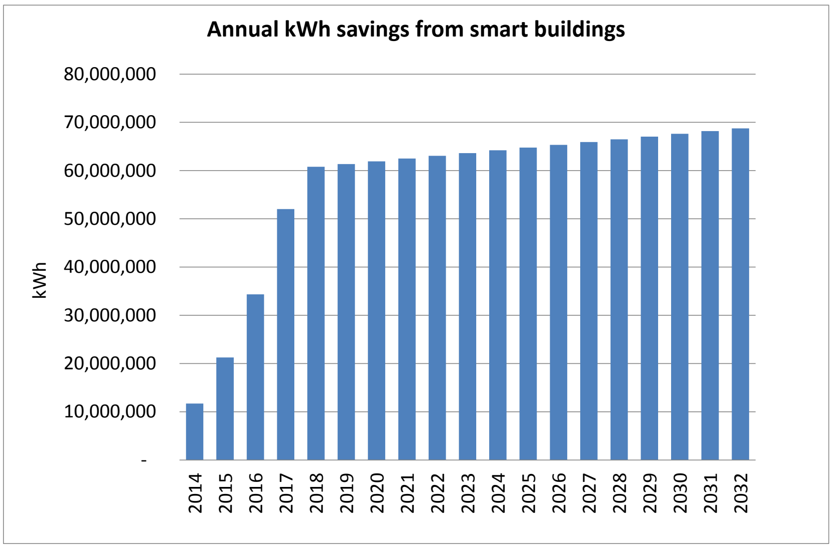


Table 1 shows estimates of the existing homes and exiting commercial stock (in square meters) following the earthquakes. We provide estimates of the numbers of new homes to be built and the commercial offices space to be built by 2023 and 2033. These are the figures that the energy efficiency benefits are based on.

Table 1 Estimates of the size of the domestic and commercial rebuilding task.

	2023	**2033**
Estimated new homes	23,000	32,930
Estimated new commercial stock (m^2)	1,106,400	1,206,400

[27] CERA *Christchurch Central City Commercial Property Market Study* May 2012

[28] :See: http://ecan.govt.nz/publications/General/LURP-Context.pdf

[29] Building Better Returns – a study of the financial performance of green office buildings in Australia September 2011

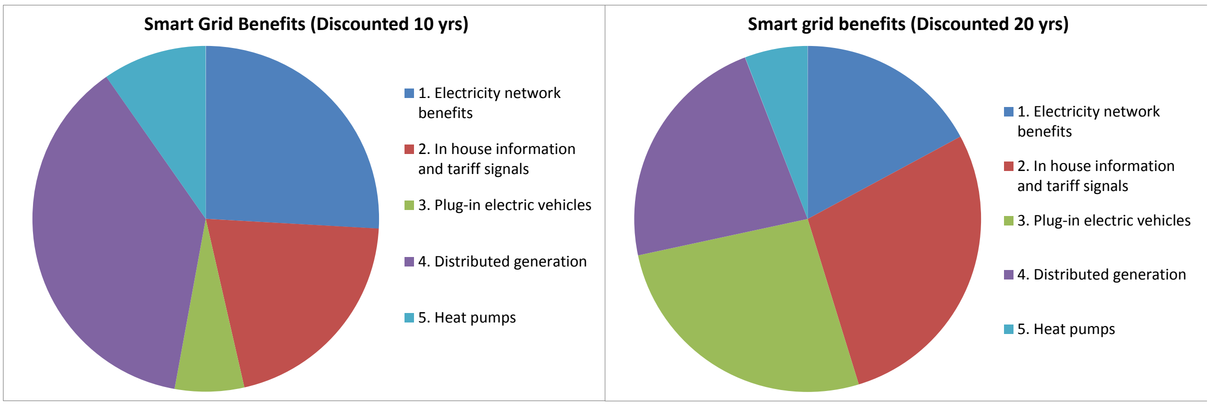
2.3 Results of the modelling: gross consumer benefits

The gross smart grid benefits are set out by category in Table 2 below:

Table 2 smart grid benefits by category.

PV	2023 (NZD million)	2033 (NZD million)
1. Electricity network benefits	$42	$118
2. In house information and tariff signals	$33	$194
3. Plug-in electric vehicles	$10	$182
4. Distributed generation	$60	$155
5. Heat pumps	$16	$41
TOTAL	**$161**	**$690**

Figure 10 proportion of smart grid benefits possible in Christchurch



The benefits of achieving a high level of energy efficiency amongst newly built houses and commercial buildings was also estimated. The present value of the gross benefits i.e. benefits from the perspective of consumers, in the Christchurch rebuild are shown in Table 3 below. It is estimated that full deployment of energy efficient buildings would provide benefits of $130 million in 2023 which is 80% of the smart grid benefits. Benefits of energy efficient buildings in Christchurch would amount to $326 by 2033.

Table 3 Benefits of energy efficiency initiatives in Christchurch.

PV (NZD million)	2023	2033
Efficient buildings - residential	$82	$205
Efficient buildings - commercial	$48	$121
SUM	**$130**	**$326**

3 Developing the roadmap for smart grids

3.2 Findings for Christchurch

Due to the long-life nature of electricity infrastructure, and the opportunity of the Christchurch rebuild, networks and other service providers should be in a capacity building phase now in anticipation of demand that will emerge sometime in the future. During interviews with decision makers in Christchurch the theme that emerged in relation to smart grid was that the more pressing problem in Christchurch is establishing the buildings and connecting them to the network. At the same time Orion has to act in the long-term interest of consumers and proposes that to do that it has to:[30]

- *Continue to prudently repair and invest in its electricity networks; and*
- *Restore the resiliency and reliability of its network to near pre-earthquake levels by 31 March 2019.*

The project work and interviews identified that the immediate problem for Christchurch is not a smart grid problem where the network is well developed in a steady state and consumers are looking to future trends as defined above. The immediate problem for Christchurch is to get the city rebuilt so the community can resume their lives where they left off before the earthquakes. In that sense the problem is ensuring that the activity that is going to have to take place is consistent with future needs of electricity consumers. That means:

- Ensuring that the buildings are as energy efficient as possible; and
- Focussing the city's decision makers on a sustainable energy future rather than the more narrow smart grid framework.

As such we have identified the following opportunities that should be integrated into Christchurch city, commercial buildings, manufacturing processes, and homes where possible, to maximise energy performance of the city's built environment through the rebuild:

- Building efficient buildings to reduce heating, cooling and lighting energy demand. A significant amount of energy efficiency can be built into the building fabric and energy systems at the design stage. High standards of energy performance are a good investment, and are easily achievable, if energy performance is made a priority during the design. Undertaking detailed energy performance modelling during design is essential;
- Install building and home energy management systems that optimise building and home power use, and can be integrated with external data/information collecting, fault finding, demand response and smart grid systems;
- Installing adequate metering so that a clear demarcation can be made between landlord and tenant energy use. This is consistent with the necessary data gathering for NABERSNZ, and this information will help to accurately share the benefits of smarter grid systems (such as providing demand response);

[30] Orion Network Proposal for a customised price-quality path 19 February 2013

- Building roofs that are ready for future installations of solar DG installation for a time when owners choose to install them;
- Testing whether it is possible to accelerate the rate at which DG and storage can be economically incorporated into the Christchurch rebuild phase by coordination amongst retailers, distributors and supplier of the various components parts of DG;
- Testing whether it is possible to develop a model for widespread incorporation of energy management systems in buildings being built in Christchurch by coordination amongst retailers, distributors and supplier of the various component parts;
- Provision for getting the best out of any backup generation (either renewables with battery storage or generators) with capacity to provide demand response;
- Christchurch institutions should further explore the potential to develop 'microgrids' that include localised generation and storage. Microgrids offer the capability to 'island' and sustain energy delivery from local generation if the grid is not available, and may help to optimise local renewable power generation;
- Using efficient hydronic heating and cooling systems in new buildings to reduce electricity demand and allow for effective energy storage options - hot and cold water and ice storage;
- Provisioning for EVs by installing chargers; developing charging stations and provisioning for charging stations at workplaces and residences. During the rebuild it would be appropriate to simply provide ducting and space for charging stations to be installed in the future; and
- Develop centralised fault-finding and energy performance optimisation systems that utilise common data protocols and analyse energy performance data from a large number of building energy management systems;

To this end we advocate that Christchurch city leaders prioritise achieving a sustainable energy future for Christchurch. Increased efforts to encourage uptake of the above energy performance priorities for the rebuild will help to achieve this goal, and that of a smarter grid in the future.

We would suggest convening a forum for the exchange of ideas and coordination of a sustainable energy strategy for Christchurch to help business rebuilding the city to take the opportunity to build for better energy performance and take changing energy demands into account

Intuitively a city in the process of a rebuilding would be a perfect opportunity to develop a smart grid. It seems that exclusive of focusing on energy efficiency a smart grid is much better suited to a steady state community. To the extent that smart grid accommodates greater small scale distributed generation and storage its relevance is even greater for cities prone to a natural disaster. The benefits in that case would include the ability for a city to be more resilient if a disaster struck that caused major destruction to the network.

3.3 Looking beyond Christchurch: a national perspective

The project work on smart grid opportunities in Christchurch raised the issue of whether the level of benefits seen for Christchurch is matched on other networks. The method taken can be readily applied to other networks or at a national level. This project considers that the national gross benefits may be of the order of 8 times the demonstrated Christchurch benefits. Interviews with distributors completed as part of the project work indicate that there is a great deal of hesitancy in pursuing a smart grid approach in all parts of the economy. It leads to the question of whether national group including participation from distributors, retailers, the Electricity Authority, EECA, the Commerce Commission and MBIE could usefully investigate the national benefits of smart grid and barriers to achieving these. Such a group could consider whether there are implications from the shift of conventional supply to the adoption of new technology and a more consumer centric world would have implications for business models and regulation. This work would be able to identify whether there is a coordinated response required in order to deliver benefits to consumers.

