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Smart New Zealand Energy Futures

Summary Presentation

Disclaimer

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Introduction

- Meridian Energy commissioned a study by Professor Goran Strbac of Imperial College, London in order to better assess the implications of smart grid technologies for New Zealand
- Professor Strbac has previously completed work for Meridian to quantify the wider system implications and costs of integrating significant amounts of wind into the New Zealand power system
- The aim of the study was to understand smart grid technology implications and opportunities from a New Zealand electricity system perspective
- Professor Strbac visited New Zealand in August 2011 to discuss his study with Meridian and electricity industry stakeholders.
- Meridian is releasing Professor Strbac's report* publicly, along with Meridian's views on the key messages from it

*G. Strbac et al. Smart New Zealand Energy Futures: A Feasibility Study. Summary Report, January 2012

Executive summary

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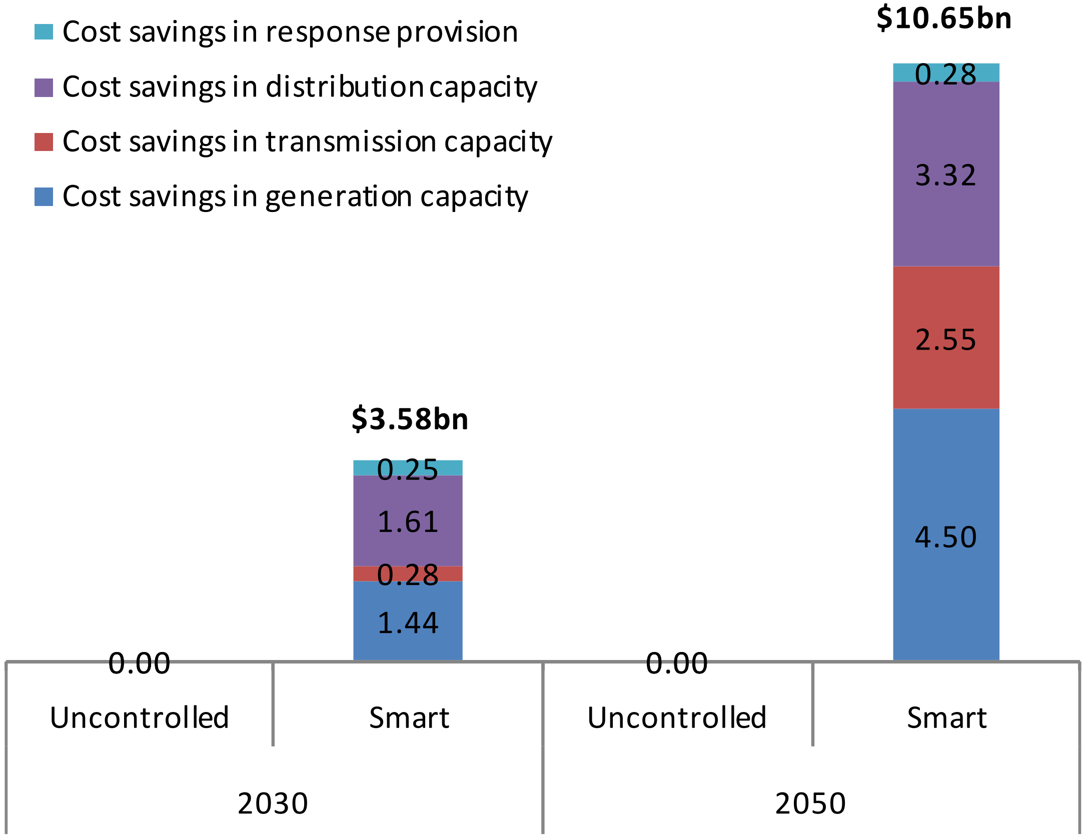
- The study quantifies the potential benefits of emerging new sources of electricity demand and control ("smart grid")
- The benefits for New Zealand are quantified in terms of the opportunity for the smart grid to defer investment in electricity infrastructure
- The study concludes that future changes in electricity demand may create a substantial economic case for a smart grid in New Zealand. If electrification of the transport sector and increased electrification of heating demand occurs then:
  - Distribution network benefits may be seen from around 2020
  - Generation benefits may appear from 2030
  - Transmission benefits are marginal in 2030 but may become significant by 2050
  - System balancing* benefits are expected to be limited due to the flexibility of New Zealand's hydro-dominated power system

*System balancing or ancillary services are generation (or load) that is held on stand-by by the system operator to ensure transmission system reliability in real time. Ancillary services include frequency keeping, instantaneous reserves, voltage support and black start.

High level results

Breakdown of estimated benefits of flexible demand in 2030 and 2050 ($bn)



- The 2030 projections have medium levels of EVs and heat pump uptake with use of flexible demand deferring over $3 billion infrastructure investment
- The 2050 projections have high levels of EVs and heat pump uptake with use of flexible demand deferring over $10 billion in investment

* All $ costs quoted in this study are in today's $ and are a cumulative calculation of the level of additional capacity required for any given scenario and its associated capital cost (these are not NPV costs and do not take into account the cost of implementing the technologies under examination)

What the study findings mean for New Zealand

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- New Zealand's market design and regulatory framework will need to evolve over time to provide the right investment signals to unlock flexible demand side participation
- Ensure that New Zealand's existing load control resource is being fully utilised

  New Zealand's hot water heating load control resource is effectively a sunk cost and can provide many of the benefits that a smart grid aims to provide
- Develop small scale concentrated trials to learn more about the benefits (and potential risks) before wide spread roll out is considered

  New Zealand faces significant uptake of heat pumps and understanding their imact and opportunities for alternative mitigation measures would be very valuable
- Encourage demand response

  There is a key role for the industry to play to raise awareness, put the systems and processes in place and to create incentives for greater demand side participation in the energy market
- At the network level New Zealand's regulatory framework may need to evolve to recognise investment in efficiency

  Network operators need the ability to make choices between innovative demand response investments against investment in network assets. Incentives to adopt technically effective and cost efficient non-network solutions need to be considered as part of the regulatory design framework

Smart grid context

What is a smart grid and why is Meridian interested?

