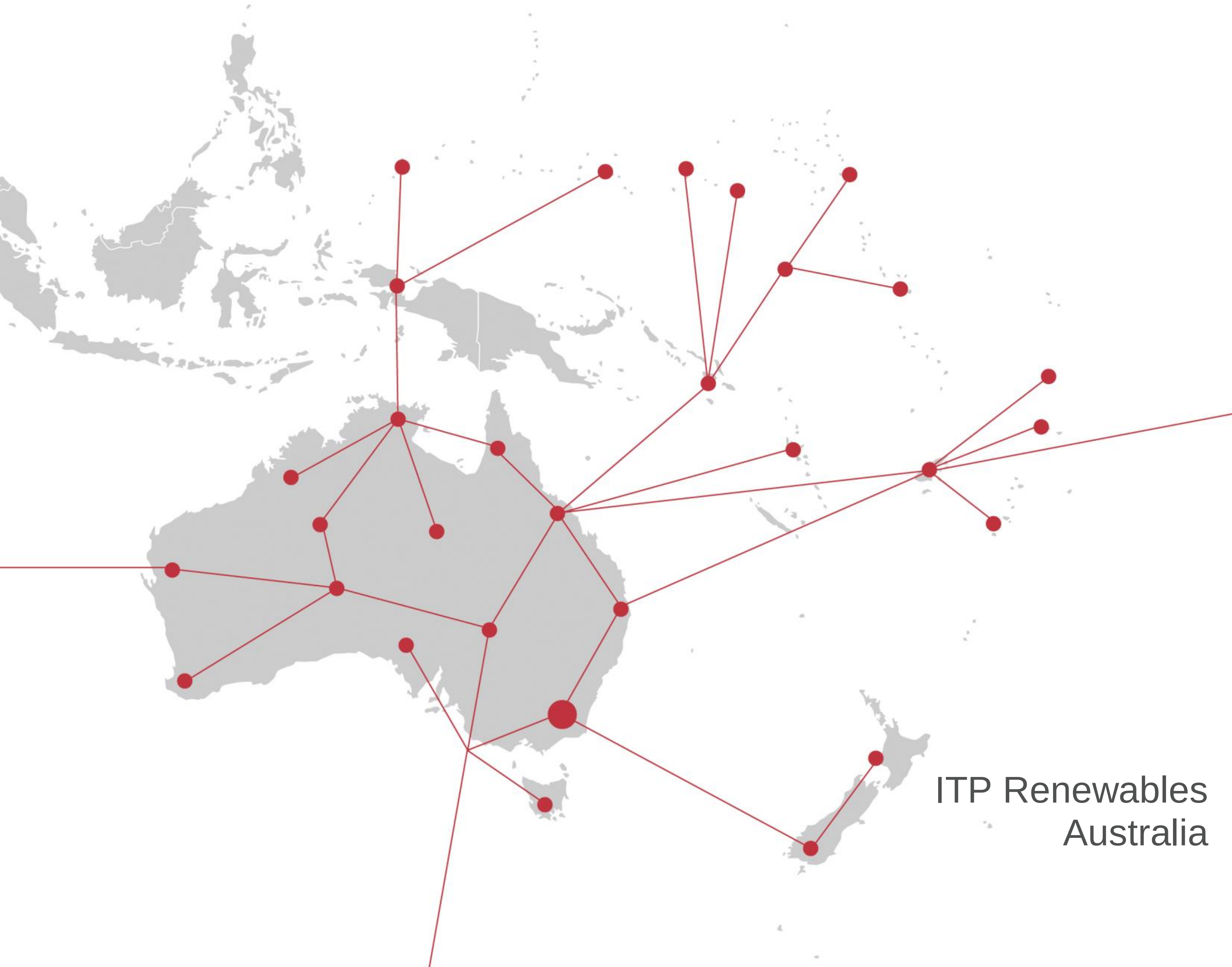
SOLAR PV AND BATTERIES IN NEW ZEALAND – CONSUMER CENTRIC ELECTRICITY

November 2016



ITP Renewables
Australia

About IT Power

The IT Power Group, formed in 1981, is a specialist renewable energy, energy efficiency and carbon markets consulting company. The group has offices and projects throughout the world.

IT Power (Australia) Pty Ltd (ITP) was established in 2003 and has undertaken a wide range of projects, including designing grid-connected renewable power systems, providing advice for government policy, feasibility studies for large, off-grid power systems, developing micro-finance models for community-owned power systems in developing countries and modelling large-scale power systems for industrial use.

The staff at ITP have backgrounds in renewable energy and energy efficiency, research, development and implementation, managing and reviewing government incentive programs, high level policy analysis and research, including carbon markets, engineering design and project management.

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EXECUTIVE SUMMARY

New Zealand households are now enthusiastically adopting new energy technologies – from energy efficient appliances, to household solar photovoltaics (PV) and demand management systems, and more recently, household batteries. This is changing the dynamics of the established electricity system, and while some utilities are taking advantage of the new opportunities, some are opposing them.

These new energy technologies provide a wide variety of benefits to customers, which go beyond simple financial returns, and attempts to prevent or limit their uptake are not only contrary to the original intentions of electrification, but are likely to fail. This report aims to provide a better understanding of what increased uptake of distributed energy (DE) opportunities means for New Zealand, and so enable the development of policies and business models that can maximise the potential benefits.

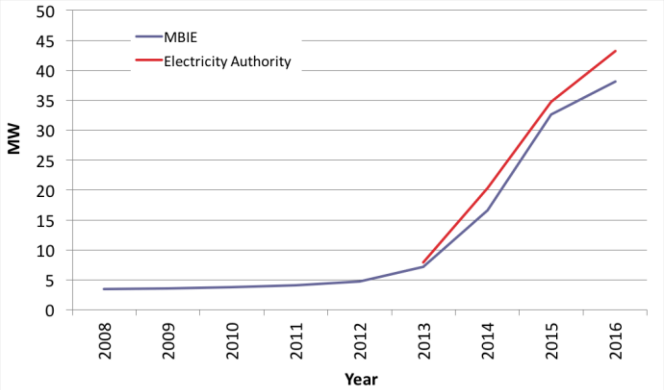


Figure 1 - Solar PV Total Installed Capacity, 2013-16 (MBIE and EA data)

Total installed capacity of solar PV has rapidly increased in the last five years. Installation rates have increased nine-fold in the period 2012 to 2016 (Figure 1). By August 2016 there were 43.25 MW of installed solar PV, with on average, about 1 MW of PV being added each month. Currently, there are over 11,000 PV customers connected to the main grid, generating about 53,000 MWh per year. Most solar PV systems are installed by households (78% of capacity installed in 2016), followed by small and medium enterprises (9%), industrial users (7%) and commercial users (6%). Battery storage is at a relatively early stage of uptake in New Zealand, but progressive Lines and Distribution Businesses have been trialling them, and solar suppliers and installers have installed hundreds of grid-connected battery and PV systems to date, and expect interest to increase in 2017.

Impacts to date

Greenhouse gas reductions

Although New Zealand has around 80% of its electricity provided by renewable energy, PV electricity generally offsets fossil fuel generators because renewable technologies such as hydro, geothermal and wind are used as 'baseload' generators, with fossil fuel generators (coal and gas) generally being used to 'fill the gap' so that demand is met. From 2013 to 2016 the solar PV installed in New Zealand is estimated to have avoided about 4,800 to 29,000 tCO_2-e per year, with a value of around $24,000 in 2013, rising to about $560,000 in 2016 (Figure 2). To provide some context, the average New Zealand household produces about 1 tCO_2-e per year through electricity use.

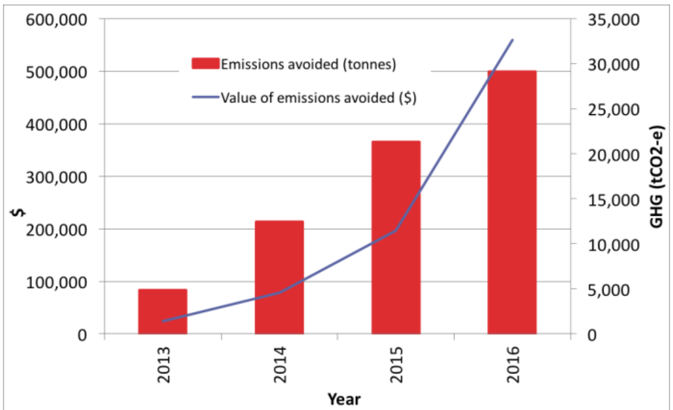


Figure 2 Environment Benefits - GHG Emissions Avoided and Value of Emissions Avoided

Financial impacts

The electricity produced by a PV system is generally used by the household onsite, with any excess exported to the grid. The onsite use reduces the amount of electricity bought from the utility, resulting in savings for the system owner. The household is also paid for the exported electricity, at a lower rate than they pay for onsite use, but this can still make a significant contribution to the financial returns.

On average, during the four years ending 2016, households that have installed solar PV are estimated to have reduced their electricity bills by around $647 per year. The total savings for all households with PV systems are around $1,261,000 in 2013, rising to $7,612,000 in 2016. Solar installers commonly recommend load shifting so that more electricity is used during the middle of the day, and less of the PV electricity is exported, and this improves the household’s financial returns. There are a number of commercially available technologies to automate this.

This is money that would otherwise have been paid to the electricity utilities, which can be divided into generators, Lines and Distribution Businesses and retailers. Of these, the generators and retailers operate in a competitive market, and so facing losses such as these due to competitors is just part of doing business. They are also free to operate within the PV and battery market and so can in fact profit from it.

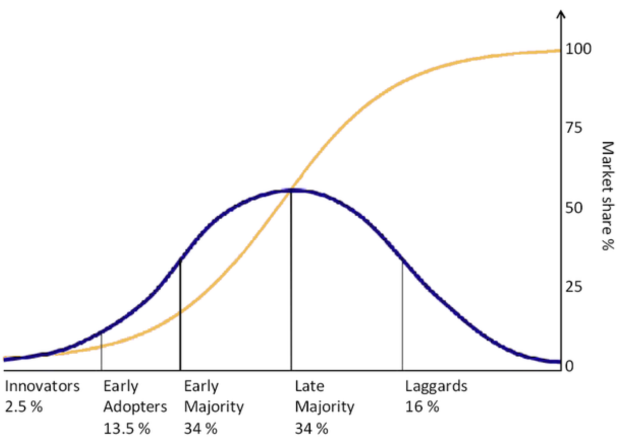
There are two ways that Lines and Distribution Businesses can compensate themselves for lower revenue because of PV. Firstly, like generators and retailers, they can also operate within the PV and battery market, although limitations are placed on them to ensure they don’t extract excessive profits. Examples of Lines and Distribution Businesses currently taking advantage of the emerging PV opportunities in New Zealand are provided in the Discussion.

Secondly, they may be able to simply increase their tariffs, depending on whether they operate under what is known as a default price-quality path. Here, to ensure that we don’t underestimate any negative impacts from PV, we have assumed that all Lines and Distribution Businesses simply increase their tariffs, and so the uptake of household PV by 2016 could therefore result in tariffs increasing by about 0.05%, which would increase the average customer’s bill by about $1 per year. It is worth noting that at current levels of solar PV uptake, the average reduction in income to Lines and Distribution Businesses from avoided network charges is less than 0.2% of their regulated revenue.

In addition, there are many reasons that a household’s electricity use can decrease, with the installation of PV being only one. Others include solar water heaters, insulation or other energy efficiency measures, or even someone moving out of the house. In fact, according to the MBIE data, average household electricity use has been declining since 2009, well before PV uptake would have had a noticeable effect.

Projected Impacts of PV in NZ

To date, the uptake of solar PV in New Zealand has been driven by the innovators – see Figure. However, as has occurred in other countries, this is followed by uptake by the early adopters, then the early majority etc. This process applies not only to PV but also to integrated distributed energy systems that include PV, battery storage, energy efficiency and DSM, all of which can be managed via mobile apps. This wider market is very important to understand because it highlights



the fact that public interest in PV systems cannot be assessed in isolation.

In the current market, batteries tend to be installed by the owners of existing PV systems because: (i) PV is cheaper than batteries so the 'first movers' install PV first, (ii) although batteries on their own may result in a payback that is too long, when combined with PV the payback is reasonable, and (iii) exported PV electricity is often paid less than the retail rate and so batteries are used to minimise PV exports.

Scenario descriptions

The Ministry of Business, Innovation & Employment (MBIE) has recently completed their Electricity Demand and Generation Scenarios that model New Zealand's electricity sector out to 2050. We have used their 'Mixed Renewables' and 'Disruptive scenario' projections that model different levels of PV and battery uptake. The MBIE present the Mixed Renewables scenario as their 'middle of the road' scenario. Then, to illustrate the potential impacts of solar PV and batteries, even at very high levels of penetration, we use the Disruptive scenario.

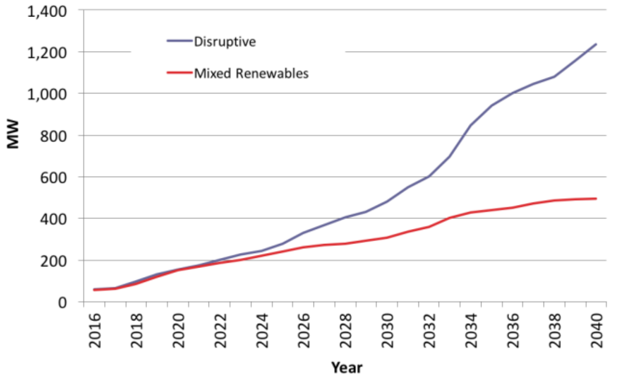


Figure 4 MW Solar Installed - Mixed Renewables and Disruptive Scenarios

The Mixed Renewables scenario assumes only 6.4% of households install PV by 2040, and that there is negligible battery uptake. The Disruptive scenario assumes high levels of both solar PV and battery uptake by 2040, with 3.3% of households having PV only, and 14.6% having both PV and batteries, bringing the total to 17.9%. Consistent with increased modernisation of consumer choice, the Disruptive scenario also assumes higher uptake of electric vehicles and therefore higher electricity use.

The amount of solar installed out to 2025 is similar in both scenarios, but after this time, both solar and batteries increase at a greater rate – see Figure 4. The levels of uptake found in the Disruptive scenario are unlikely to have any technical impacts on the grid, even by 2040, as the levels reached are less than in many Australian states already, and the clear majority of installations are expected to have batteries, which can be used to deal with any potential grid impacts. In fact, PV could help reduce the impact of daytime charging of electric vehicles.

Scenario impacts

Greenhouse gas reductions

Figure 5 shows the amount of emissions avoided by PV out to 2040 for the **Mixed Renewables** scenario, in total and for residential systems, all based on MBIE data. By 2040, PV results in an estimated 320,000 tCO_2-e being avoided each year, with a value in today's money of over $24 million. Between 2016 and 2040 an estimated total of over 4.3 million tCO_2-e would be avoided, with a value of $260 million.

