PROJECT REPORT

Investigation into the Potential Impacts, Threats and Opportunities Posed by Emerging Technologies on Orion's Network and Business

ENMG 608: Project

Master of Engineering Management

University of Canterbury

Prepared By

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For

Orion New Zealand Limited

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Submitted in partial fulfilment of the Degree Master of Engineering Management, UoC

ABSTRACT

A project was undertaken for Orion New Zealand Limited (Orion) to fulfil a partial requirement of the degree Master in Engineering Management at the University of Canterbury. The project explored *"The potential impacts, threats and opportunities posed by emerging technologies on Orion's network and business".* The emerging technologies and trends analysed include; distributed generation (solar, hydro, wind, diesel), battery storage, electric vehicles, smart homes, energy efficiency and future technologies. Each emerging technology and trend's impact has been considered in terms of Orion's customers, network and business. From this future scenarios have been identified based on different technology uptake rates and regulatory regimes. Finally recommendations have been suggested along with potential action plans Orion can follow to capitalise on these technologies as they become more established.

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DISCLAIMER

While the author has taken care to make sound recommendations the author accepts no responsibility for either the accuracy of, or occurrences resulting from the use of conclusions drawn or recommendations made in this report.

A copy of this report will be submitted to the University of Canterbury (University) as partial fulfilment of Master of Engineering Management (MEM) degree requirements. A copy will be made available to Orion New Zealand Limited (Orion) on the condition that neither the student, supervisor nor University will have legal responsibility for the statements made therein. If Orion intends to rely on the comments of this report or to implement any of its recommendations it must do so solely at its own discretion.

ACKNOWLEDGEMENTS

The author would like to acknowledge the following people who contributed towards the project and made its completion possible:

- Glenn Coates, Strategic Planner Manager, Orion New Zealand Limited;
- Beverly Hall, Administrator MEM Programme, University of Canterbury;
- The Staff of Orion New Zealand Limited; and
- The MEM Class of 2015

EXECUTIVE SUMMARY

Purpose

This project was undertaken to fulfil the partial requirements of the Master of Engineering Management Programme at the University of Canterbury. The project was sponsored by Orion New Zealand Limited with the aim of identifying:

"The potential impacts, threats and opportunities posed by emerging technologies on Orion's network and business".

Background and Justification

The New Zealand power system including distribution networks has historically been designed to take power, generated remotely by large scale generation and transport it to customers distributed over large geographical areas. This business model has worked for the past century. However change is on the horizon. New technologies are emerging that may disrupt the conventional power system and its associated business models. The actual power system impact will depend on future price and technological breakthroughs associated with emerging technologies and are therefore to some extent uncertain. This report was commissioned to address this future uncertainty by:

- Consolidating knowledge from multiple work streams and individuals;
- Analysing emerging technologies and their potential impacts;
- Envisaging future scenarios, both plausible and extreme;
- Identifying potential impacts, threats and opportunities to Orion's business; and
- Suggesting no regrets and other actions Orion can take to both mitigate and benefit from emerging technologies and business models.

Key Findings

The three considered to have the largest impact; solar, electric vehicles and battery storage all have less than 0.5% market share. With these technologies still in their infancy it is the ideal time to influence their implementation and capitalise on their future uptake.

Issues exist with the regulation of emerging technologies that need to be addressed. In particular those with PV are being cross subsidised by customers, gaining an economic benefit beyond what is reasonable.

As a leader in demand side management initiatives, Orion is in some instances uniquely poised to benefit from the uptake of new technologies. Should Orion leverage this advantage it may find in addition to greater utilisation of its assets a new business opportunity selling its expertise as a service.

At current prices the economic benefit of emerging technologies is far in excess of what a network connection can offer. At an asset value of NZ $5,250 per network connection, and battery storage alone costing NZ $3000 to $5000 installed, a doubling of network assets could take place for the same economic cost of emerging technologies. That being said prices are rapidly falling however industry has not yet theorised an inflection point between the cost of staying on or going off grid.

Conclusions

Emerging Technologies	
Emerging Technology	**Conclusions**
Distributed Generation	• Distributed hydro and wind are too expensive and location dependent to have much of an effect on the future grid. • Diesel is the only reliable form of distributed generation (in terms of any time generation). Since New Zealand is 80% renewable and growing, the economics of a Solar + Diesel off-gridding system seems counter intuitive in most circumstances, and likely will not occur.
Battery Storage	• Huge potential exists for demand side management gains and peak reduction if managed correctly through price signals or direct network signalling/involvement. • May see large network spikes on tariff time transitions. This could lead to more complicated staggered tariffs to avoid this.
Electric Vehicles	• Potential for >10% network load growth. • Similar to batteries in demand side management. • Chicken and egg scenario in terms of charging infrastructure. Industry and private partnerships have taken the initiative to deploy the infrastructure in anticipation of a large electric vehicle uptake in the near term.
Smart Homes	• The rollout of smart meters is nearing completion (2020) however competing manufacturers and protocols have fractured the market hindering its usefulness. • Large consumer oriented companies like Amazon and Google are entering the space. This could lead to a higher future uptake rate once product ecosystems have been established.
Energy Efficiency	• A continuation of appliance energy efficiency is likely to continue into the future.
Future Technologies	• Winter generation or a productive means to use excess solar distributed generation could be a game changer in terms of off-gridding.

Customer Impacts	
Network Impact	**Conclusions**
Existing	• Expect a competitive service to prevent an exodus to off-gridding. May need to be more than marginally competitive to overcome desire for energy independence and/or going off-grid for ideological reasons.
New	• Some customer segments will desire additional services beyond traditional distribution, which could be provided by Orion or others.

Network Impacts	
Network Impact	**Conclusions**
Peak	• Of the forms of distributed generation Diesel is the only reliable source of peak reduction. Solar has minimal to no impact of peak reduction. • Battery storage and electric vehicles if incentivised or controlled could drastically flatten the load curve, reducing peak.
Utilisation	• Distributed generation will have a negligible impact on network utilisation. • Battery storage and electric vehicles if incentivised or controlled could drastically flatten the load curve, increasing utilisation.
Operations	• Distributed generation will have a large impact on network protection due to bidirectional flows. This will require more sophisticated protection. • Orion could leverage its dominance in demand side management to create a service it can sell to other network operators.
Investment	• Control and communication systems are going to be a large capital cost to networks, the sooner the implementation the better. Care needs to be taken that the protocols used are market driven so that the assets do not become stranded. • Over voltage due to solar will require additional reinforcement of the low voltage network. This can be mitigated through mandating all generation has volt/var mode enabled.

Commercial Impacts	
Network Impact	**Conclusions**
Revenue and Price	• Under the current tariff structure solar is incentivised to the detriment of the network (and cross-subsidised by other customers). This will likely lead to cost reflective pricing tariffs in the near term (10 years), effecting the investment of solar installations to date.
Return	• How emerging technologies are regulated will determine whether they produce a regulated or non-regulated return. Orion needs to consider how best to use its influence to achieve an outcome that benefits itself and its customers.
Regulatory Risk	• If network utilisation were to drop due to the incorrect incorporation of emerging technologies into the network there is a risk the Commission could conduct another ODV, resulting in a write-down in Orion's RAB, reducing the company's revenue.

Recommendations

Business Aspect	Recommendation
Technology trial	(a) Conduct a customer survey looking into customers' current knowledge into, and appetite for, emerging technologies. Additionally what level of control customers are willing to cede to Orion for an incentive (subsidy, rebate, shared purchase...).
	Owner(s): Communications Department (Infrastructure)
	Time Frame: Short Term (1-2 Months)
	Resources: 40 Hours (Call Centre)
	(b) Establish partnerships with preferred emerging technology suppliers. Implement backend system + testing.
	Owner(s): Infrastructure, Information Solutions, Commercial
	Time Frame: Short Term (3-6 Months)
	Resources: 1xBattery, 1xSolar, 1xInverter, 1xControl System + Install/Test
	(c) Small scale customer trial.
	Owner(s): Infrastructure, Information Solutions, Commercial
	Time Frame: Long Term (7-36 Months)
	Resources: Capital allocation (depends on incentive used, if any)
Organisational structural and resources review	Conduct an internal review to establish the point (if any) that dedicated resources will be required to manage emerging technologies, and what structure that may take.
	Owner(s): Infrastructure
	Time Frame: Short Term (1-3 Months)
	Resources: Strategic Planning Manager (2 Days)
Monitoring system	Develop monitoring system (spreadsheet, data sources) to track the uptake of emerging technologies, program in trigger points.
	Owner(s): Strategic Planning
	Time Frame: Short Term (1-6 Months)
	Resources: Strategic Planning Analyst (1 Week)
Uneconomical customer off-gridding	Analyse uneconomic LV spurs to identify if an off grid (emerging technologies) solution is cheaper than continued maintenance (NPV analysis).
	Owner(s): Strategic Planning
	Time Frame: Medium Term (1-12 Months)
	Resources: Strategic Planning Analyst (2 Weeks)

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GLOSSARY

Term	Explanation
DSM	Demand Side Management: Direct involvement by the network operator to reduce demand.
ICP	Installation Control Point: The point of connection between a network and a customer.
ODV	Optimised Deprival Value: The value of an equivalent level of service using modern day technologies, pricing and techniques.
RAB	Regulated Asset Base: The regulated value of a networks assets, based on a set of guidelines (handbook).

1. INTRODUCTION

1.1 Purpose

This project was undertaken to fulfil a partial requirement of the Master of Engineering Management Programme at the University of Canterbury. The project was sponsored by Orion New Zealand Limited with the aim of identifying:

"The potential impacts, threats and opportunities posed by emerging technologies on Orion's network and business".

1.2 Background and Justification

The New Zealand power system including distribution networks has historically been designed to take remote large scale generation and transport it to customers disbursed over large geographical areas. This business model has worked for the past century however change is on the horizon. New technologies are emerging that may disrupt the conventional power system and its associated business models. The actual power system impact will depend on future price and technological breakthroughs associated with emerging technologies and are therefore to some extent uncertain.

A report was commissioned (See Appendix A) to address this future uncertainty by:

- Consolidating knowledge from multiple work streams and individuals;
- Analysing emerging technologies and their potential impacts;
- Envisaging future scenarios, both plausible and extreme;
- Identifying potential impacts, threats and opportunities to Orion's business; and
- Suggesting no regrets and other actions Orion can take to both mitigate and benefit from emerging technologies and business models.

As is the nature of the distribution industry the report has a 20 year outlook, this report is intended for discussion by Orion staff formulating a strategy for this period.

1.3 Orion New Zealand Limited

Orion New Zealand Limited (Orion) owns and operates the distribution network in central Canterbury, bordered by the Waimakariri and Rakaia rivers to the north and south, and the Pacific Ocean and Southern Alps to the east and west respectively. The company owns and operates the third largest distribution network in New Zealand and also owns a contracting subsidiary, Connetics, which helps build and maintain the network.

Orion is majority owned by the Christchurch (89.3%) and Selwyn (10.7%) district councils and has in excess of NZ$1 Billion in assets [1]. In 2015 these assets served 191,000 customers throughout the region, supplying 3,300GWh of electricity with a network reliability of 99.98%. The network itself is comprised of 610km of sub-transmission lines (33kV, 66kV), 10,245km of distribution lines (11kV, 400V), 53 zone substations and 11,110 distribution substations.

2. DEVELOPMENT OF A COURSE OF ACTION

2.1 Possible Project Approaches

During the initial stages of the project three approaches of varying breadth and depth were considered. Table 1 provides details regarding each approach as well as any limitations identified.

Table 1: *Considered project approaches.*

Name	Details	Limitations
Technology Specific Analysis	Involves a full breakdown and comparison of a product/technology by different manufacturers within a technology space.	Highest resolution of impacts, threats and opportunities but inter-technology relationships are not analysed holistically.
Single Model Analysis	Involves identifying statistical probabilities and effects a new technology is likely to impose which are then aggregated together to form the most likely future outcome.	Although it forms the most likely outcome it does not cover every outcome which may lead to low probability, large impact events being ignored.
Scenario Analysis	An extension of the single model, involves envisaging multiple plausible outcomes to capture less probable outcomes that may have a large effect should they occur.	The most complex and time consuming form of analysis of those listed.

2.2 Selected Approach and Justification

Scenario analysis was selected as the best option as it tied into work being conducted by external consultants and a systems view was deemed necessary to consider a range of outcomes. Figure 1 highlights the structure of the approach taken.

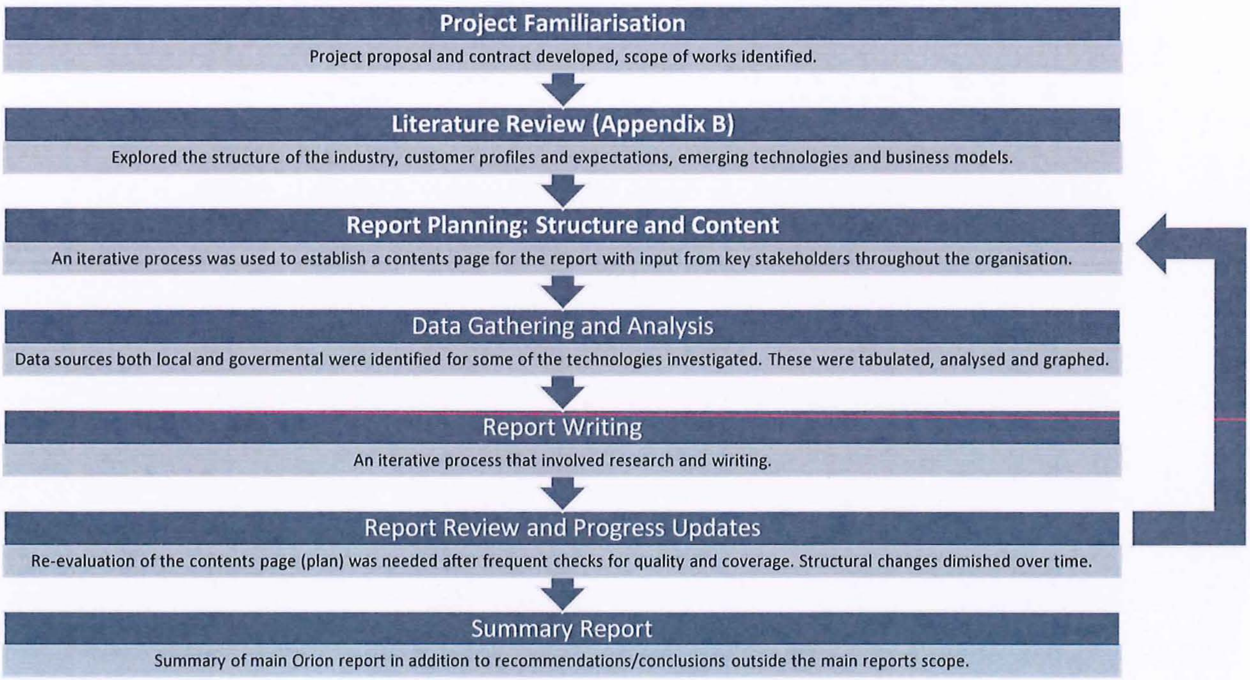

Figure 1: *Project approach methodology.*

2.3 Scenarios Considered

Five scenarios have been analysed using a modified version of Orion's load model (see Section 4.1). These scenarios were classed as either probable or plausible (lower probability, high impact) and extend to the year 2040.

Reflective Pricing (Probable)

The most probable of the scenarios analysed. Under current tariff structures customers with solar are cross-subsidised by those without it. This uneconomic distribution of wealth will see network revenue drop for the same fixed cost, driving their tariff structure towards time of use and peak charging to fairly distribute costs across customers. This will see the economics of solar fall considerable reducing its uptake. Alternatively battery storage will be incentivised as it is mutually beneficial to both the customer (through increased reliability) and the network operator.

Central Scenario (Probable)

The central scenario is business as usual with no drastic market changes observed. The uptakes of solar and electric vehicles are similar at approximately one third of eligible customers by 2040. Battery storages uptake is correlated to solar, with one in three solar installations also having battery storage. The charging profile of electric vehicles is relatively flat throughout the day with 25% charging during the pm peak.

Extreme Electric Vehicle Uptake (Plausible)

Similar to the central scenario in every aspect apart from the uptake of electric vehicles. Rising fossil fuel costs coupled with falling electric vehicle prices and governmental incentives accelerate the uptake of electric vehicles. This causes a substantial increase in both the network's peak and annual demand. Note this model assumes uptake rates greater than the historic turnover of light vehicles.

Low Electric Vehicle Uptake and Winter Generation (Plausible)

The least probable of the scenarios considered. Competitors offer solutions to manage customer's systems to offer the best value, driving a large uptake of solar and battery storage. These include home energy management systems, energy audits, solar installation and battery storage. The uptake of electric vehicles stalls due to competition from hydrogen fuel celled vehicles and low fossil fuel prices. Networks see a large fall in annual load, driving up prices, as well as a less substantial but still significant reduction in peak load.