We note that demand patterns are already changing from the basis of current investment approach. National domestic electricity consumption has started to level off. Since 2010 total domestic demand has turned down. This is reflected in both kWh per household (ICP) and kWh per person. Delivered electricity prices increased 65% from 17 c/kWh to 28 c/kWh between 2000 and 2010. Between 2010 and 2012 the population increased 1.3% and total domestic demand fell 2.8%

Figure 11 New Zealand national demand and consumption patterns

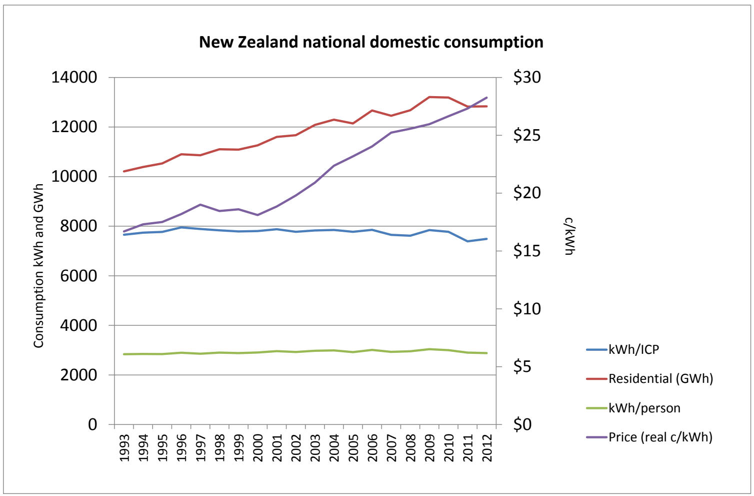
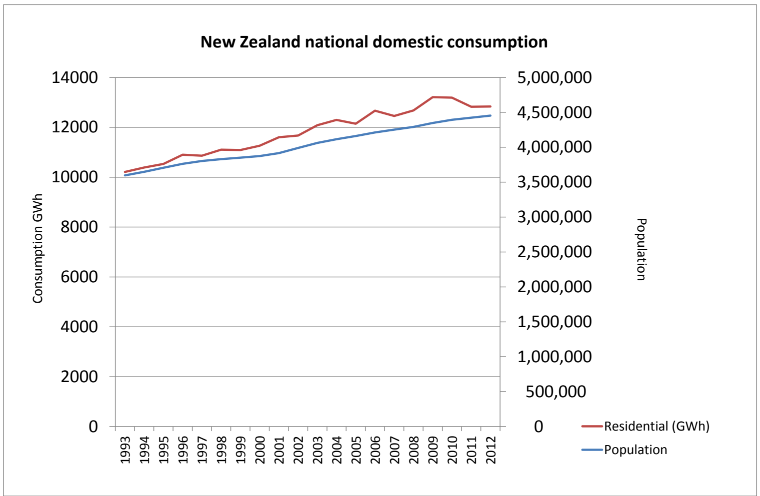


Figure 12 New Zealand national demand and population



The trend in consumption will be a response to a number of factors. Obviously a noticeable increase in household bills will illicit some response. During the period the merit of energy efficiency measures such as hot water cylinder wraps and energy efficiency light bulbs have been promoted. New builds during the period will have been more efficient as well. The relevance for smart grid is that conventional investments may become stranded as small scale distributed generation becomes more economic and energy efficiency measures continue to gather momentum. This adds to the imperative to explore non-conventional approaches to meeting electricity demand.

The delivery and coordination of smart grid outcomes is a complex task for a number of reasons, including the following:

- The transformation from traditional networks with one way electricity flows and low levels of communication on the status of the network to smart grids is occurring within existing physical electricity networks and existing commercial arrangements (it is not a green-fields proposition). All of these components were designed a number of years ago with a view to optimising the electricity system, and consumer demands of that system, as they were. Smart grids can be expected to challenge some of these physical and commercial designs and it is inevitable that there is some resistance to change. There is likely to be a disjuncture between businesses optimising their financial positions and the long-term interests of the economy and consumers:
- Some significant smart grid investments, particularly in the network operations area, are required in advance of the likely flow of benefits, and those best placed to invest may struggle to capture sufficient financial benefits to warrant the investment. This sequencing of costs and benefits, and the dispersion of likely benefits through the value chain, may pose greater challenges to the New Zealand electricity sector than in some other APEC jurisdictions, as it is disaggregated across generation, transmission, distribution, retail, and other service providers (e.g. metering);
- Economic regulatory functions and rules are pervasive in the electricity sector and pre-suppose the existing functions in the value chain will remain static, as reflected in the regulatory separation of certain functions and price control mechanisms founded on regulators forecasting the optimal path for network businesses. These regulatory rules place tight limits on the scope for and incentives to innovate, and particularly so where investment, product development and value capture need to straddle a number of the fragmented steps in the value chain;
- Sectors not typically thought of as part of the electricity sector have a large part to play in the design and successful deployment and use of smart grids. Two examples are the design, construction and management of buildings, and the personal transport sector (in the form of electric vehicles). Interdependencies are likely to emerge with other sectors. There is also a need to coordinate the introduction of enablers, as well as physical and systems interfaces and standards to get smart grid investments up; and
- The stakeholder groups that would deliver on the identified benefit categories differ. This is illustrated below. The coalition of the willing includes both stakeholders within a benefit category and well as cooperation between stakeholder groups in separate categories.

In Figure 13 we summarise the different groupings of stakeholders that would determine investments and outcomes in different groups of features.

Figure 13 smart grid features and different groupings of interested stakeholders.

Smart grid features	Stakeholders who will determine outcomes
Asset condition Asset capability Security and resilience System operation Supply quality	Decision to progress along smart grid continuum primarily up to the distributor based on the incentives it is exposed to e.g. Part 4 of the Commerce Act (as administered by the Commerce Commission) and transmission charging methodology (based on Transpower's cost recovery as agreed by the Commerce Commission)
Asset utilisation New connections	Initiatives may be led by distributors, new distributors, demand side management aggregators, retailers or consumers. Outcomes will vary depending on which party has the greatest influence.
Distributed generation Electricity vehicles Electricity storage	Any of electricity retailers, distributors or independent manufacturers could take the lead in the technologies, specifications, financing arrangements or necessary infrastructure offered to support these developments.
Smart meters Smart retail tariffs Consumer energy data	The provision of these features is currently dominated by electricity retailers but distributors could become more involved or changes may be driven by consumer demand. Specifications for what is provided for these features may be the subject of regulations
Home energy management systems Heat integration	These features could be incorporate into buildings from the outset or may be fitted later by consumers. Either retailers, distributors or independent manufacturers could take the lead in the technologies and specifications offered.
Energy efficient buildings	The lead might come from designers, owners or tenants for new buildings or retrofitting.

3.3.1 Weak coordination and bundled pricing may be a potential barrier to achieving benefits of smart grid in New Zealand

At the heart of achieving smart grid benefits lies the degree to which load can be shifted especially by flattening intraday load. Managing load shape is achieved through demand response and this can be broken down into two distinct types of activity:

- Remote load control by an agent who has secured the contractual rights to control load. This form of demand response is reliable in the sense that the central agent has control over when load is switched on and off; and
- Demand response in response to price signals. Price signals could be tariffs set at different levels for different time periods or variable prices that reflect the wholesale market price

movements. This form of demand response is less reliable in the sense that it is controlled by the consumer who has the choice to pay the higher price and continue consuming if it doesn't suit them to respond.

As we have observed elsewhere in this report the electricity industry still runs on historical arrangements and some of these will have to change to accommodate future demand by consumers and to deliver the benefits of smart grid. Nowhere is this more apparent than with the question of how to determine who gets to remotely control a consumer's load.

Arrangements for retail billing in New Zealand are similar to most jurisdictions in that consumers receive a single invoice that bundles the cost of energy, transmission, distribution, metering, other costs to serve such as call centres and any commercial margins that suppliers expect. In New Zealand the retailers may also be the supplier of the energy (New Zealand is 85% vertically integrated in this sense) while the distributor and grid owner are two separate entities. In many case the provider of the meters is an independent agent as well. There is also a possibility that an aggregator seeks to manage some of the component services such as load control.

The objectives of the generator/retailers, distributor, grid company and aggregator aren't necessarily aligned and the means for all of those parties to signal to consumers the value of controlling load in a smart grid is limited.

The distributor and grid company both have their returns overseen by the economic regulator but the regime in place has weak incentives, if any, to adopt new and potentially risky technology. Both distributor and the grid company are motivated to ensure that adequate reliable capacity is available and have an incentive to reliably flatten load, if possible, thereby reducing or deferring the need for new capacity. The distributors' revenue is based on total kWh so while they are motivated to flatten load they are not so motivated to take any action that would reduce the overall throughput on the network. Both the distributor and grid company are heavily incentivised to sustain security of supply and minimise any disruptions to the system.

Retailers' revenue is also a function of the throughput on the network but the incentives to flatten load is weaker than it is for distributor. For the retailer the issue is whether the recovered revenue is at an adequate margin over the cost of purchases from the pool. Anything that alters the half hour by half hour shape of consumer load is only beneficial compared with the half hourly cost in the wholesale market.

The introduction of smart meters provides an opportunity for distributors and retailers to set tariffs that reflect the true cost of supply and incentivise consumers to change their load shape. However the retailers have the final say in what signals are passed through to consumers. There is also a potential mismatch in the functionality of the smart meter depending on whether they have been commissioned by the retailer with their purpose in mind or by the distributor.

The use of homes energy management systems (HEMS) has the potential to provide more scope for dynamic tariff offerings and give consumers more control over their total cost of consumption. Again, however, there may be a difference between the HEMS offered by a retailer with their objectives versus a distributor.

