HOW SMART GRID DEVELOPMENTS CAN SUPPORT EMISSION REDUCTIONS

NEW ZEALAND SMART GRID FORUM

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This report has been completed by Bridget Moon on behalf of the New Zealand Smart Grid Forum

1. INTRODUCTION

This report considers how smart grid developments can support emission reductions

The New Zealand Smart Grid Forum (Forum) was established in 2014 to advance the development of smart electricity networks in New Zealand. The Forum's vision is that:

> *"In 2050, New Zealand will have leveraged the opportunities made available from emerging smart grid technologies and practices to the benefit of electricity consumers and New Zealand's prosperity and productivity as a whole".*

The Forum presented a report to the Minister of Energy and Resources (Minister) in June 2015. That report set out the Forum's views as to:

- how to make the most of market led innovation and minimise risk of stalling due to lack of coordination between different stakeholders
- how to anticipate and proactively manage any risks to power quality and reliability that might emerge from smart grid technologies and applications.

In responding to the report, the Minister requested the Forum's views on two further issues:

1. How are New Zealand's smart grid developments progressing relative to those in other countries – especially technologies and arrangements that support or facilitate new services for consumers – and what, if anything, could be done to accelerate developments in New Zealand that provide consumer benefits?
2. How might smart grid developments assist in meeting New Zealand's greenhouse gas emission reduction targets?

This report addresses the second of these issues.

Structure of this report

The following sections outline:

- The Forum's overall findings, in terms of the opportunity for greenhouse gas emission ('emission') savings, where and how it arises, and any changes required to enable or enhance that opportunity ***(section 2)***
- New Zealand's emission reduction targets, and the importance of realising emission savings through better energy use ***(section 3)***
- Why the emission savings from smart grid developments may be different in New Zealand than in other countries ***(section 4)***

- The potential of new options for <u>sourcing</u> electricity to support emissions savings ***(section 5)***
- The potential of new options for <u>using</u> electricity to support emissions savings ***(section 6)***
- The potential of new options for <u>transporting</u> electricity to support emissions savings ***(section 7)***
- How realising emission savings through smart grid developments can be enabled and enhanced ***(section 8)***

2. RESULTS AND FINDINGS

Smart grid developments could support emission savings

For some countries, smart grid developments provide an opportunity that has largely eluded them to date – to generate their electricity renewably, and hence reduce their emissions.

However, renewable generation is already the mainstay of New Zealand's electricity system, and we have more renewable resources that we could develop. Because of this, the opportunities provided by smart grid developments are different here:

- New options for sourcing electricity:
    - supply - like solar PV – probably won't have much of an effect on our emissions, as they will largely replace one renewable technology with another.
    - flexibility – like batteries and demand response - could have a modest effect on emissions by supporting even higher penetration of renewable generation.
- We should exploit new opportunities to use electricity instead of fossil fuels. Uptake of electric vehicles and electric processing technologies could result in meaningful emission savings.
- New opportunities to transport electricity more efficiently could have some minor emission benefits.

The key opportunity in New Zealand is from greater use of renewable electricity

The Forum has previously defined a smart grid as "*an electricity network that can intelligently integrate the actions of all users and equipment connected to it, in order to efficiently deliver sustainable, economic and secure electricity supplies*".[1]

Developing a smart grid – by applying electronics, computing and communication technologies to electricity infrastructure - opens up new options around sourcing, using and transporting electricity.

There is a lot of excitement about what smart grids could potentially mean for society. For some countries, smart grid developments are a key way for them to reduce emissions. This is because the 'new options' include novel ways to generate renewable electricity, and a smarter grid can integrate larger amounts of those technologies. Without a smart grid,

[1] See http://www.mbie.govt.nz/info-services/sectors-industries/energy/electricity-market/nz-smart-grid-forum/meeting-7/150619-first-year-report-to-minister-final.pdf

many countries might continue to rely heavily on coal and/or gas fired electricity generation.

Smart grid developments can support increased penetration of renewable electricity generation in New Zealand. However, the opportunity here is small compared to many other countries, because New Zealand's electricity is already highly renewable. Eighty percent of our electricity was generated from renewable resources in 2014. Furthermore, given our portfolio of consented grid-scale renewable projects, and the considerable experience we have with these technologies, renewable electricity generation can, and is likely to increase without relying on smart grid developments.

In terms of reducing emissions, ***the main smart-grid opportunity for New Zealand is to leverage off our renewable electricity base***, by supporting the use of electricity for processes that would otherwise rely on fossil fuels.

Electric vehicles play on this opportunity perfectly. Each petrol or diesel vehicle that is replaced with an electric vehicle will achieve some reduction in emissions - even in the absence of smart grid developments. However, smart grid developments will help to accommodate widespread adoption of electric vehicles, and ensure that they take maximum advantage of renewable electricity by charging at the best times.

This example highlights the key role for the smart grid in reducing emissions: that being, to ensure that new technologies and other initiatives that could reduce emissions:

- can be efficiently integrated into electricity networks
- make the maximum possible contribution to efficient energy use.

Supporting good consumer decision-making will help to realise emission savings

Maximising the use of New Zealand's renewable resources, in order to minimise emissions, requires that consumers make effective choices about how they engage with the new options opened up by smart grid developments. This is not without its challenges and limitations.

New Zealand's regulatory and institutional arrangements are well placed to respond to a consumer-led adoption of these new options as they become available.

However, success requires that the prices consumers see appropriately reflect the impact of their decisions on emissions. Favourable decision-making could also be supported by increasing awareness and understanding of the various new options opened up by smart grids, and reducing the perceived risk of unfamiliar electric technologies.

3. SUPPORTING EMISSION REDUCTION TARGETS

New Zealand is targeting significant reductions in emissions

The New Zealand Government has a number of targets for reducing emissions. Specifically, it has:

- an unconditional target to reduce greenhouse gas emissions to **five per cent below 1990 levels by 2020**, as part of our commitments under the Kyoto protocol
- made a provisional commitment to reduce greenhouse gas emissions to **30 per cent below 2005 levels by 2030**, under the international agreement to combat climate change that was agreed in Paris in December 2015. This target is equivalent to 11 per cent below 1990 levels.
- domestically legislated a long-term term target to reduce emissions to **50 per cent below 1990 levels by 2050**.

In 2013, New Zealand's gross greenhouse gas emissions were 81 Mt CO_2-e. This was **21% above 1990** levels. Forecasts by the Ministry for the Environment suggest that emissions will slowly increase if we continue with 'business as usual'[2]. Evidently, meeting our emission targets will involve a significant effort.