- Smart meters lay the foundation for a smart grid, but do not constitute the "smart grid" in and of themselves
- Definitions of what the "smart grid" is vary*, but two way information flow between the electricity system and consumers is a key principle. The Smart Grid concept is dynamic and will evolve over time
- Smart grid is in the technology "hype" cycle phase
- Meridian is investigating smart grid to:
  - maintain a watching brief on new technologies
  - contribute to industry debates
  - understand future changes in energy demand
  - understand the smart grid's potential for wind integration

* The IEA defines a smart grid as an electricity network that uses digital and other advance technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users. The smartening of electricity systems is seen as an evolutionary journey, rather than a one time event

Environmental Context

- Internationally, climate change challenges are strongly driving investigations into the benefits of a smarter grid. There are two main drivers: the need to integrate renewable generation into existing systems, and the need to meet energy requirements from electricity in preference to fossil fuels
- New Zealand's electricity system is hydro dominated and renewables based. This gives New Zealand greater flexibility to respond to the challenge of integrating intermittent generation
- Additionally, New Zealand already has a significant load control resource in place through hot water ripple heating control
- These factors mean a smart grid implementation offers fewer benefits in the near term compared to the benefits expected to be available in thermally based power systems. One of the objectives of this work is to ground the smart grid opportunity from a New Zealand electricity system perspective*
- New Zealand sometimes faces the more difficult challenge of being an energy constrained market (due to hydro fuel shortages) where demand needs to be curtailed rather than shifted

*In some European jurisdictions a strong proportion of the benefits of the value of a smart grid (over half the benefits) is attributed to the value that may be available from system balancing services. Achieving system balancing benefits, in order to integrate renewable energy, is strongly driving international smart grid research. Whereas, in the case of New Zealand, this value is found to be relatively modest and less than 10 percent of the total benefits available by 2030

The smart grid study builds on previous work

- Meridian, in 2007 and 2008, funded long term industry analysis on the integration of wind in the New Zealand power system*:
  - Modelled increased system reserve, generation capacity and transmission reinforcement costs as a result of integrating significant amounts of wind generation (assumed 3.4GW of installed wind capacity by 2030)
  - Increased costs found to be low ($2-3/MWh by 2020 and $9-12/MWh by 2030) due largely to hydro domination of New Zealand's power system

- Through this work, Imperial College developed a comprehensive toolset for analysis of the New Zealand power system under a variety of scenarios

* http://www.meridianenergy.co.nz/assets/Company/Other-reports-and-documents/Summary-of-Findings-Apr2008-NZ-Wind-Integration-Study.pdf

The current study …

… considers the changing nature of electricity demand and supply in New Zealand:

- Two main drivers of change in demand (beyond "business as usual" growth) used to test the boundaries of smart grid benefits:
  - Electrification of transportation (electric vehicles - EVs)
  - Increased electrification of residential heating (heat pumps*)
- The study also takes account of the impact of increasing use of renewables in New Zealand, in particular wind

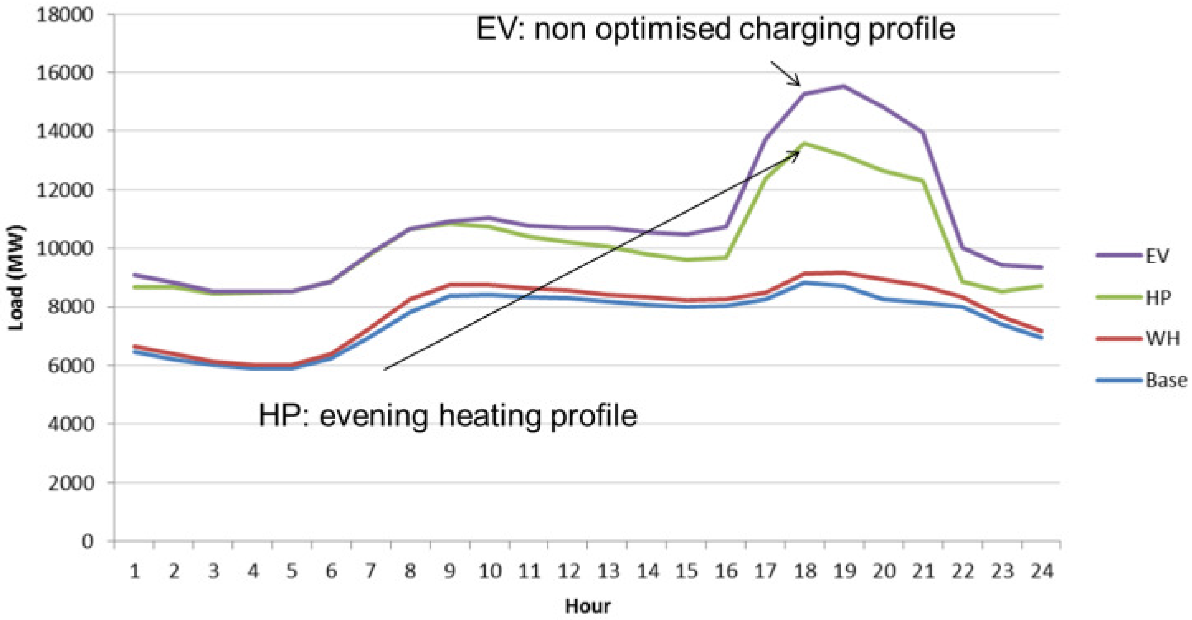
… is intended to answer some key strategic questions:

- How might residential electricity demand change in New Zealand, and what impacts could this have on long term industry investment?
- Given the commonly referred to smart grid technologies, which of these offer benefit in the unique New Zealand context?
- Where do these benefits fall, and what changes (e.g. transmission, generation investment)?