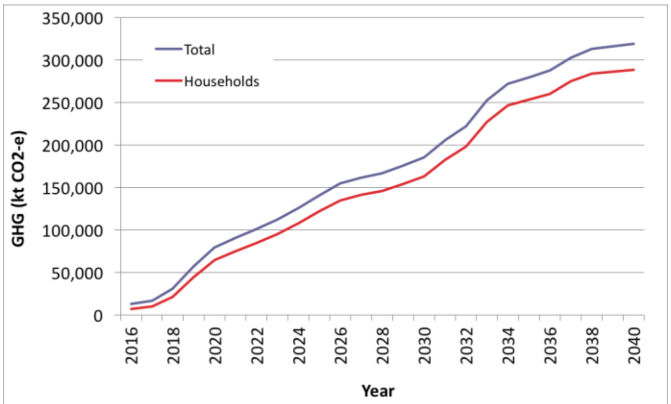


Figure 5 GHG Emissions Avoided by PV - Mixed Renewables scenario

In the **Disruptive scenario**, by 2030, the MBIE assume that all new household PV systems have batteries, which means the PV electricity doesn't 'eat down' into the renewable energy generation during the day, and is still displacing the OCGT generation, even in the evenings. Figure 6 shows the amount of emissions avoided by PV out to 2040, in total and for residential systems. By 2040, PV results in an estimated 815,000 tCO_2-e being avoided each year, with a value in today's money of almost $62 million. Between 2016 and 2040 an estimated total of over 8 million tCO_2-e would have been avoided, with a value of over $500 million.

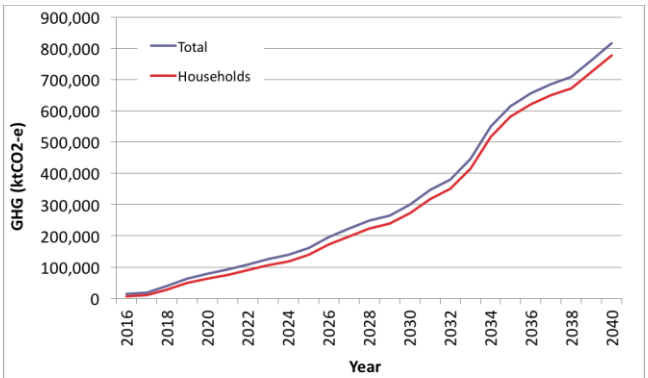


Figure 6 GHG Emissions Avoided by PV - Disruptive scenario

Financial impacts

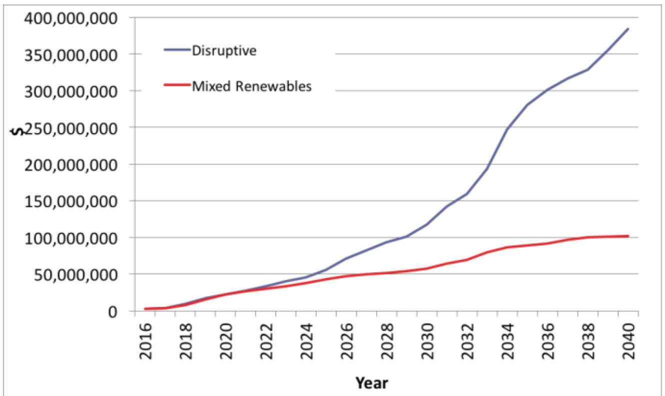


Figure 7 Value Obtained via electricity savings by Households with PV systems

The total financial value obtained via electricity savings by households that own PV systems is shown in Figure 7. The yearly values by 2040 are $102 million (Mixed Renewables) and $383 million (Disruptive), with the cumulative value being $1.35 billion and $3.4 billion respectively. This is money that stays in the communities where these households live and so drives local economic activity and local employment. Of course, at the time of installation, the household has to pay for the PV system, but between 20-25% of the cost is attributed to the installer's wages, which would typically also be spent locally.

PV Increases House Prices

Solar PV has been shown to add value to house prices. Two independent surveys in the US found that the average house price increase was slightly greater than the cost of the PV system. Although we have been unable to find equivalent analyses for New Zealand, we expect solar PV to similarly add value.

Impacts on Other Customers

In the **Disruptive** scenario, by 2040, the decreased payments to Lines and Distribution Businesses driven by uptake of household PV could result in tariffs increasing by up to 3.4%, which could increase the average customer's annual bill by around $72 – or about $1.40/week. However, this does not take into account the financial benefits that PV and batteries can provide for other households via longer-term reductions in peak demand, network size and GHG emissions.

The 490 MW reduction due to PV and batteries identified by MBIE for 2040 translates to a benefit of about $8.50 per year per household (all households, not just those with PV/batteries). Similarly, the greenhouse reduction benefit, if allocated to all households, equals about $27.50 per household per year. Of course, distributed PV and batteries can provide a range of other benefits, including lower wholesale prices because of the merit order effect on generator dispatch, reduced line losses, fuel price hedging benefits, increased self-reliance and autonomy, resilience during extreme weather events and local employment.

Employment impacts

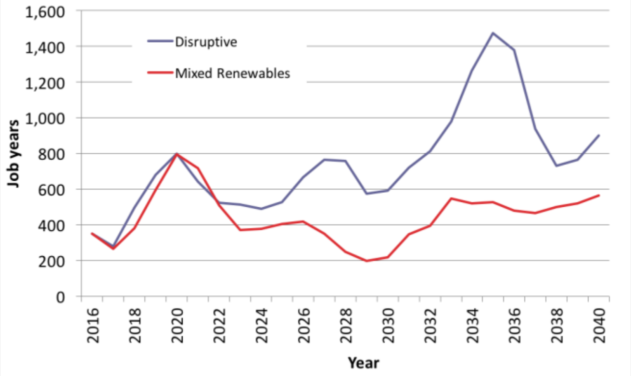


Figure 8 Direct Employment in the Solar PV Industry for the two Scenarios

The direct employment in PV installation businesses can be measured in job years/MW PV installed (so for example 10 job years/MW would mean 10 people employed to install 1 MW PV over 1 year). Figure 8 shows estimates of the direct employment for the Mixed Renewables and Disruptive scenarios. The variability from year to year occurs because the amount of PV installed each year in the MBIE scenarios varies significantly. The key messages to take from this are that under both scenarios employment increases significantly over the next 5 years, then under the Mixed Renewables scenario declines just as rapidly, staying low for an extended period. Under the Disruptive scenario, the decline from 2020 is not so great, and employment is maintained at about 600 job years, before more than doubling through to 2035. The decrease from then occurs as the amount of new PV decreases, however in reality, it is likely that these peaks and troughs would not be so marked.

Discussion

As residential grid electricity prices have been steadily increasing in real terms, PV has provided thousands of households with an alternative. These 'innovators' have already been responsible for the avoidance of about 68,000 tCO_2-e GHGs in New Zealand, with an estimated value of $860,000.

As is occurring in other parts of the world, PV is just the first step being taken down the path of increased modernisation of consumer energy choice – where integrated distributed energy systems also include battery storage, energy efficiency, and remote control of household appliances, all managed via mobile apps. In a recent New Zealand survey, just under a quarter of households were 'very' interested in having a smart home, with another 35% being 'somewhat' interested, bringing the total to just over 60%.

As PV uptake increases, and battery uptake follows, households will contribute to reducing evening peaks as well as further reducing GHG emissions. Based on MBIE data, the PV installed by households will avoid an estimated 777,000 tCO_2-e per year by 2040, with an annual value of almost $59 million – avoiding an estimated total of 7.4 million tCO_2-e with a value of $468 million between now and then. These households will also be helping New Zealand to meet its renewable energy target.

PV alone may help to reduce evening peaks because installers commonly provide detailed advice on moving demand into the middle of the day in order to minimise exports, and power diverters can be used to automatically move demand from peak times. There are a variety of other benefits potentially provided by PV and batteries, and a review of 16 different recent studies found that individuals and businesses that decide to 'go solar' generally deliver greater benefits to the grid and society than they receive.

While some Lines and Distribution Businesses in New Zealand have been taking advantage of the transition to distributed generation through the use of PV, some have been proposing there should be a 'solar tax' applied to people with PV systems. Apart from the various benefits that PV provides to other customers outlined in this report, the other cross subsidies that already exist, and the fact that solar households generally use more electricity than non-solar households and so make higher payments to networks despite their PV systems, if this approach is to be applied fairly, it implies that households who reduce their electricity use through energy efficiency improvements (such as insulation, efficient lighting or low-flow shower heads), or a move to gas, should also be taxed.

In summary, the focus should now be on how to make the most of the coming opportunities driven by increased customer choice, and in enabling the existing electricity industry to transition to the 'new normal', rather than by selectively penalising specific new technologies.

What Lines and Distribution Businesses can do

It is clear that many in the broader electricity industry are aware of these changes and the opportunities they present. In the 2016 Annual New Zealand Electricity Survey of 500 electricity industry participants, of which only 20% were Lines and Distribution Businesses, 'Embracing new technology such as solar PV and battery storage in a way which will benefit consumers' was seen as 'the best opportunity for the electricity sector', and more than half agreed with 'The industry should be providing more choice and flexibility, including innovative products and pricing, which fit customers' changing needs'.

Vector provides an excellent example of an EDB who is proactively pursuing the opportunities that distributed energy presents. It has offered customers trial battery programs, as well as free solar and battery storage systems, all in order to better understand and benefit from integration of these technologies. Vector now provides solar PV systems that incorporate the Sun Genie, an online and app-based dashboard that allows households to monitor and manage their home energy system. They have recently partnered with Tesla batteries (including the use of grid-scale batteries to reduce substation demand) and also with Power Ledger to deploy their blockchain energy trading platform (TransActive Grid), that will allow customers to buy and sell electricity from their PV without using a retailer.

A number of **electricity retailers** in New Zealand are moving to providing households with more control over their electricity use – ranging from in-home displays, online tools and apps (Electric Kiwi, Meridian Energy), through to integration with solar installers (Mercury Energy, Genesis Energy), and full cost disclosure with access to spot market-based pricing (Flick Energy).

Internationally, there is increasing recognition that electricity industries need to transform themselves. Examples are presented in the main report to illustrate what is already happening with electricity utilities around the world, and to show that regulators are getting serious about the need for regulatory change. Interestingly, in Australia, something of a battle has developed between electricity retailers and network companies – as both want to be able to participate in the 'behind the meter' distributed energy market. All the major retailers, and many of the smaller ones, are now offering some form of package that not only involves the installation of solar and batteries, but includes a web-based smart energy platform. The network operators also want to move into this market, but unlike their New Zealand counterparts, are generally unable to do so because of the regulated returns they receive via their monopoly status.

Maximising social benefits

Integrated distributed energy systems that include PV, batteries, and the array of energy efficiency options available present a significant opportunity to provide broad-reaching social benefits. Leasing options and solar PPAs can help overcome the capital cost barrier. Community-owned systems are proving popular for renters or people who have little solar access. Government housing is a prime opportunity for lower income households to reduce their costs, and of course, the interest in PV presents the perfect opportunity to also implement energy efficiency and load management options that not only provide direct benefits to households, but can benefit utilities and New Zealand as a whole.

Recommendations

1. There is a need for government/regulator leadership to ensure that customers have full and fair access to the variety of new options that will reduce their bills, enhance their lifestyles and enable personal contributions to renewable energy and GHG reductions targets. Initiatives such as the NY Reforming the Energy Vision should be reviewed for their suitability for New Zealand.
2. That the work currently underway on the regulated party transaction regime takes into consideration what is happening to network operators in Australia, where they are struggling for revenue because they are unable to operate in the competitive market. It is clear that network businesses are no longer pure monopolies, since they face competition from the range of distributed energy options, and their regulatory environment should reflect this.
3. That government and the PV industry ensure that all the appropriate standards and training are in place so that, even with significant amounts of new entrants, the quality of installations remains high. This applies not only to PV but also to batteries and fully integrated distributed energy systems. Governments should also ensure rights around solar access – because this is now an integral part of investment decisions.
4. That specific strategies are put in place to maximise social benefits through leasing options, solar PPAs, community-owned solar, Government housing, and integration of energy efficiency and demand-side management with solar uptake.

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INTRODUCTION

New Zealand households, like millions around the world, are enthusiastically adopting distributed energy (DE) technologies – from energy efficient appliances, to household solar photovoltaics (PV) and demand management systems. They are also keenly following the development of new energy storage technologies and electric vehicles. The rapid uptake of these DE technologies is changing the dynamics of established electricity systems worldwide.

Although an increasing number of utilities around the world are taking advantage of the opportunities that DE provides, and altering their business models accordingly, in areas where PV is reasonably new, the incumbent electricity sector, some regulators and to an extent government, may initially seek to limit the uptake of PV.

Their arguments are based on the premise that maintaining the structure and functions of the established electricity system is in the best interests of the country as a whole. PV is therefore seen as risking the viability of past investments, posing threats to electricity pricing policies and reducing system reliability.

The Customer Perspective

Like digital cameras, laptops, mobile phones and even the private motorcar a century ago, customers are attracted to technologies which give them more control over their activities. DE is providing this for electricity customers and, as energy systems become increasingly electrified, this interest is intensifying. Electronic control systems that can be managed via mobile apps add to the attraction for the new generation of customers. The established electricity system was designed and installed with the social benefits of universal access to electricity firmly in mind. This should remain the focus, in particular, understanding the customer perspective and adapting the electricity system so that it can readily integrate the range of new technologies emerging. As with previous waves of new technology, attempts to prevent or limit uptake of the more customised solutions now available through DE are not only contrary to the original intentions of electrification, but are likely to fail.

From a customer perspective, DE in general and PV in particular, attract customers for a number of reasons, some with direct financial benefits, others less readily quantified. These include:

- The right of a consumer to choice in the selection of their basic and lifestyle services.
- More awareness and control over electricity use and costs through self generation and the use of a range of ‘smart devices’, including energy management through controllable appliances (air conditioning, water heating, washing machine, lighting, security), electric vehicles, PV and batteries, all of which can be remotely controlled and monitored through phone apps.
- Reduced ongoing electricity bills, whether or not the overall life cycle cost is lower. This is particularly attractive to customers on fixed incomes or in jurisdictions where electricity

costs have risen significantly in recent years, or are forecast to do so. There are also financial benefits through increases in home resale value.