Energy-use will be a primary focus for emission reductions

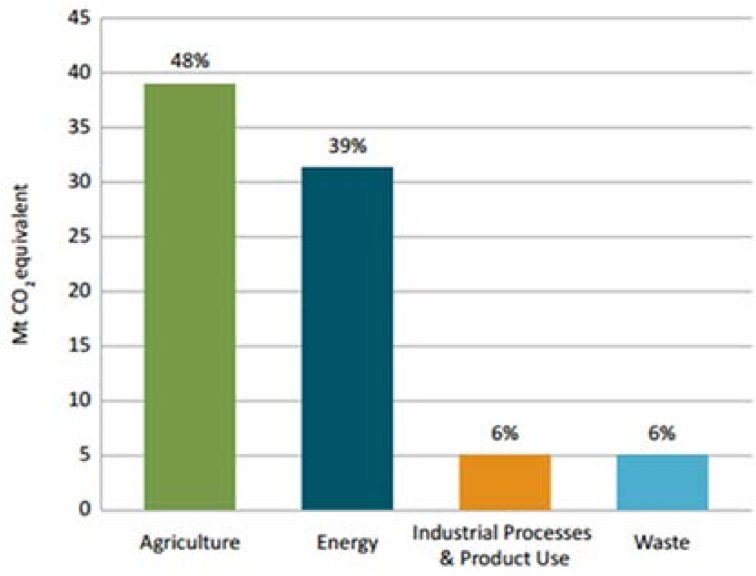
As shown in Figure 1, New Zealand's greenhouse gas emissions predominantly come from two sources:

- The biggest contributor is the agricultural sector - a big source of methane emissions. It comprised 48 per cent of total emissions in 2013.
- The second biggest contributor to emissions is energy use, including energy used for transport. Energy use contributed to 39 per cent of New Zealand's total greenhouse gas emissions in 2013. It has also been the biggest driver of increases in our total emissions since 1990. Emissions from energy use are 32 per cent above 1990 levels.
- The remaining 12 per cent[3] of emissions come from waste, and non-energy related industrial processes (e.g. cement production).

[2] See http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/second-biennial-report.pdf

[3] These figures don't add up to 100% because of rounding

Figure 1: New Zealand's greenhouse gas emissions in 2013 by sector

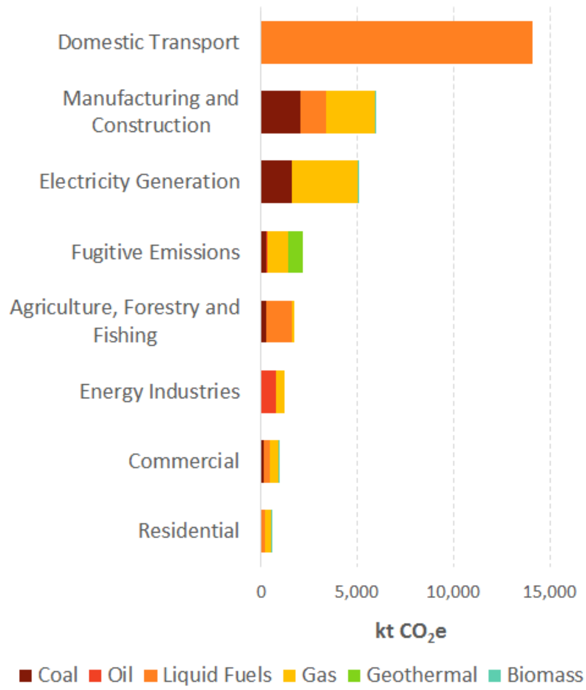


Source: Ministry of Business, Innovation and Employment

Because of the substantial contribution it makes to New Zealand's total emissions, and because there are currently very few mitigation strategies for emissions from agriculture, energy use will be an important target area for emission reductions.

A breakdown of emissions from energy use in 2013 is shown in Figure 2.

Figure 2: Breakdown of 2013 emissions by sector and fuel type



Source: Ministry of Business, Innovation and Employment emissions data

4. THE BENEFITS OF SMART GRID DEVELOPMENTS WILL DIFFER BETWEEN NEW ZEALAND AND OTHER COUNTRIES

Smart grid developments open up new options for sourcing, transporting and using electricity

The key technologies that form the basis of a smart grid are electronics, computing, and communication technologies. Applying these technologies to electricity infrastructure will facilitate:

- two-way communications that allow for real-time, actionable information to flow between decision-makers and all components of the electricity system
- two-way current flows, so that electricity can flow from lower-voltage networks to higher-voltage networks, and hence help to better integrate distributed generation
- sensing and monitoring of conditions on the grid, so that parties can react in real-time, and draw on digital and remote control capabilities to provide for an automated response
- installation of energy storage devices, which will help to manage periods of congestion on networks.
- the creation of large amounts of data, and the ability to quickly analyse it, which will allow parties to automatically identify and react to opportunities for greater efficiency and improved performance, and will support new approaches to business.

These capabilities open up new options around sourcing, using and transporting electricity.

The value of smart grid developments depends on other system features

The potential for the new options opened up by smart grids to support emission reductions has garnered a lot of attention in some countries. In particular, there is excitement about the potential to integrate greater quantities of solar PV and wind generation, with the help of battery storage.

However, any potential for emission savings will depend on a variety of factors. In particular, it will depend on the characteristics of energy supply and demand, and the existing resources and infrastructure that new technologies would have to integrate with or compete against.

The value of new options in supporting emission reductions may differ between New Zealand and other countries. This is because we have numerous direct-use energy options that can provide a low-emission alternative to electricity, including geothermal, biomass and biofuels, as well as natural gas in some circumstances[4]. Furthermore, our electricity system has a unique combination of features:

- **We are already largely supplied by renewable resources.** Eighty per cent of our electricity was generated by renewable resources in 2014, including five per cent by wind generation. In 2013, we had the fourth highest per cent share of renewable electricity in the OECD. Furthermore, we have in no way exhausted our renewable resources –over 3,500 MW of further renewable generation projects have received resource consents.
- **We need more generation in winter than in summer**, because demand for electricity is higher – particularly on cold evenings. Furthermore, hydro generation can be more constrained in winter, because rain turns to snow that sits on the mountains instead of flowing into hydro lakes. Therefore, we currently rely more heavily on thermal generation, and hence create more emissions, in winter. To significantly reduce our electricity-related emissions, we need new options that help us meet winter demand. Other hot countries like Australia need more energy in summer, and new options like solar PV can help to meet that need.
- **We already benefit from a reasonable amount of flexibility**. Our flexible hydro generation can effectively act like a giant battery, storing and releasing water to match the need for electricity. In particular:
    - it provides some mid-to-long-term storage that allows us to shift supply across weeks or months, according to the rain
    - it makes it relatively straight-forward for us to integrate generation that operates intermittently, like wind.

  Currently, many other countries rely almost entirely on thermal generation for this kind of flexibility, and hence value the potential for smart grid developments to open up lower-emission alternatives.
- **Our emissions vary with the rain.** Hydro generation meets around 55% of demand in an average year. However, it can generate more when it rains a lot, and generates much less in times of drought. Thermal generation plays an important role in offsetting these differences in hydro output. It is very challenging to displace thermal generation from this role, as most renewable generation and energy storage technologies would be unable to perform it economically.[5]
- **We are small and isolated**, so we have to make the most efficient use of the resources we have available. Some countries like Germany are able to offset their own lulls in supply by buying electricity from their neighbours, or selling it on when

[4] According to 'Consumer Energy Options in New Zealand – 2016 Update'
[5] Although they may be able to under high carbon price scenarios.

they have too much. This gives them access to a more widely diversified demand and supply of electricity.

Given these features, the following sections discuss the potential for emission reductions in New Zealand, as a result of the new options for sourcing, using and transporting electricity.