*BRANZ surveys have found a rapid growth in heat pump uptake; approximately 21% of houses in New Zealand had a heat pump in 2009 (compared with 4% of houses in BRANZ's Household Energy End-use Project (HEEP) completed in 2005)

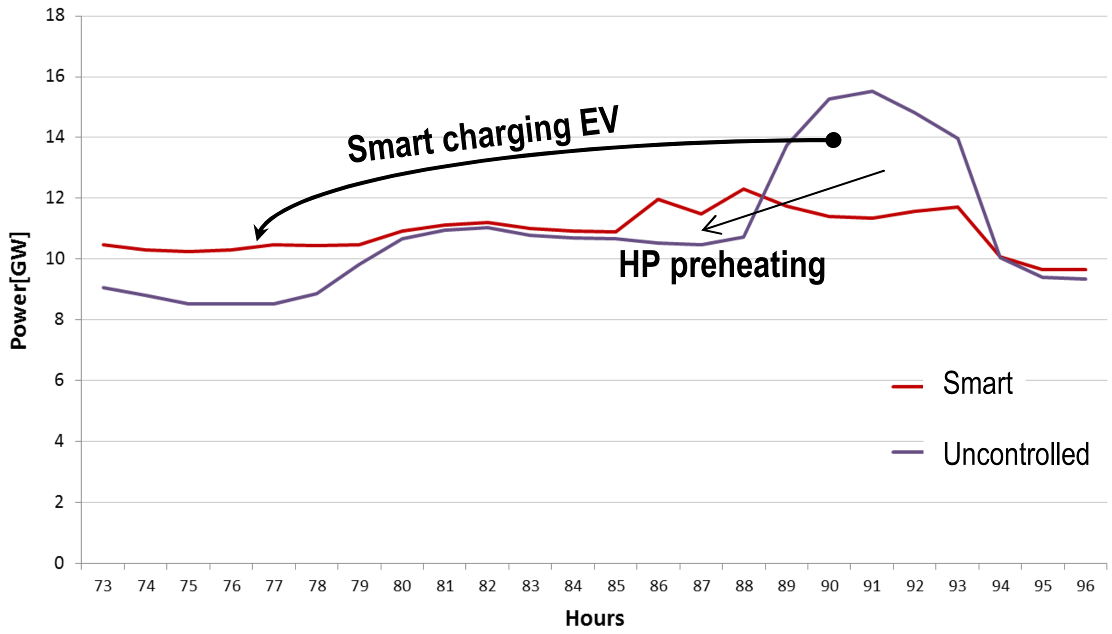
A simple explanation of the issue …

- High uptake of Heat pumps (HPs) and Electric Vehicles (EVs) could significantly increase peak demands on New Zealand's electricity system if not used in a smart fashion
- A significant increase in peak demand would require investment in new generation, and reinforcement of transmission and distribution networks (on top of "business as usual" investment)
- The graph below shows a cold winter day in 2050, with high uptake of HPs and EVs. As a result of "non-smart" HP and EV use, peak demand increases from around 9 GW to over 15 GW



… and how a smart grid can help

- A smart grid can be used to shift demand, reducing the peak
- The study models this in a way that doesn't compromise quality of service for customers, e.g.:
  - pre-heating of homes before people return from work
  - EVs charge overnight and during the day*, rather than immediately when plugged in
- This can significantly reduce the level of investment required as a result of uptake of EVs and heat pumps



* The study assumes a smart re-charging infrastructure is available

Characteristics of flexible demand

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- Flexible demand redistributes load but may not lessen the total energy used (it can increase overall energy consumption if there are losses in the storage or energy conversion process)
- Load reduction periods are followed or preceded by load recovery
- A key technical challenge is to design ways to maximise both the efficiency and use of controlled loads, while at the same time not comprising consumer comfort levels
- Power system design seeks to gain scale efficiency from demand diversity. The New Zealand power system is designed to meet around 40 percent of aggregated total household electricity demand*. This works because not all households are consuming electricity at the same time. The flexible use of demand can reduce this diversity effect and potentially increase peak demand if not well managed
- Smart software and centralised control approaches will be critical to optimise and maximise the smart use of flexible demand

* If all households in New Zealand were simultaneously consuming at their maximum level of demand. If this were the case, then considerably more generation would need to be installed. The diversity effect is one of the reasons that distributed generation is economically less competitive than large scale generation

Methodology and scenarios

Modelling of New Zealand's electricity system

- The study is based on an integrated model of generation and transmission investment in New Zealand
  - The model quantifies the investment required to provide new generation and transmission to meet demand growth, under each of the scenarios considered
  - The model assumes wind generation increases from 500MW in 2010 to approximately 3,500MW* in 2030, and then solves for the amount of additional thermal generation required to meet peak demand
  - This thermal generation is assumed to be built in the North Island, where gas infrastructure is already available
  - Given these assumptions, the model seeks to minimise total generation and transmission investment, and production costs of electricity, while still meeting demand, system reliability targets and managing operating constraints
- Distribution systems are modelled based on four representative networks (urban, semi-urban, semi-rural and rural) which are then aggregated to match actual New Zealand data
  - The model then estimates the costs of reinforcing the modelled New Zealand distribution systems to allow for future demand under each of the scenarios