Spiralling (Plausible)

The spiralling scenario poses the largest negative impact to Orion's business. A cost effective form of winter generation when coupled with solar and battery storage allows consumers to go 'off-grid'. The continuation of this trend leads to higher network prices for those still connected, further incentivising the exodus of customers to off-gridding. This leads to large uptake rates in all of the emerging technologies. Additionally with the typical customers off-grid mentality networks find it hard to incentivise electrical vehicles owners to charge at night, causing a substantial increase in network peak.

3. COLLECTION AND PRESENTATION OF DATA

Numerous sources of datasets were identified during the project and are outlined in Table 2. All data sources were tabulated in Microsoft Excel before being checked for consistency. This process identified incorrect data supplied on the NZX spot price data repository, which was rectified after an email exchange. All dataset sources have been referenced in the body of the main report (Appendix A).

Table 2: *Dataset sources and data collected.*

Source	Data Collected
Orion	• Daily load profiles. • Distributed generation connections and capacity (Orion). • Network Consumption. • Solar Import/Export ratios. • Orion Diesel generation assets. • Demand Side Management
Electricity Authority (EMI)	• Distributed generation connections and capacity (Orion and New Zealand). • Smart Meters (Orion and New Zealand). • Total number of ICPs.
NZX	• Half hour spot price.
Ministry of Business, Innovation and Employment (MBIE)	• Averaged consumption per household and price per kWh. • Average electricity bill component breakdown. • Projected electric vehicle uptake curves.
National Institute of Water and Atmospheric Research (NIWA)	• Yearly solar irradiation profile. • Daily solar irradiation profile.
New Zealand Transport Authority (NZTA)	• New Zealand car registration data. • Electric vehicle uptake curves.

Other data was gathered from Orion personnel, reports and the internet from various sources. In these instances the data was not in a dataset format and was tabulated or referenced in the body of the main report. Each data point was where possible compared against another source of the same information to validate its accuracy.

4. INTERPRETATION AND ANALYSIS OF THE COLLECTED DATA

After data validation the tabulated data was graphed and interpreted. If appropriate a coefficient of determination (R^2 value) was calculated, as well as logical thought to determine how accurate a conclusion could be drawn from projections made from the data. Additional factors likely to affect the future rate of technology adoption were also considered and modelled into any projections calculated.

4.1 Orion's Network Model

In some instances data was incorporated into a network load profile model developed at Orion. This model (Figure 2) used one of two extreme loads, a summer low or winter high, as base cases and was manipulated to examine the effect that different emerging technologies may have on the network. As well as a visual observation key network metrics (Table 3) were calculated for model comparison.

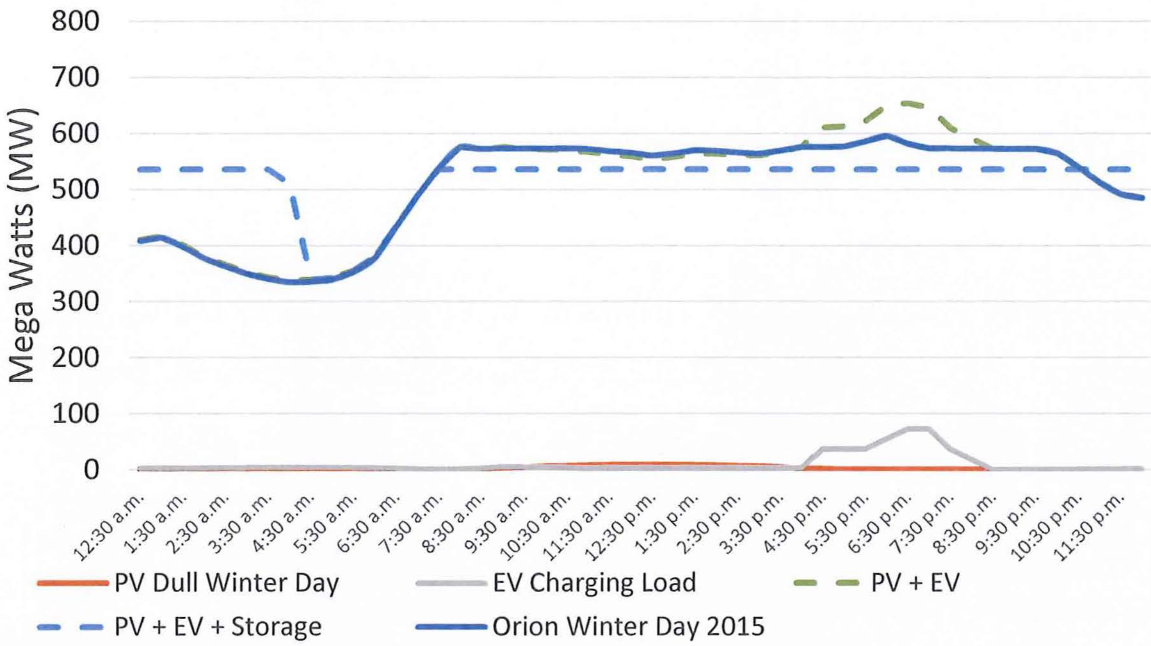

Figure 2: *Orion network model.*

Table 3: *Measured network metrics (base case).*

Network Variable	Summer Value	Winter Value
Peak Load	334 MW	595 MW
Average Load	324 MW	510 MW
Minimum Load	256 MW	361 MW
Difference (Max-Min)	104 MW	261 MW
Annual Energy	3,300 GWh	
Energy Change (%)	Calculated	Calculated
Peak Change (%)	Calculated	

5. CONCLUSIONS

5.1 Emerging Technologies

Table 4: *Emerging technology conclusions.*

Emerging Technology	Conclusions
Distributed Generation	• Distributed hydro and wind are too expensive and location dependent to have much of an effect on the future grid. • Diesel is the only reliable form of distributed generation (in terms of any time generation). Since New Zealand is 80% renewable and growing, the economics of a Solar + Diesel off-gridding system seems counter intuitive in most circumstances, and likely will not occur.
Battery Storage	• Huge potential exists for demand side management gains and peak reduction if managed correctly through price signals or direct network signalling/involvement. • May see large network spikes on tariff time transitions. This could lead to more complicated staggered tariffs to avoid this.
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Smart Homes	• The rollout of smart meters is nearing completion (2020) however competing manufacturers and protocols have fractured the market hindering its usefulness. • Large consumer oriented companies like Amazon and Google are entering the space. This could lead to a higher future uptake rate once product ecosystems have been established.
Energy Efficiency	• A continuation of appliance energy efficiency is likely to continue into the future.
Future Technologies	• Winter generation or a productive means to use excess solar distributed generation could be a game changer in terms of off-gridding.

5.2 Customer Impacts

Table 5: *Customer impact conclusions.*

Network Impact	Conclusions
Existing	• Expect a competitive service to prevent an exodus to off-gridding. May need to be more than marginally competitive to overcome desire for energy independence and/or going off-grid for ideological reasons.
New	• Some customer segments will desire additional services beyond traditional distribution, which could be provided by Orion or others.

5.3 Network Impacts

Table 6: *Network impact conclusions.*

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Peak	• Of the forms of distributed generation Diesel is the only reliable source of peak reduction. Solar has minimal to no impact of peak reduction. • Battery storage and electric vehicles if incentivised or controlled could drastically flatten the load curve, reducing peak.
Utilisation	• Distributed generation will have a negligible impact on network utilisation. • Battery storage and electric vehicles if incentivised or controlled could drastically flatten the load curve, increasing utilisation.
Operations	• Distributed generation will have a large impact on network protection due to bidirectional flows. This will require more sophisticated protection. • Orion could leverage its dominance in demand side management to create a service it can sell to other network operators.
Investment	• Control and communication systems are going to be a large capital cost to networks, the sooner the implementation the better. Care needs to be taken that the protocols used are market driven so that the assets do not become stranded. • Over voltage due to solar will require additional reinforcement of the low voltage network. This can be mitigated through mandating all generation has volt/var mode enabled.

5.4 Commercial Impacts

Table 7: *Commercial impact conclusions.*

Network Impact	Conclusions
Revenue and Price	• Under the current tariff structure solar is incentivised to the detriment of the network (and cross-subsidised by other customers). This will likely lead to cost reflective pricing tariffs in the near term (10 years), effecting the investment of solar installations to date.
Return	• How emerging technologies are regulated will determine whether they produce a regulated or non-regulated return. Orion needs to consider how best to use its influence to achieve an outcome that benefits itself and its customers.
Regulatory Risk	• If network utilisation were to drop due to the incorrect incorporation of emerging technologies into the network there is a risk the Commission could conduct another ODV, resulting in a write-down in Orion's RAB, reducing the company's revenue.

5.5 Insights

New Zealand is known for being the test bed for many new technologies, think EFTPOS, however in the case of the power system we are lagging other countries in some categories. This is a blessing in disguise. Australia incentivised solar power which caused it to have a rapid uptake relative to New Zealand. This had the emergent effect of a range of severe issues including network overvoltage [2] and network protection. Orion is now in a position to learn from Australia's and others mistakes to implement strategies to reach an ideal solution before any issues arise.

A somewhat ironic notion is that emerging technologies may in fact make the power system worse when considering two key attributes of a network connection, cost and reliability. With NZ $1 Billion in assets and 190,000 customers Orion's network is built at a cost of approximately NZ $5,250 per customer [2]. The retail cost of the alternative solution, solar + battery + inverter + diesel generator costs in excess of NZ $30,000 installed. It is true that some of these technologies are experiencing dramatic year on year declines in cost, however it will be decades until parody is reached for most customers, if at all. The niece in which an emerging technology alternative solution can compete is for locations seeking a connection that a more than 1km from current distribution lines. Installation of distribution lines cost in excess of NZ $25,000 per km to install. Orion also boasts a reliability of 99.98% uptime. Does the cost in (most) instances really justify the 0.02% increase in reliability?

Customers installing battery storage while uneconomically viable to do so (negative net present value) may reduce Orion's future earning potential. On a demand side management level there is a threshold of battery capacity that can be installed before any further capacity has no effect. If Orion is able to collect a regulated return on network level storage (this is still before regulators and may be determined an unregulated asset) then the amount of storage it can justifiably install is diminished. This may make battery sales a more appealing market segment to enter. This will depend on Orion's appetite for entering an adjacent market segment, one it exited many years ago.

6. RECOMMENDATIONS AND IMPLEMENTATION

Table 8: *Recommendations.*

Business Aspect	Recommendation
Technology trial	(a) Conduct a customer survey looking into customers' current knowledge into, and appetite for, emerging technologies. Additionally what level of control customers are willing to cede to Orion for an incentive (subsidy, rebate, shared purchase...).
	Owner(s): Communications Department (Infrastructure)
	Time Frame: Short Term (1-2 Months)
	Resources: 40 Hours (Call Centre)
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	Owner(s): Strategic Planning
	Time Frame: Medium Term (1-12 Months)
	Resources: Strategic Planning Analyst (2 Weeks)

7. ETHICAL CONSIDERATIONS

As a monopoly Orion must justifiably balance the networks cost to serve and reliability against the revenue it collects. With new technologies not yet fully regulated care must be taken to make sure consumers get a fair deal. The company also has a mandate to distribute costs across consumers fairly, unless regulated cross-subsidisation prevents this.

As this report contains information that is commercial sensitive in nature an embargo of 10 years has been sought on its contents.

8. SUMMARY REFLECTION ON PERSONAL VALUE AND BENEFITS GAINED

To me the MEM course was an opportunity to expand my skillset beyond my technically based undergraduate degree. This project allowed me to put into practice what I had learned throughout the year, in a real world context. Although I was ready to enter the workforce before the MEM, I believe with the additional knowledge and skills I have now obtained my career will be fast tracked, reaching my goal of a management position sooner. I also now have a more in-depth understanding of the power industry and how it operates, through experience passed on by fellow personnel during my placement at Orion. I look forward to what the future brings.

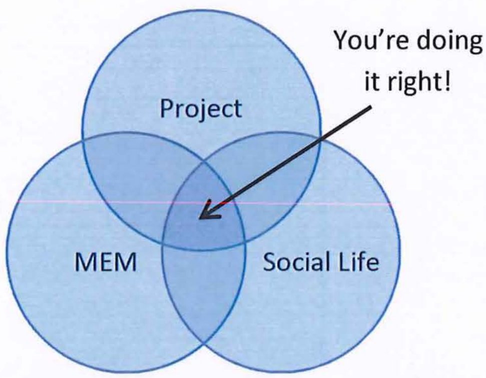
9.1 MEM Project Recommendations

To future students I recommend the following:

- Make business cards with your name, contact details and project statement. It is standard practice to exchange business cards at the start of a meeting when first making an acquaintance with an external party, something that caught me off guard. This will allow people to follow up with you and extend your network. Additionally don't be afraid to tell people you are doing a master's project, people are generally more accommodating for students.

- If your sponsor offers you a desk in their office take it. The general consensus amongst MEM students during the project period was that the MEM suite is full of distractions, and productivity within its four walls is lower than it could be. The office environment will remove the temptation of "who wants to Café 101 for a coffee?" or "who wants a game of pool?".

- Balance university, your project and outside commitments. During this transitional period from university life to working life you will have overlapping commitments from both. This means you will be doing more than 40 hours in a week for three months. Add to this a social life and you will soon find yourself running out of hours in the day. You will need to account for this make a few sacrifices in the name of getting a Masters.



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Appendix A

Emerging Technologies Report

Assembled by:

Blake Burgess

February 2016

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1. Justification and Background

The New Zealand power system including distribution networks has historically been designed to take remote large scale generation and transport it to customers disbursed over large geographical areas. This business model has worked for the past century however potential change is on the horizon. New technologies are emerging that may cause change to the conventional power system and its associated business models. The actual power system impact will depend on the future price and technological breakthroughs associated with emerging technologies and is therefore to some extent uncertain.

This report was commissioned to address this future uncertainty by:

- Consolidating knowledge from multiple work streams and individuals;
- Analysing emerging technologies and their potential impacts;
- Envisaging future scenarios, both plausible and extreme;
- Identifying potential opportunities, triggers and risks to Orion's business; and
- Suggesting no regrets and other actions Orion can take to both mitigate and benefit from emerging technologies and business models.

2. Current Environment

2.1 Network

Orion operates multiple sub-networks which aggregate together to form a regional network. The two underlying factors behind each sub-network are its voltage and customer density. Each sub-network is designed to balance the costs associated with efficiency, security of supply and the cost to serve.

Sub Transmission (66kV, 33kV)
The sub transmission network represents 15% of distribution line value. It takes electricity from Transpower's national grid at grid exit points (GXPs) and distributes it to zone substations. It is the most efficient form of distribution Orion operates (in terms of line losses per km) and has the highest cost per km to build and maintain.

High Voltage (11kV)
The high voltage (HV) network represents 40% of distribution line value. It connects network substations to zone and distribution substations. Large customers can connect directly into the HV network which may require additional assets. HV, LV and street lighting often run in parallel, sharing some of the same trench or pole infrastructure.

Low Voltage (400V)
The low voltage (LV) network represents 40% of distribution line value and is the interface between general customers and the network. The LV network is sectionalised into open rings and spurs to allow for network isolation and reconfiguration during a fault.

Street Lighting (400V)
The street lighting network represents 5% of distribution line value. The network is in a large part an extension of the LV network and is the interface to council and privately owned street lighting. It is the 5^{th} wire visible on the LV network.

Substation
A substation encompasses buildings, switchgear, transformers, protection and control equipment used for the transformation and distribution of electricity. Orion's network structure has three identified levels of substations – zone, network and distribution.

Zone substations are high voltage substations which have been identified to be of significant importance to the network. Orion's zone substations in general include a site where one of the following takes place: voltage transformation of 66kV or 33kV to 11kV, two or more incoming 11kV feeders are redistributed or a ripple injection plant is installed.

Network substations are in the primary 11kV network, all within the Christchurch urban area. They contain at least one 11kV circuit breaker per connected primary cable and one or more circuit breakers for radial distribution feeders.

Distribution substations take supply at 11kV from either a zone substation, a network substation or from another distribution substation. In some situations a consumer will own the building that houses these substations.

Urban
Orion's urban network has a customer density of (up to) 26 customers per km and contains approximately 158,000 customers (88%). It consists of both a 66kV and a 33kV sub transmission system. The urban 66kV system supplies in and around Christchurch city and is supplied from Transpower's 66kV GXPs at Bromley and Islington. The urban 33kV system supplies the western part of Christchurch and is supplied from Transpower's Islington 33kV GXP.

The urban zone substations supply a network of 11kV cables connected to network substations distributed throughout Christchurch. The low voltage (400V) system to which most of Orion's customers are connected is supplied from these distribution substations.

Rural
Orion's rural network has a customer density of 5 or more customers per km and contains approximately 22,300 customers (12%). It consists of both a 66kV and 33kV sub transmission systems and is supplied from Transpower's Islington, Hororata and Kimberley GXPs. The rural distribution system primarily consists of 11kV overhead radial feeders from rural zone substations and three small Transpower GXPs at Coleridge, Castle Hill and Arthur's Pass.