5. NEW OPTIONS FOR SOURCING ELECTRICITY

Smart grid developments support distributed generation and flexibility

Smart grid developments can open up greater potential for new sources of electricity:

- **supply**, such as intermittent and distributed generation
- **flexibility**, such as demand response and energy storage devices.

They can do this because they allow for:

- **Two-way current flows.** A 'traditional' electricity grid is only designed for current to flow in one direction - from transmission networks down through low-voltage networks to end-consumers. Reverse flows can cause voltages to exceed limits and overload equipment, and create safety and reliability issues. Therefore, a local network generating more electricity than it was consuming would create issues. Accommodating two-way current flows could hence allow for more uptake of distributed generation such as wind and solar PV, and energy storage devices.
- **Increased automation and control of generation, storage and loads.** A smart grid would allow for the necessary signals to be sent – both in terms of real-time prices and physical electronic signals – to remotely control when generators increase and decrease output, loads are turned off and on, and batteries charge or release energy.

Given the features of New Zealand's electricity system, the Forum has canvassed a number of New Zealand sources to try and understand the potential of these new options for sourcing supply and flexibility to support emission reductions.

These sources are outlined in Table 1.

Table 1: Sources used to understand the potential for emission savings from new options for sourcing electricity supply and flexibility

SOURCE	ANALYSIS
BusinessNZ Energy Council: New Zealand Energy Scenarios[6]	Modelling that has prepared two different but plausible scenarios of New Zealand's energy future

[6] Link to the BEC NZ Energy Scenarios report

SOURCE	ANALYSIS
	out to 2050, leveraging from global scenarios prepared by the World Energy Council.
Concept Consulting Group: Electric cars, solar panels and batteries in New Zealand: – How will they affect greenhouse gas emissions: [7]	Consideration of how widespread uptake of electric cars, solar panels, and batteries in New Zealand could affect emissions.
Electric Power Engineering Centre: Environmental Aspects of Photovoltaic Solar Power[8]	Consideration of the life-cycle environmental impacts of solar PV in New Zealand in the near future.
MBIE: Draft Electricity Demand and Generation Scenarios:	Modelling that provides eight potential scenarios for the future of the electricity sector out to 2040.
Meridian Energy Internal modelling[9]	Modelling of how the New Zealand electricity system would accommodate high uptake of solar PV and battery storage, from a grid perspective.
Orion: Emerging technology observations[10]	Observations of modelled impacts from extreme scenarios of uptake of solar PV, electric vehicles and batteries for the Orion network.
Royal Society of New Zealand: Transition to a low-carbon economy for New Zealand[11]	Consideration of future technologies and practices that will support emission reductions.
Transpower Internal modelling[12]	Scenario modelling, which has considered various uptakes of distributed energy technologies and the emission outcomes.

These sources all differ in their specific focus, and their approach to considering the impacts of new options for sourcing supply and flexibility on the electricity system, and on emissions. However, the Forum identified that there are a number of probable outcomes

7 Link to the Concept report
8 Link to the EPECentre Environmental Aspects of Photovoltaic Solar Power report
9 Meridian is represented on the Smart Grid Forum, and shared the findings of its internal modelling with the group in support of this work.
10 Link to presentation outlining results of Orion's modelling
11 Link to the Royal Society's report
12 Transpower is represented on the Smart Grid Forum, and shared the findings of its internal modelling with the group in support this work.

and effects that are relatively consistent across all sources, which are discussed in the following sections.

New options for sourcing electricity supply probably won't have much effect on New Zealand's emissions

The Forum identified that new options for sourcing electricity supply – specifically, solar PV - probably won't have much effect on New Zealand's emissions. Specifically, it found that:

- **The penetration of renewable generation will probably increase over time, without smart grid developments.** While the timeframe and extent of this is uncertain, it is anticipated that:
    - **The contribution from wind and geothermal technologies (both low-carbon renewables) will probably increase**. These technologies are widely expected to be instrumental in meeting any requirement for new grid-scale generation, prompted by the retirement of uneconomic thermal plant, and/or demand growth. Geothermal generation is easily accommodated on the system, and our large amounts of flexible hydro generation mean that a significant amount of wind generation can also be accommodated with relative ease.
    - **The role of thermal generation will probably reduce over time**. Unless coal, gas and carbon prices were to fall to very low levels and stay there, the expectation is that thermal generation will increasingly be displaced from operating at high utilisation rates, in favour of cheaper renewables. Instead, it will predominantly be used for short periods to meet peak demand, higher winter demand, and as cover for hydro during dry years.
- **Solar PV uptake would change the requirement for grid-scale generation.** The timing and exact effects would depend on rates of uptake and demand growth, and the many variables affecting other parties' decisions to invest in or retire generation. However, in brief, solar PV uptake could:
    - **Indirectly offset thermal generation, at least in the near-term**. Solar PV would probably displace hydro generation initially, with the unused water stored in hydro lakes for later use, when it would displace gas-fired generation. So some level of PV uptake could result in emission savings.
    - **Displace new investment in wind and geothermal plant.** Essentially, solar PV would 'compete' with these technologies to supply new load and to displace aging thermal plant. However, wind generation would do a better job of reducing emissions than solar PV. Therefore, by displacing investment in wind

generation, uptake of solar PV could result in higher emissions than would otherwise result.[13]

- **In the long-term, potentially increase the need for thermal generation to meet winter demand.** Solar PV generally generates much more in summer when demand is lower, than in winter when demand is higher. In the long-term, hydro storage may not have enough flexibility to fully make up for this seasonal supply difference. This could result in more thermal generation being required than if there were little or no solar PV, with associated emissions.

- **Solar PV uptake is unlikely to result in significantly better or worse outcomes than would be achieved otherwise:**
  - To achieve emission savings, solar PV would not only need to increase the penetration of renewable generation, but it would need to do so <u>more</u> than the renewable generation projects that it would likely displace.
  - While solar PV is not an ineffective option for reducing emissions, other technologies such as wind would be *more* effective.[14] Given the likelihood that the alternative to solar PV uptake would be investment in some mix of grid-scale wind and geothermal generation, it does not appear that solar PV uptake would result in significantly better emission outcomes. However, it also does not appear that outcomes would be substantially worse.

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13 The sources in Table 1 present a mixed view as to whether geothermal would be better or worse than solar PV at reducing emissions. While it would certainty result in lower emissions from electricity generation, it has fugitive emissions that could more-than offset this advantage

14 Because it doesn't create its own emissions, or change the operation of other generators on the system in a way that meaningfully increases emissions.

However, the Forum notes that the pace of technology development is rapid. Solar PV technologies and the way they are installed is likely to improve over time, in a way that makes their generation more consistent through-out the year. [15] This would mean they contributed more to meeting demand in winter when it is highest, improving their effect on emissions.

In the longer term, smart grid developments could also support integration of fledgling technologies like tidal or wave generation, which may be effective at reducing emissions.