* An alternative scenario with 7,100 MW of wind is also modelled

Modelling of electric vehicles and heat pumps

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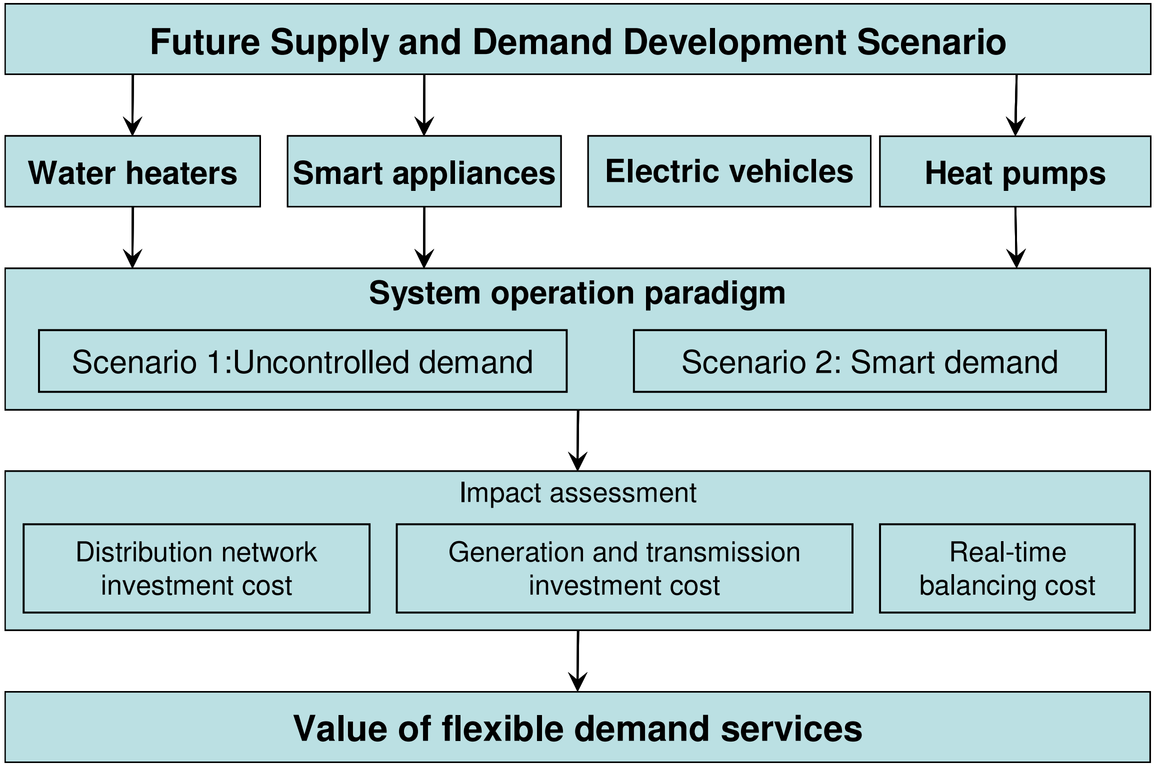
- Transportation flows are modelled using European and UK data, calibrated to New Zealand driving patterns:
  - 40,000 different types of EV journey modelled
  - The model simulates energy use for each journey
  - The model simulates when the EV is stationary and available for charging, and when it will be next required (and therefore when charging must be completed)
- Heat pumps modelled based on:
  - Detailed models of residential space heating loads for existing and new built houses
  - Individual regions within NZ are modelled separately, but using North Island and South Island temperature data (for simplicity)
  - Houses are assumed to be well insulated (by 2030) which means there is an opportunity to manage heat pump demand (pre-heating) without compromising quality of service for the homeowner
- Other potential sources of smart demand also modelled: hot water heating and smart appliances (dishwashers, refrigerators)

Methodology



- The study uses a scenario approach to explore the value of flexible demand services, focusing on system wide integration issues for alternative potential New Zealand system development futures between 2030 and 2050

Scenarios considered

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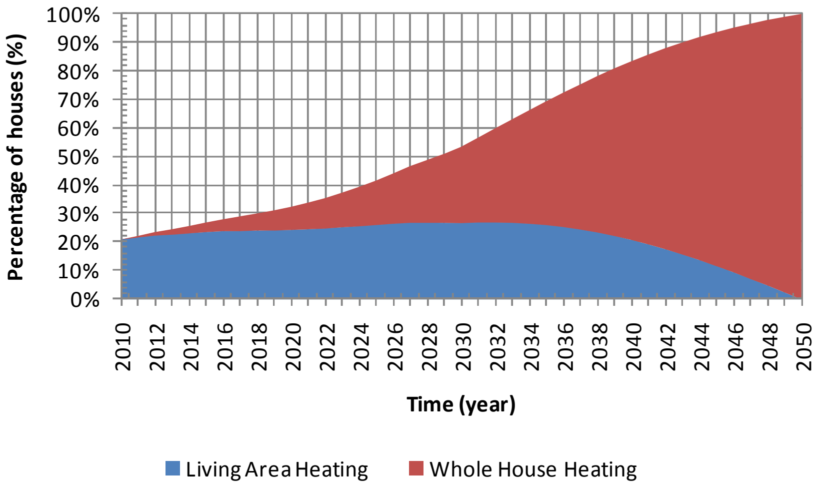
Scenario full name	Description	Referred to in charts as
Business as usual 2030	Business as usual demand growth forecast based on Electricity Authority forecasts	**Business as usual**
Uncontrolled high demand scenario with integrated EV & heat pumps, 2030 and 2050	Business as usual demand growth, plus 50 % electrification of heating and transport by 2030, and 100% by 2050 – with uncontrolled demand	**Uncontrolled**
Smart high demand scenario with integrated EV & heat pump control, 2030 and 2050	Business as usual demand growth, plus 50 % electrification of heating and transport by 2030, 100% by 2050 - with smart use of flexible demand	**Smart**