- Personal and visible contribution to greenhouse gas reduction and wider environmental benefits – even when grid electricity is predominantly renewable, the need for supplementary fossil fuel use may be reduced. PV on rooftops may also be perceived to have lower environmental impacts than other types of renewable energy.
- The attraction of being a “Prosumer” and sharing surplus generation with others in the community. There is also interest in net energy neutral homes, with smart supply/demand controls adding new opportunities to households previously attracted to low energy buildings. The disappointment of low buy back rates, combined with solar taxes, causes greater resentment and distrust of electricity utilities.
- Self-reliance and increased autonomy in an age where customers may feel they are losing control over many aspects of their lives. There is also change in attitude across generations – whereas older people wanted public services and didn’t want to be involved, the younger generation are more used to online purchasing, rapid feedback, and access to cost and other data, and the increased control that provides.
- The visible benefits of new local businesses and local jobs, as well as new opportunities for community projects and programs

This report aims to provide a better understanding of what increased uptake of DE opportunities means for New Zealand, and so enable the development of policies and business models that can maximise these benefits.

It firstly describes the current state of play with PV and distributed battery storage in New Zealand, including the associated financial impacts and reductions in greenhouse gas (GHG) emissions. It then uses two of the Ministry of Business, Innovation & Employment (MBIE) scenarios to assess the potential financial, GHG and employment impacts of higher uptake of PV and battery storage. Finally, it discusses the opportunities that distributed energy provides, and illustrates what the Lines and Distribution Businesses and regulators can do to maximise DE uptake, with a focus on maximising social benefits.

DISTRIBUTED PV IN NZ – CURRENT UPTAKE & IMPACTS

Total installed capacity of solar PV has rapidly increased in the last five years. Installation rates have increased nine-fold in the period 2012 to 2016 (Figure 1). Prior to this, only small numbers of PV systems were installed.[1] By August 2016 there was 43.25 MW of installed solar PV, with on average, about 1 MW of PV being added each month. Figure 2 shows larger systems over 10 kW represent around 10% of systems installed.

[1] The MBIE source shows historic data from 2008 to 2014 and forecast results thereafter, with 2016 data prorated by ITP to end of August 2016. Electricity Authority data is built off a live system which is subject to change with registry updates and 2016 data is as at 31 August 2016.

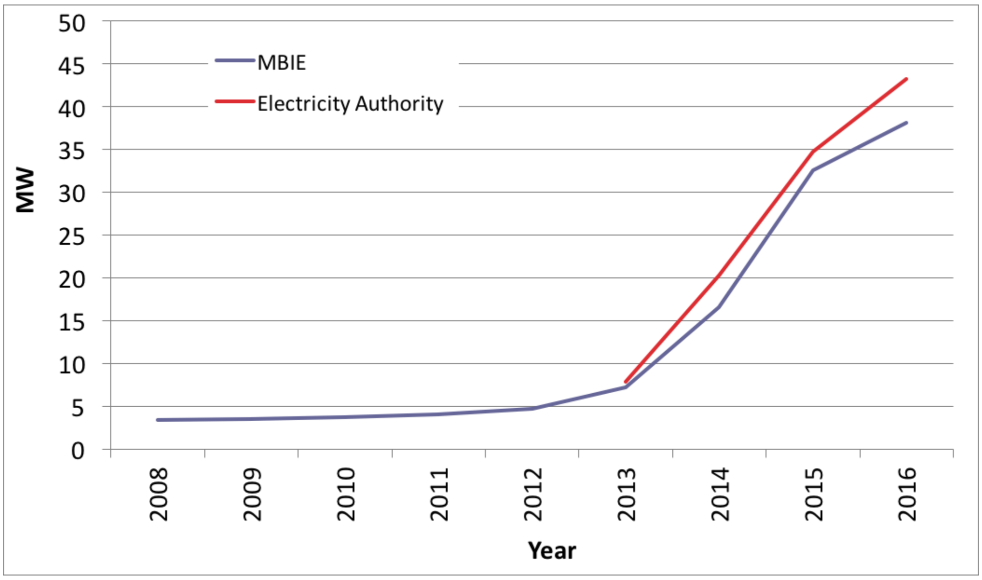

Figure 1 Solar PV Total Installed Capacity, 2013-16 (MBIE and EA data)

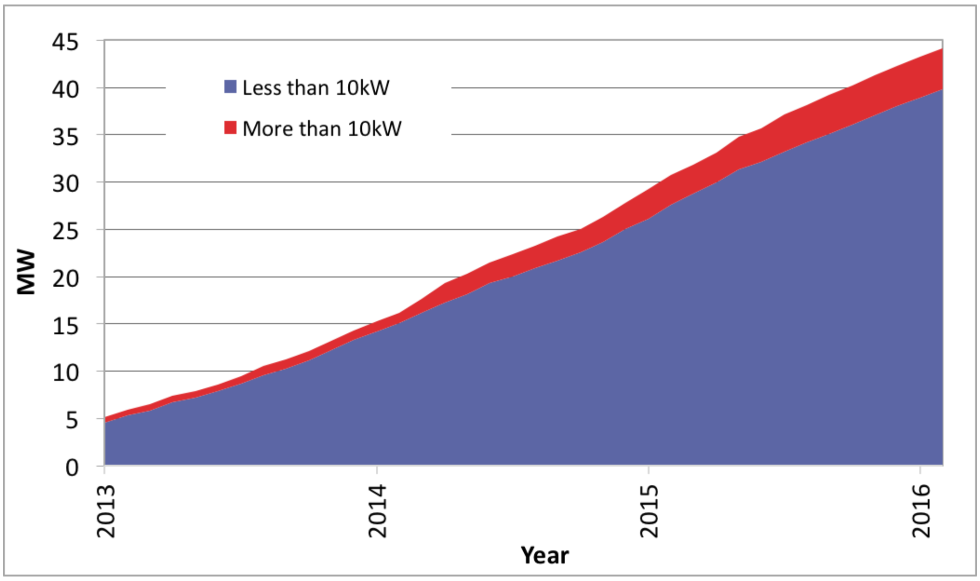

Figure 2 Solar PV Installations by System Size, Less than 10kW and More than 10 kW

Table I shows there has been a corresponding rapid increase in the number of PV customers connected and the amount of electricity generated from PV systems. Currently, there are over 11,000 PV customers connected, generating about 53,000 MWh per year. Average system sizes, for household through to commercial and industrial, have fluctuated around just under 4kW in the last four years. The average system size for residential solar installations is 3.5 kW. The Average

System Cost for 2016 is based on SEANZ member generic survey data for 2014 and 2016 and SEANZ data for 2016 (in real terms and today's prices).[2]

Table I Current PV Statistics (EA data)

	2013	2014	2015	2016
PV Generated (MWh)	9,718	24,938	42,621	53,039
PV customers connected	2,119	5,087	8,914	11,217
Installed Capacity (MW)	7.92	20.33	34.75	43.25
Average System Size (kW)	3.74	4.00	3.90	3.86
Average System Cost ($/kW) incl GST	–	–	–	3,150

Figure 3 shows that most solar PV systems are installed by households (78% of capacity installed in 2016), followed by small and medium enterprises (9%), industrial users (7%) and commercial users (6%). The relative proportion of uptake by these different types of customers has remained unchanged in the four-year period as at 31 August 2016.

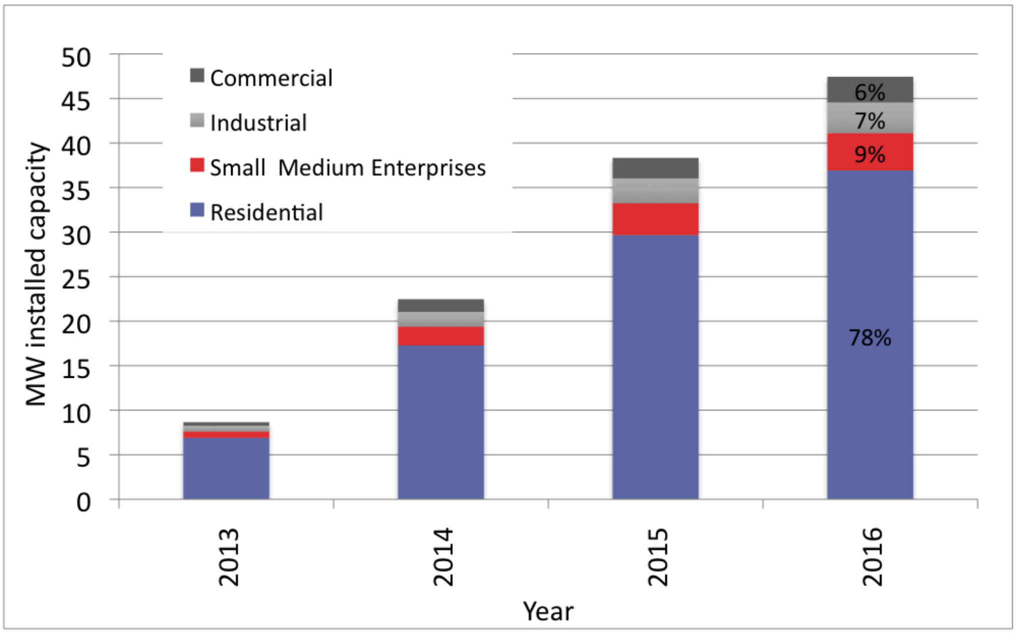

Figure 3 Share of Solar PV Installed Capacity, By Customer Type

[2] These PV system costs are based on actual sales by SEANZ members and are below other published prices, which are typically sourced from retail pricing of tier 1 suppliers.

The amount of PV installed per person in New Zealand is relatively low by international standards at 9.2 watts per capita (in comparison, Australia has about 190 watts of solar PV per person).[3] Rates of installation are higher in regional centres than in urban areas. Figure 4 shows that installed watts per capita in urban centres such as Auckland, Wellington and Christchurch range between 5.27 to 11.5 watts per capita. Figure 5 shows rates are over 20 watts per capita in regional centres of Northland, Nelson, Tasman and Marlborough. Marlborough in particular has the highest per capita rates of solar PV installed in New Zealand, at over 30 watts per capita.

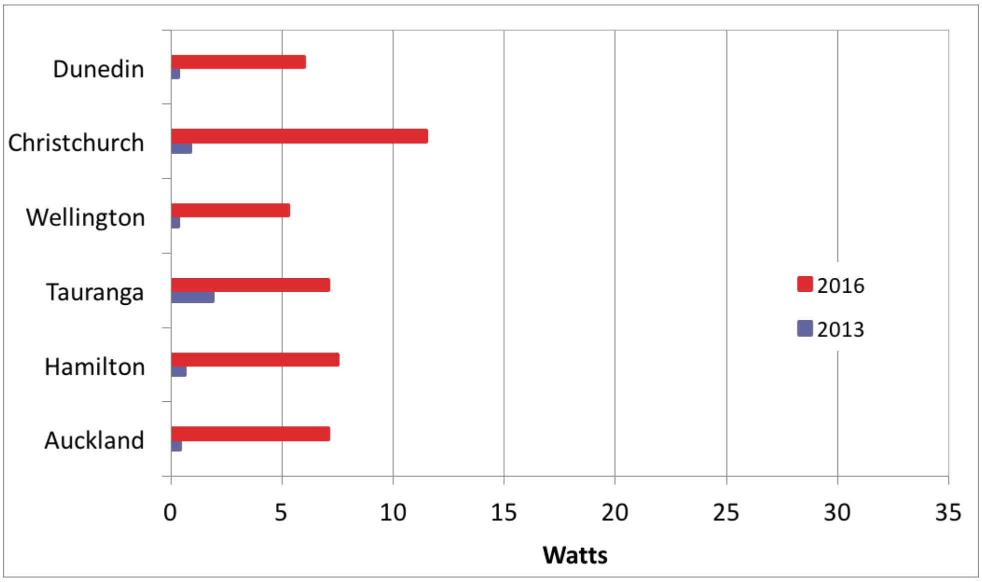

Figure 4 Installed PV Watts per Capita in Urban Centres 2013 and 2016

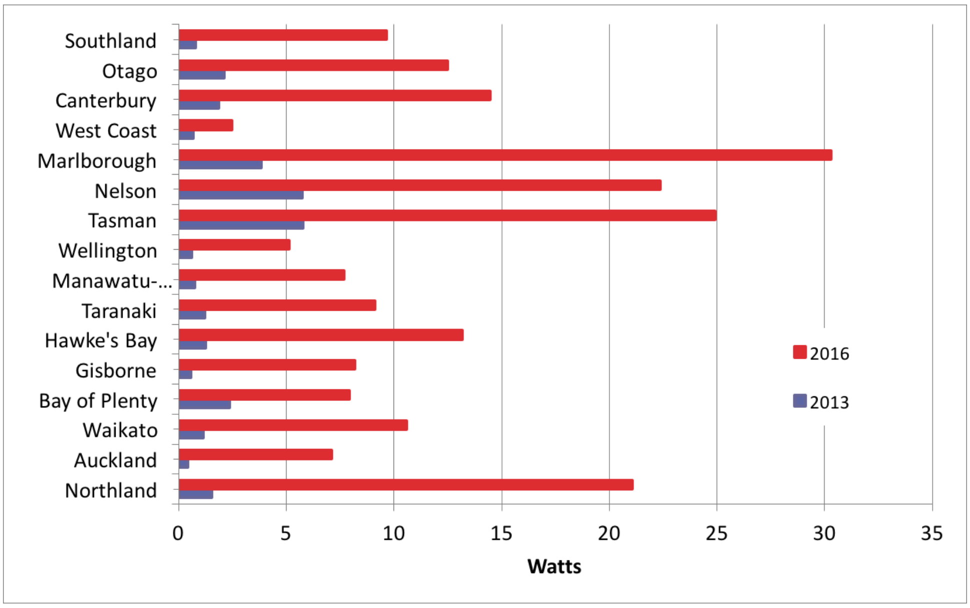

Figure 5 Installed PV Watts per Capita in Different Regions 2013 and 2016

[3] Based on data from the Australian PV Institute and Australian Bureau of Statistics, as at 30 June 2016.

Battery storage is at a relatively early stage of uptake in New Zealand. Enphase Energy, a US developer of micro-inverters, announced the launch of its battery systems to the Australia and New Zealand markets in early 2016 with reportedly high interest from customers. Around 300 Vector PV and storage solutions using Sunverge technology (11.65 kWh storage with 6kW PV) have been deployed into the Vector distribution network in Auckland as part of a behind-the-meter trial for residential and commercial customers.[4] Solarcity supply the Panasonic battery with PV systems under a 'solar energy as service' offering and it is believed that many other solar suppliers and installers have installed hundreds of grid-connected battery and PV systems to date, and expect interest to increase in 2017. It is also understood the grid-assisted market, an emerging sector, has dozens of batteries and systems installed.