Figure 3: Concept Consulting Group analysis of emissions impact of 4 kW solar PV - NZ and overseas

Source: Reproduced from referenced Concept Consulting Group report

New options for sourcing flexibility could support some emission savings

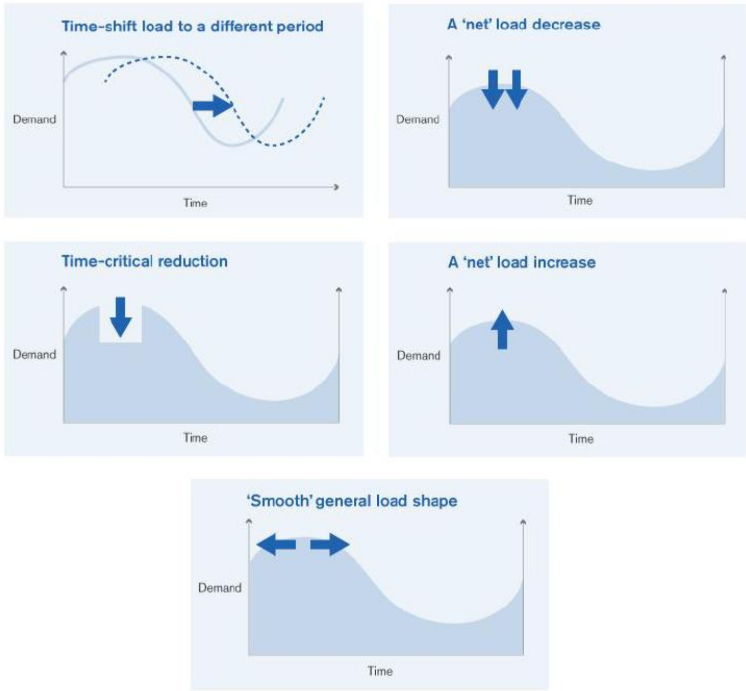
The Forum identified that new options for sourcing flexibility – including energy storage and demand response – could support some emission savings. Specifically:

- **Flexibility would mostly be available on a within-day basis.** For example:
  - Energy storage devices such as batteries would probably be charged overnight or during periods of high wind/solar generation, and would be dis-charged during peaks in demand – i.e. they would probably operate in some kind of daily, or day/night cycle.
  - Demand response would probably reduce or move load over hours. For example, heat pump load might be moved to the afternoon to pre-heat a consumer's house, rather than concentrating its load during the evening peak in demand. Similarly, appliances or electric vehicle load might be targeted to overnight periods when demand is low.

15 For example, dynamically altering the tilt angle of a solar PV array can improve the consistency of its output, and this functionality could become more economic and hence more common in the future.

- **Utilising this within-day flexibility could help us reach higher penetration of renewables than we might otherwise**. For example:
    - o managing load around wind flows, or having it better mirror sunshine hours could assist in accommodating the uncontrolled output of a large amount of wind and solar PV
    - o smoothing out peaks in demand and filling in troughs makes the overall demand profile flatter, which means that more demand could be met by generation that operates at a steady rate all the time, such as geothermal.
    - o the need for fast-start thermal generation to otherwise provide a flexible response could be reduced, which may help to displace it from the market.

Figure 4: How flexibility can influence net load



Source: Link to UK Office of Gas and Electricity Markets' report

- **These new sources may not make a significant contribution to New Zealand's need for long-term flexibility:**
    - o They are unlikely to provide seasonal flexibility to meet winter demand. It wouldn't be economic to charge batteries once during summer for use in the winter, and they would lose their charge over that kind of timeframe anyway. It is also unlikely that there will be meaningful opportunities to reduce or shift consumers' load across weeks or months - while 'smart' energy management could increase energy efficiency by reducing *wasted* electricity, reducing useful load for long periods during winter would create significant disruption for consumers.
    - o The need for dry-year security would also remain – although there may be some potential to reduce load during dry years given they are relatively infrequent events, if consumers were given sufficient incentive.
- **The emission savings are likely to be relatively modest:**
    - o The majority of our within-day flexibility is currently provided by hydro generation, and supplanting this would not reduce emission. However, some

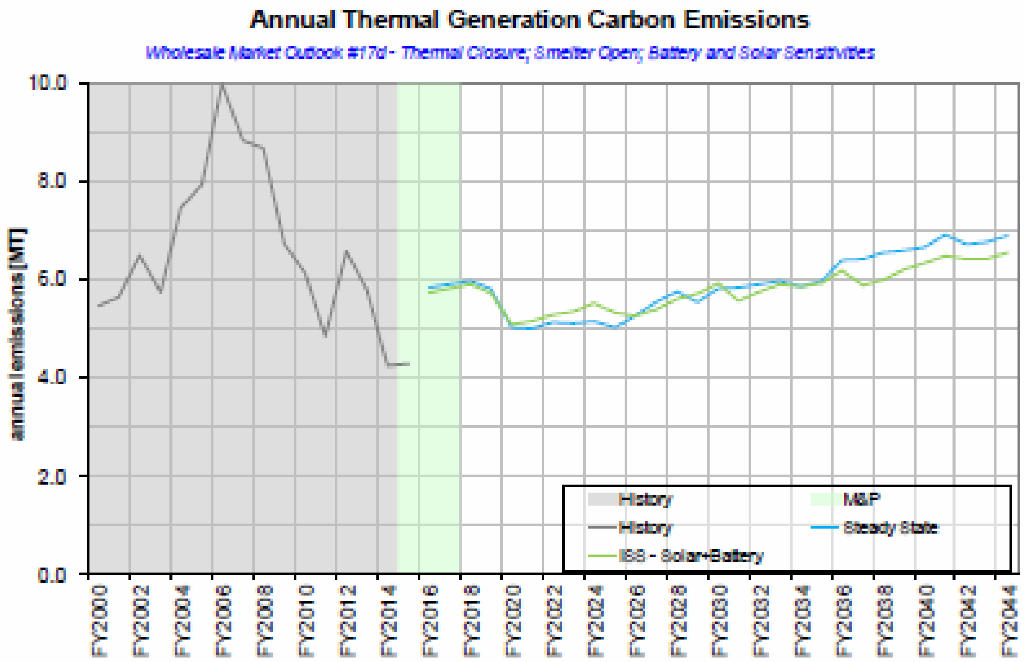
fast-start thermal generation also helps meet this need – particularly in winter, and hydro's ability to provide a flexible response does have limitations. Therefore, new options for flexibility do have some potential emission benefits.

- Thermal generation currently plays an instrumental role in meeting our need for long-term flexibility. The new sources of flexibility that smart grid developments open up seem limited in their ability to displace thermal generation from this role, affecting their potential to support emission savings.

The subdued impact of solar PV and batteries on emissions is demonstrated by Figure 5, which Meridian Energy provided for use in this report. It shows the likely emission outcomes if one million households have solar PV and batteries by 2043, versus the likely outcomes without solar PV and batteries.

Orion's analysis suggests that peak demand on its system could be reduced by eight per cent if 45 per cent of households on its network had a battery installed, and used it to help flatten the system load. However, it is interesting to note that their analysis also suggests that energy efficiency could reduce peak demand by a further 10-20 per cent.

Figure 5: Meridian Energy modelling of the emissions impact of 1 million solar PV and batteries



Source: Meridian Energy

6. NEW OPTIONS FOR USING ELECTRICITY

Smart grid developments could support greater use of electricity in place of thermal fuels

Smart grid developments open up new options for using electricity, specifically including:

- **electric vehicles**
- **electric processing technologies**
- **energy management technologies**.