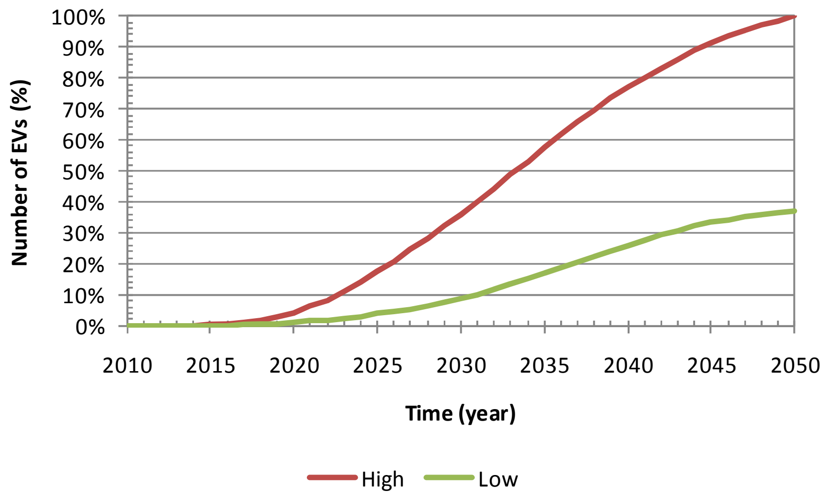
- These scenarios are possible, but not forecasted, futures. Making a forecast is not the purpose of the scenarios
- They are high demand scenarios which are used to test the bounds of total cost savings available through the application of smart grid technologies
- The scenarios help understand the drivers of future system costs and to assess the order of magnitude of possible savings that may be made by integrating flexible demand in New Zealand system operation and development

HP and EV uptake assumptions

1. Heat pump uptake (based on projecting BRANZ data)



2. Electric vehicle uptake – European data



- Penetration levels of heat pumps in New Zealand in 2030 reaches 50%, with some whole house heating
- Penetration level of heat pumps in 2050 reaches 100%, with full whole house heating

- European electric vehicle data used as a proxy for New Zealand uptake
- High and low uptake scenarios modelled: 100% electrification of transportation by 2050 and just under 40% electrification of transportation by 2050
- A mid point estimate is used to calculate point cost savings presented later in the study

Study scope

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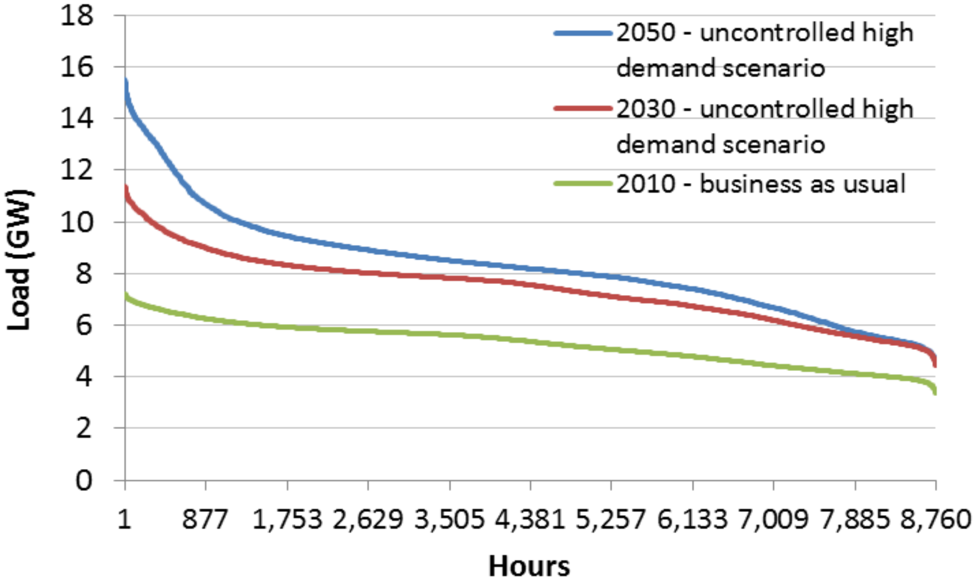
- In scope:
  - Quantify the order of magnitude cost savings available from deferring the need for electricity system investment, through using consumer sources of flexible demand enabled by smart grid technology
- Out of scope:
  - An NPV business case for a New Zealand smart grid deployment
    - The study looks only at potential benefits (cost savings) from a smart grid, not the costs of implementing it
  - Other benefits of smart grid, such as consumer utility of smart grid technologies
  - Commercial and industrial electricity demand, which already respond to price signals
  - Regulatory and market arrangements that will be required to unlock a smart grid future
  - Savings in the study are generated by not building assets; current regulatory settings may not incentivise this

Overall goal is to provide informed quantification of potential benefits, under certain future scenarios, in order to evaluate the potential opportunity, and where / when it may impact given New Zealand's unique system characteristics

Results – distribution, generation and transmission benefits

Savings come from reducing peak demand

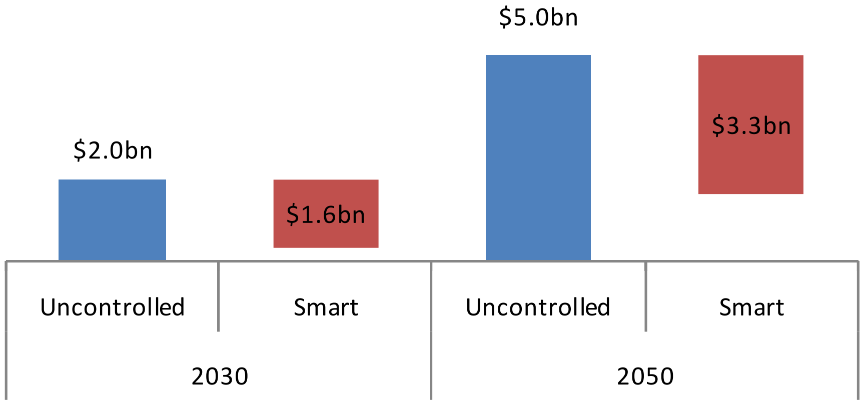
- Annual peak demand increases from around 7 GW now to around 11 GW in 2030 and around 15 GW in 2050, in the high demand scenarios
- Smart grid applications can reduce these peaks and therefore reduce the level of investment required