Impacts to date

Greenhouse gas impacts

New Zealand has around 80% of its electricity provided by renewable energy, mainly hydro, and so the amount of greenhouse gas emissions from electricity is quite low. For example, the emissions intensity of NZ electricity is about 0.13 tonnes CO_2-e/MWh, whereas in Australia it is about 0.82 tCO_2-e/MWh.[5] This means that when technologies such as PV generate electricity in New Zealand, and so avoid generation from the main grid, their GHG benefit is lower than in many other countries.

However, it is also important to consider the type of generator that PV is offsetting. The NZ electricity system operates using renewable technologies such as hydro, geothermal and wind as 'baseload' generators, with fossil fuel generators (coal and gas) generally being used to 'fill the gap' so that demand is met. Although hydro can be displaced by PV, this just frees up hydro reserves that are used at a later date, displacing fossil fuel generators. This means that PV electricity generally offsets the coal and gas-fired generators, which have a higher emissions intensity. The type of gas-fired generators most likely to be offset by PV are called OCGT,[6] and new entrant plant of this type have an emission intensity of around 0.54 tCO_2-e/MWh.[7]

From 2013 to 2016 the solar PV installed in New Zealand is estimated to have avoided about 4,800 to 29,000 tCO_2-e per year, with a value of around $24,000 in 2013, rising to about $560,000 in 2016 (Figure 6).[8] To provide some context, the average New Zealand household produces about 1 tCO_2-e per year through electricity use.

[4] Presentation by Phil Keough 2015, Sunverge to Australian Energy Storage Conference, June 3.

[5] From http://greenmarkets.com.au/resources/review-of-the-nem-2015

[6] Open Cycle Gas Turbine

[7] ACIL Allen, 2016, 'Emissions Factors: Assumptions Update', for the Australian Energy Market Operator by ACIL Allen Consulting, May 2016.

[8] At a carbon price of $5 per tonne of CO_2-e in 2013 and using average spot prices for 2014, 2015 and 2016 ($6.25/t$CO_2$-e, $9.25/t$CO_2$-e and $19.25/t$CO_2$-e).

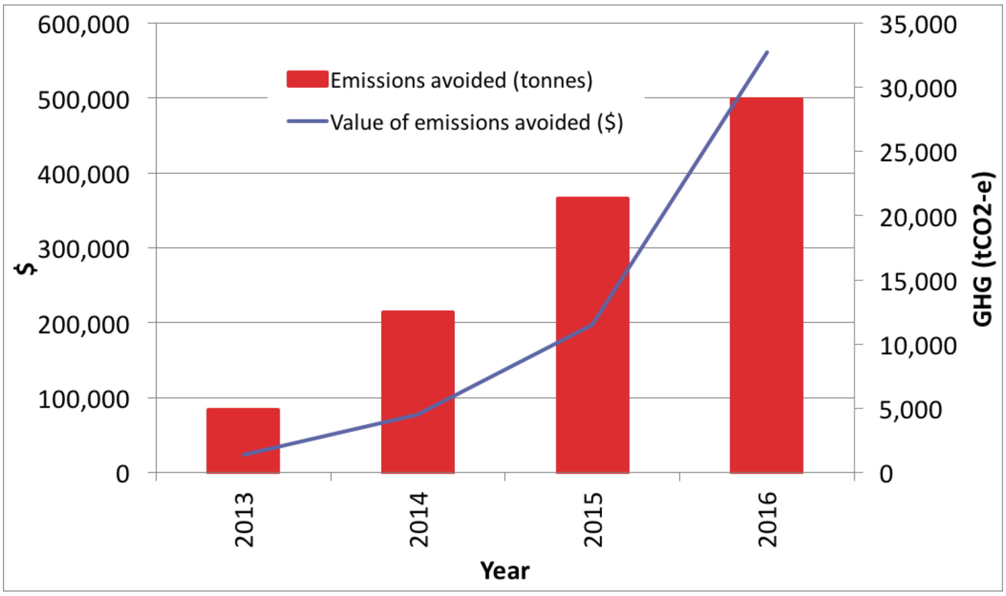

Figure 6 GHG Emissions Avoided and Value of Emissions Avoided

Financial impacts

The electricity produced by a PV system is generally used by the household onsite, with any excess exported to the grid. The onsite use reduces the amount of electricity bought from the utility, resulting in savings for the system owner. The household is also paid for the exported electricity, at a lower rate than they pay for onsite use, but this can still make a significant contribution to the financial returns.

To calculate the value to the household of an average PV system we have used the average retail tariffs provided through the MBIE Quarterly Retail Sales Survey (QRSS) for 2013 to 2016 (March, 2016).[9] The MBIE QRSS also separates out the Lines and Distribution Business's tariff component, which allows us to isolate the impacts on the Lines and Distribution Businesses. To calculate the value of exported electricity we used 9c/kWh, as was used by the MBIE for their scenario analysis, as discussed below.

The amount of PV electricity used onsite depends on the size of the system, its orientation (whether it faces true north), the amount of sunshine at any particular time, and the household's load profile (the lower the use in the middle of the day, the less is used onsite). The MBIE scenarios assume PV systems are 3kW. According to the MBIE QRSS, the average household uses just under 7,300 kWh per year. We expect that, for a household with an average load

[9] The MBIE Quarterly Retail Sales Survey (QRSS) is used to collect information on the total value of sales, the total volume of electricity sold, and the number of connections. The residential electricity cost per unit (the per kWh retail tariff) is derived by dividing the dollar value of residential electricity sales by the number of kilowatt-hours (kWh) sold to residential customers. It includes any after-discount costs which reflect actual uptake of prompt payment discounts, dual fuel discounts, and incentive discounts for attracting or retaining a customer.

pattern, a 3kW PV system would export about 55% of the PV electricity on average through the year.

Therefore, on average, during the four years ending 2016, households that have installed solar PV are estimated to have reduced their electricity bills by around $647 per year, which includes $182 per year for electricity exported to the grid (Figure 7). The total savings for all households with PV systems are around $1,261,000 in 2013, rising to $7,612,000 in 2016. These values are based on MBIE and Energy Authority data for real systems, which include some that may not face true north or may have some shading, and so the value obtained is lower than can be achieved with a well positioned system. The financial outcomes for a particular household are of course also dependent on their circumstances. If they are on a higher electricity tariff then the savings will be greater. Similarly, if they use more electricity during the day, and so export less of the PV electricity, the savings will also be greater. As discussed below, solar installers commonly recommend load shifting in this way, and there are a number of commercially available technologies to automate this.

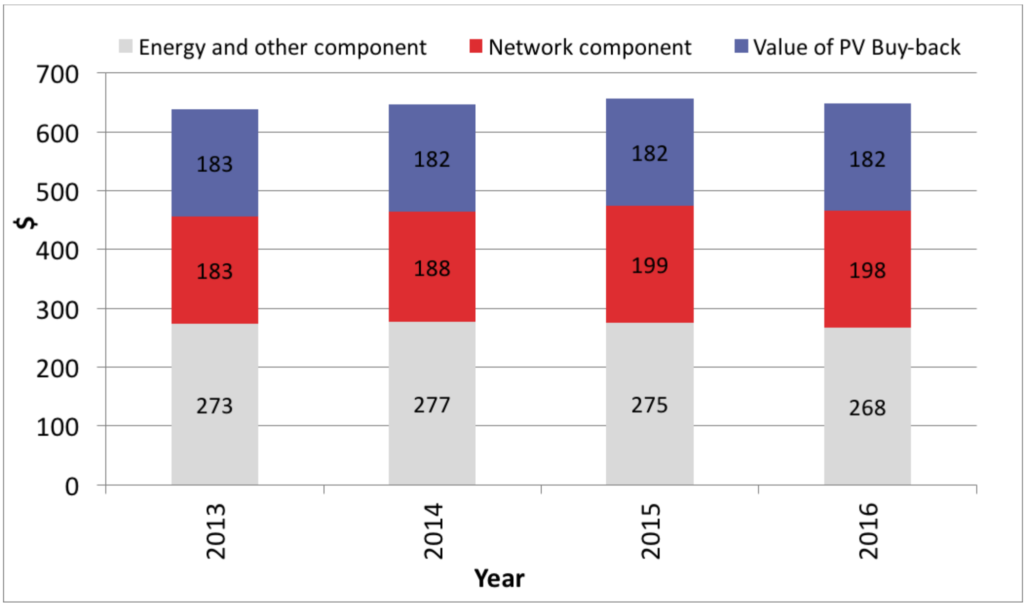

Figure 7 Average Savings for each Household from Installing Solar PV

This is money that would otherwise have been paid to the electricity utilities. Utilities can be divided into generators, Lines and Distribution Businesses and retailers. Of these three, the generators and retailers operate in a competitive market, and so facing losses such as these due to competitors is just part of doing business. They are also free to operate within the PV and battery market and so can in fact profit from it.

The Lines and Distribution Businesses are treated differently because they are regulated monopolies. The historical reason for this is that Lines and Distribution Businesses were seen as providing an essential service that was best provided by a monopoly – because duplication of the poles and wires would be a waste of resources and so competition could not be relied on to control prices.

There are two ways that Lines and Distribution Businesses can compensate themselves for lower payments from households with PV. Firstly, like generators and retailers, they could also operate within the PV and battery market, but only in a restricted way. Limitations are placed on them through the regulated party transaction regime, which aims to ensure that activities outside their normal 'poles and wires' operations, such as the use of solar PV or batteries, cannot be manipulated in a way that allows them to extract excessive profits. This is different to Australia, where the network operators are not allowed to operate outside their normal 'poles and wires' activities at all, and so can't use participation in the PV/battery market to compensate themselves for lost revenue. Examples of Lines and Distribution Businesses currently taking advantage of the emerging DE opportunities in New Zealand are given in the Discussion.

Secondly, they may be able to simply increase their tariffs. Of the 29 Lines and Distribution Businesses, 12 can simply increase their tariffs, but another 17 operate under what is known as a default price-quality path, which effectively limits how much they can increase tariffs. The Commerce Commission is now proposing that, as has occurred for the network operators in Australia, the Lines and Distribution Businesses should transition across to a revenue cap, which would mean they could increase tariffs to compensate themselves for lost revenue – and vice versa if electricity use increases.

Here, to ensure that we don't underestimate any negative impacts from PV, we have assumed that all Lines and Distribution Businesses simply increase their tariffs, and so the uptake of household PV by 2016 could therefore result in tariffs increasing by about 0.05%, which would increase the average customer's annual bill by about 98c.[10]

It is also worth noting that at current levels of solar PV uptake, the reduction in income to Lines and Distribution Businesses from avoided network charges is insignificant relative to total revenues. In 2016, this was around $2.3 million. The maximum expected revenues set by the Commerce Commission for Lines and Distribution Businesses subject to default price-quality regulation was $1.16 billion in 2016,[11] and so the amount lost due to PV represents about 0.2% of this.

In addition, there are many reasons that a household's electricity use can decrease, with the installation of PV being only one. Others include solar water heaters, insulation or other energy efficiency measures, or even someone moving out of the house. In fact, according to the MBIE data, average household electricity use has been declining since 2009, well before PV uptake would have had a noticeable effect.

[10] There are many other influences on the final tariffs, and this 0.05% increase ignores any of these other effects.

[11] Commerce Commission NZ, Default price-quality paths for electricity distributors from 1 April 2015 to 31 March 2020. This is a conservative estimate as it does not include revenues of a further 13 EDBs which are not subject to electricity default price-quality path regulation by the Commerce Commission.

PROJECTED IMPACTS OF PV IN NZ

This section describes the scenarios used for the following projections and impact assessments. To date, the uptake of solar PV in New Zealand has been driven by the innovators – see Figure 8, which shows the Rogers Technology Adoption Curve. However, as has occurred in other countries, this is followed by uptake by the early adopters, then the early majority etc. As discussed in the Introduction, there are many different reasons that people are attracted to PV. Although financial considerations are relevant, new technologies are often adopted even though they may not be a good financial investment at the time (PV systems installed to date have a payback time of about 15 years).

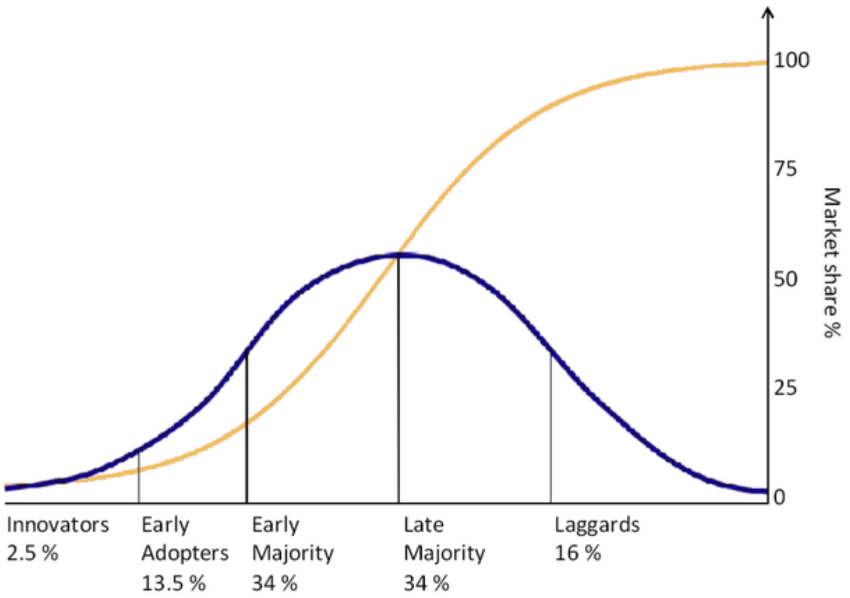

Figure 8 Rogers Technology Adoption Curve: for adoption of new technologies such as solar PV and batteries[12]

These benefits apply not just to PV systems but to integrated distributed energy systems that include PV, battery storage, energy efficiency and DSM, all managed via mobile apps. This wider market is very important to understand because it highlights the fact that public interest in PV systems cannot be assessed in isolation.

Although financial considerations may not be the predominant driver for innovators and early adopters, the natural progression of adoption of these technologies is of course affected by financial considerations, with the cheapest generally being adopted first, followed by the more

[12] From http://www.ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption/

expensive options.[13] This means that, although in theory households could install batteries without PV systems, batteries tend to be installed by the owners of existing PV systems because: (i) PV is cheaper than batteries so the 'first movers' install PV first, (ii) although batteries on their own may result in a payback that is too long, when combined with PV the payback is reasonable, and (iii) exported PV electricity is often paid less than the retail rate and so batteries are used to minimise PV exports. A very good example of this is in NSW, Australia, where the 60c/kWh feed-in tariff (FiT) is due to end in Dec 2016. PV systems installed under this FiT were often only 1 to 1.5kW, and so many households are already moving to install larger PV systems, combined with batteries to minimise exports.