Operation
Orion operates its network using a 24 hour control room which uses the General Electric software package PowerOn. PowerOn is a combination SCADA, Outage Management and Distribution network management system. PowerOn captures the 66kV, 33kV and 11kV network including the 11kV/415V distribution transformers and transformer LV isolator. Orion are investigating a GE distribution power flow extension to PowerOn to enable real time switching analysis etc. The inclusion of the 400V network is also being investigated.

2.2 Regulation

As a natural monopoly Orion is heavily regulated to emulate competition. With the company's positive industry reputation and it being the third largest network by customer numbers Orion is in a position to give input into industry, regulatory and legislative discussion. The company has representation on the ENA's regulatory working group (RWG) and Smart Technology Working Group (STWG).

2.2.1 Governance

Electricity Networks Association (ENA)

Represents the 29 electricity distribution companies (EDBs) operating in New Zealand. Facilitates industry working groups focusing on common areas of interest and provides a unified voice to industry and regulators.

Ministry for Business, Innovation and Employment (MBIE)

Used by regulators to commission reports and studies into the electricity sector. Produces a quarterly and annual energy modelling outlook which includes industry statistics and projections.

Electricity Authority

Responsible for regulation of the New Zealand electricity market. The primary mechanism in which it does this is through the Participation Code (2010). The Code sets out the Authority's duties and participant's roles and responsibilities in relation to:

- System security
- Metering
- Billing
- Information management
- Quality of supply
- Trading arrangements
- System agreements
- Quality of security
- Reconciliation
- Distributed generation

Commerce Commission

Promotes competitive markets by setting economic regulation in regards to pricing, quantities and quality of service which are in the long term interest of consumers. The Commission governs under the Fair Trading Act (1986) and the Commerce Act (1986), setting EDB pricing and quality constraints through its Default and Customised Price-Quality determinations based on a predetermined set of rules (Input Methodologies).

2.2.2 Default and Customised Price-Quality Determination

The purpose of default/customised price-quality (DPP and CPP) regulation is to provide a relatively low cost way of setting price-quality paths for electricity distributors, while allowing the opportunity for individual distributors to have alternative price-quality paths that better meet their particular circumstances. Price-quality paths are set in advance based on a set of Input Methodologies (IMs).

Price-quality paths work by specifying:

- Limits on the prices distributors may charge;
- The quality standards distributors must meet; and
- A five year regulatory period which the price-quality path applies for.

2.2.3 Input Methodologies

Input methodologies are a range of upfront regulatory rules, processes and requirements. These cover matters such as the valuation of assets, the treatment of taxation, the allocation of costs, the specification of price, and the cost of capital. They are governed under Part 4 of the Commerce Act.

2.3 Pricing

The Commission specifies a maximum chargeable price limit that Orion can collect across all customers based on a number of factors including Orion's regulated asset base (RAB) value, depreciation, tax, avoided transmission charges, and a weighted average cost of capital (WACC) set by the Commission. The price limit is composed of a 'starting price' which applies at the start of a regulatory period, and a 'rate of change' which applies for every subsequent year of the period there after (1+4 years). The rate of change is the consumer price index (CPI) plus some percentage factor X (CPI + X).

The price limits are structured to provide EDBs with an incentive to focus on the costs that they can control, with costs that they have little or no control over being treated separately. Other 'pass through' and 'recoverable' costs like local authority rates, or Transpower transmission charges do not form part of the price limit and can be passed to the consumer.

Orion chooses how it allocates its price limit to each consumer through its pricing methodology[1]. This process involves grouping consumers into connection categories (Table 1) based on their needs and allocating costs to each connection category proportionally based on use. Each category is then assigned a set of tariffs (Table 2, Table 3) with the aim of promoting economic efficiencies through cost reflective pricing signals.

Table 1: *Orion connection categories.*

Connection Category	Connection Breakdown	Explanation
Street Lighting	19.1%	All connections to the street lighting circuit. Council and private street and park lighting.
General	80.2%	All residential and most business connections. Make use of all network assets besides street lighting circuitry.
Irrigation	0.5%	Primarily all connections 20kW and over used to pump water to irrigate farmland. Orion determines the connections that are allocated to this category.
Major Customer	0.2%	For connections between 250kVA and 300kVA the customer (or their retailer) may elect to be classified as a major customer connection, or where the loading level is above 300kVA the connection is classified as a major customer connection. Orion determines the connections that are allocated to this category and require each to have half-hour interval metering.
Large Capacity	<0.1%	Offered to very large consumers based on their size and impact to the network. May have different security of supply requirements, require additional assets, pose a significant stranding risk on the cessation of supply and have the ability to enter into long term contracts with Orion.

[1] http://www.oriongroup.co.nz/assets/Company/Corporate-publications/PricingMethodology.pdf

Table 2: *Types of tariff structures.*

Consumer Tariff	Explanation
Volume Charge	Based on electricity transported, expressed as price per kWh. Can be a flat rate or incorporate time of use (TOU) pricing variance.
Fixed Charge	Prices fixed per day or month.
Control Period Demand Charge	Reflects maximum demand, expressed as price per kW during an indicated time period.
Capacity Charge	Reflects installed or specified maximum capacity, expressed as price per kW.
Interruptibility Rebate	A financial incentive to allow Orion to interrupt load (DSM) during times of peak load or a grid emergency.
Power Factor Correction Rebate	A rebate for loads with installed and maintained power factor correcting equipment.
Peak Period Charge	A percentage allocation of charge based on a customer's average real power loading (kW) during an indicated peak power period spanning 30 minutes. Orion aims to indicate 200-300 of these periods during winter.
Equipment Charge	A charge for customers requiring additional connection equipment for their connection.

Table 3: *Connection categories and tariffs.*

Tariff Type	Street Lighting	General	Irrigation	Major	Large Capacity
Volume Charge					Individually Assessed
Fixed Charge					
Control Period Demand Charge					
Capacity Charge					
Interruptibility Rebate					
Power Factor Correction Rebate					
Peak Period Charge					
Equipment Charge					

2.4 Customer

2.4.1 Historic Expectations

An outlook many customers have with the network is out of sight out of mind. A network supply is an integral part of daily life, however it is rarely considered by customers unless that supply is interrupted or something goes wrong. Customer expectations are highlighted in Table 4.

Table 4: *Historic expectations of customers.*

Expectation	Explanation
Prices Affordable and fair	Network connection costs and prices are not considered excessive and costs are allocated fairly between different customer groups.
Reliability	The power stays on with few interruptions.
Security	Power is restored quickly following failures on the network.
Safety	No harm comes to the customer or those operating and maintaining the network.
Resilience	The network is built and operated in a manner that ensures an appropriate resilience to major events (snow storms, earthquakes, etc.) and to changing customer needs.
Someone to talk to	All communication is simple, prompt, accurate and personalised to the customer.
To be informed	Of all impacts the network may have on a customer's daily life (loss of power, road works).
Hassle free	Interaction with the network is simple with a fast turnaround (new connections…).

Not all customers share the same level of expectation, with a recent survey finding that 18% of respondents would be prepared to pay more for a higher level of security of supply, with 68% indicating they would not be. Customer expectations are expected to change and are discussed in Section 3.1.

2.4.2 Industry-Customer Relationships

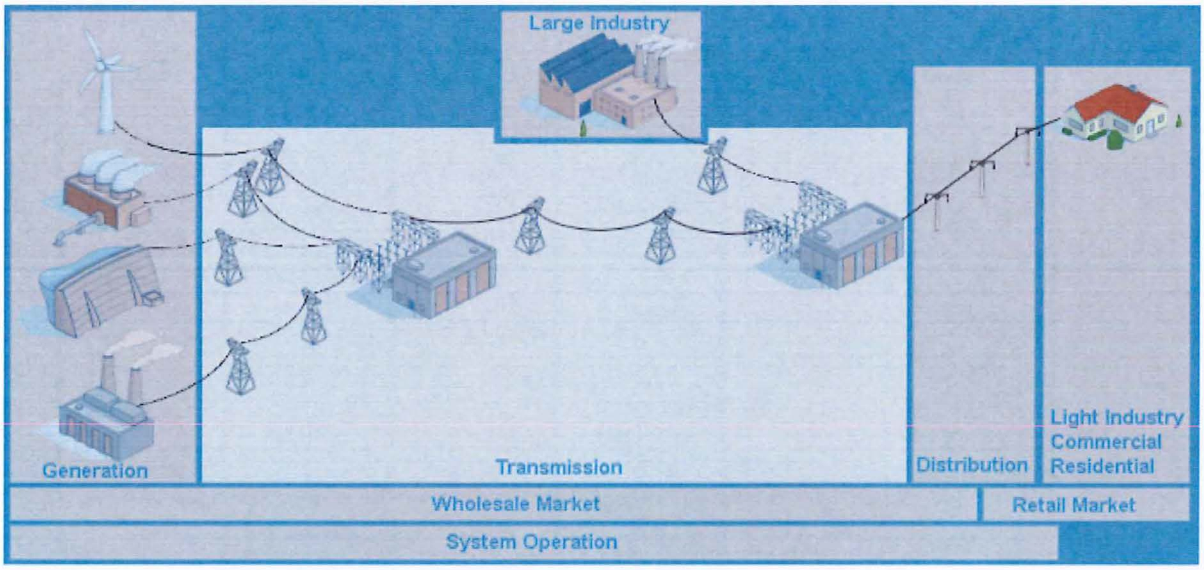


Figure 1: Overview of New Zealand's electricity industry.

System Operator (Transpower)

The system operator (Transpower) is responsible for the integrity and operation of the overall power system and electricity markets. Real time scheduling and dispatching of generation is used to match supply to customer demand, ensuring system stability. Additionally the system operator is active in the co-ordination of transmission or generation outages, facilitating the commissioning of new generating plant, and the procurement of ancillary services to support power system operation. Most of the System Operators revenue is received via a contract with the Electricity Authority.

Generation

Generators bid to produce electricity on the wholesale market based on a lowest cost first dispatch methodology. A clearing house matches retail consumption to the proportion of power generated during each 30 minute pricing period, with Retailers providing payment for the generation output.

Large generators maintain four types of generating assets including base load (geothermal and some gas), variable (hydro), peaking (gas, thermal, diesel) and intermittent (wind and solar). They are also typically integrated with a retail unit as a form of natural hedge for pricing variability between dry and wet years. Six major generators operate in New Zealand representing 90% of generation.

Transmission (Transpower)

Transpower owns and operates the majority of the national transmission grid assets (220kV, 110kV, 66kV) which form the basis of the national grid. It also owns 33kV and 11kV assets at the distributor interface although a recent trend has been to divest these assets to EDBs. It interfaces to EDBs through GXPs and generators through grid entry points (GEPs). Transpower also maintains the HVDC link that connects the North and South Islands. The company receives revenue from generators, distributors and direct connect customers.

Distribution

Distribution companies are responsible for taking electricity from Transpower's GXPs and distributing it to consumers dispersed over large geographical areas. Lines charges are set through the numerous tariff structures networks operate and are generally collected from the consumer by the retailer on behalf of the network. Large consumers (dairy processing, timber mills...) are directly billed by distribution networks. Distributed generation may also be present within a network.

Retail

Retailers are the industry interface to consumers, providing electricity pricing and billing. Retailers purchase electricity from the spot market and repackage all costs associated with the electricity supply chain into a single product, which they market to the consumer. New business models are emerging, for example Flick Electric, which communicates all industry costs straight through to the consumer directly (including the spot price), adding a margin on top.

Consumer

Both residential and business consumers are provided access to the grid through their local distribution network, and purchase electricity from a retailer. Some consumers own distributed generation to offset internal consumption, and export excess generation back into the grid.

2.5 Demand Side Management

Despite poor regulatory/market mechanisms Orion is internationally renowned for its demand side management (DSM) practices. The company is known for its strong DSM brand in the electricity sector and to some extent by customers. A catalyst to Orion's DSM rollout was its community ownership model, which allowed it to take on the risk of development in the customer's best interest. An additional benefit is the strategic regulatory leveraging value of being seen as acting in the long term interest of customers through cost reduction.

Table 5: *Capability of Orion's current DSM methods.*

Type	Reduction	Comment
Upper South Island Load Management	30 MW	Coordinated with other EDBs. See section below.
Retailer Peak Pricing and Hot Water	50 MW	Anytime hot water cylinder control.
Irrigation	28 MW	Anytime interruptible irrigation.
Night Tariff	50 MW	Night rate price option to shift day load to night.
Control Period	10 MW	Price signal for major customer load response
Power Correction Rebate	-	Reduces loses and increases capacity.
Customer Generation	15 MW	Generation credits PV: 0.039 c/kWh Generation credits non-PV: 1.128 c/kWh Generation credits peak period: 79.02 c/kWh
Diesel Generation	10 MW	See Section 3.3.1.
Total:	193 MW	Theoretical maximum, unlikely to occur at the same time.

There are a number of reasons why the growth of energy can diverge from peak demand (e.g. summer irrigation growth not adding to winter peak demand) but the above DSM efforts have significantly contributed to the divergence of energy deliverance and peak demand as shown in Figure 2.

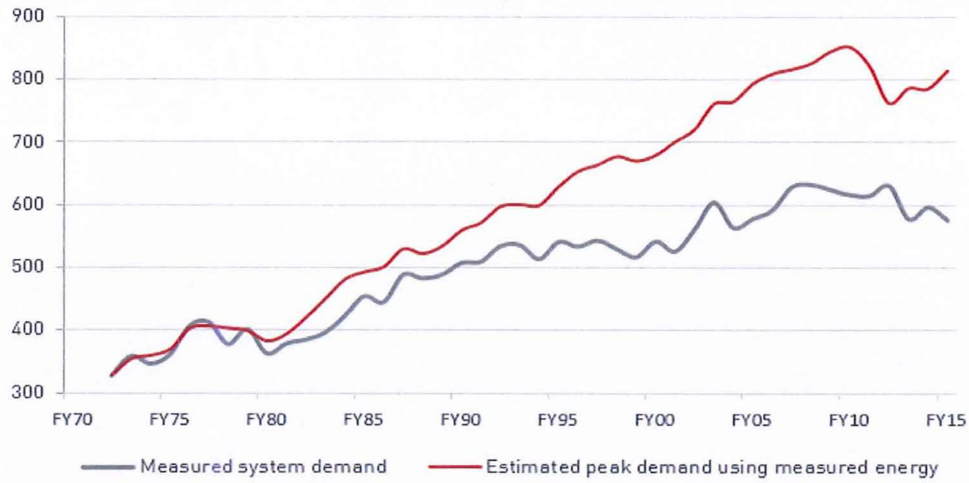


Figure 2: Orion peak demand capping.

Orion's DSM extends beyond its own Network. In 2009 Orion was an integral part in the formation of the Upper South Island Load Management (USILM) collective along with:

- Marlborough Lines
- Alpine Energy
- Network Tasman
- Electricity Ashburton
- Main Power
- Buller Electricity
- Westpower

Commissioned by Transpower, Orion with the co-operation of the other upper South Island EDBs implemented a region wide DSM initiative that dynamically allocates allowable supply from Transpower to each EDB, such that the collective does not breach Transpower's supply limitations. By arbitraging excess supply between EDBs, similar benefits to that of network level DSM have been obtained (reduced and deferred investment in supply side capacity).

As a last resort during a grid or network emergency Orion has the ability to remotely change zone substation voltage set points, to reduce voltage outside of its usual allowable operating range. This provides a small reduction in load however consideration needs to be given end of spur customers, who may experience a voltage drop outside of the regulated limits.

Grid Emergencies
Two categories of grid or network events can occur including *developing* (A) (example: low lake levels) or *immediate* (B) (example: major generator failure).

Category A events require rolling blackouts with supply priority given to feeders with high profile connections (hospitals, emergency services...). As required by the Authority Orion has a system operator rolling outage plan[2] (SOROP) which would be followed during such an event.

Category B events Transpower will signal an Automatic Under-Frequency Load Sheading (AUFLS) response, requiring Orion to shed (depending on the severity) between one or two blocks, each representing 16% of total load. A Category B event has never occurred in the South Island.

3. Looking Forward

3.1 Customers

3.3.1 Emerging Expectations

Customers of the future will look to have greater choice and control over the cost, social and environmental choices and outcomes associated with energy usage. It is anticipated that customers will have new expectations as outlined in Table 6.

Table 6: *Emerging expectations of customers.*

Expectation	Explanation
Additional Services	Beyond the delivery of electricity customers may desire energy audits and energy management systems to identify and reduce their energy usage.
New Technologies	The ability to connect and use complementary technologies alongside a network connection.
Independence	Customers may seek energy independence from the network for economic or ideological reasons.
Environmental Concerns	Customers may wish to contribute to reducing their impact on the environment. An example would be distributed generation offsetting the need for distribution infrastructure or large scale generation.
Social Acceptance	Of the technologies and methods used by networks (information privacy...).