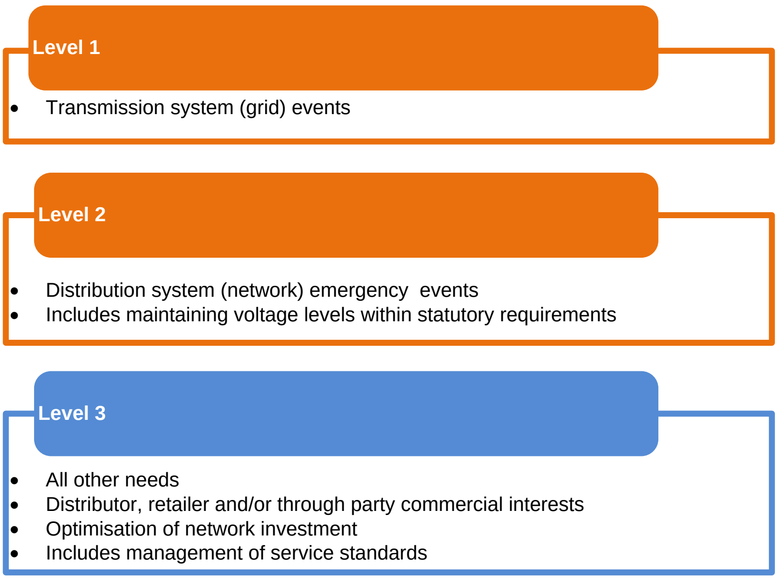
The clearest point where the different types of organisations (e.g. retailers, distributors or aggregators) and different organisations amongst each type would compete for consumers is the right to remotely control some part of a domestic household's load. Current arrangements are based on load control physically switched centrally by the distributor. As a rule the use of load control follows a hierarchy of purposes dictated by the distributor. In some networks arrangements are in place that allow the retailer to dictate load control if the distributor is not currently using it. Currently the distributors will offer a lines tariff that differentiates between access to load control or not and this is reflected in the charge the retail offers. This set of arrangements may be about to change as smart grid technology is adopted more and more.

In 2013 New Zealand retailers and distributors worked on a set of principles and protocols for the use of load control so they could enter into bilateral arrangements and essentially compete with the other for access to discretionary load control.[31] The New Zealand Electricity Networks Association (ENA) reports there is widespread agreement amongst retailers and distributors over the principles. The two leading principles are:

1. Customers own the rights to control their load.
2. Development and implementation of load management to support the long term interests of customers.

The hierarchy for deployment of load control incorporated into the principles at this stage of the market's development is summarised in Figure 14 below.

Figure 14 Hierarchy for access to in-home load control



Source: ENA 2013

The arrival of smart meters and the introduction of HEMS and the emergence of other technologies able to control hot water as well as a wide variety of other load control mean competition for the right to control consumers' load may heat up. In time, if all of the purposes of load control set out in

[31] ENA Newsletter October 2013

the diagram above are priced, consumers will be able to make informed choices about how they would have their load control put to use and who would have access to it.

We consider that this context indicates that the long-term interests of consumers may not be best served by relying solely on existing commercial and regulatory frameworks to ensure timely and efficient deployment of smart grids. We have therefore identified commercial and regulatory frameworks in the list of enablers of smart grids, along with other items. This change and other changes required to facilitate the accelerated delivery of the benefits will need leadership, and will need the support of a coalition of the willing at a national level.

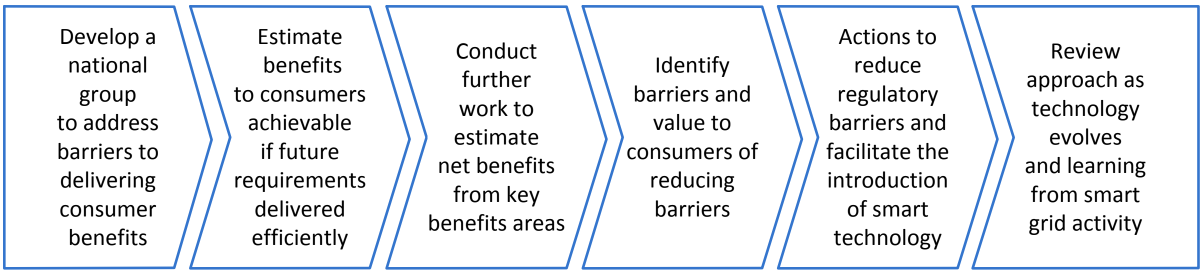
3.4 A national forum

A national forum of regulators and the various participants in the delivery of electricity services would be able to examine existing commercial and regulatory frameworks and demine whether they are likely to lead to greater long term benefits to consumers given the changes discussed in this paper.

A national New Zealand Smart Grid Implementation Group (NZSGIG) would be similar to the Great Britain Smart Grid forum that has proven to be effective in delivering benefits to UK consumers. In April 2010 the Imperial College of London and the UK ENA completed a benefits-only assessment similar to the approach this project has taken to Christchurch. In the UK case this approach established that it was worth proceeding with a work program to prove up the benefits, establish the costs and incorporate the thinking into regulatory settings. Having established that there were social, environmental and economic benefits the GB Forum confirmed a pathway to delivering those benefits. Subsequent work in the UK has become more and more detailed and has led to innovation becoming a core element of network company business plans now. We have noted that the cost/benefit analysis in GB required development of new analytical modelling tools and the collection of data for 'future solutions' that is problematic to derive. A benefits-only assessment in GB gave the Smart Grid forum the confidence to proceed and the cost/benefit modelling was funded and overseen by the network companies over a period of about 18months. It is now at Version 4.0.0 and is under an industry wide governance and change control process.

The steps from here for a national smart grid roadmap are shown in Figure 15 below:

Figure 15 roadmap to delivering smart grid benefits at a national level



In the New Zealand context the further work would comprise:

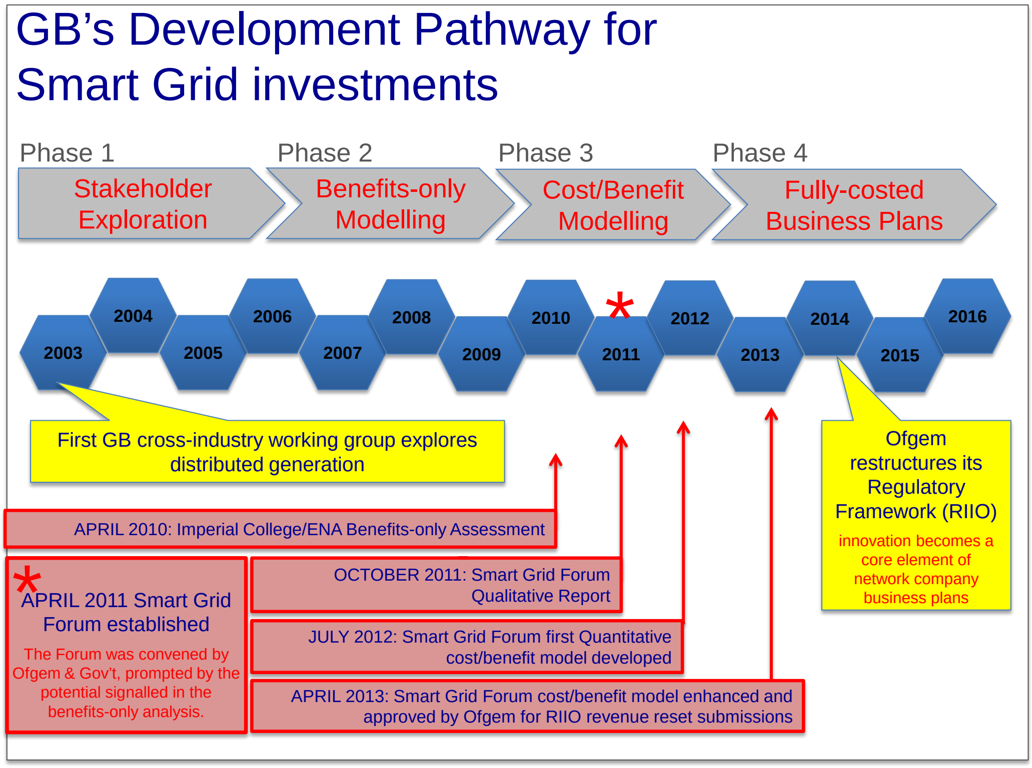
- Draw up a terms of reference for a Smart Grid Implementation Group (SGIG) to provide a focal point for carrying out the steps that follow this project;
- Form a view of possible future consumer requirements to inform the best opportunities for smart grid;

- Rerun the model developed for Christchurch on a national basis and identify a benefits only view of smart grid. This output would guide the subsequent work a national forum would use to ensure that eventually the consumer benefits are delivered;
- Focus on costs of delivering a smart grid. The Imperial College/ENA Benefits only assessment in the UK resulted in a number of work streams focused on understanding the costs and delivering those benefits;
- Work on the cost side will be most beneficial if it is done in conjunction with network companies and retailers who are assessing technology choices, working on pilots and making business decisions in the present. They are best placed to provide authentic indications of cost;
- Refine the social, environmental and economic benefits achievable and worth achieving based on the work on costs. Include the option value of preparing for smart grid in anticipation of consumer demands rather than waiting until demand for innovation on the grid has emerged;
- Work with stakeholders to determine ways that costs can be minimised through cooperation amongst stakeholders An example might be that through better coordination amongst retailers, distributors and suppliers it may be possible to accelerate the rate at which DG and storage can be economically developed;
- Apply the same benefits analysis technique as carried out for Christchurch to at least one other city in New Zealand. This will show the difference in benefits for a city with another electricity distribution company and without a significant rebuild underway; and
- Clarify the barriers that remain once the possibilities that can be achieved through a coalition of the willing have been determined. Develop a strategy to reduce barriers. Developing the roadmap and determining the benefits.