Scenario	Peak demand (MW)	Annual electricity consumption (TWh)	Load factor (%)
2010	7,214	46	73%
2030	11,386	65	65%
2050	15,527	73	53%

Distribution network – deferred investment benefits

New Zealand distribution reinforcement costs for uncontrolled scenario and savings achieved from controlling flexible demand (Smart) in 2030 and 2050

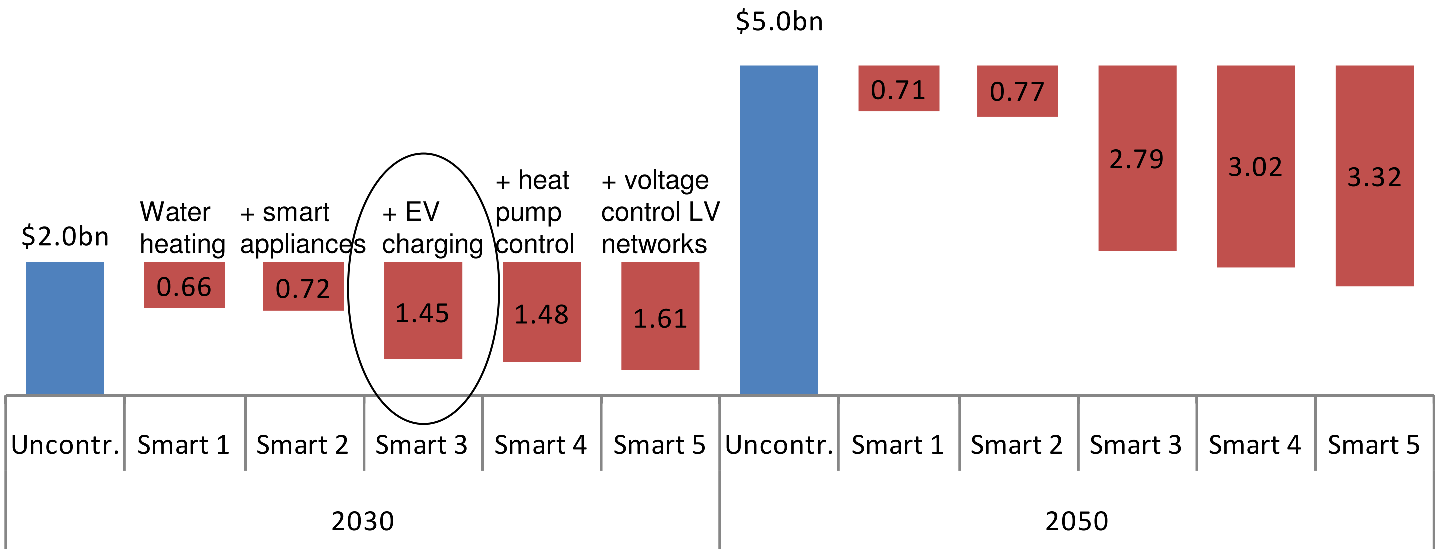


- "Uncontrolled" assumes high demand (EVs and heat pumps) and no smart grid
- "Smart" assumes flexible* demand from a smart grid, and offers significant benefits for reducing the need for distribution network infrastructure investment. It can largely offset the need for additional network investment in the uncontrolled scenario by 2030, and more than halve the investment required by 2050

* Flexible demand sources include: smart electric vehicle charging, smart heat pumps, smart appliances, water heating control & voltage control

Value of different forms of flexible demand at distribution network level

New Zealand distribution reinforcement costs for uncontrolled scenario and cumulative savings from controlling various flexible demand technologies for 2030 and 2050



- The biggest impact by far is associated with controlling charging of EVs. The additional contribution of controlling heat pumps and controlling voltage in low voltage (LV) networks is lower, but still important, particularly when penetration of EVs and heat pumps is high
- The value of controlling smart appliances (e.g. smart fridges and dishwashers) is marginal, as water heating control can already do most of it
- The order that technologies are applied affects the results; if EVs are applied first, the additional contribution from other technologies is small. But other technologies will be or are already deployed: heat pumps already have significant uptake, and water heating control already exists in NZ

Generation – deferred investment benefits

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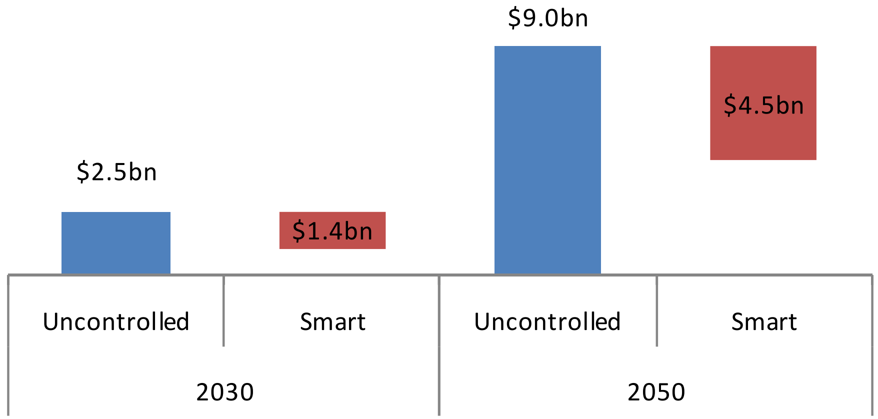
Additional generating investment needed to accommodate electrification of transport and heat sectors in Uncontrolled and Smart futures