[2] http://informer/EmergencyManagement/NW204009.pdf

3.1.2 Customer Profiles

ACTIVELY INVOLVED Actively involved customers will take full control of their energy usage and actively match demand to price signals. They are likely to be prosumers (consumers who also produce electricity) and will be more likely to take up emerging technologies.	*OFF GRID* The lowering cost of new technologies will allow at least some customers to substitute their network connections for an off grid system. Under a traditional model these households and businesses would no longer be a customer, and now a customer of off grid solution providers.
SET AND FORGET Set and forget customers will after an initial investigation period hand over some control of power usage to their local utility or an energy management system. These customers will determine a level of control that suites them and be rewarded for the flexibility with a cheaper electricity rate or lower energy usage.	*BUSINESS AS USUAL* Traditional customers who are happy with what the local network has to offer and have no desire to install emerging technologies on their side of the meter.

3.2 Emerging Trends

3.2.1 Energy Efficiency and Changing Customer Behaviour

The Energy Efficiency and Conservation Authority (EECA) was established by the government to promote energy conservation, efficiency and the use of renewable sources of energy. Its efforts have resulted in the implementation of minimum energy performance standards, and an energy efficiency rating system for appliances sold in New Zealand. The Equipment Energy Efficiency Program (E3) has caused a downward pressure on annual household consumption which peaked in 2005, with a 10% reduction in annual household consumption observed since that time. The areas of greatest impact have been improvements in home insulation, lighting and heating/cooling.

As well as governmental initiatives a whole industry exists based around providing energy audits to households and businesses and financing the implementation of any efficiencies identified. An example is Energy for Industry (Pioneer Energy) who have partnered with Cowley services to design the Christchurch City Energy District Plan, taking advantage of the city rebuild to implement energy savings.

Residential

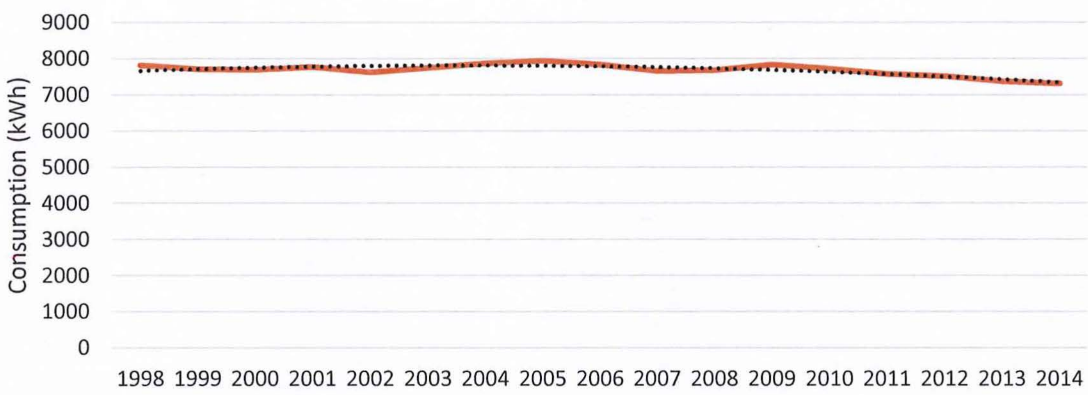


Figure 3: Averaged annual electricity consumption per residential connection[3].

[3] http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/electricity

MBIE data shows residential demand per customer has trended downward over the last 15 years, falling 6.46% (500 kWh). The rate of decline since 2009 has remained a relatively constant 0.44% per annum. Projecting forward to 2030 using a 0.44% rate of decline would see a further 500 kWh decrease per residential customer.

Commercial

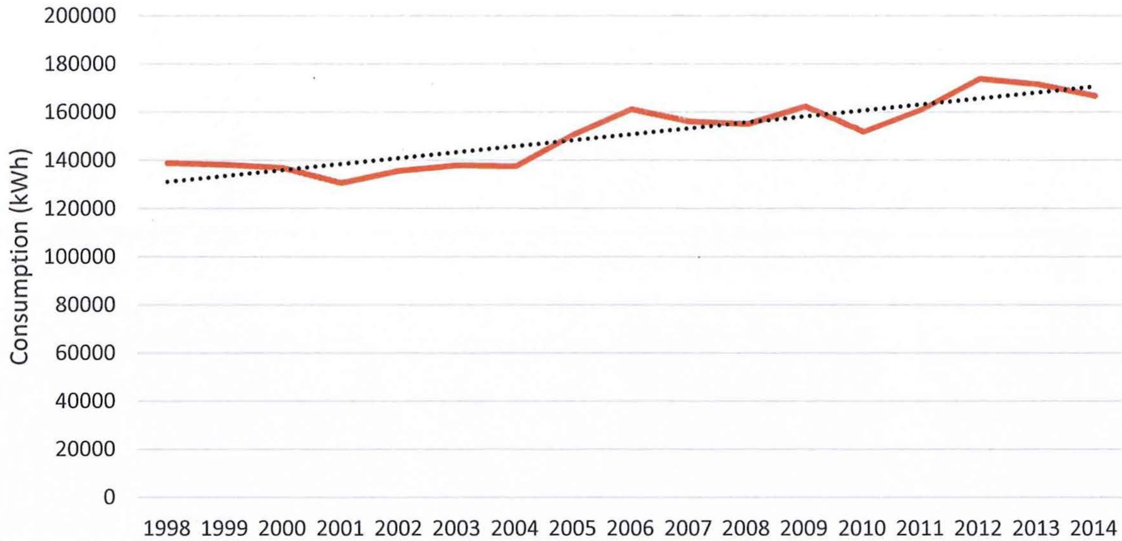


Figure 4: Averaged annual electricity consumption per commercial connection.

As outlined in Figure 4 commercial customers have experienced an increase in annual consumption of approximately 30,000 kWh since 1998, at an average rate of 2,500 kWh per annum. An underlying trend of load growth per customer has outpaced any savings from increases in efficiency.

Industrial

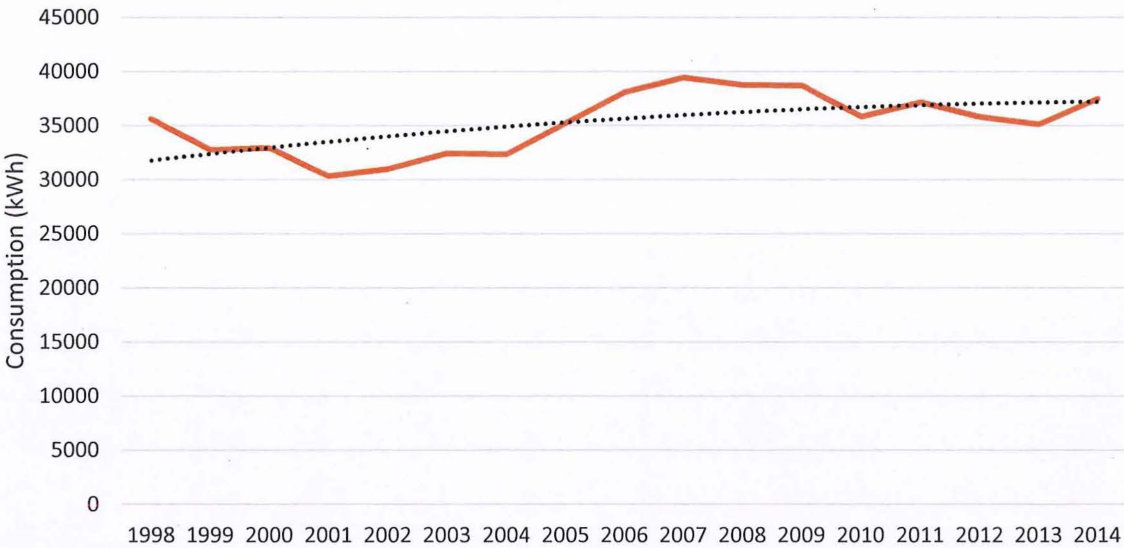


Figure 5: Averaged annual electricity consumption per industrial connection.

Industrial customers have experienced a mixed trend in annual average consumption since 1998 with a net gain of 3,000 kWh. As the industrial category includes the Tiwai Aluminium Smelter, which accounts for 14% of total New Zealand consumption, energy efficiency signals are lost based in its varying demand profile.

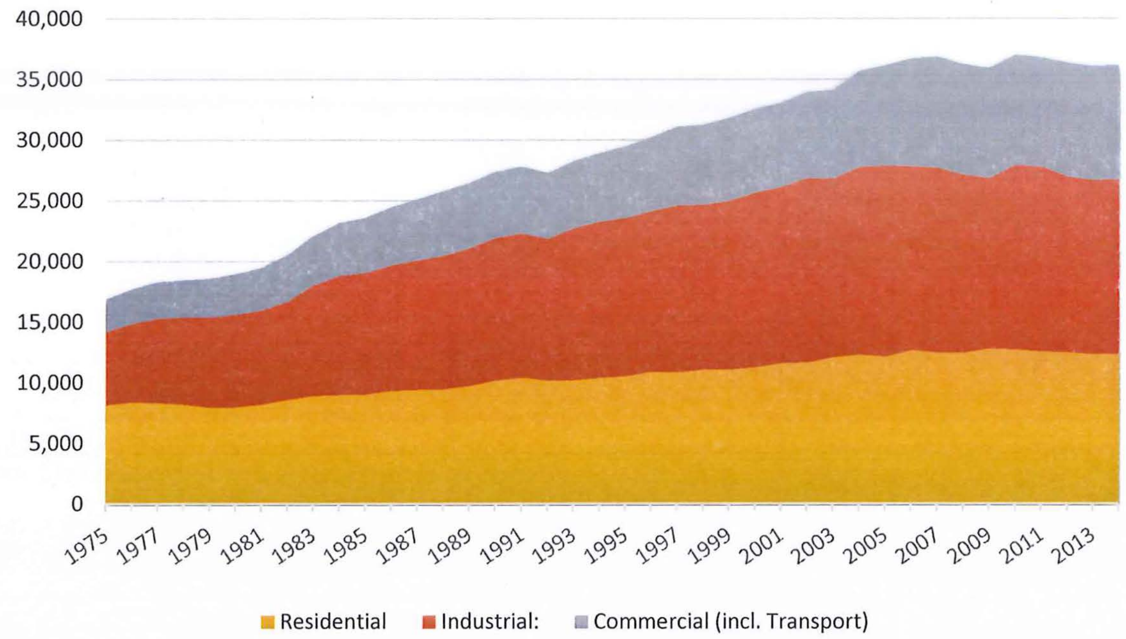


Figure 6: Annual national demand for the residential, commercial and industrial sectors.

3.3 Emerging Technologies

Although the uptake of technologies may be minor to begin with the full effects could be apparent early on for small segments of network due to clustering. There is a direct influence in customer purchasing behaviour due to conspicuous consumption (keeping up with your neighbours).

3.3.1 Distributed Generation

Historically on a cost per kW/h basis large scale generation was the most cost effective method of electricity generation. This required transmission and sub transmission networks to deliver power to customers spread over large geographical areas. Current trends in distributed generation see small scale technologies becoming cheaper (in particular photovoltaics), bringing them towards parody with the cost of large scale generation and transportation.

Table 7: *Number of distributed generation connections[4].*

Area	ICPs	Residential	Commercial	DG Penetration
Orion	191,835	961	101	0.553%
New Zealand	2,061,028	8,709	379	0.441%

Uptake of distributed generation has been minor to date within Orion's network. Current application numbers are growing at a rate of 31 connections per month. Note that Orion currently has approximately 10 MW (17%) of distributed generation within its network that it owns and operates.

[4] http://www.emi.ea.govt.nz/ [31/01/2016]

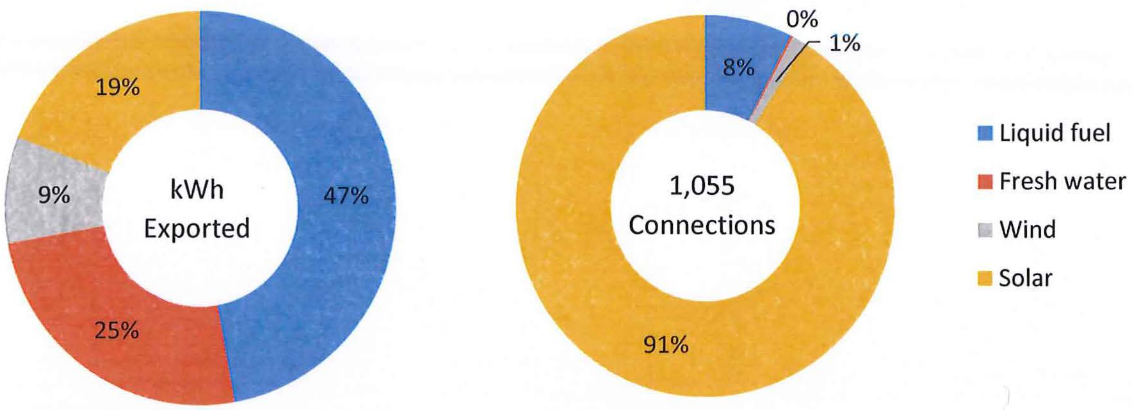


Figure 7: Orion's embedded distributed generation 2016[5].

Photovoltaic

Solar photovoltaic (PV) generation converts solar irradiation into electricity. PV follows daily and yearly trends however its output is completely weather dependent. A typical yearly solar profile is demonstrated in Figure 8, with average yearly peak hours per day of 5.2 hours in summer, 2.6 hours in winter and 3.4 hours in spring and autumn. Solar irradiation (W/m^2) in winter is approximately 70% of that in summer. A daily generation profile is shown in Figure 9.

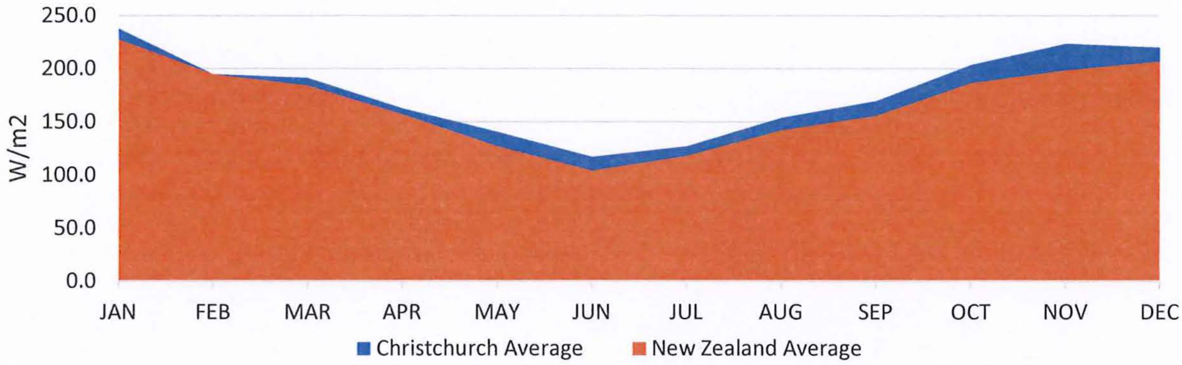


Figure 8: Yearly solar irradiation profile by month.

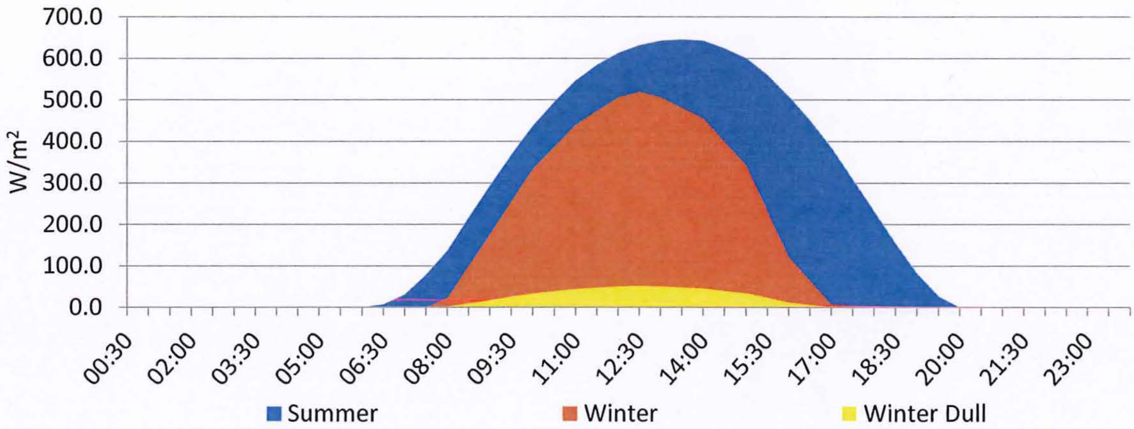


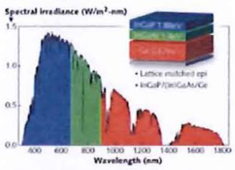
Figure 9: Daily solar irradiation profiles.

[5] http://informer/teams/Commercial/Network Analysis/Distributed Generation Connections.xlsx

PVs uptake to date is at levels well below that of other countries, with 955 installations within Orion's network with a combined capacity of 3.8 MW_p (as at 31/01/2016). On an economic basis solar generation is currently priced between 16.09 c/kWh and 41.0 c/kWh[6]. As New Zealand has 80% renewable generation the government did not see it fit to subsidise solar to reduce CO_2 emissions.