3.4.1 Parallel thinking and approach in Great Britain

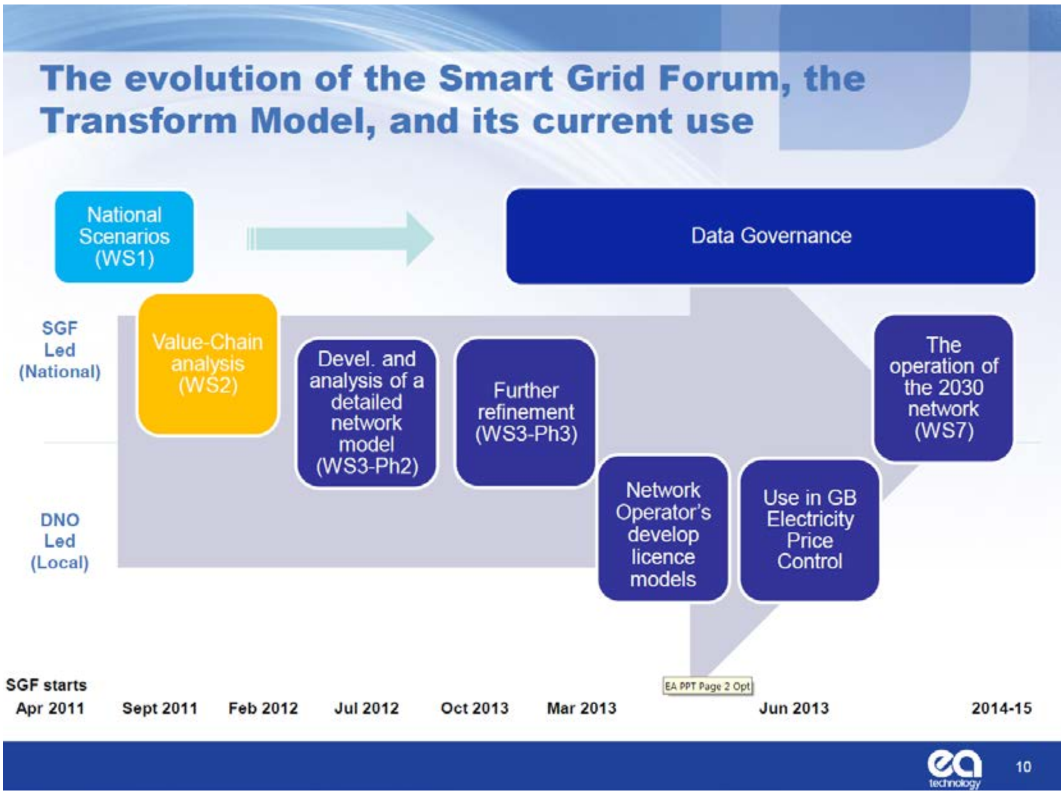
Conducting a national benefits only assessment as discussed above is the identical step taken in the UK that led to the establishment of the Great Britain Smart Grid forum in 2011. This is illustrated in the GB forum time line shown below in Figure 16 below:

Figure 16



The GB smart grid forum established 7 work streams as shown in Figure 17 below

Figure 17 GB smart grid work streams and the transform model



Following the development of comprehensive cost benefit work the transform model was developed.[32] This model is based on real data from distribution networks local authorities, central government and a range of other sources. It can assess and optimise investment over a range of conventional and 'smart" strategies and involving a wide range of solutions. Two different models have been developed, to reflect the different levels of granularity between GB and a DNO licence. The datasets for the licence model are tuned by the local DNO.

The UK Institute of Engineering and Technology (IET) have recently released a position paper commenting on the complexities facing networks in the future. They argue that engineering, commercial and regulatory interests should work together in the best interests of consumers. They appear to be as worried about failure as they are about delivering consumer benefits. Their problem definition and recommendations are:[33]

> *The impact of changes such as solar photovoltaic (PV) farms and large scale adoption of domestic solar PV energy, electric hybrid vehicles, replacement or supplementing of gas fired heating by electric heat pumps, community energy schemes, and the introduction of large scale wind generation have potentially profound impacts on networks and the electricity system as a whole*
>
> *At the distribution level managing the impacts of reverse power flows, fault level, and voltage rise will become increasingly challenging*
>
> *The IET's key recommendations*
>
> 1. *The Department of Energy and Climate Change (DECC) should work with industry to establish a System architect role to achieve a whole systems approach*
> 2. *Government/Industry stakeholder groups should explore ad address effective interactions between engineering market and regulatory aspects to determine change needed*
> 3. *DECC/Ofgem should develop the regulatory arrangements that will enable demand response and distributed storage to participate in maximising whole system synergies and the mitigation of risks*
> 4. *Network companies should together determine how to address the impact of a data rich environment, including the mechanisms for improved internal and external data exchange*
> 5. *Network companies' procurement arrangement should facilitate greater access for specialist providers to bring benefits in smart grids, demand management and new customer services*
> 6. *Network companies, the IET, and other interested parties should work out how to address the requirements for increasing engineering commercial and business complexity, including the means to access skills and research and test facilities and the sharing of knowledge*

[32] The Transform Model® is available from EA Technology on a commercial basis; all funding Network Operators, DECC and Ofgem have a licence to use the software for their own analysis

[33] The Institute of Engineering and Technology (IET) Electricity networks Handling a shock to the system IET position statement on the whole system challenges facing Britain's electricity network launched 5 December 2013

4 A smart grid forum in New Zealand

In parallel with this project the Ministry of Business, Innovation and Employment and the New Zealand Electricity Networks Association were looking specifically at the role of national coordination on smart grid. Their thinking was driven by the same themes contained in this report and there was cross dialogue between the project group for this work and those organisations. In February 2014 the New Zealand Minister of Energy and Resources announced the establishment of a national Smart Grid forum[34].

In his announcement the Minister observed;

- *Emerging technologies will make different demands on the electricity systems of the future*
- *Smarter electricity networks will be needed, capable of transferring energy between a more diverse range of generators and consumers, while balancing demand and supply*
- *We need to ensure New Zealand is well placed to capture the benefits of solar energy, electric vehicles, and advanced meters, as well as developments in distribution automation, distributed storage, and demand response*
- *The establishment of the forum reflects the Government's commitment to the responsible and savvy use of resources and technology to secure New Zealand's energy future, and lift our standard of living*

The SGF'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.*

To achieve its purpose the SGF will:

- *Promote its objectives to parties involved in smart electricity network development to encourage the active participation of the diverse elements of the power demand and supply chain in Forum activities*
- *Promote and facilitate a collective understanding of current smart electricity network developments*
- *Collaborate and seek synergies with associated initiatives in areas such as electricity load control, innovation, data sharing, system security and data security, and consumer empowerment*
- *Identify barriers to investment and the means to address those barriers*
- *Develop and communicate a collective understanding of relevant developments in other jurisdictions.*

We hope that this work and the approach taken to the benefits modelling will be utilised by the smart Grid Forum.

[34] http://www.med.govt.nz/sectors---industries/energy/electricity/new---zealand---smart---grid---forum

Appendix 1: Smart grid features

In this section we describe each of the 16 distinctly smart grid features, the opportunities, enablers and dependencies amongst the features.

1. Asset Condition

Description	Traditionally the condition of electrical plant could only be investigated during maintenance or repair outages with the plant de-energised. In a Smart Grid, asset condition is continuously observable and can be cost-effectively maximised at individual and system levels. Innovative techniques are becoming available to assess the condition of power grid assets in real time with the plant energised and in service. For example: real time analysis of dissolved gases in transformer cooling oil enables early detection of transformer over-heating and the on-set of insulation breakdown; partial discharge techniques, that measure electrical insulation breakdowns at a micro-scale, are being applied to individual equipment such as switchgear as well as wide area surveillance (e.g. across a whole substation). Further development is extending this to underground cables, including location of incipient defects.
Opportunities	Real time assessment of condition, anticipating defects and failures, enables proactive asset maintenance and planning for cost-effective asset renewal - neither too soon nor too late. Network reliability is enhanced as defects can be intercepted before they cause a failure. Network availability is enhanced and consumer disruption minimised though shorter planned down time. Asset refurbishment and replacement planning is more cost-effective through maximising usable life while minimising failures. The last of these aspects is of growing importance in a network with ageing assets where asset renewal becomes a significant financial investment and effective prioritisation and timing will keep costs down.
Enablers	Suitable sensors need to be developed for retrofit applications, and new equipment needs to be designed and procured as sensor-equipped or sensor-ready. A basic feature of real-time condition assessment is the significant amount of data that needs to be communicated, managed and interpreted in a secure and integrated data environment. Communication and data storage systems need to be developed on a whole-system engineering basis to ensure that data becomes information, and that information can be readily accessed by its users, for example operational control staff, planning staff and asset management teams. Data policies and communication protocols should be developed in advance of implementation to ensure that IT system boundaries in organisations are not barriers to necessary data movement, and that data security and application integration is achieved effectively. Companies that neglect this do so at their cost. Sophisticated data sifting, analysis and forecasting routines are required to translate large data volumes into useful information for decision making.
Linkages/ dependencies	Communications Asset Capability, System Operation, Supply Quality.