Scenario descriptions

The MBIE has recently completed their Electricity Demand and Generation Scenarios that model New Zealand's electricity sector out to 2050.[14] They use a number of complex interlinked models to assess the impact of a number of different possible scenarios. They incorporate the effects of:

- technology costs (for existing and emerging generation)
- resource availability and cost
- responses to climate change
- the size and structure of the economy
- the future of heavy industry in New Zealand
- the size and structure of the population
- the price of electricity compared to alternative energy sources
- energy efficiency and demand management
- the uptake of new technologies such as electric vehicles, PV and batteries.

The latest report models five different scenarios. We have used their 'Mixed Renewables' and 'Disruptive scenario' projections that model different levels of PV and battery uptake. The MBIE present the Mixed Renewables scenario as their 'middle of the road' scenario. It reflects moderate GDP and population growth, and current views on technology cost and expected fuel and carbon prices. We use this as our baseline scenario. Then, to illustrate the potential impacts of solar PV and batteries, even at very high levels of penetration, we use the Disruptive scenario. We also highlight and discuss some of the impacts of the Mixed Renewables scenario compared to the current day.

The Mixed Renewables scenario assumes only 6.4% of households install PV by 2040, and that there is negligible battery uptake. The Disruptive scenario assumes high levels of both solar PV and battery uptake by 2040, with 3.3% of households having PV only, and 14.6% having both PV and batteries, bringing the total to 17.9% - see Table II. Consistent with increased modernisation of consumer choice, the Disruptive scenario also assumes higher uptake of electric vehicles and therefore higher electricity use. In both scenarios, where PV systems are installed, they are

[13] Adoption of energy efficiency could be argued to be an exception to this, with a range of non-price barriers restricting uptake, despite it most often being the cheapest option available to reduce costs and GHG emissions.

[14] MBIE, 2016, 'Electricity demand and generation scenarios', Ministry of Business, Innovation and Employment, New Zealand Government, March 2016.

assumed to be 3kW, and where batteries are installed, they are assumed to have a capacity of 6.4kWh.

Table II Comparison of 'Mixed Renewables' and 'Disruptive' scenarios[15]

	Mixed Renewables	Disruptive
Households with PV	6.4%	3.3%
Households with PV + batteries	0%	14.6%
Residential MW PV	484	1,225
Total MW PV	495	1,236
Total electricity demand (GWh)	51,474	53,982
Annual peak demand (MW)	7,685	7,282

We believe the actual level of uptake of PV is likely to be higher than in the Mixed Renewables scenario. Current rates of installation (about 11.5MW/year) would result in about 314MW PV by 2040. With the projected declines in PV prices and increases in electricity prices, the uptake of PV is more likely to increase and approach the levels in the Disruptive scenario. This would mirror what has happened in other parts of the world.

The amount of solar installed out to 2025 is similar in both scenarios, with the Disruptive scenario increasing at a greater rate from this time – see Figure 9. It is around this time that the number of solar systems that include batteries starts to become significant in the Disruptive scenario – see Figure 10.

The levels of uptake found in the Mixed Renewables scenario would not have any technical impacts on the grid, even by 2040, as less than 7% of households would have PV.[16] Even in the Disruptive scenario, only 18.3% of households have PV by 2040, which is less than October 2016 levels in the Australian states of Qld (30.3% of households), SA (29.4%) and WA (23.5%).[17] PV installations only reach 10% by 2033 in the Disruptive scenario, by which time the clear majority of installations are expected to have batteries, which can be used to deal with potential impacts such as reverse power flow and voltage rise (which generally only occur above penetration rates greater than 30% anyway). By flattening the residential load profile, batteries can also increase utilisation of the network. It is in fact possible that PV could help reduce the impact of day-time charging of electric vehicles (which could otherwise cause under-voltage issues).

[15] Based on MBIE, 2016, 'Electricity demand and generation scenarios', Ministry of Business, Innovation and Employment, New Zealand Government, March 2016

[16] Watson, J.D., Watson, N.R., Santos-Martin, D., Wood, A.R., Lemon, S. and Miller, A.J.V., 2016, 'Impact of solar photovoltaics on the low-voltage distribution network in New Zealand', *IET Generation, Transmission & Distribution*, 10(1), p1-9.

[17] http://pv-map.apvi.org.au/historical#4/-26.67/134.12

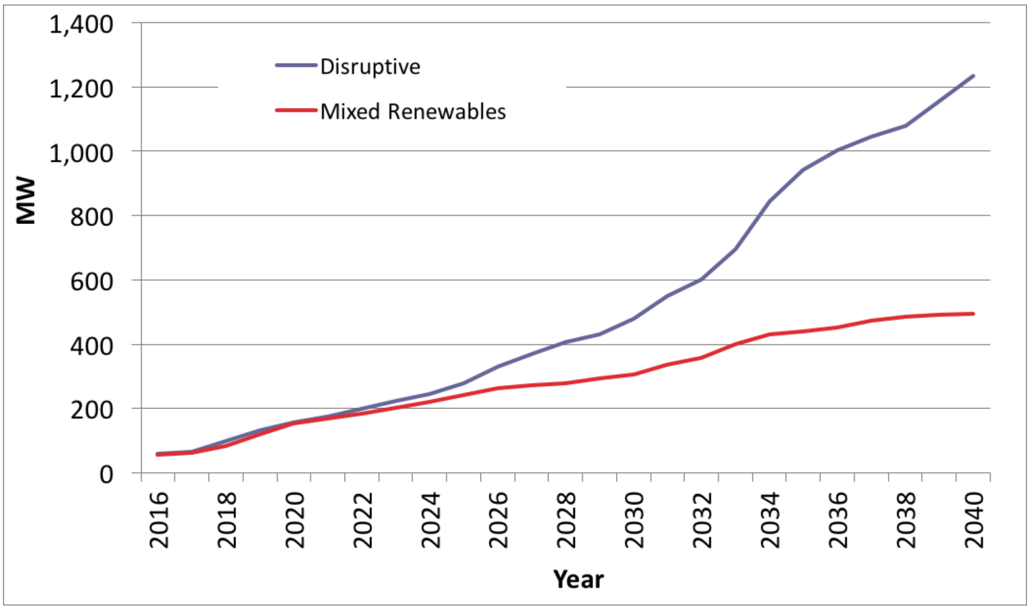

Figure 9 MW Solar Installed Under the Mixed Renewables and Disruptive Scenarios

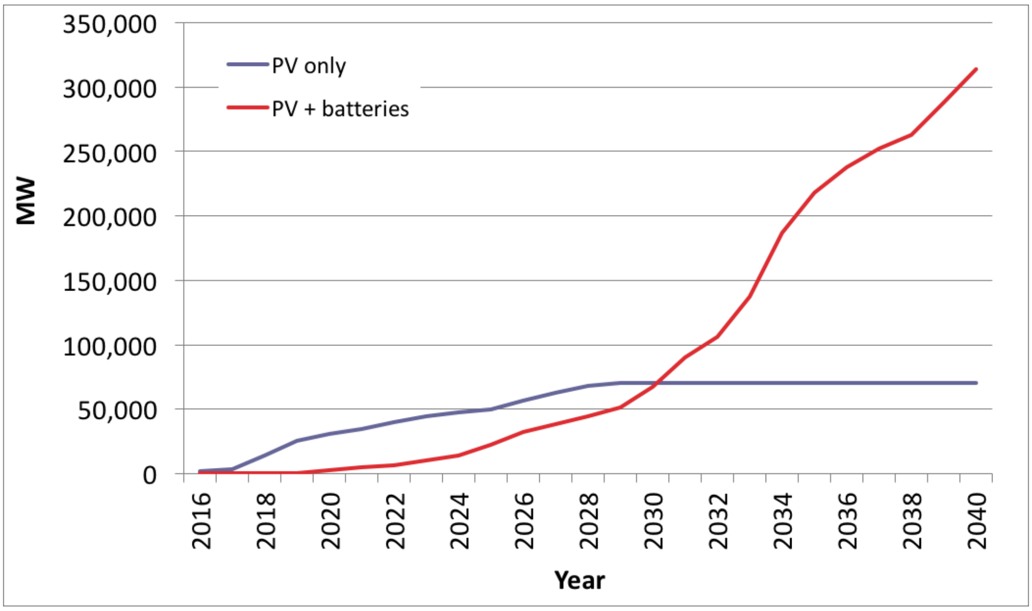

Figure 10 Solar and Solar/battery Installations Under the Disruptive Scenario

Scenario impacts

Greenhouse gas impacts

In the **Mixed Renewables** scenario, which is the MBIE's 'middle of the road' scenario, the level of PV uptake is quite low. By 2040, solar electricity makes up only a small proportion of the total (1.2%), and only 3.54% of residential use. The total capacity of PV installed is only about 6.4% of the grid's peak demand. In both the Mixed Renewables and Disruptive scenarios, OCGTs are still operating in 2040, and in fact new OCGTs are built. With this level of PV uptake, it is most likely that PV will be offsetting OCGT generation, and so we assume an average offset emissions intensity of 0.5 tCO_2-e/MWh.[18]

Figure 11 shows the amount of emissions avoided by PV out to 2040, in total and for residential systems, all based on MBIE data. Figure 12 shows the financial value of these avoided emissions.[19] It can be seen that, by 2040, PV results in an estimated 320,000 tCO_2-e being avoided each year, with a value in today's money of over $24 million. Between 2016 and 2040 an estimated total of over 4.3 million tCO_2-e would be avoided, with a value of $260 million. The PV installed by households would avoid 288,000 tCO_2-e per year, with an annual value of over $22 million – avoiding a total of 3.9 million tCO_2-e with a value of over $230 million by 2040.

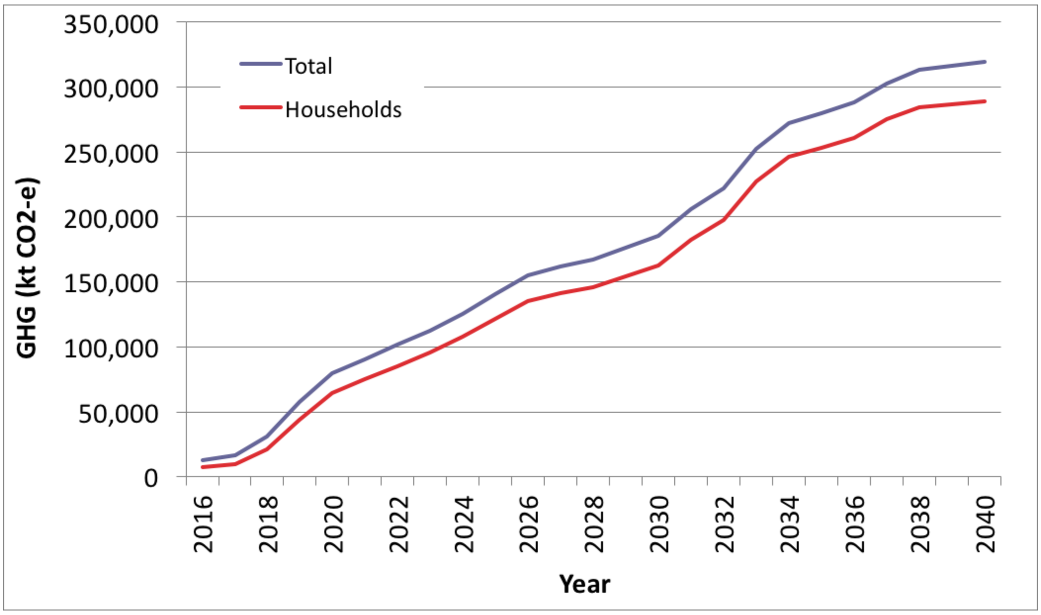

Figure 11 GHG Emissions Avoided by PV – Mixed Renewables scenario

[18] This is slightly lower than 0.54 tCO_2-e/MWh cited above because we allow for new OCGT generators being more efficient.

[19] For all our analysis we use the Mixed Renewables scenario values for pricing of greenhouse gas emissions. These are given in real 2014 dollars. In the Disruptive scenario the values are much higher, but we use the Mixed Renewables values to be conservative. Use of the Disruptive scenario values would result in the value provided by PV being much greater.

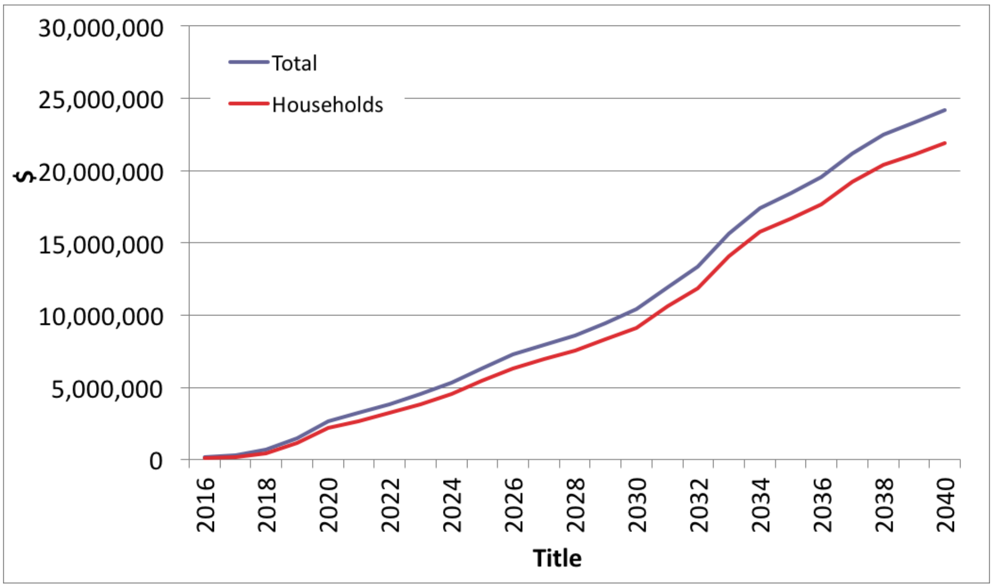

Figure 12 Value of GHG Emissions Avoided by PV - Mixed Renewables scenario

In the **Disruptive scenario**, solar electricity makes up a greater proportion of the total (3%), and 9.6% of residential use. Although the total capacity of PV installed is a greater proportion of the grid's peak demand (17% by 2040), as shown above, from around 2020, households start installing batteries along with their PV systems. By 2030, the MBIE assume that all new household PV systems have batteries, which means that a proportion of the PV generation is used to charge the batteries and so doesn't 'eat down' into the renewable energy generation during the day, and so the remainder is still displacing the OCGT generation. The solar/battery systems then discharge in the evenings, which according to the MBIE, means that "Less peaking plant [OCGT] is required in the Disruptive scenario because household batteries help to shift demand from peak periods".[20] In fact, "solar and battery systems reduce the evening peaks by around 490 MW in 2040 and 800 MW in 2050".[21]

Figure 13 shows the amount of emissions avoided by PV out to 2040, in total and for residential systems. Figure 14 shows the financial value of these avoided emissions. It can be seen that, by 2040, PV results in an estimated 815,000 tCO_2-e being avoided each year, with a value in today's money of almost $62 million. Between 2016 and 2040 an estimated total of over 8 million tCO_2-e would have been avoided, with a value of over $500 million. The PV installed by households would avoid 777,000 tCO_2-e per year by 2040, with an annual value of almost $59 million – avoiding a total of 7.4 million tCO_2-e and saving $468 million.