Panel Types

Table 8: *Panel types and properties.*

Type	Profile	Properties
Solar Thermal		Doesn't produce electricity but harnesses rooftop heat which is piped to a hot water cylinder, swimming pool or underfloor heating. The process is more efficient than electricity generation at 50-75%[7].
Crystalline	 Mono  Poly	Crystalline PV cells are wafers embedded with impurities, and then fitted with conducting circuitry and housing. They are the most efficient and expensive of the single junction technologies. Two types exist including poly crystal and mono which is the more efficient and expensive option.
Amorphous Thin Film	 Amorphous	Amorphous (non-crystalline) panels are the simplest, cheapest and least efficient of the solar cells currently on the market. They have the benefit of being flexible and require no rare earth materials or heavy metals.
Multijunction		Multijunction cells are single cells (usually crystalline) of alternate composition stacked on top of each other to capture different ranges of the solar spectrum. They are the most efficient cells overall but are considerably more complex and expensive.
Solar Windows		Demonstrated in 2014 using transparent organic cells with 1% efficiency. Expected to reach 10% efficiency by the end of a decade with high rise buildings being the target market[8].

Panel Efficiency

Commercial panels currently on the market typically operate with 15%-20% efficiency. The most efficient panel (created in a lab) has an efficiency of 46.0% (see Appendix A). SolarCity, a solar financing company in the United States and top installer of panels in the American market recently unveiled a 22.04%[9] efficient commercial panel. Production is set to ramp up to 10,000 units a day in 2017. Trina Solar (who supply Vector) commercial panels have an efficiency around 16.0%[10] (20.8% non-commercial).

[6] http://www.epecentre.ac.nz/research/EEA_2015/EEA_Paper_2015_PV%20Economics%20and%20Uptake-r12.pdf
[7] http://energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater
[8] http://www.extremetech.com/extreme/188667-a-fully-transparent-solar-cell-that-could-make-every-window-and-screen-a-power-source
[9] http://ecowatch.com/2015/10/05/elon-musks-solarcity/
[10] http://www.trinasolar.com/us/product/PDG5.html

Solar Inverters

Inverters are required to take the variable DC output from solar generation and convert it to AC mains. They typically come in three form factors as outlined in Table 9. Two inverter manufacturers have offices in Christchurch and are listed in Table 11.

Table 9: *Inverter types.*

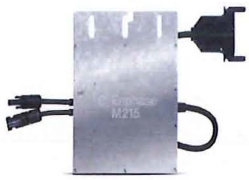
Type	Power	Inverter Efficiency	System Efficiency	Comment
Central	Above 100 kW_p	98.5%[11]		A single localised inverter. Have the highest efficiency and generally the cheapest option on a kW basis. Suffer from system level optimisation as opposed to unit level which can cause large efficiency losses for marginal shade coverage. Central inverters also require large DC voltages to be transported from the panel to the inverter, a safety factor that needs to be considered.
String	Up to 100 kW_p	98.0%		Smaller inverters connected in parallel. Lower efficiency however optimisation is at a functional unit level, allowing for less losses due to marginal shading. Capacity can be further upgraded at a later date by adding more inverters.
Micro	Module	96.5%[12]		Single inverter attached to each panel, with no single point of failure. Allows power output from each panel to be optimised. Generally have longer life spans due to lower power/heat loads. Cost effective for systems up to approximately 2kW. Higher system efficiency may justify use in larger installations. Capacity can be further upgraded at a later date by adding more inverters.

Table 10: *Inverter Functionality.*

Function	Description
Anti-Islanding	A safety feature that prevents export during a loss of power in the grid event. Prevents a back feed from harming lines crews working to repair a line.
Maximum Power Point Tracking	An optimisation process that increases the efficiency of the DC-AC conversion process.
Controllable Power Factor	Option to set the inverter system to either generate or absorb reactive power to minimise grid losses and stabilise voltage.
Two Way Communication	Most inverter manufacturers have built in, or offer an external device, for the monitoring of their devices to give an indication of system performance.

[11] http://www.webcitation.org/6TTjaprUM
[12] https://enphase.com/en-us/products-and-services/microinverters

Table 11: *Inverter manufacturers with Christchurch offices.*

Manufacturer	Inverter	Background
EnaSolar		A local designer and manufacturer which produces a range of grid tied inverters spanning 1.5kW to 5.0kW, with built in Wi-Fi functionality for real time monitoring[13]. EnaSolar also offer another product that manages excess generation export, giving priority to water heating storage over grid export.
Enphase		A Californian based company with a research and development division based in Christchurch, and manufacturing based in China. Enphase specialise in the niece market of micro inverters and also produce a solar monitoring device that tracks each inverters output giving real time analytics and reporting[14].

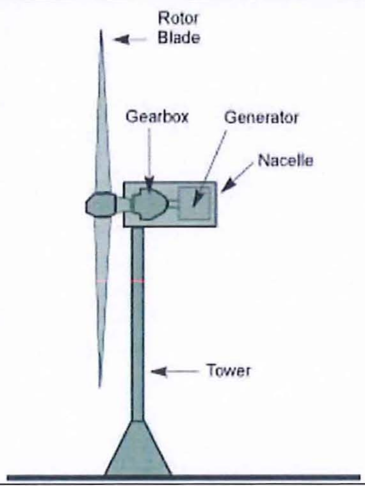
Hydro

Distributed Hydro comes in many sizes depending on the application and is generally classified by its generation capacity as either Pico (<5kW), Micro (5-100kW) or Mini (100-1000kW). Operation requires free flowing water, or a reservoir with a head differential to a discharge outlet. Hydro is one of the cheapest forms of electricity generation however it is heavily dependent on a suitable water source. Additionally environmental factors such as habitat destruction or water over allocation can prevent resource consents being granted. Fereday Island Hydro is an example of a Mini Hydro scheme that allowed a dairy farm near the Rakia River to go from a net importer of electricity to a net exporter. The scheme has 4x90kW river flow generators with a further 2x90kW consented.

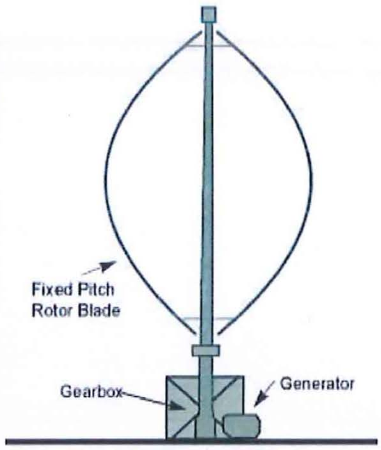
Wind

Distributed wind comes in two form factors, turbines with a vertical or horizontal axis, each with their own trade-offs. Wind power typically produces 10-40% of its rated generation due to inconsistent and sporadic wind speeds. This figure is considerably lower in urban areas (including household roofs) where vertical obstructions (houses, trees) cause turbulent wind profiles.

Table 12: *Wind turbine form factors.*

Turbine	Type	Attributes
	Vertical	**Advantages** • Height gives access to higher wind speeds. • Higher efficiency, blades horizontal to the wind receive more power. **Disadvantages** • Higher installation and maintenance costs due to height, additional machinery. • Have a higher visual impact on the environment.

[13] http://www.enasolar.net/products
[14] https://enphase.com/en-us/products-and-services

	Horizontal	**Advantages** • Will work in any wind direction. • Can operate in lower wind speeds. • Requires less height (no tower). • Visible to wildlife, has same profile while spinning or at rest. • Generator is installed at the base of the turbine, cheaper maintenance costs. **Disadvantages** • Lower heights have lower wind speeds, less efficient/cost effective.

The Blueskin Bay (Otago) community trust has established a company (Blueskin Energy) to build and maintain three community owned wind turbines (3x900kW) at a cost of \$5 to \$6 million. The installation will supply 26% of the Palmerston area (north of Dunedin) and connect to an Otagonet 33kV feeder. It has not been designed as an off grid solution.

Diesel

Diesel generators (Gensets) vary in size from 8 kW, suitable for a home, to shipping container sized 1.8 MW systems suitable for networks and large consumers. Gensets are Orion's current go to form of distributed generation for peak reduction and generation during outages as they are highly mobile and have a reliable output compared to renewable alternatives. Environmental impacts are limited because of the low number of operating hours. Operating costs are linked to maintenance costs and the current cost of diesel.

Table 13: *Embedded diesel generation cost (indicative only).*

Size	Customers Served	Capital Costs
8 kVA	House, Small Business	2,000
550 kVA	Street	100,000
2,000 kVA	Factory, Hospital…	1,000,000

Table 14: *Orion's Diesel generator units.*

Description	Number	Generator kVA	Generator kW	Sync
Mobile (Truck Mounted)	1	440	352	1/1
Mobile (Truck Mounted)	1	400	320	1/1
Mobile (Truck Mounted)	1	375	300	1/1
Mobile (Truck Mounted)	1	110	88	1/1
Transportable (400V)	10	550	440	3/10
Static (11,000V)	2	2,500	2,000	2/2
Wairakei Road Building	1	550	440	1/1
Armagh hot-site	1	30	24	0/1
Total capacity	18	12,405	9,924	10

Orion currently has resource consents to install 2x11.5 MW of Diesel generating capacity at the Bromley and Belfast substations. Orion forecasting assumes 2 MW of customer owned peak diesel generation will be added to the network each year.

Orion maintains its diesel supply using six diesel tanks ranging in size from 2,900 to 16,155 Litres in addition to a 1,500 Litre trailer mounted tank.

3.3.2 Battery Storage

Battery storage allows for the short term storage of energy as either a method to increase security of supply or shift supply off peak. It comes in a wide range of sizes for either residential, commercial or network scale. Recent cost reductions from the automotive industry have seen a dramatic decrease in cost, with Tesla now offering home storage at a cost of NZ $630 kWh, plus installation.

Further cost reductions are expected from economies of scale, with manufacturers building large 'Giga Factories' to decrease costs by an estimated 30%[15]. Additional savings are expected from the repackaging of EV battery packs into battery storage once a lifecycle has been established.

Current Technology

The two leading technologies at present for distribution are Lithium Ion and Redox Flow batteries. When choosing a battery for any purpose many characteristics (Table 15) need to be considered depending on the application.

Lithium Ion batteries can be further defined into different chemistry types, but share a common form factor, individual cylindrical cells (similar to AA). These cells are then packaged together to form battery packs, which also include charging and temperature control circuitry and componentry.

Redox Flow batteries pump two different liquids past each other with a membrane as an interface. Ion transfer occurs through the membrane, when charging or discharging the battery. Due to their size they are not in a form factor suitable for individual residential residences.

[15] https://finance.yahoo.com/news/panasonic-backs-teslas-gigafactory-investing-190107913.html

Table 15: *Desirable characteristics of battery technologies.*

Characteristic	Explanation
High specific energy	Storage capacity per unit mass (weight to storage ratio).
High specific power	Ability to output power (rate at which stored energy can be discharged).
Affordable	Cost per kWh and number of cycles.
High cycles	The rated number of charge/discharge cycles under warrantee.
High round trip efficiency	The ratio of energy output to that input through a full charge-discharge cycle.
Long shelf life	Degradation of a battery over time while not in use.
High safety	Some battery chemistries are prone to fire, while also posing a shock hazard if improperly managed (dangerous elements, pressurised…).
Wide operating range	Some battery cycle management systems limit the depth of discharge in which a cycle can operate to extend the life of the battery. This band can be initially inhibited and then increased to keep a similar performance over the battery's lifetime. Other chemistries see considerable drops in performance once a discharge threshold has been reached. Additionally a wide operating temperature range is desirable.
Non-toxic	Depending on the chemistry toxic compounds may be used. Can determine the ability to recycle.
Fast charging	The time taken to charge a battery between 0-80% or 0-100%.
Low self-discharge	If left alone battery's will self-discharge over time.
Life cycle	Technologies with adequate end of life contingencies (recyclability, reuse).
Response time	How fast the battery can react to a change in demand.

Types and Chemistries

Common battery types include Lithium-Ion, Sodium Sulphur (NaS), Redox Flow, Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH) and Lead–Acid. Table 16 outlines a comparison between the alternatives (Green: Desirable, Orange: Neutral, Red: Poor, Black: Data unavailable). It should be noted that each battery type has sub-chemistries and ratios that can effect each property to some extent depending on its desired purpose.

Table 16: *Comparison of different battery chemistries (indicative only)*[16].

Property	Li-Ion	NaS	Flow	NiCd	NiMH	Lead-Acid
Specific energy	Green	Green	Green/Orange	Red	Orange	Red
Specific power	Green	Red	Green	Red	Green	Red
Cost	Red	Red	Orange	Red	Orange	Green
Number of cycles	Green	Orange	Green	Orange	Orange	Red
Round trip efficiency	Green/Orange	Orange	Red	Red	Black	Green/Orange/Red
Lifetime	Orange	Orange	Green	Orange	Green	Orange/Red
Safety	Red	Red	Green/Orange	Green	Green/Orange	Orange
Operating range	Orange	Green	Green	Orange	Orange	Green
Non-toxic	Green	Orange	Green	Red	Green	Red
Fast charging	Green	Red	Green	Green/Orange	Orange	Red
Self-discharge	Orange	Red	Red	Red	Red	Green
Form factor	Green	Red	Orange	Green	Green	Green
Shelf Life	Orange	Orange	Black	Red	Green	Green
Year commercialised	1992	1960	1993	1956	1990	1881

[16] http://www.mpoweruk.com/chemistries.htm

Alternative chemistries that have the potential to displace Li-Ion in the next two decades are shown in Figure 10, with the potential for an order of magnitude increase in battery capacity if Lithium Air batteries are commercialised.

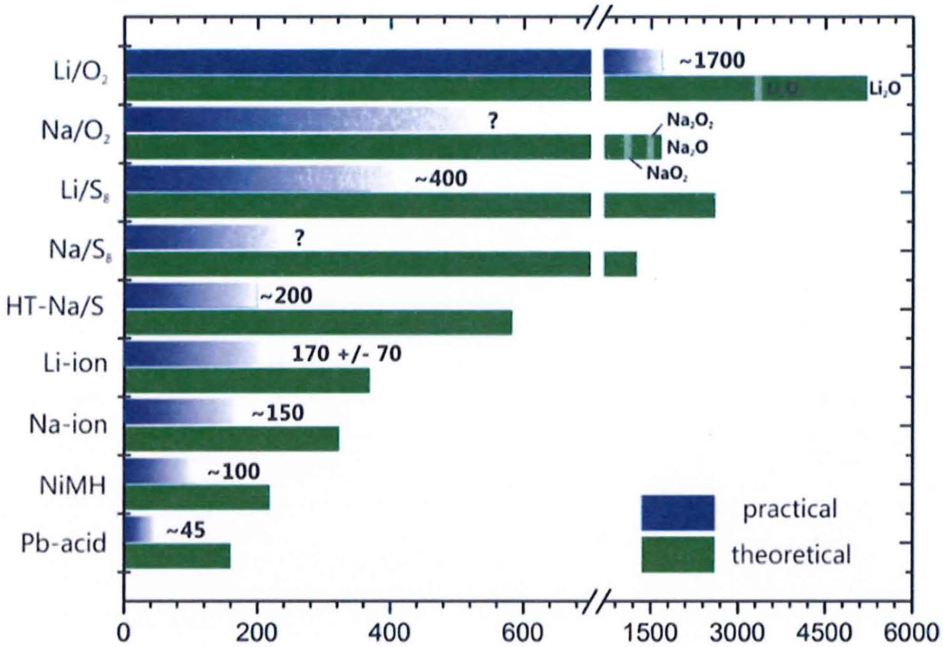


Figure 10: Specific energy of different battery chemistries.

Technology Issues

Conversion losses will decrease electricity efficiency. Three sources of energy loses exist including battery heating/cooling, non-ideal charging characteristics and AC-DC conversion through the inverter. Additionally the batteries long life design and specific energy rating impact the peak power it can output. This may see consumers needing to design battery storage systems based on energy draw and not storage capacity.

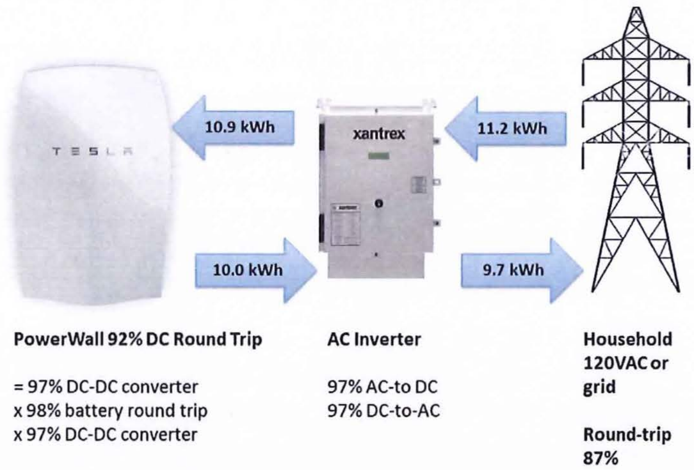


Figure 11: Tesla battery cycle losses.