2. Asset Capability Enhancement

Description	Innovative approaches are emerging that enhances traditional power system assets such as transformers, overhead lines and underground cables to carry increased power flows and improve utilisation. This includes both passive upgrades, such as installation of new types of overhead line conductor that have superior thermal performance or use of insulated cross-arms, and active upgrades (leveraging off monitoring asset condition) such as real-time ratings that assess actual operating conditions to determine capacity, rather than the widely-used approach of 'seasonal' design values, and active voltage control.
Opportunities	Where network capacity is reaching constraints, increasing the capability of existing assets may be: more cost-effective than investing in additional or replacement network equipment; more rapid to install; and less disruptive in terms of excavation of roads and pathways, or requirements for new land. In an uncertain context for primary network investment where, for example, new demand for electric vehicle charging may (or may not) be offset by more distributed generation, upgrading asset capability 'buys capacity and time' at relatively low cost. This avoids premature investment and the potential for stranded assets.
Enablers	Active enhancement of asset capability can be achieved in some situations by retrospective installation of sensors, communications and intelligent analysis facilities, in other situations equipment specifications need to be developed that enable equipment to be sensor-equipped for the future. Enhancement of asset capability requires that policies and designs are developed in advance and made available to network planners as 'Business as Usual' options when they are considering reinforcements; there may be safety case, and construction and maintenance considerations, each of which take time to resolve and will be a barrier to adoption if not developed in a timely way.
Linkages/ dependencies	Asset capacity enhancement is specific to local network and development requirements. The life of the technique in terms of headroom gained before primary investment is required is an important consideration and these innovative techniques will have greatest value where network demand growth is relatively slow, where there is considerable uncertainty, or where there are likely to be long lead-times for primary asset installation. In the case of active upgrades it may be necessary to associate the deployment with local demand response capability to provide a contingency option to secure the network under adverse out turns such as unseasonal weather conditions. The technical/economic case for deployment will vary across system voltage levels, usually strengthening at higher system voltages. Forecasting tools are required for planners and operators to assess the potential for utilising enhanced plant capacity in short and longer term timescales, depending on, say, ambient conditions or demand patterns. Asset capacity enhancement is an example of increasing the complexity in power network companies and requires a co-ordinated approach between field operations, ICT architectures, and operational applications - success depends on all parties having a common understanding and shared objectives.

3. Security and Resilience

Description	A smarter grid will exhibit greater security of supply and resilience in the face of internal disruptions, for example equipment failures, and external disruptions such as natural disasters, at a system wide level. System approaches that enhance resilience include automated network configuration, intentional islanding, and micro-grids. Network reconfiguration, sometimes described as 'self-healing' is a more advanced form of automation that can adapt network feeding arrangements to make best use of available capacity, optimise losses, or respond to faulted network elements. It is an established technique in telecommunications engineering, offering high levels of resilience at low cost. Islanding refers to the condition in which local generation continues to power demand even though grid connection is absent. Intentional islanding is an established technique where traditional (controllable) generation is available, for example diesel generators for emergency supplies at critical locations. Distributed generation (utilising renewable sources) makes available widespread generation sources for islanding, but is variable will require innovative operational management utilising local storage and demand control. Micro-grids are purposely designed islands, localised groupings of generation and demand that may operate autonomously from the main grid, connected through a single point that may be disconnected.
Opportunities	Supply security and resilience are of importance to all stakeholders, especially where external threats (e.g. weather extremes and earthquakes) may result in widespread and disruptive outcomes. High impact, low probability (HILP) events are known to be difficult for network designers to address cost-effectively and the smart grid alternatives described here can form part of an attractive longer term solution, especially in high risk locations.
Enablers	Network reconfiguration will benefit from a mesh rather than radial arrangement, to provide flexible re-configuration options. Self-healing and intentional islanding require a high level of network observability (sensors, communications and state estimation) and will be better suited to new system control architectures that are less centralised and semi-autonomous and distributed.
Linkages/ dependencies	Considerable research is needed to develop techniques for network control including stability management; this requires a long term programme that progresses from theoretical analysis to modelling and controlled demonstration projects; this is a high challenge area, but one that has potentially high rewards. The more advanced forms of power system resilience described here are examples of large *system* applications and in many cases require the engagement of consumers; a high degree of consumer energy awareness will need to be developed for the options to be understood, supported and implemented.

4. System operation and operators	
Description	System operation refers to the management of an integrated whole, a system of component parts, to deliver energy that best meets consumers' requirements. In a smart grid system components can include distributed and renewable generation, integrated heat systems, electricity storage and electric vehicle charging in addition to traditional consumer demands, distribution and transmission assets, and generation sources. In liberalised markets there are likely to be multiple overlapping systems players for: transmission system; distribution system; wholesale and retail markets; bidding capacity and dispatching generation; advanced metering; intermediary systems for demand side aggregation and distributed generation; and end use systems (e.g. co- or tri-generation or home energy management). Generally smarter system operation will involve system sensors collecting data about system components, sophisticated data analysis, state estimation and forecasting techniques, and (automated) active management of system components to optimise system performance.
Opportunities	Smarter system operation is key to releasing latent capacity in grid assets, enabling new connections and deferring or eliminating the needs for primary asset investment (capital costs), minimising losses and other running costs (operating costs), and enhancing supply quality and security. In the longer term it may be anticipated that electricity will become more closely integrated with heat, transport and other forms of societal infrastructure; for this to become a reality, smarter system operation and all that supports it, will be of critical importance. A new role of Distribution System Operator (DSO), providing a regional equivalent of today's Transmission System Operator (TSO), is a model being explored in GB.
Enablers	The foundations of smarter systems operation are the sensors, communications and intelligent analysis facilities that enable active management by system players. For larger systems, such as transmission and distribution networks, new system control architectures involving distributed semi-autonomous control may be more cost effective than traditional centralised control systems managing ever more data, analysis and automation. Early resolution of data security and cyber security issues will be important as greater integration requires closer attention within and between systems. Systems Engineering approaches to the integration of systems require effective co-ordination where all operators have commonly agreed goals, open/shared data standards and communication protocols.
Linkages/ dependencies	The optimisation of *systems* will involve dependencies, to a greater or lesser extent, between all the parties involved. Some of these dependencies will be new and many will cross traditional boundaries between companies and sectors. Risk for all parties will be minimised by establishing mutual understanding, and commercial frameworks that provide effective incentives and business rewards. A problematic inter-party dependency can arise where the costs fall to one party but the benefits fall to another, creating a barrier to beneficial innovations that may require policy/regulatory attention to resolve. Fresh consideration may have to be given to commercial frameworks and regulatory structures.

5. Supply quality	
Description	Consumers traditionally value both less frequent interruptions and shorter duration interruptions. Increasingly consumers also value waveform quality – digital consumer (and network) equipment is particularly susceptible to mal-operation or failure due to distorted waveforms or power interruptions. Many of the individual techniques for asset (fault observation and prediction) and system management (automated rerouting and active voltage control) have positive effects for supply quality. In addition to these: • Network meshing is an alternative to radial feeding arrangements for LV and HV networks; this technique requires special attention to network design (e.g. for fault protection and fault-rupturing capacities) but can be used to provide enhanced continuity of supply and improved asset utilisation. • Waveform management deploying filters and other solutions to preserve both delivered voltage and waveform pure sinusoidal shape from distortions and harmonic frequencies injected by power electronic devices (especially AC/DC invertors).
Opportunities	Supply quality is of increasing importance as consumers become progressively more dependent on electricity supplies to support their standard of living, their business activities, and their wider expectations for '21st Century energy'. Supply quality is of importance to all stakeholders and impacts upon the needs of homes, businesses and industry; it goes beyond convenience and has impact for safety, environmental protection, and the care of vulnerable consumers.
Enablers	Automation on distribution networks, unlike transmission, requires volume application if it is to have benefit at a societal scale; this requires close attention to cost-effective solutions and these are most likely to be attained through a commoditised approach utilising open systems, international procurement and standardisation aligned with international norms.
Linkages/ dependencies	As discussed elsewhere, there is a shared dependency for success here upon sensors, communications, data management and whole-systems engineering, ensuring a holistic approach to technical and commercial systems and their integration with business processes. This task should not be under-estimated.

6. Asset utilisation

Description	Due to the variability of consumer demand and design redundancy (to ensure continuity of supplies in the event of a network component requiring maintenance or failing in service) electrical power networks typically exhibit a relatively low overall utilisation of available capacity. Improvements in utilisation of asset capacity can be achieved by addressing both demand and supply side constraints. Innovative supply side techniques, such as Flexible A.C Transmission System (FACTS) and Fault Current Limiter (FCL) devices and improved network sensors and monitoring, support the network operating closer to maximum capacity while protected it from unacceptable power surges under fault conditions (for example created by distributed generation or greater network meshing). Consumer demand response techniques are evolving. For a long time large commercial and industrial consumers have had the incentive to invest in sophisticated measurement, analysis and control. Mass market consumer access to similar techniques is being facilitated by smart meters, superseding separate circuit controlled load and ripple control techniques. Smart meters offer the potential to integrate network sensors and communication hubs for demand response, eliminating duplication.
Opportunities	Improvement of asset utilisation avoids or defers the replacement or augmentation of existing primary assets and the associated costs, disruptions and risks. Improved monitoring enables the network company to intercept emerging constraints before they impact on consumer service and supply quality.
Enablers	Techniques that smooth network demands require close attention to engagement with consumers, the mechanisms deployed to enact demand response, and where appropriate the associated commercial frameworks and tariff signals. The development of design requirements for primary equipment and associated communication interfaces may have a significant lead-time and must be undertaken in advance of application need; this is particularly important where the equipment has to be tailored to the particular network operational context, as is often the case in practice. The increasing value of improved sensors, especially at lower network voltages, may be facilitated by ordering new equipment with sensors incorporated, or being sensor-ready for retrospective installation. The case for this might be justified ahead of immediate need where the immediate costs are marginal and the future benefits are high.
Linkages/ dependencies	The examples described above have an 'asset focus' but must also be considered in the context of the wider power network and its operational performance. It will be important that the performance of new types of asset can be accurately modelled in power system simulation tools used by network planners and operators An integrated approach to Smart Meters as network and consumer functions requires an agreed approach between parties (meter provider, reader, network, retailer and demand manager) to common data and communication standards and commercial frameworks.