[20] From page 15, MBIE, 2016, 'Electricity demand and generation scenarios', Ministry of Business, Innovation and Employment, New Zealand Government, March 2016

[21] Below what they would have been otherwise. From page 10, MBIE, 2016, 'Electricity demand and generation scenarios', Ministry of Business, Innovation and Employment, New Zealand Government, March 2016

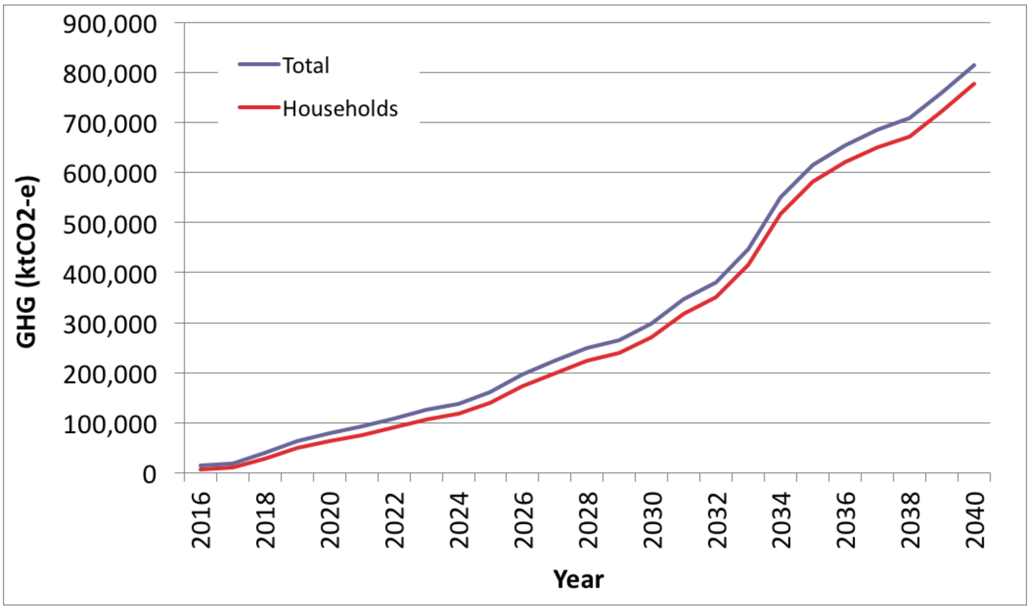

Figure 13 GHG Emissions Avoided by PV – Disruptive scenario

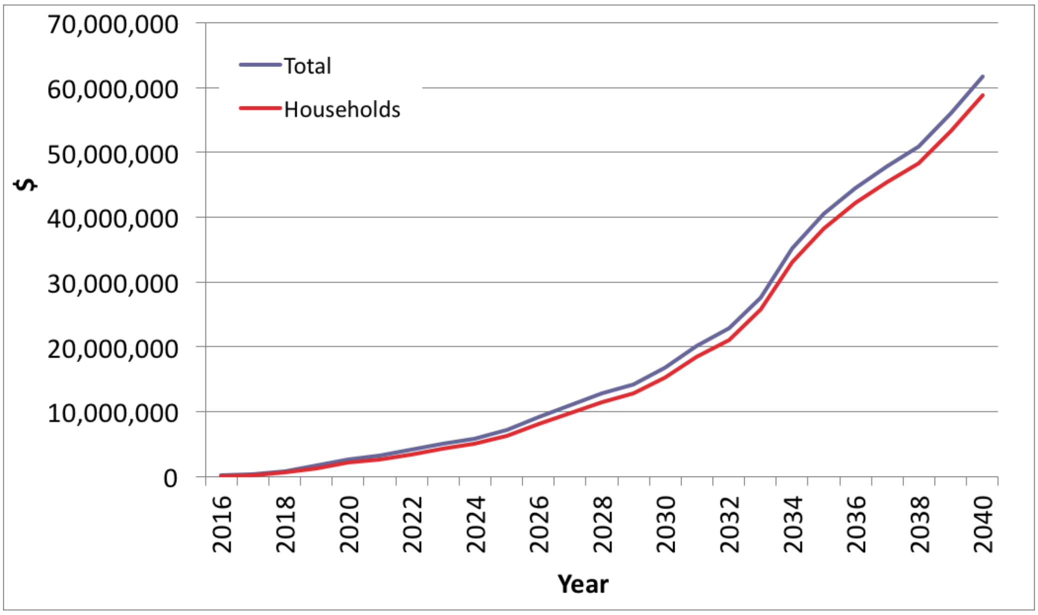

Figure 14 Value of GHG Emissions Avoided by PV - Disruptive scenario

There can be significant variation in emissions intensity between different OCGT generators. A recent study of existing Australian OCGT plant ranged from 0.4 tCO_2-e/MWh to 1.4 tCO_2-e/MWh, with a median value of around 0.6 tCO_2-e/MWh. When Scope 3 emissions are included (which include extraction, production and transport of the gas), the median is around 0.7 tCO_2-e/MWh.[22] It is also possible that PV could be, to some extent, offsetting generation from renewable sources (which would decrease the average emissions intensity of the electricity it offsets) or from coal-

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fired plant (which would increase it). Therefore, we have conducted sensitivity analysis for the emissions offset by household PV by varying the emissions intensity to either 0.4 tCO_2-e/MWh or 0.7 tCO_2-e/MWh – see Table III.

Table III Sensitivity Analysis Varying the Emissions Intensity of Generation Offset by PV

	0.4 tCO_2-e/MWh	0.5 tCO_2-e/MWh	0.7 tCO_2-e/MWh
MIXED RENEWABLES			
tCO_2-e avoided in 2040	231 million	320 million	404 million
Value in 2040	$17.5 million	$24 million	$30.6 million
tCO_2-e avoided 2016 to 2040	3.1 million	4.3 million	5.4 million
Value 2016 to 2040	$185 million	$260 million	$324 million
DISRUPTIVE			
tCO_2-e avoided in 2040	622 million	815 million	1,088 million
Value in 2040	$47 million	$62 million	$82.4 million
tCO_2-e avoided 2016 to 2040	5.9 million	8 million	10.4 million
Value 2016 to 2040	$374 million	$500 million	$655 million

Financial impacts

To calculate the value to the household of an average PV system in the Mixed Renewables and Disruptive scenarios, we have used the latest 2016 average retail tariff provided through the MBIE Quarterly Retail Sales Survey (March, 2016).[23] To calculate the value of exported electricity we used the same tariff as was used by the MBIE for their two scenarios. These values are shown in Table IV.

Table IV Tariffs Used in Financial Analysis

	Tariffs (c/kWh)
Lines component	11.95
Energy and other	16.17
Total	28.12
PV export	9

[23] The MBIE Quarterly Retail Sales Survey (QRSS) is used to collect information on the total value of sales, the total volume of electricity sold, and the number of connections. The residential electricity cost per unit (the per kWh retail tariff) is derived by dividing the dollar value of residential electricity sales by the number of kilowatt-hours (kWh) sold to residential customers. It includes any after-discount costs which reflect actual uptake of prompt payment discounts, dual fuel discounts, and incentive discounts for attracting or retaining a customer.

We have conservatively assumed that electricity rates do not increase above inflation. The MBIE believe that although there is a range of factors that will influence prices, “Lower demand growth and an excess supply of committed new generation should put strong downward pressure on prices for the next decade”.[24] Closure of the Tiwai Point smelter would decrease prices, as could higher penetration of solar PV, and although higher carbon costs would increase prices, New Zealand’s electricity is not greenhouse-intensive, and this would reduce even further as renewable energy levels increase. The impact of the Lines and Distribution Businesses ‘poles and wires’ costs is hard to predict, with the experience in Australia being that PV and batteries place downward pressure on network augmentation costs, although there may be some grid integration costs.

As discussed above, we assume the average PV system is 3kW and 55% of its electricity is exported unless batteries are installed, with households using just under 7,300 kWh per year (whether from the grid or via their PV system).

The total financial value obtained via electricity savings by households that own PV systems for the two scenarios is shown in Figure 15. The yearly values by 2040 are $102 million (Mixed Renewables) and $383 million (Disruptive), with the cumulative value being $1.35 billion and $3.4 billion respectively. This is money that stays in the communities where these households live and so drives local economic activity and local employment. Of course, at the time of installation, the household has to pay for the PV system, but between 20-25% of the cost is attributed to the installer’s wages, which can then be spent locally.

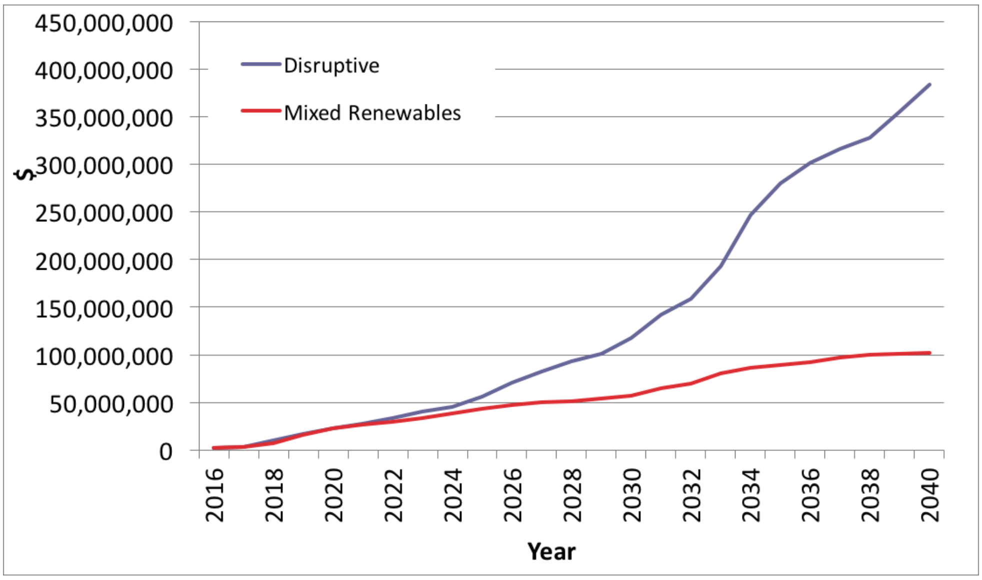

Figure 15 Financial Value Obtained via electricity savings by Households with PV systems

[24] From page 10. MBIE, 2016a, ‘New Zealand’s Energy Outlook: Electricity Insight’, Ministry of Business, Innovation and Employment, New Zealand Government.

PV Increases House Prices

Solar PV has also been shown to add value to house prices. A survey in the United States by the Lawrence Berkeley National Laboratory of 18,871 non-PV homes and 3,951 PV homes over the period 2002 to 2013 found that PV added USD4.18/W to the value of a home, on average, whereas the cost to the homeowner of the PV system was USD4.14/W. This level of value was maintained over time as the installed costs of PV decreased significantly, and through the US housing bubble, crash and recovery.[25]

Another US study, by the National Bureau of Economic Research, of houses in San Diego (364,992 house sales for one type of analysis and 80,182 for another) and Sacramento (90,686 house sales), found similar results, with the average home increasing in value by USD5.65/W, which is again greater than the average cost of the PV system in those Counties, USD5.24/W.[26] Although we have been unable to find equivalent analyses for New Zealand, we expect solar PV to similarly add value.

Impacts on Other Customers

In the **Mixed Renewables** scenario, by 2040, the decreased payments to Lines and Distribution Businesses driven by uptake of household PV result in tariffs increasing by 0.7%, which would increase the average customer's annual bill by up to $15. In the **Disruptive** scenario, the higher levels of penetration of PV could result in tariffs increasing by up to 3.4%, which could increase the average customer's annual bill by around $72 by 2040 – or about $1.40/week. However, these amounts do not take into account the financial benefits that PV and batteries can provide for other households via longer-term reductions in peak demand, network size and GHG emissions.

As discussed above, in the **Disruptive** scenario, the use of batteries is expected to decrease the system-wide winter demand peaks. As well as decreasing the need for peaking generation such as OCGT, this decreases the size of the EDB's networks that are required to supply customers – which reduces costs for all customers.[27] For example, according to the EDB Vector "The effects of PV + storage on network demand profiles could be significant in the medium term".[28]

Demand peaks are still expected to increase under the Disruptive scenario – meaning that PV/batteries act to make the peaks smaller than they otherwise would have been. The cost of increasing the size of the network is commonly expressed in terms of Long Run Marginal Cost (LRMC), with $150/kVA/year being a recently used average value for the type of analysis

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[25] Hoen, B., Adomatis, S., Jackson, T., Graff-Zivin, J., Thayer, M., Klise, G.T. and Wiser, R., 2015, 'Selling into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes', Ernest Orlando Lawrence Berkeley National Laboratory.

[26] Dastrup, S., Graff Zivin, J.S., Costa, D.L. and Kahn, M.E., 2011, 'Understanding the Solar Home Price Premium: Electricity Generation and "Green" Home Status', an NBER Working Paper, by the National Bureau of Economic Research.

[27] Campbell, M., Miller, A. and Watson, N., 2016, 'Impacts of new technologies on load profiles', EEA Conference & Exhibition 2016, 22 - 24 June, Wellington.

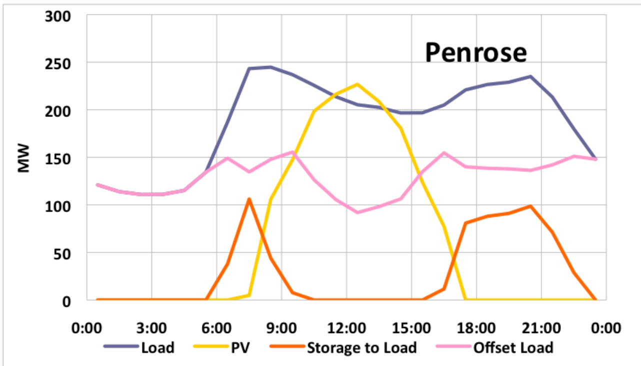
[28] Murphy, K., 2016, 'Key Findings from Vector's Residential PV trials', GREEN Grid Conference 2016, *Renewable Energy and the Smart grid*, 10 Feb, MBIE, Wellington.