In New Zealand, these new options present the main opportunity to reduce emissions through smart grid developments. This is because they allow us to leverage off our existing and undeveloped renewable resources.

Any process that can substitute thermal fuels with renewable electricity will support emission savings. For example, smart grid developments could provide the electronic, computational and communication infrastructure to:

- support the widespread adoption and efficient charging of electric vehicles, in place of petrol or diesel vehicles
- bring renewed relevance to electric technologies for industrial processing, many of which are not new, but have traditionally been disadvantaged by higher costs than fossil-fuelled technologies
- encourage use of energy management systems that can control heating, appliances and equipment within the home or business, which may encourage greater use of electricity in place of gas.

In some cases, smart grid developments and the new options they open up may provide the impetus for consumers to switch fuels, because of two factors:

1. **increased 'quality' advantages of electricity as an energy option.** Specifically, smart grid developments will:
    - facilitate greater control and automation of heating, appliances and devices, so that consumers can optimise their energy use to suit their requirements and desires
    - facilitate use of increasingly 'smarter' electric technologies that might develop over time, such as robotics, self-driving cars, smart security systems, advanced energy management systems etc.
    - provide a consumer with the ability to tailor the level of electricity 'service' they receive - in terms of reliability, capacity etc. - to reflect their needs and the value they place on it.

2. **the increasing potential for cost advantages over thermal fuels.** As the costs of technologies such as solar PV and batteries come down:

    - the upfront costs of technologies such as electric vehicles will also come down, which in combination with 'smart-charging' to minimise running costs, will make the lifetime costs of electric vehicles much more competitive against similar petrol or diesel vehicles
    - behind-the-meter solar PV and battery set-ups will increasingly compete with grid-supplied electricity on a cost basis, and may become a cheaper option for some consumers

    Smart grid developments can also reduce cost barriers to switching fuels, because they can help to minimise the investment required to integrate new load into the electricity network, and hence the costs associated.

These benefits to using electricity would be in addition to other advantages that electricity already has as an energy source. For example:

- an electric engine is substantially quieter than an internal combustion engine, has more direct drive control, and does not produce smoke or particulate emissions
- a household heat pump heats a room quickly, has good temperature control, can also be used for cooling, and does not create moisture like some heating options that rely on thermal fuels, which can lead to health benefits
- industrial technologies such as induction or infra-red heating can take up less physical space, heat objects through more consistently or selectively, and operate with greater flexibility, and more sensitive and accurate control than thermal fuelled technologies.

Using electricity in place of thermal fuels could reduce emissions

Electric technologies typically have a very high end-use efficiency, which means that converting existing thermal processes to electricity can result in some emission savings, even where the electricity is generated by gas or coal (at an energy efficiency of around 35-50%). For example:

- an electric engine can be more than 90% energy efficient, while an internal combustion engine is closer to 30% efficient
- household heat pumps are around 300% energy efficient, while a flued gas heater is closer to 85% energy efficient
- for certain industrial applications, some electric technologies can reach energy efficiencies of over 1000% (mechanical vapour recompression being a specific example).

However, where the electricity can be generated largely by renewable resources, the opportunity for emission savings is substantial.

The Forum has canvassed a number of New Zealand sources, to try and understand the potential emission benefits from the electrification of the vehicle fleet and industrial processes, and from energy management systems. These sources are outlined in Table 2.

Table 2: Sources used to understand the emissions impact of new options for using electricity in New Zealand

SOURCE	ANALYSIS
BusinessNZ Energy Council: New Zealand Energy Scenarios [16]	Modelling that has prepared two different but plausible scenarios of New Zealand's energy future out to 2050, leveraging from global scenarios prepared by the World Energy Council.
Centre for Advanced Engineering Electric Vehicles: Impacts on New Zealand's Electricity System[17]	Consideration of the impacts of plug in electric vehicles on electricity generation and distribution, and carbon emissions.
Concept Consulting Group: Electric cars, solar panels and batteries in New Zealand: – How will they affect greenhouse gas emissions: [18]	Consideration of how widespread uptake of electric cars, solar panels, and batteries in New Zealand could affect emissions.
Electric Power Engineering Centre: Electric Vehicles in New Zealand: From Passenger to Driver? [19]	Review of electric vehicle developments in New Zealand, and the resulting effects of electric vehicle uptake on the environment and health.
MBIE: Internal modelling[20]	Analysis of New Zealand's emissions, and modelling of future emissions.
Imperial College London and Meridian Energy Smart New Zealand Energy Futures: A Feasibility Study[21]	Study of smart grid technology implications and opportunities from a New Zealand electricity system perspective.
Ministry of Transport	Annual statistics of New Zealand's vehicle fleet, and forecasts of the uptake of electric vehicles out to 2030

16 Link to the BEC NZ Energy Scenarios report
17 Link to CAENZ report
18 Link to the Concept report
19 Link to EPECentre Electric Vehicles in New Zealand: From Passenger to Driver report
20 MBIE shared the findings of its internal modelling with the Smart Grid Forum in support this work.
21 Link to the Imperial College London report

SOURCE	ANALYSIS
Vehicle fleet statistics[22] and internal modelling[23]	
Orion: Emerging technology observations[24]	Observations of modelled impacts from extreme scenarios of uptake of solar PV, electric vehicles and batteries for the Orion network.
Royal Society of New Zealand: Transition to a low-carbon economy for New Zealand[25]	Consideration of future technologies and practices that will support emission reductions.
Transpower Internal modelling[26]	Scenario modelling, which has considered the impact of uptake of electric vehicles.

The potential emission savings from electric vehicles could be significant

While acknowledging the differences in focus and approach of the different sources it canvassed, the Forum has identified that:

- **The avoided tailpipe emissions from electric vehicle uptake would be significant.** New Zealand's 3.4 million light passenger and commercial vehicles caused direct emissions of around 9 Mt CO_2-e in 2014; or an average of over 2.5 t CO_2-e each. Each petrol or diesel vehicle that was replaced with an electric vehicle would avoid most of these tailpipe emissions.
- **This would be partially offset by an increase in demand for electricity, which would have indirect emission impacts.** The timing and exact effects are uncertain, as they will depend on rates of electric vehicle uptake, and the particular generation technologies that would meet the increased demand. However, generally speaking:
    - **Electric vehicles may necessitate some increase in thermal generation.** In the short term, the increased load may be absorbed by existing gas-fired generation that is under-utilised. There could also be an increased need for flexible gas-fired generation if electric vehicle charging was uncontrolled, as hydro generation could run out of flexibility to match the variation in load.

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22 Link to vehicle fleet statistics webpage

23 The Ministry of Transport was invited to share its analysis with the Smart Grid Forum, in support of this work.

24 Link to presentation outlining results of Orion's modelling

25 Link to the Royal Society's report

26 Transpower is represented on the Smart Grid Forum, and shared the findings of its internal modelling with the group in support this work.

However, neither of these effects would be large enough to offset the avoided tailpipe emissions.

  - **Wind and geothermal generation is likely to be instrumental in meeting any need for new grid-scale generation**. Wind generation has very low emissions associated with it, and geothermal has a fairly small emissions impact. Therefore, if new grid-scale generation is required to meet demand from electric vehicles, the associated emissions could be quite low, and hence the net-emission reduction from changing from a petrol to electric vehicle could be significant.