7. New connections

Description	A Smart Grid must cost-effectively accommodate a larger number and wider range of consumer connections and device connections, including power-takers, power-producers, and storage owners. Challenges include new demand (e.g. electric vehicle charging or heat pumps) that cause network overloading and generation or storage (e.g. PV panels, fixed batteries, or electric vehicles used as mobile storage devices) that create two-way power flows in the local distribution network. New connections can be competitive, and approved parties other than the local network can undertake connection works, including, design, procurement and the actual works, with the local network company merely checking compliance and safety before energisation.
Opportunities	Many of the individual techniques associated with smart grid features described previously could assist address these challenges. Advantageous common themes of these options are the release of latent capacity in existing network assets (so avoiding the costs and delays of installing new primary assets) and the location of these innovative devices in substations and other facilities remote from consumers (avoiding the social disruption and delays of excavating roadways and footpaths, or obtaining new land or rights of way Competition for new connections has potential to bring significant consumer advantages including connection specialisation (offering economies of scale through integrated multi-utility connections), faster connections due to an open connections market on the supply side, and better integration between network and site configurations. It can be an enabler for alternatives to network capacity for new connections, including distributed generation, demand response, and gas.
Enablers	As discussed elsewhere, there is a common dependency for success here upon sensors, communications, data management and whole-systems engineering. Where new user connections are being considered, it is important that innovative solutions are available at scale and are viewed by network planners as 'Business as Usual'. While they remain unproven or at a demonstration stage they are unlikely to be deployed especially where a consumer is pressing for a rapid solution and certainty. This is an example of where company providing connections will benefit from developing an Innovation Strategy and having a long term plan in the form of a Road Map as components of their business plan. Some solutions will take a number of years to develop and prove and strategic management will be needed for success, bringing long term benefits to consumers. New connections services need to be competitive and connection charges unbundled from network service charges.
Linkages/ dependencies	Business as Usual deployment of innovation requires the solution to be viewed with a common mind across all parts of the network company, from consumer interfaces, to network designers and network operators; there is a cross-organisational dependency here that must be addressed in a systematic way as part of smart grid deployment. The involvement of third parties in competitive connections requires management of a further complexity here.

8. Distributed generation

Description	Renewable distributed generation (DG) includes solar photo-voltaic (PV) and small scale wind generation infrastructure embedded in the grid at the consumer's site. DG has mass-market deployment at a residential level and is scalable to medium and large commercial and industrial consumers. Local geothermal energy is emerging as a source for domestic and commercial building heating and cooling. DG is distinctive in that its renewable sources are typically intermittent (dependent on daylight or wind) so that they do not completely displace remote power supply – it is likely to require energy storage to be an off-grid solution. DG is distinguished by its lack of controllability from other embedded generation such as emergency diesel generation for critically dependent consumers such as hospitals, and thermal electricity generation, discussed under Heat Integration below.
Opportunities	Distributed generation offers a competitive alternative both to remote thermal and large scale remote renewable generation, avoiding primary energy use and GHG emissions (to the extent remote generation is carbon based). In some markets with high penetration, such as Germany and South Australia, there is evidence DG reduces wholesale electricity prices. In response to rising electricity prices, DG has provided consumers competition and choice for controlling their energy cost. DG changes the grid customer's role from consumer to consumer and producer. Customers can sell excess energy generated into the grid. DG avoids the often substantial transmission infrastructure required to transfer power from remote renewable generation, such as large scale wind farms. DG can provide greater resilience during periods of system stress (due to infrastructure outage, exceptional demand conditions or short term primary energy shortage).
Enablers	Both technology and market deployment are rapidly advancing, driving down cost (from $12/watt to $2/watt over the past four years) and investment payback periods. DG is rapidly becoming cost effective for consumers compared with remote thermal generation with or without an imputed cost of carbon and without a premium export tariff incentive.
Linkages/ dependencies	Export tariffs (and export metering) allow customers sell (rather than waste) energy generated excess to consumption. Most often peak generation is not coincident with peak consumption, requiring energy storage. If DG is to provide energy during grid outages, customers need to be 'islanded' from the grid for network safety – in many situations today they are automatically shut down and cannot provide electricity within the residence during outages. Off-grid street lighting and other public services can be energised by DG and energy storage.

9. Electric vehicle integration	
Description	In the Smart Grid context and modern consumer imagination, electric vehicles (or EVs) are distinguished from well-established electrified public transport systems (trains, trams and trolley buses). EVs are personal transportation vehicles (cars, trucks, and motorcycles) with an on-board rechargeable electricity storage system (typically batteries) supplying an electric motor for propulsion. EVs displace consumers' direct use of primary energy (oil) for private transport. Consumers' charge their EVs by 'plugging in' to the grid. At a gross level, mass market take up of EVs represents a shift of a major proportion of a nation's energy consumption from oil distribution infrastructure to electricity, creating the potential for a substantial increase in overall capacity for electricity generation and distribution.
Opportunities	Electric vehicles are an essential element for substitution of fossil fuels as the primary energy source for the private transport fleet. To the extent that electricity generation is not carbon based, the GHG emissions of transport can be reduced. EVs potentially offer similar functionality to distributed energy storage, along with associated benefits, albeit at a higher cost (more expensive than single purpose storage due to higher energy density required; and there may be an opportunity cost of exports for the distance not travelled). EVs provide consumers more choice and drive competition.
Enablers	Substantial reductions in cost and improvements in performance in energy storage, the EV core technology, are required to make EVs competitive with other transport energy options and promote mass market penetration. Standardised smart grid interfaces and control systems are required to support integration between the grid and EVs (probably the largest single load in a dwelling). This includes sensing and control linkages to HEMS and potentially AMI remote control systems to enables coordinated charging (and discharging). Integration systems are necessary to avoid or minimises potential network and generation capacity and reliability and safety risks, especially from coincident and long duration charging cycles, in the event EVs gain a significant market penetration, especially taking into account the likely "clustering" of early EV adoption, for example in high income neighbourhoods.
Linkages/ dependencies	Sophisticated retail tariff structures can signal the marginal cost (or value) of importing (or exporting) electricity. Aggregation of grid ancillary services could deliver value to EV owners, for example if their vehicles provide demand response (downward and upward) using either frequency as a trigger or by direct signalling instructions.

10. Energy Storage	
Description	Energy storage enables the generation of energy and its use to be separated. The bulk storage of electricity has until recently been impractical, with the exception of very large scale pumped-hydro systems. A range of storage types are now being deployed or are under demonstration at commercial scale and may soon become practical at medium and small (domestic) scale. These include batteries, production of hydrogen for subsequent use in fuel cells and hydrogen, compressed air, liquid air, and flywheels. Each form is suited to different applications matching their storage characteristics e.g. differing charge/discharge rates.
Opportunities	Energy storage is receiving considerable attention internationally because it has potential: • to assist the economic deployment of variable, renewable generation sources; • to optimise the efficiency of thermal generation (minimising rapid/frequent ramping of plant output); and • as an alternative to network capacity investment offering high levels of standby reliability. There are significant advantages from local storage, which is being deployed at domestic, street and community levels. In particular local storage (including using electric vehicle batteries) matched with distributed generation improves the economics and reliability of residential and small commercial scale power systems. The power electronic interfaces associated with storage devices also bring benefits for networks, including local volt/var control.
Enablers	Substantial reductions in cost and improvements in performance are still necessary to make large scale storage feasible (including a large volume of small scale storage devices). Costs per unit of energy stored remain high, while storage system components often have only a limited number of charge/discharge cycles, and significant energy is lost in charge/discharge cycles. The effective large scale deployment of storage devices is likely to include the aggregation of services and a requirement for commercial frameworks; regulatory structures may also require refinement to recognise 'loads' that are also 'generators'.
Linkages/ dependencies	Storage devices are usually DC devices, requiring DC/AC power electronic invertors to be deployed at local and network (kW and MW) scales. These are an entirely new type of equipment for most network companies. Integrating storage into a power network needs considerable care; for example the automation needed for charge/discharge management, modelling and forecasting, and risk and uncertainty management and coordinated dispatch. Home Energy Management Systems will integrate automated charge/discharge management of domestic storage integrated with home distributed generation - storage control could be designed to avoid interaction beyond the residence boundary. Like DG, if energy storage is to provide electricity during grid outages, customers need to be 'islanded' from the grid for network safety.

<table>
<tr><th colspan="2">11. Advanced metering infrastructure</th></tr>
<tr><td>Description</td><td>Advanced metering infrastructure (AMI) combines two way communication with interval meters/load detection and control at individual connection points. It includes the meter and the associated communications infrastructure and various integrated back-office, and market systems to manage AMI data and services. AMI enables:
• remote acquisition of interval metering data (advanced meter reading or AMR)
• a platform for various smart grid services including (but not limited to):
o Remote disconnect and reconnect
o Monitoring connection status (outage)
o Operation of Time of Use (TOU) demand tariffs
o Operation of export tariffs for distributed generation, via two way export/import metering (gross or net)
o Load control and/or linkage to Home Energy Management Systems
o Sensor capability for power local network conditions including voltage sag/swell, waveform quality and harmonic distortion.</td></tr>
<tr><td>Opportunities</td><td>AMI is an enabling interface between consumers and the energy grid/market. For industry, AMR avoids scheduled and unscheduled manual meter reading costs and provides for timely interval meter reading for market settlement and smarter network tariffs; AMI provides better detection and management of technical and non-technical network losses, management of connection points, and improved Quality of Supply.

For consumers AMI improves service reliability (through earlier detection and repair of outages) and enables new consumer products and features including smarter retail tariffs, pre-paid and higher frequency retail billing, demand side energy management and local generation and storage (via measurement of energy exports).</td></tr>
<tr><td>Enablers</td><td>In liberalised markets, the full suite of AMI services is a joint product, involving coordinated decisions and activities by meter service providers, communications systems providers, retailers, electricity networks, market operators, and others.</td></tr>
<tr><td>Linkages/ dependencies</td><td>AMR including communications infrastructure and supporting data systems, processes and warehouses.

Standardised interval data formats and structures across the industry in a given locality (c.f. Australia’s NEM12 format/structure).