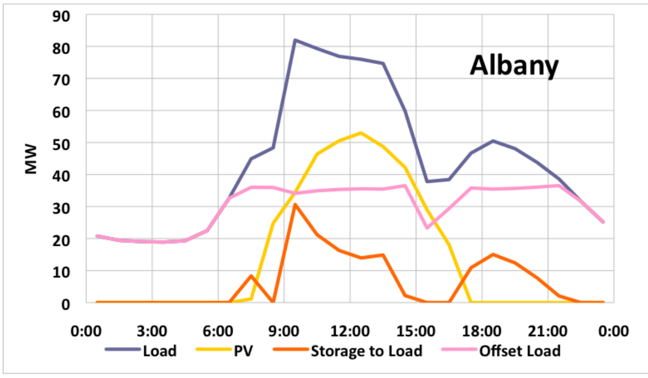
undertaken here.[29] The actual value will differ depending on local circumstances: being higher in areas in imminent need of network augmentation, and lower in areas with more delayed grid constraints. Nonetheless, using $150/kVA/year as a reasonable average, the 490 MW reduction due to PV and batteries identified by MBIE for 2040 translates to a benefit of about $8.50 per year per household (all households, not just those with PV/batteries). Similarly, the greenhouse reduction benefit, if allocated to all households, equals about $27.50 per household per year. Although these values are approximate, they do serve to illustrate their relative impact, and that the final financial impact on households that do not have PV is likely to be very small.

The following charts are used to illustrate the potential impact of solar and batteries at the zone substation level at the time of the annual demand peak. The substations have a variety of load profiles as shown in Table V. In each case, actual load data has been used, and modelled against a solar PV system designed to meet one third of the daily load, with half the solar generation used to reduce the load peaks. Of course, it is also possible for solar charging to be used to meet the evening peak, and grid charging for the morning peak. It can be seen that in all cases, the combination of solar and batteries can have a significant impact in reducing the peak.

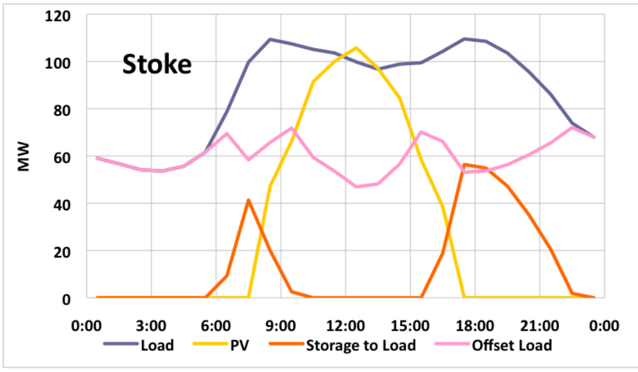
Table V Substation Descriptions

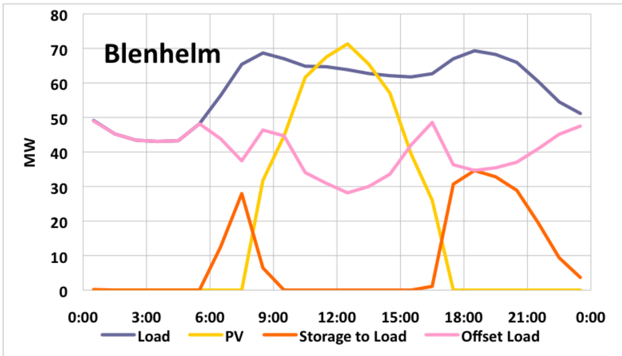
Location	Description
Auckland	
Penrose	Industrial area with some households
Albany	High density retail and commercial activity
Nelson	
Stoke	Pine mill, food manufacturing
Blenhelm	Wine industry with some households
Christchurch	
Bromley	Residential suburb
Culverdine	Country town with rural, horticulture, manufacturing

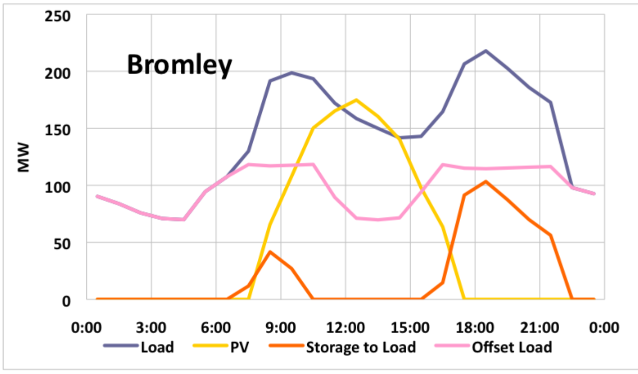


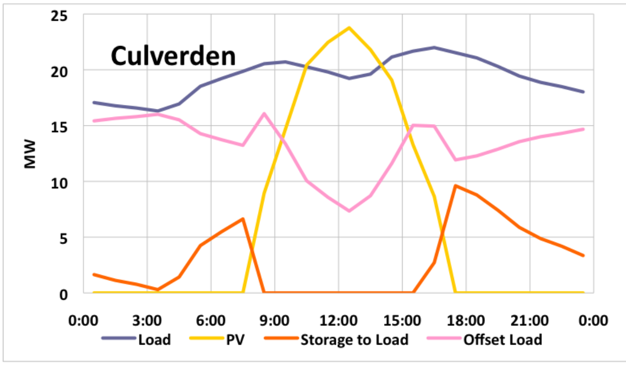


[29] CCG, 2016, 'Electric cars, solar panels, and batteries in New Zealand Vol 2: The benefits and costs to consumers and society', Concept Consulting Group, June, 2016.









It is also worth noting that distributed PV and batteries can provide a range of other benefits, including lower wholesale prices because of the merit order effect on generator dispatch, reduced line losses, fuel price hedging benefits, increased self-reliance and autonomy, resilience during extreme weather events and local employment.[30]

Employment impacts

The direct employment[31] in PV installation businesses can be measured in job years/MW PV installed (so for example 10 job years/MW would mean 10 people employed to install 1 MW PV over 1 year). When an industry is first developing, the jobyears/MW multiplier is relatively high, and then decreases as the industry matures and becomes more efficient and the workforce more fully utilised. In Australia, in 2009/10, when the amount of PV installed per person was about 10.5 watts per capita (similar to the 9.2 watts per capita currently in New Zealand), the installation of PV generated about 36 job years/MW. In New Zealand, about 8.5 MW is now being installed per

[30] Kildegaard, A. and Wente, J., 2015, ‘An optimization approach to parallel generation solar PV investments in the U.S.: Two applications illustrate the case for tariff reform’, *Energy Policy*, 87, p295-302. Weissman, G. and Fanshaw, B., 2016, ‘Shining Rewards: The Value of Rooftop Solar Power for Consumers and Society’, Frontier Group and Environment America Research & Policy Centre.

[31] Direct employment refers to those working directly for PV companies supplying, selling, installing or maintaining PV systems. There is also indirect employment, including legal and financial support services, general transport, government regulators, etc.

year, and about 350 people are employed on a full time equivalent (FTE) basis,[32] which produces an employment multiplier of 41 jobyears/MW.

To assess the employment impacts of the MBIE scenarios for PV uptake, we have applied this employment multiplier to the annual installations; decreasing it based on the trajectory experienced by Australia (ie. according to the correlation between employment per MW installed and the installed watts per capita). Once the employment multiplier reaches around 10 job years/MW, it is generally decreased by about 4.9% per year, which is much less than the decline rate we have applied to the higher multipliers here.[33]

Since battery storage is such a new business, there is no data available on its employment impacts. Therefore, to allow for the additional employment generated by battery installation in the Disruptive scenario, we applied the lower 4.9% decline rate once battery installs became significant (from 2025), when the employment multiplier was still at 19.5 job years/MW. Prior to this time it is likely that battery installs would just be integrated into normal PV installer business activities, and so would not generate significant amounts of additional employment. From 2035 onwards we also allow for the employment created through the replacement of older systems.

Figure 16 shows estimates of the direct employment for the Mixed Renewables and Disruptive scenarios. The variability from year to year occurs because the amount of PV installed each year in the MBIE scenarios varies significantly. For this chart the employment has been averaged over three years, and would otherwise vary even more. The key messages to take from this are that under both scenarios employment increases significantly over the next 5 years, then under the Mixed Renewables scenario declines just as rapidly, staying low for an extended period. Under the Disruptive scenario, the decline from 2020 is not so great, and employment is maintained at about 600 job years, before more than doubling through to 2035. The decrease from then occurs as the amount of new PV decreases, however in reality, it is likely that these peaks and troughs would not be so marked.

The challenge for policy-makers will be in smoothing out employment to create certainty in the industry, avoiding boom and bust cycles, which can be so damaging to the workforce. There will also be a need for the PV industry to ensure that all the appropriate standards and training are in place so that, even with significant amounts of new entrants, the quality of installations remains high.

[32] Data provided by SEANZ.

[33] Teske, S., Muth, J., Sawyer, S., Pregger, T., Simon, S., Naegler, T., O'Sullivan, M., et al., 2012, 'Energy [r]evolution. A sustainable world energy outlook', Greenpeace International and European Renewable Energy Council.

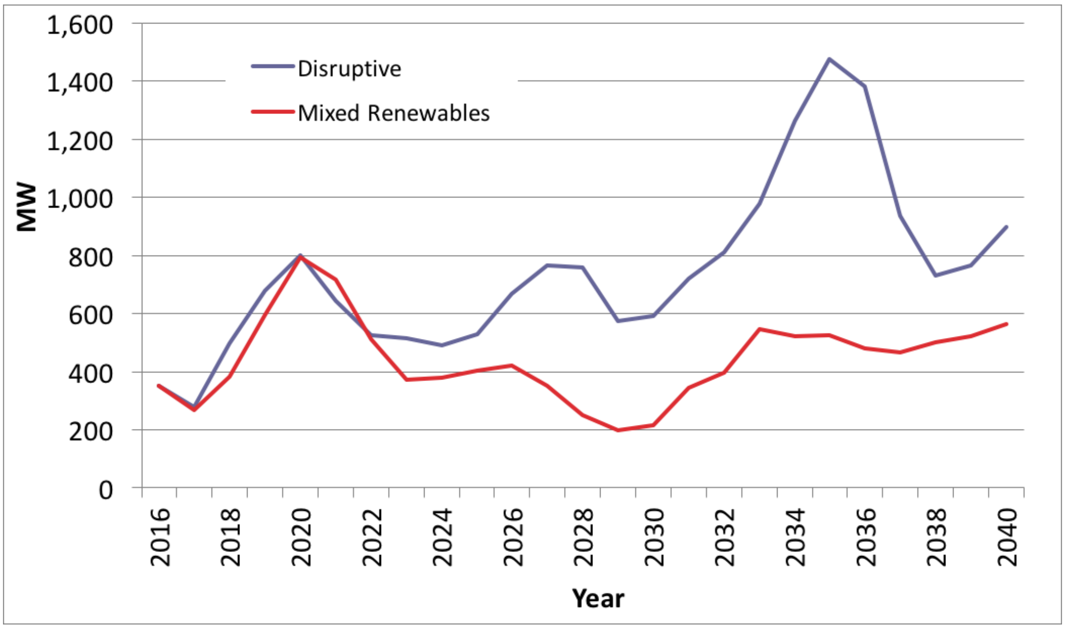


Figure 16 Direct Employment in the Solar PV Industry for the two Scenarios

DISCUSSION

As residential grid electricity prices have been steadily increasing in real terms, especially since 2000, solar PV has provided thousands of households with an alternative. As the installed costs of PV systems continue to decline, these innovators are expected to be followed by the 'early adopters', then the 'early majority', and so on. These households have already been responsible for the avoidance of about 68,000 tCO_2-e GHGs in New Zealand, with an estimated value of $860,000.

As is occurring in other parts of the world, PV is just the first step being taken down the path of increased modernisation of consumer energy choice – where integrated distributed energy systems also include battery storage, energy efficiency, and remote control of household appliances, all managed via mobile apps.

In a recent New Zealand survey, just under a quarter of households were 'very' interested in having a smart home, with another 37% being 'somewhat' interested, bringing the total to just over 60%. Global expenditure on 'smart homes' was estimated to have increased by 150% from 2012 to 2016, and was projected to increase at a faster rate from now on.[34]

[34] Ford, R., 2016, 'Smart-grid technologies: Consumer uptake and potential impacts', at the GREEN Grid Conference 10 February 2016.

As PV uptake increases, and battery uptake follows, households will contribute to reducing evening peaks as well as further reductions in GHG emissions. Based on MBIE data, the PV installed by households will avoid 777,000 tCO_2-e per year by 2040, with an annual value of almost $59 million – avoiding a total of 7.4 million tCO_2-e with a value of $468 million between now and then. These households will also be helping New Zealand to meet its renewable energy target.

There is also anecdotal evidence to suggest that installing PV systems can in fact contribute to reducing evening peaks. This occurs because installers commonly provide detailed advice on moving demand into the middle of the day in order to minimise exports, and power diverters can be used to automatically move demand from peak times. Products already available in New Zealand include the Power Genius,[35] the Solar Power Diverter,[36] the Elios Power Reducer,[37] EnaSolar inverters with integrated power diverter,[38] Econnex,[39] and Splash.[40] These provide excellent examples of how solar PV should not be viewed in isolation, but instead as one part of an integrated distributed energy package. Households can also become much more aware of their energy use when PV systems include in-home displays, and many solar businesses also provide energy efficiency services that can help reduce evening demand, such as LED lighting – which can now be controlled via mobile apps such as Apple HomeKit.[41]

The financial impact on households who don't have PV or batteries is more difficult to quantify. Although PV can reduce income to Lines and Distribution Businesses, who may then increase the tariffs paid by all customers, PV can also provide GHG reduction benefits and, especially with batteries, can reduce network costs, which should directly benefit all households. As discussed above, there are a variety of other benefits potentially provided by PV and batteries, and a review of 16 different recent studies found that individuals and businesses that decide to 'go solar' generally deliver greater benefits to the grid and society than they receive.[42]

This question of cross subsidies for PV is complicated by the fact that other cross subsidies already exist in the New Zealand electricity system: with urban households subsidising the lines used by rural households,[43] and with households that have high demand at the time of network peaks being subsidised by those that don't. And of course there are the subsidies to fossil fuels, which the International Monetary Fund recently estimated globally to be $5.3 trillion in 2015 or

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[35] https://www.powergenius.co.nz/

[36] http://www.whatpowercrisis.co.nz/Products/solar-power-diverter

[37] http://taspacenergy.co.nz/case-study-elios-power-reducer/

[38] https://www.enasolar.net/

[39] http://www.econnecx.com/Energy-efficiency-smart-home-control-__I.12842

[40] http://www.splashmonitoring.com/products/solar-pv/

[41] http://www2.meethue.com/en-nz/

[42] Weissman, G. and Fanshaw, B., 2016, 'Shining Rewards: The Value of Rooftop Solar Power for Consumers and Society', Frontier Group and Environment America Research & Policy Centre.