3.3.3 Electric Vehicles

Electric vehicles (EVs) are a direct substitute to internal combustion engine (ICE) vehicles which currently dominate the market. They are inherently simpler and more efficient, requiring 41% and 30% of an ICEs maintenance and fuel costs respectively. Currently a car battery accounts for 25% of an electric vehicles cost, however future advancements in battery technology and manufacturing economies of scale are projected to see this cost dramatically decrease by a further 30% by 2020. Four key issues confining EVs to a niece in the consumer automotive market at present including:

Table 17: *Electric vehicles uptake constraints.*	
Constraint	**Description**
Cost	The cheapest EV currently on the market, the Nissan Leaf costs $40,000 compared to $31,000 for an equivalent ICE vehicle (Toyota Corolla). An electric-combustion vehicle cost parody of US$ 150 kWh of battery storage is expected to be reached in 2020-2025 (US $300 kWh presently)[17].
Charging Time	EVs currently use three charging modes being *Quick Charge* (15-30 minutes, 80%), *Normal Charge* (7-8 Hours, 80%) and *Trickle Charge* (14 Hours, 100%) for the 120 km range 26 kWh batter used in the Nissan leaf. Specialised charging stations are required for quick and normal charging, with a household plug being adequate for trickle charging. This is in stark contrast to the instant refuelling capability of ICE and hydrogen vehicles.
Range	The average New Zealand driver travels 39 km a day. Entry level EVs have a theoretical range of 170 km (Nissan Leaf), with the top of the line Tesla capable of traveling 320 km on a single charge. Tesla's CEO stated in an interview he expects EVs to be capable of 1,200 km on a single charge by 2020 and to increase at a rate of 5-10% per annum[18].
Choice	In 2015 only one model of EV (Nissan leaf) was available for sale in New Zealand, with a further seven hybrids available. Many manufacturers are now manufacturing completely electric vehicles including Nissan, BMW and Chevrolet, to list but a few.

New Zealand's EV uptake has lagged other countries with Norway having the highest penetration at 12.5%[19]. Additional factors that will affect EV uptake are listed in Table 18.

Table 18: *Factors contributing to the uptake rate of electric vehicles.*	
Factor	**Explanation**
Incentives	Currently EV owners do not need to pay road user charges until 2020 equating to an average saving of $66.80 per 1000km[20]. Other countries allow electric vehicles to occupy bus lanes, car pool lanes, and subsidise their purchase.
Charging Infrastructure	The rate of charging infrastructure installation will help alleviate range anxiety.
Business Fleets	To foster the uptake of EVs the EECA has launched a *'Vehicle total cost of ownership'*[21] website allowing businesses the ability to compare their fleet needs against cars registered for sale in New Zealand. Meridian Energy and Air New Zealand have publically stated they intend to replace their commercial fleet vehicles with electric equivalents where appropriate, with more companies likely to follow. Orion currently has one all electric vehicle and seven hybrids in its fleet and plans to acquire more hybrids as vehicles come up for replacement.

[17] Third Horizon: Phase 1 Summary of Findings, Version 3, Page 6
[18] http://www.greencarreports.com/news/1100204_elon-musk-hints-at-50-percent-more-range-for-tesla-model-s-video
[19] https://www.iea.org/evi/Global-EV-Outlook-2015-Update_1page.pdf
[20] http://www.nzta.govt.nz/vehicles/licensing-rego/road-user-charges/ruc-rates-and-transaction-fees/
[21] https://www.eecabusiness.govt.nz/tools/vehicle-total-cost-of-ownership-tool

Second Hand Vehicles	The majority of New Zealand's vehicles are bought second hand (54%). This creates a lag behind other countries while an import market is established. The average age of a vehicle in New Zealand in 14 years[22].
Hydrogen Vehicles	Hydrogen fuel cell powered vehicles are an alternative technology that could challenge ICE for dominance. Hydrogen is more expensive than electricity with a lower total efficiency however it can be refuelled instantly like ICE vehicles if the hydrogen infrastructure is put in place.
Hybrids	To some extent plug-in hybrids (PHEV), electric vehicles that also contain an ICE to charge the battery and add performance, are enabling the market transition from ICE vehicles to EVs while battery technology reaches an economical level.
Autonomy	Automakers have incorporated into EV design road sensing technologies, capable of hands free parallel parking and lane changing. Over air updates are expected to make these vehicles self-driving in the future. Tesla's CEO stated in a 2015 interview that vehicles would be technically capable of being autonomous by 2018, but would likely be restricted by regulation.

Table 19: *Snapshot of light vehicle fleet as at August 2014*[23].

Location	Diesel	Petrol	Electric	Hybrid
Christchurch	~66,000	~484,000	64	41
New Zealand	571,699	2,780,892	782	644

Charging Infrastructure

Another technology that is enabling the uptake of electric vehicles are charging stations. 142 public charging stations are available in New Zealand, 9 of which are high voltage DC chargers (which are required for Quick Charging). Quick chargers require an 80A 400V three phase connection near a distribution transformer that can support a 55kVA load. They cost approximately $75,000 to $100,000 per installation.

An initiative to facilitate the roll out of charging infrastructure is underway by an organisation called Drive Electric, backed by Meridian, Contact and multiple EDBs. The organisation has developed an 'electric highway' concept which plans to install 32 fast charges along the length of State Highway 1. Although an initial scoping study has been completed the project has stalled. In its absence networks (North Power, Delta, Orion and Vector) have installed or plan to install fast chargers in 2016.

Another initiative is underway by a private company, charge.net, who plan to install a nationwide network of 100 fast chargers, with an expected 43 to be installed by the end of 2016 (Appendix B).

Orion as part of the Christchurch EV Forum is planning to install 5 fast chargers and several standard chargers throughout its network in 2016. Locations for these chargers have yet to be finalised.

3.3.4 Smart Homes

Smart homes and appliances use information technology to empower consumers to make better energy consumption decisions, or automate decisions in their entirety. Better decision making

[22] www.transport.govt.nz/assets/Uploads/Research/Documents/NZ-Vehicle-Fleet-Graphs-2015Q3-v1.xlsx
[23] http://www.transport.govt.nz/assets/Uploads/Research/Documents/NZ-Vehicle-Fleet-Graphs-2014-v4.xls

includes shifting power usage off peak, decreasing power consumption when it is not needed or increasing efficiency by changing appliance consumption profiles when time is not a factor.

Smart Meters

Smart meters monitor customer consumption in real time and facilitate the two way communication between a customer's residence and the grid.

Smart meter capabilities include:

- Total harmonic distortion measurement
- Min and Max Voltage measurement
- Tamper and outage detection
- Phase angle measurement
- Half hour consumption and interval data gathering and storage
- Waveform measurement
- Lead/Lag measurement
- Remote load limiting and cut off
- Home area network (HAN) functionality
- Remote reading and two way communication (radio, mesh or cellular)

Table 20: *Smart meter market penetration.*

Area	ICPs[24]	Smart Meters[25]	Market Penetration
Orion	190,602	169,956	89.2%
New Zealand	2,052,424	1,327,673	64.9%

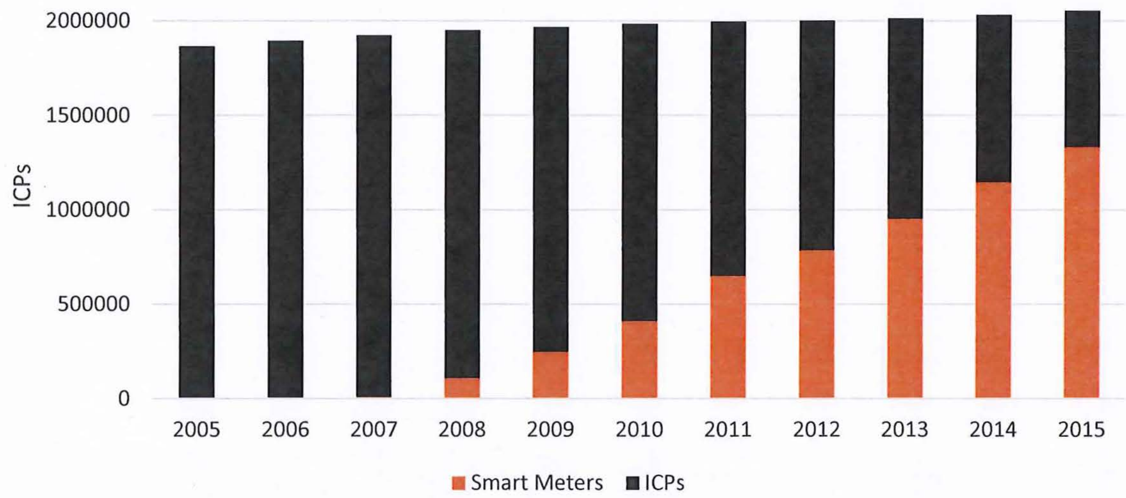


Figure 12: Uptake of smart meters in New Zealand.

The average rate of Smart Meter installation is trending at 8% of total ICPs per annum. If this rate continues market saturation will occur in 2020.

Home Energy Management Systems

An example HEMS system is the Smappee. This device is attached to a customer's switchboard and is able to tell when lighting, appliances and other power using devices are turned on or off based on total power usage and switching noise/transient measurements. The system also allows control of

[24]http://www.emi.ea.govt.nz/Reports/DataReport?param_RegionType=REG_COUNCIL&param_MarketSegment=All&param_Show=Count&param_DateTo=30/9/2015&reportDisplayContext=Gallery&categoryName=Retail&reportGroupIndex=19&reportName=H3WIHL&eventMode=Async

[25]http://www.emi.ea.govt.nz/Reports/VisualChart?reportName=AWNGPD&categoryName=Retail&reportGroupIndex=11&reportDisplayContext=Gallery#reportName=AWNGPD

appliances through the use of smart plugs which can operate remotely through user intervention or based on logic like inactivity, geo-fencing (using a phones GPS), breaching a usage threshold or timing. Cisco, Belkin and other companies are also developing and offering similar devices.

Figure 13: Snappee home energy management system.

Another HEMS technology is (Alphabet's) Nest thermostat. The Nest measures the temperature, humidity, ambient light, near-field and far-field motion sensing to make better heating decisions for the owner. The Nest ecosystem also learns an owner's heating habits over time to allow for more efficient heating and cooling cycles. It can communicate this information to other devices with studies claiming that the Nest alone can reduce a households heating bill by 13% to 29%[26].

Smart Appliances

Smart appliances have the 'smarts' in the device itself and can operate in isolation (from other devices) or communicate with each other or a central hub over a local network (HAN, internet). They have the control and scheduling functionality built in and do not require smart plugs.

3.3.5 Future Technologies

Distributed Winter Generation

Solar power is currently limited to day time generation. Should a cost effective form of winter generation be developed in the future it could facilitate the off-gridding of traditional customers becoming economical.

Hydrogen Fuel Cells

Hydrogen is seen as a potential alternative method to transport and store energy, although it has issues that need to be overcome. Hydrogen fuel cells convert hydrogen and oxygen to pure water, generating electricity in the process. Currently 98%[27] of the worldwide Hydrogen production is derived from fossil fuels, however an alternative method known as hydrolysis (passing a current through water) can be used with renewable generation to create a clean energy source.

Although hydrogen fuel cells are more efficient and energy dense than petroleum based fuels they will require similar production and refuelling infrastructure which is not yet prevalent.

[26] https://nest.com/downloads/press/documents/efficiency-simulation-white-paper-nl.pdf
[27] http://www.mpoweruk.com/fuel_cells.htm

Issues with fuel cells include:

- A Low cell voltages between 0.6V to 0.7V, 200V-300V is needed to power an electric drive train.
- Non-reversible fuel generation (in the cell itself) which prevents regenerative breaking without additional hardware.
- A low dynamic output range and slow transient response times. This can be mitigated somewhat with a power boost from batteries or super capacitors.
- Freezing of the electrolyte (batteries are needed for fuel heating).
- The use of rare earth materials and expensive catalysts.

Hydrogen also suffers from being a pressurised explosive gas that poses a risk during transportation or in a collision.

Superconducting Magnetic Energy Storage (SMES)

Still in its infancy, SEMS is a technological substitute to grid side storage that may become economically feasible in the future. Energy is stored in a cryogenically cooled superconducting ring that has minimal losses (besides cooling) giving a 90-95%[28] round trip efficiency for short time storage. Although a SEMS installation requires a large capital cost it has many benefits over battery technology including its ability to both absorb and expel large currents instantaneously with a highly variable output.

DC Homes

Future household energy efficiencies may be gained from converting a portion of wiring in households to DC instead of the full AC systems used currently. Table 21 highlights some of the underlying forces that may bring about this change.

Table 21: *Factors contributing to a DC household future.*

Factor	Explanation
Battery Storage	Battery storage is a natural DC supply in a household. In some instances multiple conversions take place between the grid and the consuming device an example being: Grid->inverter (DC battery)->rectifier (mains)->inverter (DC device) DC household wiring could remove the last two conversion steps to reduce losses for many devices throughout the house.
USB 3.1	The new USB standard comes with a 100W rating which will be able to power many devices including LEDs, cell phones and laptops. Additionally all devices will be connected to an internal private network which will allow for a more secure 'internet of things' in the home than wireless. USB cables do not require an electrician's certificate to install.
Uptake of DC technology	The DC portion of household load is continuously increasing with the uptake of new consumer electronics. Inverters in other larger appliances could also be removed to increase the DC to AC consumption ratio further.

[28] http://www.iec.ch/whitepaper/pdf/iecWP-energystorage-LR-en.pdf

4. Potential Impacts on Core Network Business

4.1 Customer Impact

4.1.1 Customer Choices and Business Cases

Diffusion of Innovation Theory

To model the uptake of emerging technologies the diffusion of innovation theory was used. The theory profiles the mind set of consumers based on how early they buy into a new technology.

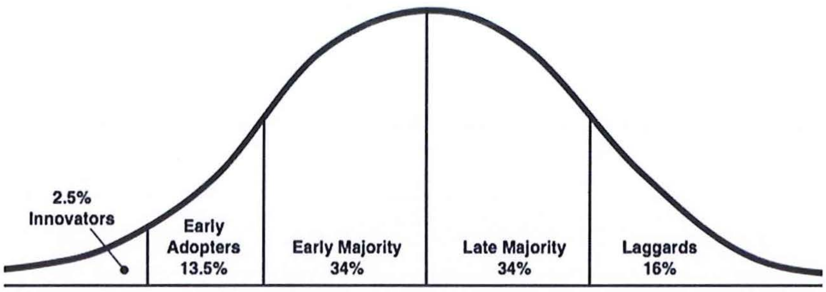


Figure 14: Technology uptake curve.

Table 22: *User segments of a market [6].*

Profile	Proportion	Explanation
Innovators	2.5%	Forward thinkers who see potential in new technologies even though they have yet to be fully developed. Are willing to take risks on unproven/unfinished technologies and get enjoyment from their use.
Early Adopters	13.5%	Have time and money to invest, like to be leaders in business and life. Slightly more reserved than Innovators.
Early Majority	34%	Adopt technology when it has been refined and proven to work. Often have contact with innovators and early adopters.
Late Majority	34%	Approach innovation with a high degree of scepticism. Will adopt a new technology only once it has been proven in the marketplace (by the early majority).
Laggards	16%	Typically last to adopt new technologies, have an aversion to change and will only use a technology if necessary or restricted financially.

The accumulated uptake generally resembles Figure 15, with slow uptake initially, exponential growth after a 25% uptake and then a tapering down after 75% uptake (approximates). A technology is thought to be established as a viable substitute when a 5%[29] market share has been achieved.

[29] https://books.google.co.nz/books?id=VuEaBgAAQBAJ&printsec=frontcover#v=onepage&q&f=false Page 37

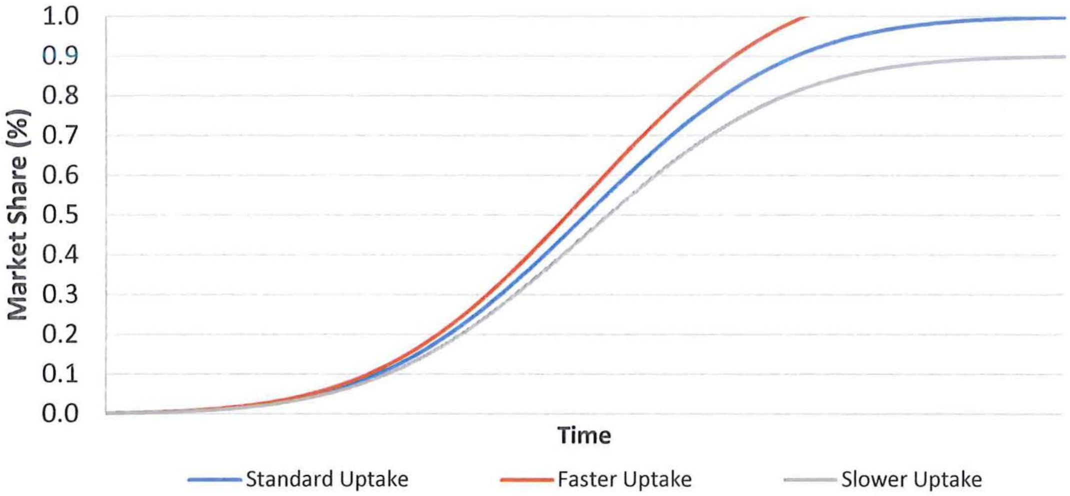


Figure 15: Theory of Innovation typical S curve uptake model.