A no reversion rule (to minimise/manage adverse selection risks where retailers seek to game between intervals and deemed profile settlement).</td></tr>
</table>

12. Smart tariffs	
Description	Traditional network and retail tariffs average local and temporary supply costs over large customer groups and long periods of time. Smarter tariffs are more reflective of actual supply costs for various customer segments; to the extent this is efficient. Smart network tariffs signal locational and other costs, such as reactive power/power factor, to both generators and retailers. Smart retail tariffs signal costs such as high demand for generation or network congestion to consumers. This potentially makes demand response, distributed generation and storage more attractive. A wide range of smart tariffs (time-of-use, dynamic peak pricing, peak time rebate) have been deployed in mass markets. Consumers or authorised representatives have access to dynamic tariffs in real time and make consumption (or generation/EV discharge) decisions accordingly.
Opportunities	Price signalling is the major instrument to engage consumers in demand management, especially regarding reducing peak demand and avoiding associated infrastructure and operating costs for suppliers, avoiding primary energy use and GHG emissions (to the extent remote generation is carbon based). It contributes to greater grid resilience during periods of system stress (due to infrastructure outage, exceptional demand conditions or primary energy shortage). Engaging consumers reduces generator market power due to the current invariance of large swathes of demand to wholesale price, and increases the competitiveness of retail markets to provide optimum products at least price. To the degree that consumers match their retail products to their underlying cost of supply they can minimise their energy bills.
Enablers	Interval metering provides the base data for tariffs that reflect the cost of energy when it was consumed. Interval data must be used for wholesale market and network settlement (including cost reflective network tariffs) so there is a linkage between prices and supply costs. Hence for efficient market operation as well as effective consumer engagement in real time, the full suite of AMI infrastructure, including interval meters, local and wide area communications and back-office data processing systems, is required. Traditional tariffs have been in place over one hundred years and smart tariffs are difficult, if not actually threatening, for some consumers to understand. Consumer education in energy literacy and reliable and accurate tariff comparator services are required to demonstrate the advantage of smarter tariffs to meet consumer needs, either as standalone products or in combination with other demand side responses. Automation is likely to assist practical application of smart tariffs.
Linkages/ dependencies	In addition to the general communication system issues discussed above, low latency communications infrastructure may be a pre-requisite for real time applications. Consumer access to their own energy data is a prerequisite for either comparing smart retail tariffs or managing energy consumption in response to price signals. Likely linkages to electric vehicles if price is used to ration network capacity during peak charging periods, or if EVs are to provide energy storage. Similarly, likely linkages to distributed generation for export tariffs.

13. Consumer data access

Description	Consumers (and their authorised intermediaries) are able to conveniently access both long and short term information on their energy usage and its costs, to enable them to manage their energy use. Consumption data may be accessed via a range of applications. It could include a simple in home display, a complex in home display, or a data portal accessible via consumer devices and to authorised consumer representatives. This may be via the internet from back office data systems or via wireless data transfer direct from local meters. An important component is convenient data access by authorised third parties – the third parties access data directly, not via the consumer. Consumption data involves large, complex data sets, and most consumers have neither the energy literacy nor data skills to convert these to simple information useful to informed decision-making. Intermediary providers are making services available to meet this gap.
Opportunities	Consumption data enables consumers to make informed decisions about alternative tariff offerings, retailer offerings, and the potential payoffs from investments in a range of energy efficiency opportunities including local storage, renewable generation and investment in thermal upgrades (double glazing etc). To the degree that consumers match their retail products to their underlying cost of supply they can minimise their energy bills. It also enables consumers to make informed decisions about their energy consumption in response to price signals, including in real time, and thereby achieve targets in demand reduction, avoided costs and GHG emissions. Information access is an important driver of retail competition, to ensure that the potential gains from smart grids are translated into improved outcomes for consumers that smart grid related cost savings are converted into lower retail prices than otherwise (but not necessarily lower retail prices *per se*). This reflects growing recognition that legitimacy of smart grids investment (and cost recovery from consumers) is contingent on consumer engagement and concrete consumer benefits.
Enablers	A clear statement of AMI data access rights for customers, and data access provision obligations for consumption data custodians in the supply industry. Interoperability of systems employing consumer data via standardised data structures (e.g. definition of consumption intervals) and data and file formats. Privacy and data security safeguards, including encryption and standardised process for consumer authorisation to enable third parties to access data directly. A central retail data hub may not be necessary but it may be cost effective. Data are used for wholesale market settlement, so commercial opportunities are manifest for intermediaries and competing retailers.
Linkages/ dependencies	In addition to the general AMI and communication system issues discussed previously, low latency communications infrastructure may be a pre-requisite for real time applications. Data access is a pre-condition for price comparison and hence retail competition once complex smart tariffs are widespread. Likely linkages to electric vehicles if price is used to ration network capacity during peak charging periods, or if EVs are to provide energy storage. Similarly, likely linkages to distributed generation for export tariffs.

14. Building Energy management Systems	
Description	Building energy management systems provide equipment to use, generate, and communicate energy data. Sophisticated energy management systems have been available to commercial and industrial building managers for some time. Systems for the home are referred to as Home Energy Management Systems (HEMS). These are now becoming more widely available at a low cost allowing domestic consumers to monitor and control energy usage by circuits, equipment and appliances within the individual connection point (including production, storage and discharge circuits where available). Control can include 'set and forget' preferences and/or real time remote control of individual appliances via secure internet access. A HEMS typically involves the following components: • Consumer control and display devices (increasingly likely to be integrated with tablets and smart phones), • Measurement and control devices on circuits (lights, space heating/cooling) and appliances (kitchen/laundry/entertainment), • An in home (wireless) data hub (typically referred to as the Home Area Network or HAN), • Software to integrate and operate the building management systems , and • Data encryption systems and standards (including prevention of inadvertent interference with neighbours' appliances). HEMS may or may not be connected to retailer and/or network smart grid systems, see discussion below.
Opportunities	Home (or building) energy management is a principal method for consumers to actively engage in management of their own demand, including overall load reduction, load shifting avoiding peak demand and local outage recovery. HEMS offers direct benefits to consumers in terms of reduced bills, and associated benefits regarding reducing and avoiding associated infrastructure and operating costs for suppliers (hence lowering prices), avoiding primary energy use and GHG emissions (to the extent remote generation is carbon based).
Enablers	As a Smart Grid feature with direct economic benefit for consumers a HEMS market can operate independently of Smart Grid development within the energy industry, based on clamp meters, solid state power switches and standard ICT communication standards . Smart Grid inputs to decision making, such as smart tariffs or responses to peak demand signals, must be entered manually. Fully integrated HEMS include a data link between the HAN and AMI that facilitates metrology and non-metrology data from the meter. This link may be either direct to the local meter via wireless functionality or via remote data hub(s). This permits Smart Grid operators to control the HEMS within consumer preferences, including network load control and retailer dynamic price signalling.
Linkages/ dependencies	Integrated HEMS requires the general AMI and consumer energy data issues discussed previously, including low latency communications infrastructure for real time applications. Some form of HEMS is probably essential for households with complex combinations of distributed generation, heat integration, energy storage and electric vehicles.

15 Heat integration	
Description	Distributed thermal generation creates opportunities for heat (and cooling) integration. The essential feature is that "waste" heat required for the electricity generation process is used to deliver space and water heating - co-generation or combined heat and power (CHP). With an additional relatively modest investment, the system can also provide cooling - tri-generation or combined cooling, heat and power (CCHP). Integrated heat and power systems may operate on fossil fuels but increasingly also bio-fuels, fuel cells, geothermal and central solar heating. Large CHP systems have been commercially viable for three decades. Since 2000 cogeneration has become viable at the single dwelling/ small office building scale – so called micro-CHP. Micro-CHP is mostly driven by heat demand with electricity as the by-product, potentially exporting excess generation to the grid. District heating further distributes heat generated in a centralised location for residential and commercial space and water heating. Existing district housing schemes vary in scale from a few tens of buildings to entire cities.
Opportunities	Co- and tri-generation enable very high thermal efficiency rates (80%-90%) compared with conventional centralised generation, where more than 50% of energy is typically emitted into the environment, even in combined cycle generators. Hence the consumption of primary energy is reduced for total energy utilisation, with associated reductions in GHG emissions, generation and network infrastructure capacity requirements. Micro-CHP can generate a substantial portion of a building's electricity requirement where fuel must be purchased for heating. District heating plants provide scale efficiencies over localized heaters and boilers in both energy efficiency and pollution control. District heating requires dedicated infrastructure to distribute heat from the DG plant to a set of nearby buildings, along with associated end heating devices. It is usually prohibitively expensive to retrofit distribution and end heating devices. Hence construction of new "precincts" in a city rebuild offers a rare opportunity. Heat output may also be used for industrial processes and agriculture.
Enablers	A commercial framework whereby a single party is able to buy both heat and electricity, as the business case relies on near universal penetration of the integrated service within a given heat/electricity distribution footprint. Such a framework may not exist in modern, liberalised energy markets. Residential/building density may be a determinant of the feasibility of particular CHP/CCHP, micro-CHP or district heating options. An environmental framework for local pollution and effective noise control of combustion CHP/CCHP systems. Efficient hot water storage and access to primary energy sources (e.g. natural gas, propane or bio-fuels) are required.
Linkages/ dependencies	As with all DG, some form of export tariff and associated metering and settlements systems are required. DG often fails to compete with network capacity augmentation because it is unable to offer the extremely high levels of reliability and near instantaneous availability associated with network capacity and multiple generation sources. Hence there is a significant synergy with storage. There are also likely to be advantages from portfolios of DG facilities that offer redundancy in the same way a generation fleet would.