- **'Smart charging' would minimise the emissions from generating electricity to charge electric vehicles.** Electric vehicle charging will have a smaller impact on electricity-related emissions if smart grid developments could be used to ensure that it:
  - **is done away from periods of high demand.** Charging at off-peak times means that the energy is less likely to be provided by flexible gas-fired generation.
  - **occurs mainly overnight.** By filling in the overnight 'troughs' in electricity demand, electric vehicles could help to make the overall demand profile flatter. This will encourage more investment in technologies like geothermal and wind generation than if there were no new overnight load, because these technologies need to operate at high rates of utilisation. This means that not only will the electric vehicle load be met by renewables, but some existing daytime demand could also be met by renewables, when it otherwise might have been met by thermal generation.

Because New Zealand can draw on renewable electricity for charging, the net impact of electric vehicles on our emissions would be very positive. In comparison, countries that would rely on coal to meet the new electric vehicle load would see virtually all of the avoided tailpipe emissions offset by the emissions from burning coal.

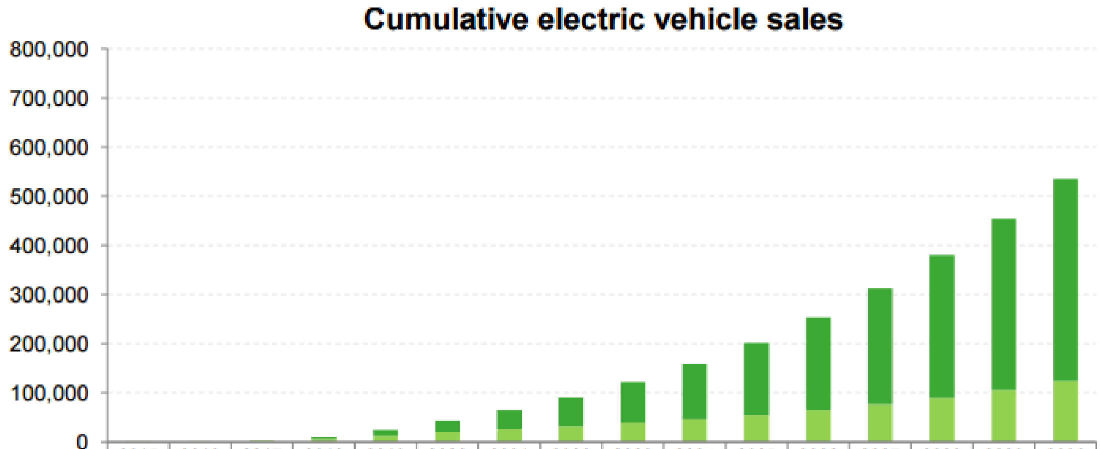
The actual scale of benefit for New Zealand will depend on rates of electric vehicle uptake. This will depend on a number of factors, including, amongst other things:

- the fleet's turnover rate – vehicles typically remain in the fleet for upward of 15 years[27]
- consumers' acceptance of and familiarity with electric vehicle technology
- the availability of electric vehicle models – both new and second hand
- whether consumers choose pure battery electric vehicles, or hybrid electric vehicles that may have lower emission benefits.

[27] See http://www.transport.govt.nz/research/newzealandvehiclefleetstatistics/

The New Zealand Ministry of Transport expects that an increasing number of people will start to choose electric vehicles over petrol or diesel vehicles. At the Forum's request, it shared its analysis of some hypothetical uptake scenarios with the group. One of these hypothetical scenarios is shown in Figure 6.

Figure 6: Ministry of Transport hypothetical cumulative electric vehicle sales



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
New EV sales	444	444	453	4116	11470	23067	38846	58815	83148	112310	147146	188274	236206	290166	348656	410874
Used EV imports	83	408	2158	5833	12633	19883	25883	31883	38633	46133	54633	64758	76508	89820	105633	123945

Source: Ministry of Transport

Conservatively assuming that an average electric vehicle results in forty per cent of the emissions of a petrol vehicle, the approximate emissions reduction from uptake of electric vehicles is shown in Table 3.

Table 3: Indicative emission reductions from electric vehicle uptake

Number of EVs	Emissions reduction (kt CO2-3)	Per cent of total 2013 emissions
50,000	**-100**	**0.1%**
100,000	**-190**	**0.2%**
500,000	**-980**	**1.2%**
1,000,000	**-1,900**	**2.3%**
2,000,000	**-3,900**	**4.8%**

Source: Reproduced from Ministry of Business, Innovation and Employment modelling

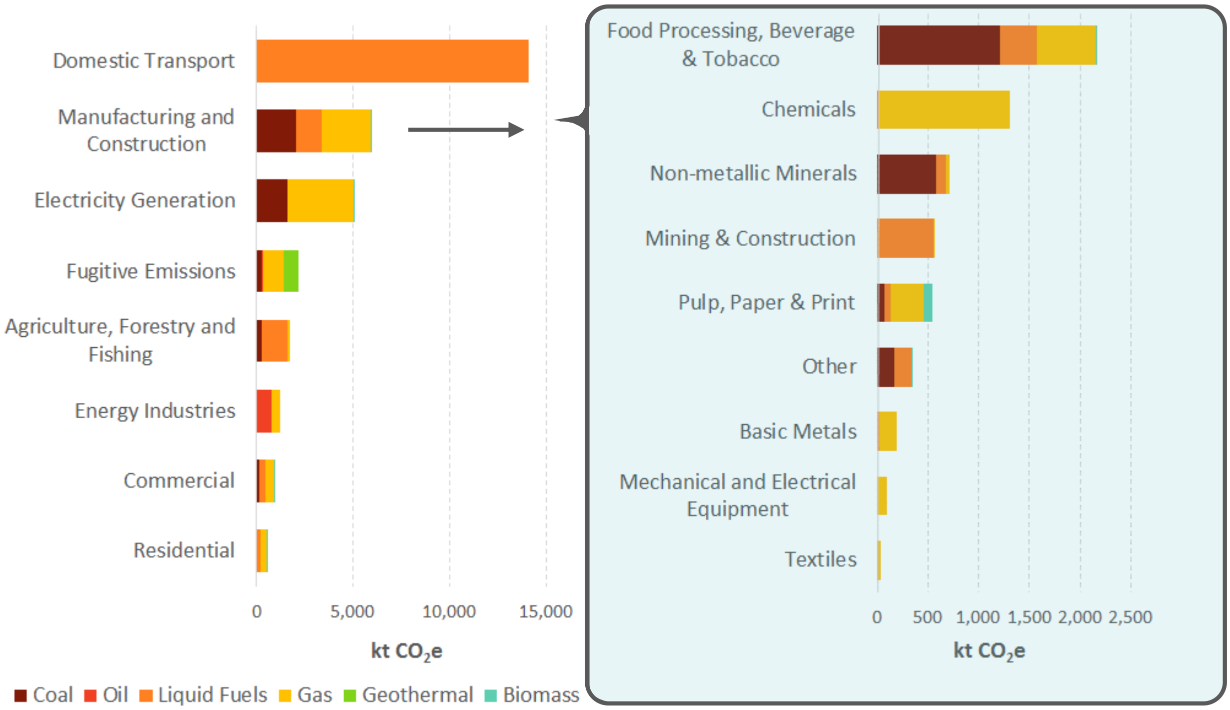
Electric processing technologies could support emission savings

THERE IS SIGNIFICANT *POTENTIAL* FOR EMISSION SAVINGS

The Manufacturing and Construction sector contributed the most to non-transport energy emissions in 2013, at around 6 Mt CO_2e, or around seven per cent of total emissions. A breakdown of this sector is shown in Figure 7.