Distributed Generation

The current Retail price structure means that for distributed generation to become economical for a customer it must only match the total cost of delivered electricity, not the generation cost. This gives it a 20.78 c/kWh margin (total delivered price minus grid generation cost) in which to compete with large scale generation, assuming all things being equal. Orion charges an $80 dollar connection fee for distributed generation connections ($100 max allowable under regulation).

Table 23: *Indicative Breakdown of a typical electricity bill[30] (indicative only).*

Component	Percentage of Cost	Cost c/kWh
Generation	28%	8.08
Retail	30%	8.65
Distribution	23%	6.64
Transmission	7%	2.02
Other (GST, Regulatory)	12%	3.45
Total	**100%**	**28.86[31]**

Table 24: *Average New Zealand consumption per customer[32].*

Year	Cost per household	Consumption per Household
2015	$2,101	7280 kWh

For distributed generation to be truly competitive with the current electricity model it must not only compete on an economic basis but also in terms of reliability, security of supply, ease of use and time of use.

[30] https://www.ea.govt.nz/consumers/my-electricity-bill/

[31] http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/prices/electricity-prices/sales-based-residential-prices.pdf

[32] http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/prices/electricity-prices/sales-based-residential-prices.pdf

Solar PV

The uptake curve (Figure 16: Green: Residential, Blue: Commercial) exhibits exponential uptake characteristics however the customers are 'early adopters' and the technology's adoption is not yet widespread with less than 0.5% uptake.

Recent advancements in PV technology have seen a rapid change in system cost, dropping from NZ $40,000 installed in 2008 to $9000 installed in 2015 for a typical residential 3kW$_p$ system[33]. Excluding the installation cost, 50% of the cost can be attributed to PV panels and 50% to inverters. A further 40% reduction in panel cost is expected over the next 4-5 years[34]. In addition to this finance business models (Table 25) are facilitating solar powers uptake with zero money down options already available. Commercial users are expected to take PV up later than residential users as their size allows them to pay less per kWh for electricity from the grid, decreasing the economics of PV investment.

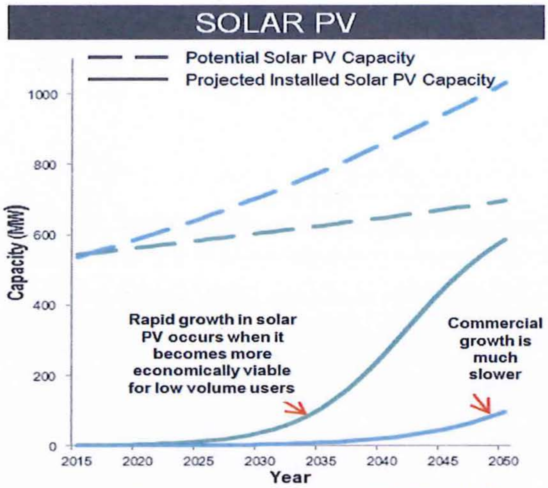


Figure 16: Projected uptake curve of Solar PV[35].

Table 25: *PV finance models.*

Method	Initial Capital	Ongoing Payments	Ownership
Outright Purchase	Customer	Nil	Customer
Power Purchase Agreement	Financer	For power	Financer
Lease Purchase Agreement	Financer/Customer	Instalments	Financer/Customer
Mortgage	Financer/Customer	Instalments	Financer/Customer

Micro Hydro

Other Canterbury residences have used Pico Hydro as a substitute to installing lines to a new rural property that can cost in excess of $25,000 per km. Pico Hydro systems cost $1,000-$2,000 per kW with a $10,000-$15,000 installation and fixture cost including a battery bank.

Hydro power coupled with water schemes also have the potential to indirectly reduce load for a greater area. When a scheme is implemented ground water pumps are no longer required, with additional reductions from hydro generation at the schemes intake or outtake offsetting regional pumping.

At least two hydro system manufactures operate in New Zealand, with Hydroworks producing Mini Hydro or greater systems and Powerspout producing Pico Hydro systems. Although distributed hydro is a relatively mature technology its uptake is low. This can be attributed to few adequate water sources (relative to connections) and it only being cost effective as a substitute to offsetting lines installations to a remote location.

[33] https://www.mysolarquotes.co.nz/about-solar-power/residential/how-much-does-a-solar-power-system-cost/
[34] https://www.db.com/cr/en/concrete-deutsche-bank-report-solar-grid-parity-in-a-low-oil-price-era.htm
[35] Third Horizon: Phase 2, Version 1, Page 4

Micro Wind

Like hydro, wind turbines have been installed as substitutes to installing lines to remote rural sections. Micro wind installations typically cost $10,000 per kW[36] with a $4,000 installation and wiring fee. Larger units are cheaper per kW with a 500 kW system costing in the order of $300,000.

A number of turbine manufacturers operate in New Zealand including Windflow which sell 500 kW units and Power House selling 2kW units. Again like hydro the uptake of distributed wind generation is low. This can be attributed to its cost per kW, inconsistent generation profile and need for a suitably windy site. Currently its uptake is limited to large scale deployments or substituting for the installation of distribution lines in remote areas.

Diesel

Diesel generation has the second highest uptake rate behind PV and is predominantly used for backup power in the event of an emergency. As other forms of distributed generation take off, particularly PV, diesel may find a secondary market as a form of winter generation. The economics of diesel generation for a purely generative basis are negative. However considering the cost a customer associates with a loss of supply can make it a cost effective investment.

Battery Storage

The uptake curve (Figure 17: Green: Residential, Blue: Commercial) exhibits exponential uptake characteristics however the customers are 'early adopters' and the technology's adoption is not yet widespread with less than 0.5% uptake.

The uptake battery storage is heavily aligned with PV installations, as synergies between the two leads to the greatest net benefit under the current market structure. Table 26 outlines the years projected that battery storage will become cost effective for different customer bases. The uptake rate is inversely proportional to the price a consumer pays, with high volume residential consumers forming the early majority. Current batteries range between 1.2 and 10 kWh with the cheapest option being $630 kWh excluding installation. To become economical the lifecycle cost of a battery must be less than Orion's current day/night differential, which is 15 c/kWh.

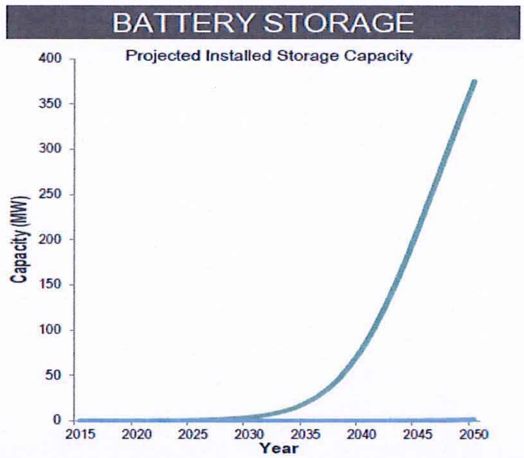


Figure 17: Projected uptake curve of battery storage[37].

Table 26: *Projected uptake rate of battery storage[38].*

Customer Type	Usage	Projected Uptake Year
Residential	Low Volume	2029
	High Volume	2023
Commercial	Small	2040
	Mid-Large	2045

[36] http://www.powerhousewind.co.nz/products.htm
[37] Third Horizon: Phase 2, Version 1, Page 4
[38] Third Horizon: Phase 1 Summary of Findings

It is thought that there are very few batteries within Orion's network at present. Customers installing batteries are currently under no obligation to inform their local network making their uptake hard to track.

Electric Vehicles

The uptake curve (Figure 18: Green: Light Passenger, Blue: Light Commercial) exhibits exponential uptake characteristics however the customers are 'early adopters' and the technology's adoption is not yet widespread with less than 0.5% uptake.

Customers must consider both the upfront and ongoing costs when comparing EVs and ICE vehicles. EVs cost approximately $12.41 per 100 km in energy costs (including road user charges) compared to $17.10 per 100 km (petrol $1.80/L), a 27% reduction. With fewer moving parts EVs also require less maintenance costs. Surveys have found that customers care less about ongoing costs, focusing on the upfront cost when purchasing a vehicle.

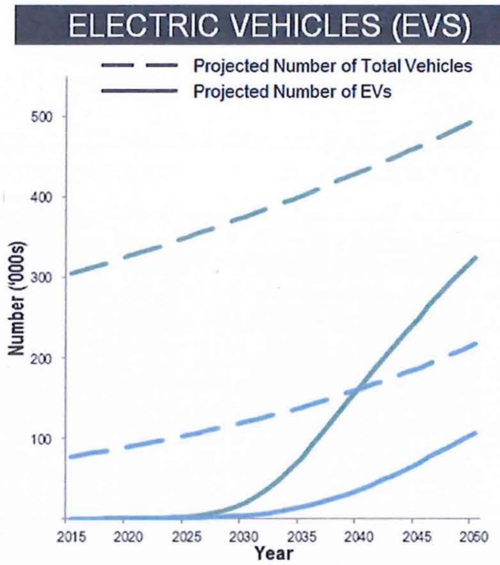


Figure 18: Projected uptake curve of light electric vehicles in Canterbury[39].

Off-Grid

It is unlikely that going off-grid will become economical in the foreseeable future for all but a few extreme cases, for example new connections with large connection fees due to line construction. As such off-gridding will be driven by emotion and ideological reasons, rather than economically driven. Projections[40] show that in 2025 an 8kW PV, 20 kWh battery system with a backup generator would be approximately 200% the equivalent yearly cost of a grid connection with solar and battery system. This will fall to being 50% more expensive in 2040.

Depending on connection costs seasonal off-gridding may take place over the summer period with a PV and battery system, reconnecting again in winter offsetting the need for a generator. This would change if a reliable and cost effective form of winter generation was to be developed and brought to market. This could be inhibited by re-connection fees which can erode the benefit of seasonal connections.

[39] Third Horizon: Phase 2, Version 1, Page 4

[40] Third Horizon Phase 1, Page 28

Summary

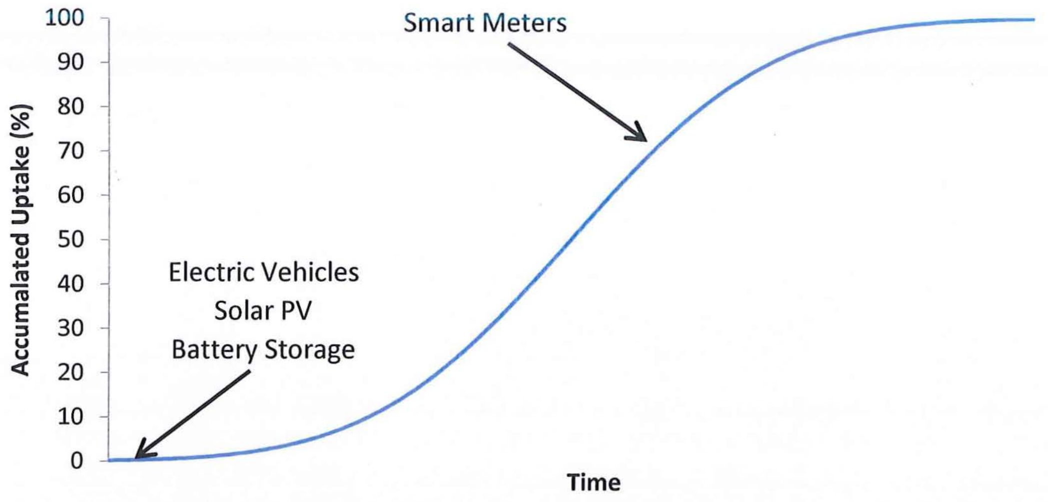


Figure 19: Current uptake position of emerging technologies in the Canterbury region.

4.2 Network Impact

4.2.1 Peak

Distributed Generation

PVs generation profile does not correspond to the network peaks, which generally occur between 08:00 and 11:00 for the am peak, and 16:00 and 21:00 for the pm peak. The generation and load profiles in Figure 20 are not uncommon on a cloudy winter's day implying that solar cannot reliably reduce the risk of peak demand. As such its contribution to peak load reduction is marginal and will pose little consideration in terms of designing the network for peak load.

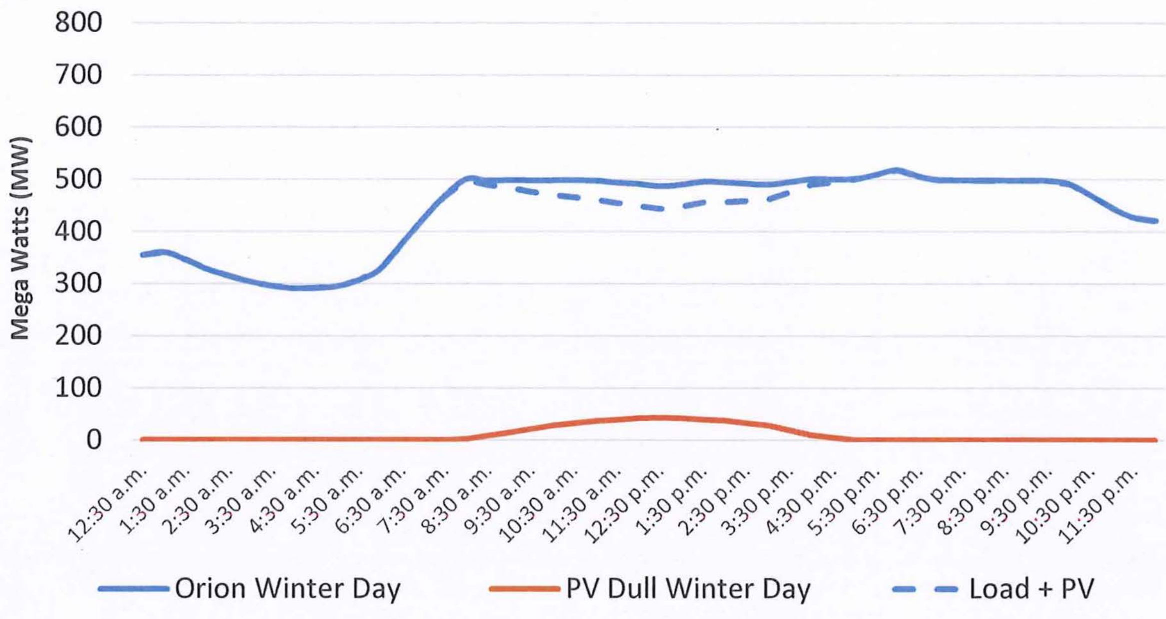


Figure 20: Solar PV load profile on a cold winter day, 100% solar uptake with 3kW installations.

Distributed hydro's generation profile is flat for run of the river schemes or controlled where water storage is possible and is therefore useful for managing network peak demand. Distributed wind's profile is sporadic and thus cannot reliably reduce peak load. Distributed diesel is currently incentivised to reduce peak load. Additional diesel generation will likely increase its effect.

Battery Storage

Battery storages impact on peak load could be either beneficial or detrimental, depending on the aggregate charging and discharging profile. Figure 21demonstrates a perfectly balanced load curve using arbitration between high and low load periods. Under this scenario peak load is reduced from 595 MW to 510 MW. Alternatively if charging occurred in conjunction with peak load it could drastically increase the required infrastructure needed. Orion may have some influence over the timing of charging and discharging through price signals or direct influence like the hot water ripple system.

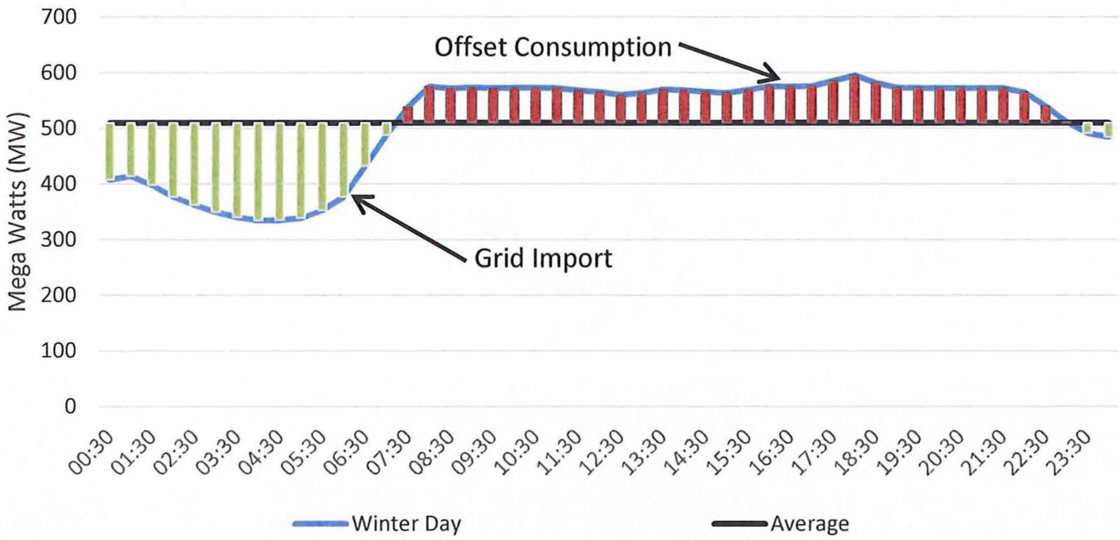


Figure 21: Supply shifting using battery storage.