- Generation capacity investment can be reduced through the use of smart electric vehicle charging and heat pump control
- Medium benefits seen by 2030, and significant benefits seen by 2050

Assumptions around new generation

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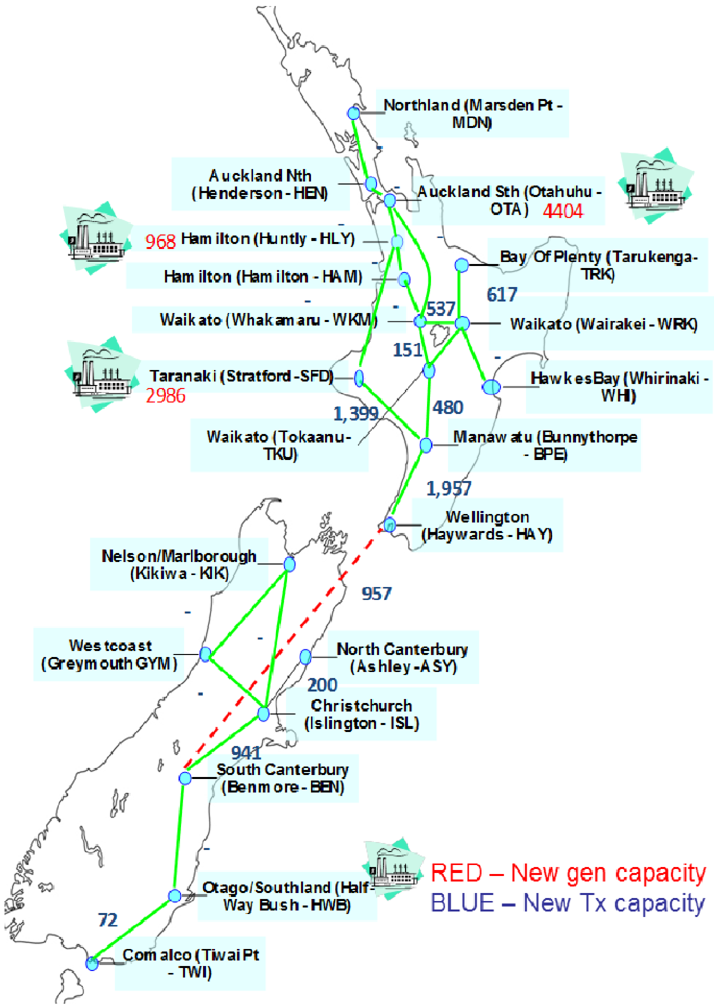
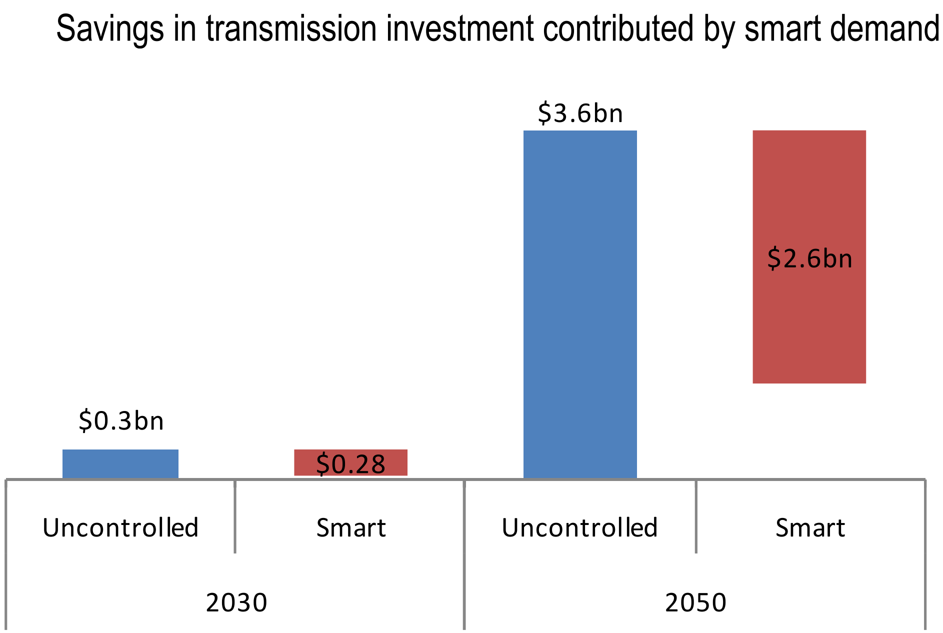
- The study assumes that to ensure system reliability, additional thermal generation would be required to:
  - support the level of wind generation capacity assumed; and
  - support the additional heat pump and EV load.
- The study assumes this is built in regions with developed gas infrastructure: Auckland, Huntly, Hamilton, and Stratford
- Quantifying the extent to which this investment in thermal generation can be deferred is one of the key sources of value of a smart grid
- The generation assumptions are not a forecast of New Zealand's future generation build mix
- The purpose is to develop and test the bounds of the potential New Zealand smart grid opportunity
- The study does not rule out other possible future generation scenarios, such as a future with a greater uptake of distributed generation



Transmission – deferred investment benefits



- Transmission capacity investment can be reduced through the use of smart electric vehicle charging and heat pump control
- Benefits are limited in 2030 but are significant by 2050
- The HVDC and its utilisation is a significant factor in these results