[43] OME, 2013, 'Review of Section 62 of the Electricity Act 1992 (2013 review)', Office of the Minister of Energy, New Zealand Government.

$10 million per minute.[44] In New Zealand, fossil fuel subsidies target the oil and gas sector and were reported to be $46 million in 2012/13.[45]

While some Lines and Distribution Businesses in New Zealand have been taking advantage of the transition to distributed generation through the use of PV (as discussed below), some have been proposing there should be a 'solar tax' applied to people with PV systems - because they use less electricity and so increase tariffs for other customers. Apart from the various benefits that PV provides to other customers outlined above, the other cross subsidies that already exist, and the fact that solar households generally use more electricity than non-solar households and so make higher payments to networks despite their PV systems,[46] if this approach is to be applied fairly, it implies that households who reduce their electricity use through energy efficiency improvements (such as insulation, efficient lighting or low-flow shower heads) should also be taxed. Similarly, if a customer moves to gas, should they be put on a 'gas tax'?

Although these examples may seem frivolous, they do highlight an important point – that the focus should now be on how to make the most of the coming opportunities driven by increased customer choice, rather than by selectively penalising specific new technologies.

What Lines and Distribution Businesses can do

Lines and Distribution Businesses in New Zealand, like other network businesses around the world, are facing a period of rapid change. Although the conventional electricity system is based on a 'top down' structure for consumers who simply buy electricity, options such as solar PV, batteries and energy efficiency are providing customers with a significant number of alternatives that allow them to actively participate in a new energy system growing from the bottom up. Consumers are becoming more involved in their energy services and are increasingly choosing to manage their own supply and use. These trends will continue, and so the challenges, and opportunities, are in enabling the existing electricity industry to transition to the 'new normal'.

As discussed above, there are two quite different approaches that Lines and Distribution Businesses can take. One is to try to maintain the status quo and apply punitive charges to households who take up distributed energy options, and the other is to actively participate in the distributed energy opportunities and profit from them. Attempts to maintain the status quo and focus on simply building networks will likely leave customers with a legacy of sunk costs which they will have to pay for, whether or not they use them or want them. This approach locks New Zealand into old technology and old business models, which will keep electricity prices high, erode the competitiveness of existing businesses and limit the opportunities for development of new technologies and new businesses.

It is clear that many in the broader electricity industry are aware of this change and the opportunities it presents. Average residential electricity use has been declining since 2009, well

[44] Coady, D., Parry, I., Sears, L. and Shang, B., 2015, 'How large are global energy subsidies?', an IMF Working Paper, Fiscal Affairs Department.

[45] WWF, 2013, Fossil Fuel Finance in New Zealand: Part 1 Government Support, WWF NZ.

[46] Vector, 2016, 'Vector is creating a new future', presentation by Vector CEO Simon Mackenzie.

before any significant uptake of PV,[47] with some areas declining for the last 10 years.[48] In the 2016 Annual New Zealand Electricity Survey of 500 electricity industry participants, of which only 20% were Lines and Distribution Businesses, 'Embracing new technology such as solar PV and battery storage in a way which will benefit consumers' was seen as 'the best opportunity for the electricity sector', and more than half agreed with 'The industry should be providing more choice and flexibility, including innovative products and pricing, which fit customers' changing needs'.[49]

Vector provides an excellent example of an EDB who is proactively pursuing the opportunities that distributed energy presents. Back in 2012, Vector offered customers the ability to benefit from solar through a trial leasing program, where Vector invested in battery storage on the customer's premises behind the meter as a network asset. The units were aggregated across the network using software and communications to provide optimised output of a virtual power plant with localised network benefits. The value was shared between customers (bill savings) and EDB (through efficiency, utilisation, avoided augmentation etc). Under the trial, around 300 units were deployed.

In August 2015, Vector offered 100 free solar and battery storage systems (3kW solar with Tesla Powerwall home battery). For the first 10 years, Vector will retain ownership of the systems, after which time ownership will pass to the household. The initiative was to enable Vector to assess advantages for individual users and the network as a whole.[50]

Vector now provides solar PV systems that incorporate the Sun Genie, an online and app-based dashboard that allows households to monitor and manage their home energy system. They are also partnering with Tesla to distribute the Tesla battery to Australasia, including the Powerwall (6.5kWh/10kWh residential/SME) and Powerpack (100kWh-10 MWh commercial/utility).[51] In the Australian market, it is focussing on the commercial and industrial sectors, where businesses are facing increased demand charges. The company also sees opportunities in off-grid and edge–of-grid locations, which could result in savings in reduced diesel and cheaper grid augmentation.

In September 2016, Vector announced a partnership with Australian blockchain energy company Power Ledger to deploy Power Ledger's energy trading platform. It will be called TransActive Grid and will allow customers to buy and sell electricity from their PV without using a retailer.[52] The trial is planned to begin in December 2016 across up to 500 sites in Auckland.

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[47] MBIE, 2016, 'Electricity demand and generation scenarios', Ministry of Business, Innovation and Employment, New Zealand Government, March 2016.

[48] Vector, 2016, 'Vector is creating a new future', presentation by Vector CEO Simon Mackenzie.

[49] EN&ABB, 2016, 'Annual New Zealand Electricity Survey 2016', by Energy News and ABB, July 2016.

[50] Bright future for some Auckland individuals, families, schools and community groups, https://www.vector.co.nz/newsdisplay/130-solar-power-and-battery-systems-up-for-grabs-3-August-2015 (Date accessed 1 November 2016).

[51] Vector Presentation, Vector is Creating a New Energy Future, CEO Simon MacKenzie

[52] Peer to peer energy trading to be trialled in NZ, https://www.vector.co.nz/newsdisplay/Media-Release-Peer-to-peer-energy-trading-to-be-trialled-in-NZ (Date accessed 1 November 2016)

In October 2016, Vector completed installation and integration of a 1MW/2.4 MWh grid-scale battery system on a residential zone substation in Glen Innes near Auckland.[53] The system uses Tesla Powerpack technology and is being deployed by Vector to reduce peak demand and extend the life of the substation, defer capital expenditure and provide supplementary power to the Glen Innes region. Vector is also integrating Tesla Powerpacks at a further five substation sites.

A number of **electricity retailers** in New Zealand are moving to providing households with more control over their electricity use – ranging from in-home displays, online tools and apps (Electric Kiwi, Meridian Energy), through to integration with solar installers (Mercury Energy, Genesis Energy), and full cost disclosure with access to spot market-based pricing (Flick Energy).

International examples

Internationally, there is increasing recognition that electricity industries need to transform themselves. The following examples are used to illustrate what is already happening with electricity utilities around the world, and to show that regulators are getting serious about the need for regulatory change.

Australia

In Australia, something of a battle has developed between electricity retailers and Lines and Distribution Businesses – as both want to be able to participate in the 'behind the meter' distributed energy market. All the major retailers, and many of the smaller ones, are now offering some form of package that not only involves the installation of solar and batteries, but includes a web-based smart energy platform that allows their customers to better manage their consumption of both grid and rooftop solar electricity. The Lines and Distribution Businesses also want to move into this market. As a result of this, the Australian Energy Regulator has established a process to develop a guideline that will separate the competitive and regulated parts of Lines and Distribution Businesses, and so support the development of competitive markets for energy services and efficient investment in network and customer services.

State governments in Australia are also starting to see the value in distributed energy. Recently, the Victorian government has approved the introduction of a time-varying feed-in tariff that rewards PV exports depending on the time of day, and up to 30c/kWh during critical peak periods. The tariff will also include a component that rewards households for avoiding GHG emissions. A review into the network benefits of PV will be completed in 2017.[54]

[53] Vector Energy Storage brochure http://vectorenergy.com.au/documents/1397460/0/Glen+Innes+Feature+Brochure/c6ef6dd2-22cb-4d2b-b0a6-940542cbdb4b?version=1.0 (Date accessed 1 November 2016)

[54] http://delwp.vic.gov.au/energy/electricity/victorian-feed-in-tariff

Germany

The German utility, E.ON has implemented a restructure to move its fossil fuel assets into a new company separate from an entity focussed on renewables, distribution and customer solutions.[55] The company has indicated that distributed energy is a key driver of the shift and also highlighted the value of interconnectivity along the value change from homes with smarter grid controls and distribution networks. E.ON is also an investment partner for AutoGrid, a utility data analytics firm, and smart home developer, Leeo.

USA

The US utility, NRG Energy, has also implemented a corporate reorganisation based on an assessment that a distributed generation-centric future was inevitable.[56] NRG Home division focuses in on residential solar, electric vehicle charging infrastructure and connected homes, which places emphasis on diverse energy offering in addition to the one-size fits all retail electricity option. The approach embraces new technology as the catalyst for changing the centralised model for delivery and replaces it with a demand-driven, decentralised service model to empower consumers.

New York Reforming the Energy Vision (REV) Initiative[57]

The REV was initiated in 2014 by the New York Public Service Commission, further developed by local utilities, and is now in the early stages of implementation. The focus of the REV is to align markets and regulatory settings with "…policy objectives of giving all customers new opportunities for energy savings, local power generation, and enhanced reliability to provide safe, clean, and affordable electric service."[58] Ultimately, it aims to drive the development of new revenue and business models for Lines and Distribution Businesses so that distributed energy and incumbent utilities can thrive. It involves new obligations for Lines and Distribution Businesses to develop five year plans for integrating distributed energy into the grid, facilitate customer choice and market innovation. In November 2016, utilities will formally lodge plans with the Commission on how it will encourage distributed energy deployment and coordinate with providers of distributed energy. The plans are to align with a new revenue approach which links performance metrics relating to peak load reduction, energy efficiency, customer engagement and information access to new forms of revenue streams from distributed energy.

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[55] Energy Storage News, E.ON's new focus on renewables and what it could mean for energy storage and distributed generation, http://www.energy-storage.news/guest-blog/e.ons-new-focus-on-renewables-and-what-it-could-mean-for-energy-storage-and (date Published:29 January 2015, Date Accessed: 31 October 2016)

[56] Utility Dive, What happened when NRG Energy disrupted its own business model, http://www.utilitydive.com/news/what-happened-when-nrg-energy-disrupted-its-own-business-model/401472/ (Date Published 1 July 2015, Date Accessed 31 October 2016)

[57] Utility Dive, REV in 2016: The year that could transform utility business models in New York, http://www.utilitydive.com/news/rev-in-2016-the-year-that-could-transform-utility-business-models-in-new-y/412410/ (Published 20 January 2016, Date accessed: 31 October 2016).

[58] New York State website, Reforming the Energy Vision, http://www3.dps.ny.gov/W/PSCWeb.nsf/All/CC4F2EFA3A23551585257DEA007DCFE2?OpenDocument (Date accessed 1 November 2016).

Overall, the REV initiative aims to move utilities towards performance-based regulation and mitigate revenue loss from distributed energy. The New York Public Service Commission has recognised that a greater focus on distributed energy may require increases in operating expenditures and decreases in capital expenditure, which is inconsistent with current incentive frameworks for Lines and Distribution Businesses. To align those incentives, the Commission has proposed reforms to how utilities earn revenues: including allowing Lines and Distribution Businesses to retain expenditures that would have been spent in the utility's capital program if distributed energy supplants the need for a capital project and also allowing Lines and Distribution Businesses to earn revenue from operating expenditure associated with facilitating distributed energy. Other reforms being considered include tariff design reforms, such as demand charges to coincide with peak usage on the grid, or other rates to provide cost-reflective price signals, in conjunction with upgraded metering infrastructure and billing practices to support changes in tariffs.

Maryland Review of Electricity Distribution Systems[59]

In September 2016, the Maryland Public Service Commission announced it was undertaking a review to ensure electricity distribution systems in Maryland deliver customer benefits, choice, affordability, reliability and environmental sustainability. Similar to the REV, the review will consider new business models and ways that Lines and Distribution Businesses can better use energy storage, advanced metering and distributed energy such as solar PV, tariff design (particularly for electric vehicles), how energy storage should be valued, distribution system planning and protecting low-income customers.

Maximising social benefits

Integrated distributed energy systems that include PV, batteries, and the array of energy efficiency options provide a significant opportunity to provide broad-reaching social benefits. However, specific strategies need to be put in place to achieve these benefits. Leasing options, where systems can be provided at no upfront cost and are paid off through bill savings, can help overcome the capital cost barrier. Another option is solar PPAs, where the installer owns the system on a household's roof and sells them electricity at less than the retail rate. And for renters or people who have little solar access, community-owned solar systems are proving popular worldwide – where households can own a share of a solar system on a local shopping centre. Government housing is a prime opportunity for lower income households to reduce their costs, whether they are tenants or owners. And of course, the interest in PV presents the perfect opportunity to implement the energy efficiency and load management options that not only provide direct benefits to the households (both financial and quality of life through improved housing stock), but by flattening the load curve, can benefit the utilities and New Zealand as a whole.

[59] Utility Dive, Following New York's lead, Maryland targets electric distribution transformation, http://www.utilitydive.com/news/following-new-yorks-lead-maryland-targets-electric-distribution-transform/427257/ (Date Published: 29 September 2016, Date Accessed: 31 October 2016).

RECOMMENDATIONS

Distributed Energy has captured the imagination of households and other energy users in New Zealand and worldwide. This represents a fundamental shift in energy system usage, and with it design and operation. It therefore requires policy response at national and regional level. Because of the rapid market uptake of the new technologies, this response needs to be timely if perverse outcomes are to be avoided and the full benefits of the transition are to be captured for New Zealanders.

1. There is a need for government/regulator leadership to ensure that customers have full and fair access to the variety of new options that will reduce their bills, enhance their lifestyles and enable personal contributions to renewable energy and GHG reductions targets. Initiatives such as the NY Reforming the Energy Vision should be reviewed for their suitability for New Zealand.
2. That the work currently underway on the regulated party transaction regime takes into consideration what is happening to network operators in Australia, where they are struggling for revenue because they are unable to operate in the competitive market. It is clear that network businesses are no longer pure monopolies, since they face competition from the range of distributed energy options, and their regulatory environment should reflect this.
3. That government and the PV industry ensure that all the appropriate standards and training are in place so that, even with significant amounts of new entrants, the quality of installations remains high. This applies not only to PV but also to batteries and fully integrated distributed energy systems. Governments should also ensure rights around solar access – because this is now an integral part of investment decisions.
4. That specific strategies are put in place to maximise social benefits through leasing options, solar PPAs, community-owned solar, Government housing, and integration of energy efficiency and demand-side management with solar uptake.

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