There is significant potential to reduce the emissions from this sector by supporting a transition away from thermal fuels towards renewable electricity.

Figure 7: Breakdown of 2013 manufacturing emissions by sector and fuel type



Source: Ministry of Business, Innovation and Employment emissions data

Consumers that might provide the largest benefit in terms of reduced emissions include:

- **Those currently using coal**, which produces the most emissions of the thermal fuels, followed by oil and liquid fuels.
- **Those whose consumption would be lower in winter and higher in summer**, so could reduce the seasonal difference in electricity demand, and hence the role of thermal generation. The dairy industry is a specific example of a set of consumers whose load could help smooth these seasonal differences, noting that dairy processing is a dominant source of emissions under “Food Processing, Beverage & Tobacco” in Figure 7.
- **Consumers that contribute a large proportion of emissions**. For these consumers, their individual decision could have a big impact on emissions.

THE LIKELY SAVINGS ARE UNCERTAIN BECAUSE OF VARYING CONSUMER CIRCUMSTANCES

It is challenging to estimate the potential emission savings from consumers changing to electricity from thermal fuels, because:

- Each consumer will value the quality benefits from electricity differently, and realise cost advantages at different times depending on their individual circumstances.
- Any decision to switch to electricity would generally be made when equipment is up for replacement or major maintenance. Equipment for industrial processing usually

has a long life. Seeing a meaningful emissions impact from fuel switching is likely to take time.

- Changing to electricity could be difficult for some consumers – particularly those whose contribution to emissions may be the greatest. This may be influenced by:
    - The cost and availability of substitute technologies. Some processes that currently use thermal fuels might not have a practical electrical equivalent, and the up-front costs might be prohibitively expensive. For example, it may not be practical or affordable to buy electric versions of the very heavy vehicles used for mining and construction.
    - The nature of a consumer's business. Businesses that are involved in the manufacture of commodities compete solely on price, so any decision to switch will be strongly dependent on whether they can save money by doing so. Similarly, a listed company's decision may be more dependent on cost savings than that of a privately owned company.
    - Their openness to change – some electric technologies will be unfamiliar for consumers, and stepping away from the status quo may be perceived as a risk.
    - Their awareness and understanding of the available options. For various reasons, consumers may make decisions based on limited but easily accessible information, rather than full information.
- There are a range of low-emission energy sources that consumers may be able to transition to - including geothermal, biomass and biofuels. In some cases, these may present a better emissions outcome. They may also just present a more desirable option for various reasons. However, each consumer will have different choices open to them, and see different costs and benefits.
- For some applications, switching to electricity might not achieve substantial emission savings. For example:
    - Gas or coal generation might increase if the new electricity load occurs strongly at times of peak demand or during winter, and it cannot be effectively managed through load control or demand response.
    - High uptake of behind-the-meter solar PV uptake could have a net-negative impact on electricity generation emissions if it displaced other grid-scale renewable generation.

Energy management systems could support emission savings through energy efficiency and conservation

In addition to facilitating dynamic demand response, energy management systems can support more efficient use of energy. For example, they could:

- monitor energy consumption and help to identify issues with appliances and opportunities for savings
- ensure appliances operated at the most efficient settings
- ensure lighting and appliances were turned off when not in use.

The Energy Efficiency and Conservation Authority suggests that monitoring and tracking the operation of appliances can save businesses anywhere from 2 to 25 per cent of their electricity costs.[28] While this doesn't necessarily translate into a similar sized emissions benefit, it does indicate the large scale of energy savings that could be achieved if energy management systems were adopted widely by businesses and households. This would in turn lead to an emissions benefit that could be material.

7. NEW OPTIONS FOR TRANSPORTING ELECTRICITY

Smart grid developments could support reduced losses

Smart grid developments open up new options affecting the transportation of electricity.

When electricity is transported through transmission and distribution networks, some of the energy is lost as heat. Transmission and distribution losses increase with distance, and if electricity is delivered through constrained networks. Smart grid developments have the potential to:

- **Reduce the average distance that electricity needs to be transported.** Increased uptake of distributed generation technologies means more electricity will be generated at, or close to where it is needed, reducing the need to transport electricity through long networks.
- **Reduce congestion on networks, to support 'easier' transportation.** A smart grid will allow network operators to install and monitor devices and electronics that can sense conditions on networks, and respond to those conditions in real-time so that they are always operating at high efficiency. For example, it will allow network operators to:
    - have more control over voltages at various levels of their networks, which can reduce congestion and hence minimise losses

[28] According to EECA's website

- install energy storage devices on the edge of networks, and have them discharge to meet demand beyond lines that are under high load, reducing congestion and hence avoiding losses.

Reducing losses reduces the amount of electricity that needs to be generated to meet the same level of demand. If this reduction meant a thermal generator was asked to decrease its output, this could result in emission savings.

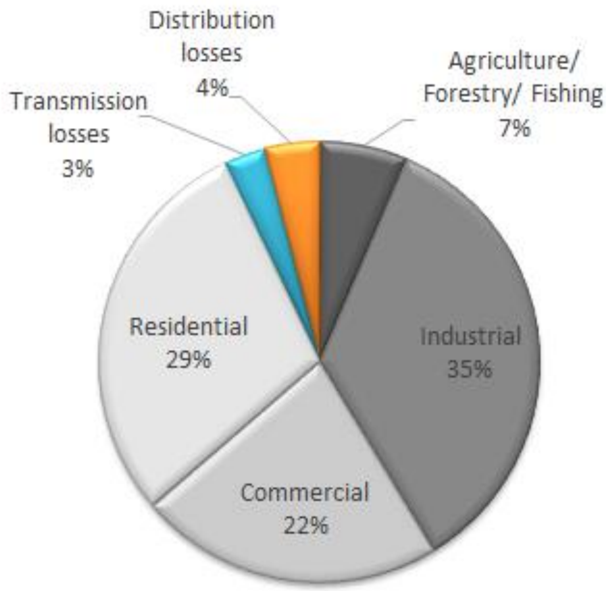
The potential scale of the emission savings is small

Around 7% of all electricity generated in New Zealand is essentially wasted through transmission and distribution losses. This is shown by Figure 8.

However, not all of these losses could be avoided, and those that could will not necessarily make a significant contribution to emission reduction targets, keeping in mind that:

- The widespread uptake of distributed generation technologies, and investment in the devices and electronics that allow for improved network operation will take time.
- Reducing losses will only result in emission savings if it impacts the output of thermal generators. On this point:
  - Reducing congestion is likely to result in some emission savings. This is because networks are generally more constrained at times of high demand, and thermal generators are more likely to be the ones that are asked to scale back their output at these times.