16Energy efficient homes and businesses	
Description	New homes and appliances use substantially less energy than older stock, reflecting technology, materials and design improvements. Key elements include: • Energy efficient building orientation and design (passive energy efficiency); • Thermally efficient building materials – notably double glazing and insulation; • Efficient water heating – including on-demand, gas and solar, water efficient shower heads; • Efficient space heating and cooling – including heat pumps; • Efficient lighting – high efficiency, long life globes (LED); • Efficient media devices – LED instead of plasma or CRT; • Management of standby power (low standby consumption or convenient management via HEMS); • Efficient appliances (fridges, washing machines, driers etc.); and • Others including combined heat and power and district heating Increasingly 'smart appliances' will not only minimise their energy consumption in ordinary use, but will also integrate directly with HEMS as a system operator.
Opportunities	Energy efficient homes and buildings has long been an accessible method to consumers to reduce their own demand, and remains one of the cheapest. Available Australian AMI data [SP Ausnet] indicate this could contribute to a 30 per cent reduction in typical household peak demand. Energy efficiency offers direct benefits to consumers in terms of reduced bills, and associated benefits regarding reducing and avoiding associated infrastructure and operating costs for suppliers (hence lowering prices), avoiding primary energy use and GHG emissions (to the extent remote generation is carbon based). Energy efficient homes reduce energy poverty rates (energy poverty defined as 10% or more cent of weekly household expenditure is allocated to domestic energy) and the incidence of cold and damp residences.
Enablers	Building codes that explicitly take into account market failures associated with energy efficiency in the built environment. Appliance standards promoting energy efficiency, including consumer information and minimum energy efficiency performance standards, for example, maximum stand-by energy consumption standards. Various other regulatory interventions and incentive schemes aimed at energy efficiency.
Linkages/ dependencies	Active energy efficiency management (identifying energy inefficient appliances, monitoring the energy efficiency of appliances, managing the use of appliance relative to conditions e.g. limiting hours or temperatures for heating and cooling) requires some degree of HEMS and energy consumption data. Note also the rebound effect i.e. some consumers may consume the same amount at the same cost but with greater comfort/utility levels with energy efficiency.

Appendix 2: The Orion network

Sapere: Christchurch Smart Grids Road Map project

Prepared: March 2013

Question: To what extent does Orion deploy, or is thinking about deploying, the following technologies/solutions?

	1	2	3	4	5	6	
	Not investigated in any detail yet	**Watching Brief only**	**A trial is being developed**	**Trial deployment is in hand**	**Aware of technique but not considered appropriate currently**	**Installations where need identified (BAU)**	**Notes**
Demand Response - I&C loads						*	By price + information signals; approx 80-100 hours per year, some 15-20 MW of demand
Demand Response - I&C generation						*	By price + information signals; approx 120-150 hours per year, some 20-30MW of generation; start signalled at same time as above but a post peak separate signal is used to encourage some generators to run on longer to smooth load restoration

Demand Response - domestic loads, by instruction				*	Send out a price signal to Retailers because they are billed at GXP level. The level of technical response is determined by the Retailers who offer a discount to consumers for controllability. Ripple receivers in smart meters for Christchurch. Ripple signal is sent by Orion, but the receivers are the Supplier's responsibility. Approx 50MW of DR. In addition a large amount of water heating load has been shifted to the night via day/night retailer pricing.
Demand Response - domestic loads, by price signal				*	
Home Energy Management systems HEMS	*				HEMS systems are commonly associated with smart meters but this technology is only just starting to emerge by private owners. Some retailers are trialling these.
Real Time Thermal ratings - overhead lines		*			Orion has one overhead 66kV circuit with real time rating. Unlike Transmission, where easing a line constraint may assist economic generation dispatch, for a lines company there are more limited opportunities to utilise RTTR. In general, lines companies deliver load and they have to have the capacity to cope with the most extreme day. There may be value where there is an emergency event but this is relatively rare and is unlikely to add up to a business case. The GB context was noted where RTTR is offering potential for managing DG export (more wind results in more wind farm output, and helpfully higher line ratings), and also where there is greater uncertainty with new loads appearing. RTTR can often add new capacity with less disruption and delays than a traditional reinforcement. Operationally it may be prudent to match it with DR that can be called upon if weather conditions are unhelpful in regard to R/T capacity being available.
Real Time Thermal ratings - transformers			*		Orion utilises OFAF continuous (static) ratings. They are considering the business case for dynamic (i.e. cyclic) ratings that make use of the transformer thermal time constants to meet a variable load curve. This is an 'off-line' approach rather than a Real Time evaluation. There may be opportunities here following technical modelling and examination of the business case.
Real Time Thermal ratings - underground cables			*		Route analysis has been undertaken for all 33 and 66Kv cable routes and some strategically important 11kV routes; this determines the peak worst case (i.e. winter) continuous loading capabilities. Newer XLPE cables had optic fibre installed for possible temperature monitoring but the fibres suffered EQ damage. This technique may have value if non-winter peaking loads are encountered in the future (as are being experienced in some CBD areas of the UK).
Partial Discharge monitoring, real time			*		Not applied continuously in real time, but utilised off-line as a part of maintenance; helpful post-EQ to assess latent damage to switchgear; may have a business case as asset age profiles change or as a risk mitigation approach if type defects become evident

Dissolved gas analysis in transformers, real time					*		This technique is now commercially available; probably most applicable for nursing a strategic transformer approach its end of life phase; value of investment in this will depend on asset replacement strategy and the age portfolio of plant
Fault Current Limiters	*						Orion can currently manage fault levels by selection of transformer impedances and by co-operation with Transpower for, say, deployment of series reactors; the business case may change in favour of devices such as Fault Current Limiters (saturated core and superconducting designs are now available), particularly if DG penetration increases.
Neutral Earthing dynamic tuning						*	Arc Suppression coil automated tuning is widely deployed on rural networks using devices from Swedish Neutral AB.
Quad Boosters to control power sharing	*						Orion does not currently have power sharing issues between parallel circuits; there may be a business case as demands grow and the network becomes more reticulated.
Electricity Storage - domestic scale batteries or similar devices		*					Orion is monitoring developments. At a domestic level this might be more retailer led.
Electricity Storage - community scale batteries or similar devices		*					
Energy Storage utilising heat	*						Orion notes that there may be opportunities in the future to build on the experience with hot water ripple controls, as network characteristics change (for example surplus wind or PV generation being available); there is Retailer involvement here potentially, but also a mechanism for a Lines company to control D-network exports in areas of high DG penetration. Interesting examples are becoming available in GB for increasing the energy stored by domestic hot water tanks.
HV automation (distributed)				*			One changeover scheme in service at 66kV. Logic programmed into substation relays. Otherwise not utilised.
HV automation (centralised from DMS)		*					The development roadmap for the control room SCADA (GE's Power On) includes migration to a DMS facility that could be a mechanism for this if the business case is demonstrated.

LV automation (devices in fuse frames and link boxes etc)	*				The DMS roadmap noted above may incorporate a VOLL analysis, alongside SAIDI and SAIFI measures, which may provide a case for more developments at LV (note that in GB the D-network companies are strongly incentivised by the Regulator to improve LV network performance, but this is not the case in NZ.) In GB innovative devices are coming into service to improve LV fault performance; this can also be helpful for consumers experiencing repeat intermittent failures on LV cable networks for example, or for detecting pecking faults before they develop fully.
Area Network Control				*	Orion use automated area control systems at GXP level, utilising ripple signals for hot water load control; also, from their control centre by manual instigation, to manage irrigation loads at times of network stress (prior contracts with consumers); this can defer considerable rural capex investment.
Active Network Management e.g. DG curtailment to manage network constraints (semi-autonomous real time network controls)	*				Active network management may have application as DG penetration increases, or as distributed electricity storage becomes deployed [Note -GE Power On provides main SCADA system (and future DMS), Foxboro LM system / Ripple is at end of economic life, and Catapult provides USI load management system. Looking at upgrading Foxboro. Maybe merge with GE power on or catapult of something else. This underlies the bigger issue of who controls the load and owns the technology. All developments in this area require technical solutions combined with commercial arrangements.]
Active Network management - with heat integration	*				There are currently no community heating schemes; Orion note that heat provides a form of energy storage that in principle could be integrated with the power network in the future. Also, fuel switching between electricity and gas could be an option for energy optimisation in the future.
State Estimation of LV networks		*			The ability to make LV networks fully observable even though measurements may be sparse, might be a bigger issue with big EV uptake; State Estimation is well established at Transmission levels but needs development to be applied at LV where the electrical characteristics of the network are different (X/R).
Volt/VAR management - PF correction			*		To date there has not been a need to use capacitors for voltage support on Orion's network. Ripple plants are capacitive so there are vary sources at every substation. Urban networks are underground so no PF problem there as cables are capacitive. Might be a requirement for rural networks Vary support; Orion are starting to look at this. STATCOMs may be justified at wind farm connections in the future.
Volt/VAR management - intelligent voltage control	*				
Volt/VAR management - power electronics e.g. STATCOM		*			

Smart Meters as network sensors	*	Orion have not deployed smart meters, but Meridian and Vector have in Christchurch; some but not all have additional capabilities that may be helpful for network 'smarter grid' applications; in addition to capabilities Orion recognise that there are significant 'big data' issues and costs to address if s/meters are integrated for networks benefits; business case is being explored here also at a business case level for applying smart meters at transformer level for substation monitoring
Electric Vehicle charging management	*	Early days - ideally everyone should charge overnight and at a modest kW rate; however consumer behaviours may not be so rational. Orion is thinking about how to address this. Not a great pricing ($ cost) incentive to do that but convenience factor? EV diversity will be important to avoid network overloading; charging control techniques and incentives are likely to be beneficial.
Network intentional islanding	*	Customers may island themselves in response to price signals (as was done following the EQ, using controllable generation); Orion note that a network with high penetration on (uncontrollable) DG would be an altogether different challenge, but perhaps with some benefits in the longer term.
Advanced forecasting techniques for DG, PV and EV loads on networks	*	Orion has reasonably elaborate forecasting down to zone substation, which relies on numbers of households. Looking at different penetration levels for PIEVs and impact. Not seen to be a major concern. No work at the LV feeder level. LV architecture review process coming up. That would point to what Orion should do with its forecasting. Orion considering scenario analysis to assess what level of detail is worthwhile.
DSO role for distribution network owners	*	Orion considers its current load management signalling including DG is already a basic DSO role. Furthermore the USI (8 distributors coordinating load response) load management application requires the DSO role to be further developed. Further DG and DSM opportunities are likely to increase the importance of this role and in particular how the DSO coordinates with the grid SO and other demand side aggregators.

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Urban Development Smart Grid Roadmap – Christchurch Recovery Project

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