HVDC flows under different scenarios

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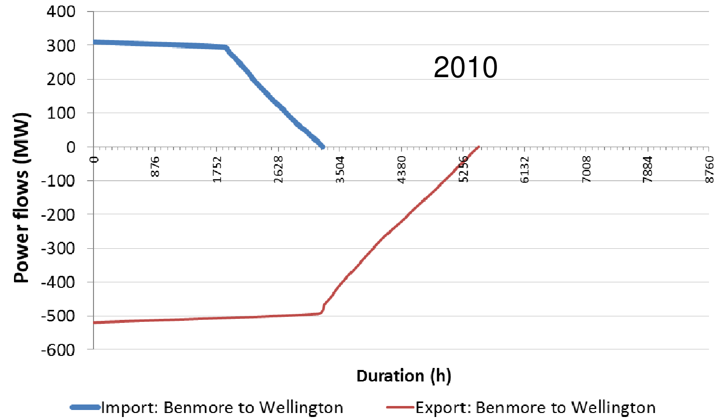
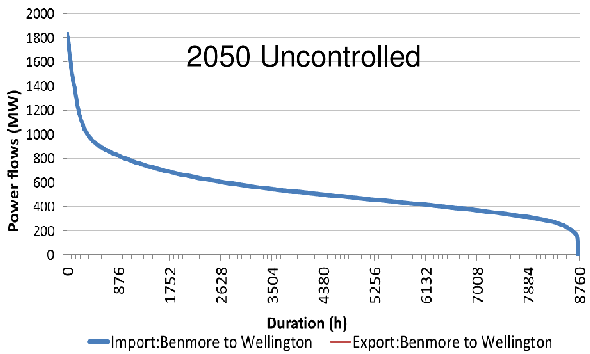
- HVDC flow is mostly south to north at present, but with significant flows the other way
- By 2030 under the uncontrolled scenario the predominant flows begin to reverse, but the present HVDC link is adequate; therefore no additional costs, and no savings from smart grid
- By 2050 under the uncontrolled scenario, HVDC flow is always north to south, and a larger HVDC is required to cope with short periods of peak South Island demand
- Under the smart grid scenario, the peak HVDC north to south flow is smaller, which generates cost savings
- The future HVDC flows are driven by the assumption that new thermal generation is built in the North Island

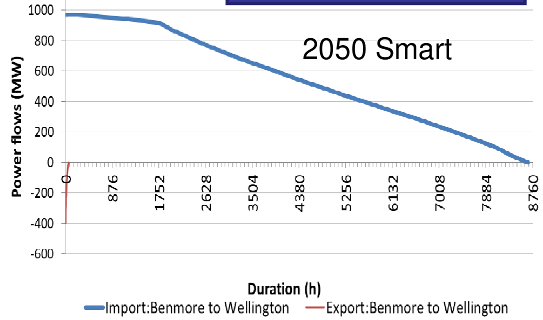


North-South HVDC link

Flow duration curves

SMART: Smaller capacity, higher utilisation factor





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System Balancing – deferred investment

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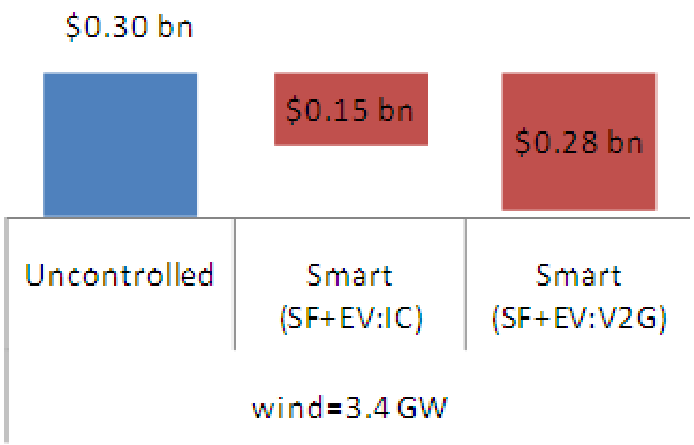
2030 Capitalised value of cost and savings in providing frequency response services



- System balancing (i.e. ancillary/reserve services) costs can be reduced significantly by using smart appliances and electric vehicles as sources of storage ("vehicle to grid").
- This value is low compared to other Smart Grid applications, because system balancing is not costly in New Zealand's hydro dominated system

High level findings

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- No particular urgency for smart grid technologies to manage intermittency of generation or supply peak demand (due to high proportion of hydro)
- Additional electricity system investment will be required to accommodate the electrification of the heat and transport sectors in New Zealand; these new sources of demand will cause significant peak issues
- The deployment of smart grid technologies to manage this demand can significantly mitigate the additional amount of investment required
- The most valuable sources of this flexible demand are smart EV charging and smart heat pump control, as penetration increases. When there is high uptake of EVs and heat pumps, smart charging of EVs and control of heat pump demand will be of critical importance to smooth and manage peak demand periods
- Water heater control will continue to be important in deferring the need for local network reinforcement, especially when penetration of EVs and heat pumps is low
- Control of smart appliances makes only a modest contribution to smoothing peak demand
- Deployment of smart EV charging and smart heat pump control technologies could bring significant benefits at a distribution network level from 2020 onwards; similar benefits may be available at a generation level around 2030

What the study findings mean for New Zealand

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- New Zealand's market design and regulatory framework will need to evolve over time to provide the right investment signals to unlock flexible demand side participation
- Ensure that New Zealand's existing load control resource is being fully utilised

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Trials

- Trials with two way information flows to test customer engagement and tailor products to suit customer needs will be an important step to learn about the value a smarter grid can bring to both consumers and the electricity industry. New Zealand retailers have begun experimenting in this space
- Specific areas of investigation in the nearer term could also include:
  - trialling hot water heating control approaches augmented with smart metering information
  - monitoring of heat pump operation and investigating opportunities for control
  - using smart metering data to deepen understanding of electricity consumption patterns across various consumer segments, potentially augmented with appliance monitoring and consumer behavioural research
- Smart appliances will be of limited benefit from a electricity system perspective so trials in this area are likely offer less national benefit
- There will be future opportunities for technology transfer around EV charging infrastructure and smart communication