Figure 8: Breakdown of total electricity generation by end-use in 2014



Source: Ministry of Business, Innovation and Employment quarterly electricity data tables

  - Reducing the average distance that electricity is transported is likely to result in fewer emission savings. This is because electricity is more likely to be transported through long networks when demand is relatively low[29], and renewable generation is more likely to be asked to scale back at these times.

- Changes in demand and where it is centred will affect the average distance that electricity is transported, and levels of network congestion. For example, these would increase if the aluminium smelter at Tiwai were to shut down, and/or if Auckland continued to grow in size.
- While it will be practically possible to reduce losses, it will not be possible to avoid them entirely.

Therefore, there may be an opportunity to save emissions through improved use of transmission and distribution networks. However, this opportunity is likely to be very small.

8. ENABLING AND ENHANCING THE CONTRIBUTION FROM SMART GRID DEVELOPMENTS

Existing regulatory and institutional settings broadly support smart grid developments

The Forum identifies two ways to enable and enhance the emission savings that could be supported by smart grid developments. These are:

- ensuring that the prices consumers see appropriately reflect the impacts of their decisions on emissions
- increasing awareness of how engaging with the new options opened up by smart grids can support emission reductions, and reducing 'soft' barriers to change.

In its first year report, the Forum concluded that *"the regulatory and institutional settings in New Zealand are capable of accommodating a consumer-driven adoption of the opportunities and business models that new technologies on the power system offer us as a country."*

In New Zealand, the primary opportunities for emission savings from smart grid developments are from new options for using electricity. Therefore, consumer-driven adoption will be effective in reducing emissions, as long as consumers have the necessary information and incentives to make efficient decisions.

29 At times of lower demand, a greater proportion of the North Island's demand for electricity will be met by South Island hydro generators, so the electricity will be transported a long way. Conversely, when demand is high and 'all hands are on deck', it is more likely that a nearby generator will be operating, so the average distance will generally be smaller.

Furthermore, the metering and monitoring equipment installed through smart grid developments will generate large amounts of data. This data has a key role in enabling the identification of opportunities to reduce emissions through improved energy use.

Consumers require effective price signals

Cost considerations will generally be a dominant factor influencing consumers' decisions to invest in and engage with the new options opened up by smart grids. The cost of emissions therefore needs to be well signalled.

There are two issues that currently reduce the sharpness of these signals for consumers. Government agencies have identified these issues, and are currently considering what they should do about them. These issues are:

- **The effective price of emissions**

  The New Zealand Emissions Trading Scheme (ETS) places a price on emissions that is intended to incentivise people to make investments and decisions that reduce emissions. The Ministry for the Environment is undertaking a review of the ETS and, in November 2015, published a discussion document on potential changes to the arrangements. In that document it said:

  > *"Some participants have recently indicated that the NZ ETS is not affecting their investment decisions, due to current low carbon prices and the effect of the transitional measures. In some cases, these firms could be relying on continued protection from full NZ ETS emissions obligations in the medium-to-long term. Projections indicate that New Zealand's current policy measures, of which the NZ ETS is the main instrument, will have little impact on gross emissions in the future if current settings continue."*

  The Climate Change Minister has indicated that the ETS settings are likely to change, in order to raise the cost of carbon and hence increase the scheme's effectiveness[30]. If and when the effective price of emissions rises, consumer-led reductions in emissions will likely increase along with it – including through engagement with the new options opened up by smart grids.

- **The need for cost-reflective electricity tariffs**

  The Electricity Authority has highlighted that the majority of consumers do not currently receive cost-reflective electricity tariffs. In November 2015 it released a consultation paper: Implications of Evolving Technologies for Pricing of Distribution Services. The paper stated:

[30] As reported by Energy News, 16 March 2016, following the Minister's comments at the Asia Pacific Energy Leaders' Summit.

> *"Distribution prices affect the way consumers invest in and use these evolving technologies. If prices are designed correctly, consumers' decisions will help all New Zealanders to benefit from the advances in technology. However, most distribution prices for residential and small commercial consumers are poorly designed for this purpose.*
>
> *Existing pricing makes it unnecessarily costly to operate electric vehicles and use battery storage systems to smooth electricity consumption, and encourages over-investment in solar panels."*

The Electricity Authority's consideration of distribution pricing will not specifically include price signals in support of emission reductions, as it is outside the scope of its statutory objective. Regardless however, cost-reflective electricity tariffs affect the potential for emission reductions because:

- Passing through the costs of emissions can only provide an effective signal to consumers about the emission-impacts of their decisions if there are no other price distortions clouding that signal.
- It is generally the case that electricity will cost more to supply and transport, at the same times that the emissions associated with electricity are higher (because of greater thermal generation and network congestion). This means that if electricity tariffs are cost-reflective, decisions that consumers make to minimise their electricity costs are also likely to result in lower emissions.

'Soft' barriers to adoption should be minimised

Consumers need to appreciate the emission-saving benefits of engaging with the new options opened up by smart grids. In addition to providing effective price signals, this could be supported through:

- **Increasing awareness and understanding**

  The Forum has already identified the need for improved information for consumers about the new options opened up by smart grids. In its first year report, it recommended that "*The Government establishes an information and advisory service to help consumers understand and compare the opportunities for new smart grid technologies and changing commercial arrangements, ideally using existing channels and agencies (such as the Electricity Authority, ConsumerNZ or EECA)*"

  This should include information about the potential to support emission reductions by engaging with these new options.

- **<u>Reducing the perceived risk of change</u>**

  Some of the new options for using electricity that are opened up by smart grids include novel technologies that consumers may not have a lot of familiarity with, and may perceive as risky. For example:

  - Some consumers may be discouraged from purchasing an electric vehicle because of 'range anxiety' and/or concerns about battery life.
  - Some electric technologies for industrial processing are not currently used by New Zealand companies. There may be concerns about the need for experienced parties to design, install and maintain the equipment. They may also be apprehensive to be a technology-leader, particularly if they place a high value on certainty or are risk-averse.

  An appropriate way to overcome the perception of risk may be to find ways to 'normalise' these technologies. For example, the perceived risk of electric technologies for industrial processing could be reduced by seeking opportunities to operate pilot and demonstration projects. While the initial pilot may require some incentive for the consumers involved, they may act as an example or beacon for others, that can encourage wider adoption of the technology.

  As a specific example, The Energy Efficiency and Conservation Authority has published a case study of a pilot project for ammonia-based refrigeration, undertaken by Active Refrigeration[31], which stated:

  > *"'We'd given a paper at a conference extolling the virtues of high temperature ammonia heat pumps, but we hadn't had the chance to build one. Ashburton Meat Processors gave us that opportunity. We did all the engineering work for free because we wanted to prove this technology will be a game changer.;*
  >
  > *… 'The thermal energy source has changed from Light Fuel Oil (LFO) to a mixture of electricity and LPG. This has reduced the plant's carbon footprint by 42% (690 tonnes), lowering exposure to future emissions trading taxation, and making a good marketing story.'"*

  There may be other similar opportunities to operate pilot programmes that help to demonstrate and normalise electric technologies for consumers.

[31] See https://www.eecabusiness.govt.nz/resources-and-tools/case-studies/active-refrigeration/