Electric Vehicles

EVs impact on peak demand is dependent on the timing and required load needed. Figure 22demonstrates two hypothetical EV profiles and their potential impact. The charging profiles assume one EV per household with the charging distributions:

Profile	Overnight (21-8)	AM Peak (8-11)	Daytime (11-15)	PM Peak (15-21)
1	40%	20%	20%	20%
2	100%	0%	0%	0%

In profile 1 an additional 83 MW of capacity would be required to meet the new peak demand. In profile 2, where all charging occurs off-peak at night, no additional network upgrades would be needed. In reality the true EV charging profile will differ however Orion has some influence through pricing and educating customers.

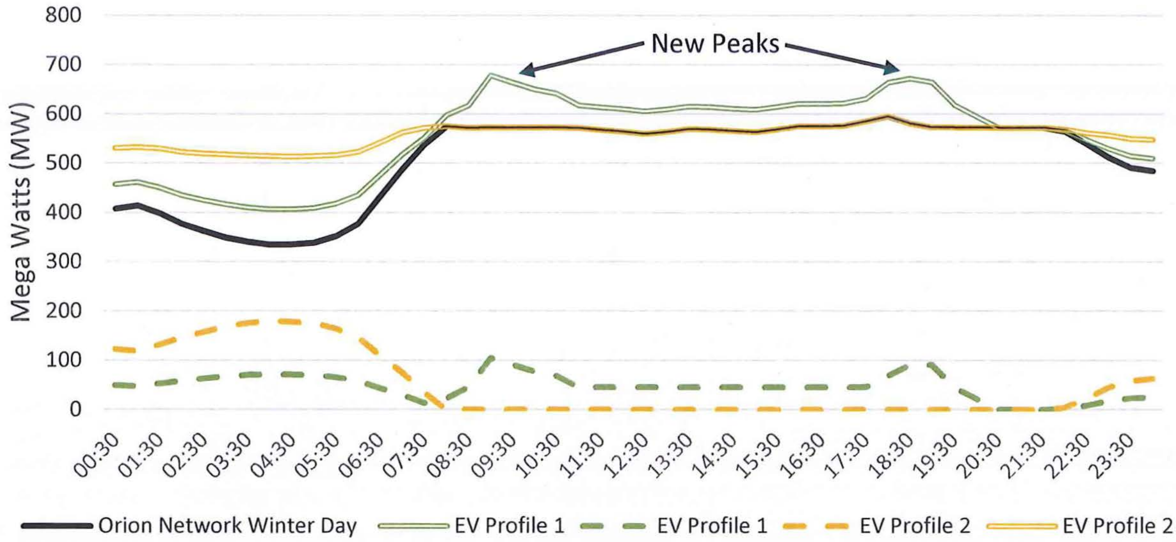


Figure 22: Electric vehicle charging profile impact comparison on peak demand.

EVs would also be capable of acting in a similar manner to battery storage, and could be used to reduce peak load by offsetting consumption to reduce a household's load during peak periods.

Other Emerging Technologies

Alternative forms of distributed generation (micro hydro, micro wind and diesel) along with efficiency gains per household when aggregated together will offset and reduce local demand to reduce peak load. The decrease will be variable in nature depending on the types of distributed generation installed. Additional peak load reductions will come from smart homes and appliances shifting load to off peak if incentivised to do so.

4.2.2 Utilisation

Three factors are considered when calculating Orion's network utilisation including the capacity utilisation, load factor and network losses, each is outlined in Table 27. Capacity utilisation is measured by dividing the maximum demand experienced on the network by the networks distribution transformer capacity. The load factor is calculated by dividing the average load by the maximum load experienced in the year and has trended upward by 0.7% per annum for the last 15 years. Distribution losses are the difference between energy entering the network (mainly from Transpower GXPs) and the measured volume delivered to customers.

Table 27: *Network efficiency*[41].

Category	Achieved F14	Achieved five year average
Capacity Utilisation (%)	29.5	30.5
Load Factor (%)	58.3	60.0
Loses (%)	<5 estimated	<5 estimated

The ideal demand curve is a flat line near network capacity. Any changes in net load that flatten the load curve increase network utilisation. Technologies (like distributed generation) may decrease peak and average load in the short term as the network was built for a higher previous peak, however if they flatten the load profile load growth will cause an increase in utilisation long term.

[41] 2015 AMP, Page 31

Distributed Generation

PV generation causes net demand during the day to deviate from its idealised straight line due to its non-uniform generation profile. The shaded area of Figure 23 highlights the decrease in network capacity utilisation from PV. PV also decreases the networks load factor, with the drop in average network load not corresponding so a similarly sized drop in maximum network load. In real terms (kWhs) PV will reduce losses on the network because less energy is being transported. However, as a percentage of total network delivery, PV will increase losses because losses are greatest at times of peak demand when PV is not effective.

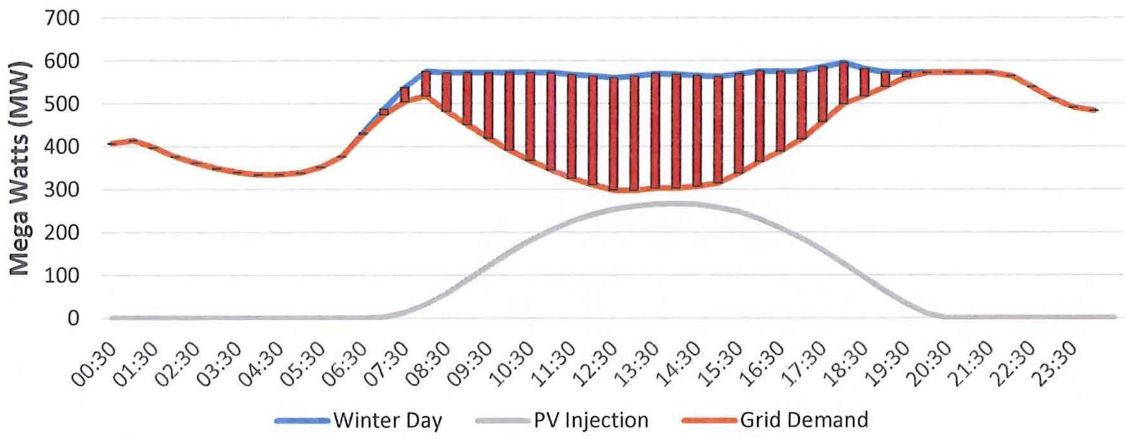


Figure 23: Decreased network utilisation from PV.

The effects different forms of distributed generation have on the network have been listed in Table 28.

Table 28: *Distributed generation's impact on network utilisation.*

Generation Source	Capacity Utilisation	Load Factor	Losses / kWh as % of delivered energy
Photovoltaic	Neutral	Large Decrease	Decrease/Increase
Hydro	Decrease	Small Decrease	Decrease/Neutral
Wind	Decrease	Decrease	Decrease/Increase
Diesel (as a peak demand reduction)	Decrease	Increase	Small Decrease/Small Decrease

Battery Storage

Battery storage will be capable of flattening the demand curve. As the maximum load is reduced the load factor will increase. Network losses will remain close to neutral as battery charge/discharge cycle losses will be on the consumer side of the meter, and will appear as an increase in overall load rather than losses. The falling peak demand will reduce capacity utilisation of the network. On the 66kV and 33kV sub transmission network (and to some extent on the 11kV network), spare capacity can be used to supply new urban sprawl and other underlying growth in demand. Spare capacity in the low voltage network cannot be transferred to other adjacent areas so utilisation will reduce.

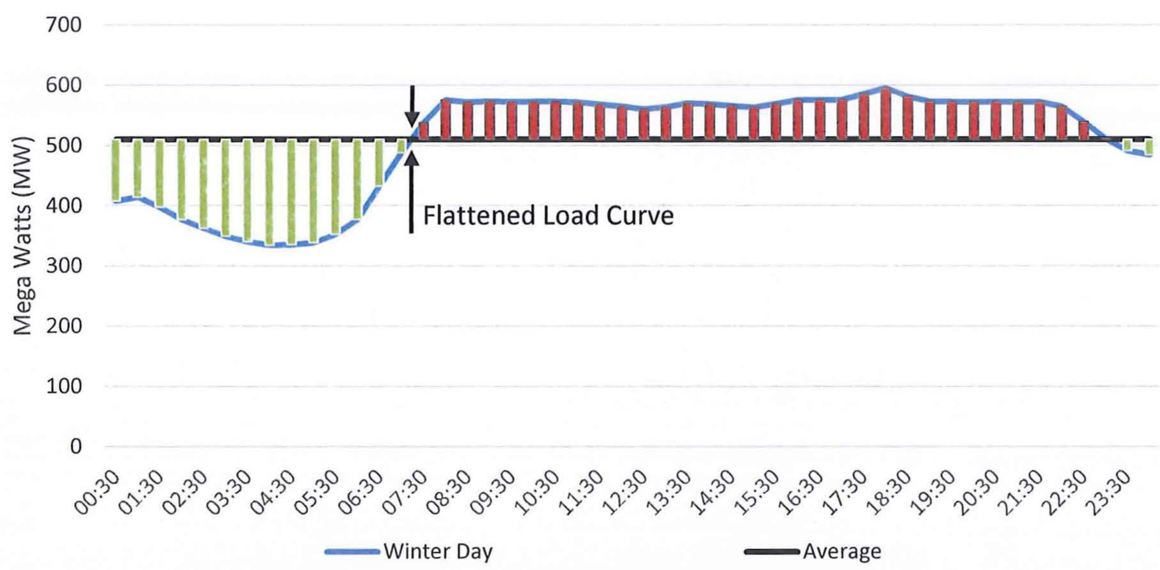


Figure 24: Flattened load curve from battery storage.

Electric Vehicles

Capacity utilisation could be increased or decreased by EVs, depending on how charging is managed. Under an ideal situation (Figure 25: Electric Vehicle charging in Orion' network, assumes one EV per connection.) a dramatic increase in utilisation could be realised. In contrast should charging load contribute disproportionally more to maximum load than during off peak a dramatic decrease in capacity utilisation would be observed. The networks load factor would be effected similarly, with network losses remaining relatively neutral under any scenario, all things being equal.

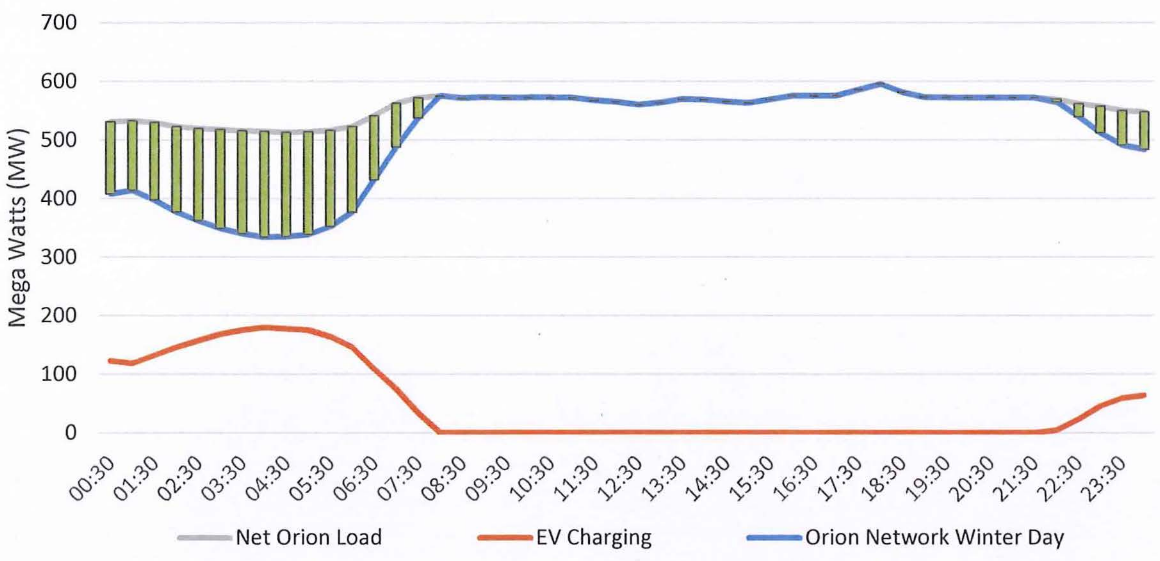


Figure 25: Electric Vehicle charging in Orion' network, assumes one EV per connection.

4.2.3 Operations

Bidirectional Flow

Clustered distributed generation has the potential to create instances of power flow reversal within sections of the network. Preliminary analysis suggests that although network protection was developed for unidirectional flows it may also be adequate for bidirectional flows on the low voltage network.

Another issue is that uncontrolled reversed flow at a macro level (Figure 26) would collapse the grid. If all networks became net exporters during peak sunlight hour's demand would no longer match supply, resulting in a nationwide grid loss of stability.

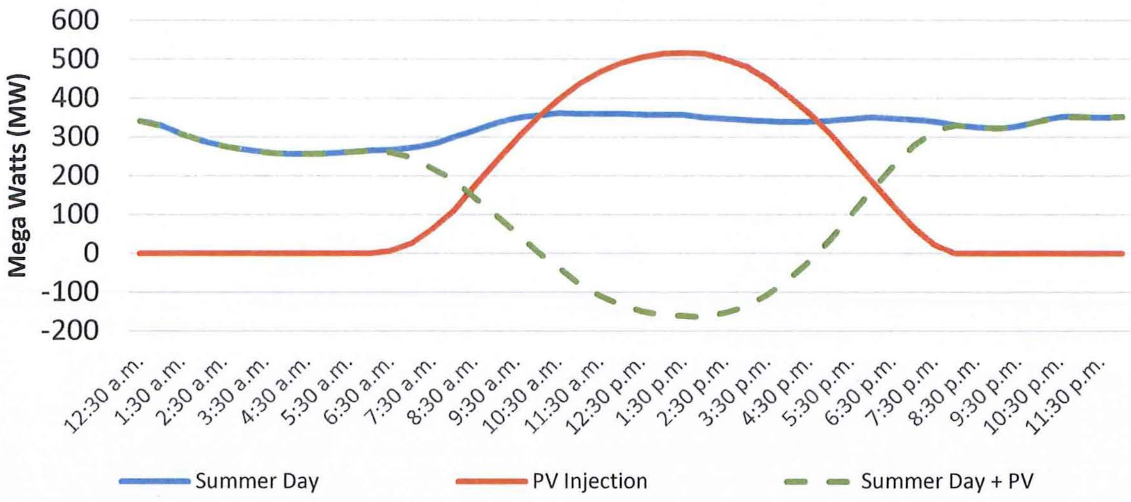


Figure 26: Reverse power flow due to excess PV generation.

Battery Storage

Whether its network or customer level storage a new DSM initiative would be possible should Orion have influence over battery charging and discharging. During a peak a signal, Orion could instruct storage to offset internal consumption in a similar manner to hot water cylinder control. Similarly, and perhaps more commonly by customers, batteries could be used as a charging load during times of high PV production to avoid export.

Safety

Testing by the Green Grid Forum has found that distributed generation and inverters do not significantly contribute to fault currents in both magnitude and time.

4.2.4 Investment

Network infrastructure is typically installed on a 'set and forget' basis until end of life – particularly true for low voltage networks in suburban sprawl areas. With an asset base of $1 Billion and 190,000 customers the network has a value of approximately $5,250 per customer. At present 50% of distribution asset value can be attributed to managing peak load, with 17% of asset value being contingent and used to maintain supply after a fault.

Both distributed generation and battery storage may prove to be effective alternative investments to traditional network peak capacity and/or contingency capacity. The financial benefit of deferred sub transmission network upgrades or the additional DSM these technologies can offer could result in leaner network designs and investment in future networks.

As distributed generation and battery storage become more prevalent it may become economical to maintain the network's quality of service at a lower level (assuming regulators are on board), resulting in a lower cost to serve. Customers wishing for a higher level of quality could couple the grid with battery storage system that can run as a local island during loss of service.

Long term set and forget planning is likely to give way to short and medium term planning (all things being equal) due to the uncertainty posed by emerging technologies. This will reduce the likelihood of assets becoming stranded.

Low Voltage (LV) Investment

Orion has assigned $1.2 million in LV CAPEX over the next 10 year period to investigate the effect emerging technologies will have on the LV network. The first stage of this will be installing feeder level measurement devices as well as the communication and the back office systems needed to run them.

Value of Lost Load

A key driver of network investment is the value of lost load (VOLL), a unit of measurement for the lost economic output for a loss of service which is currently priced[42] at $6.97 per kW for the initial fault and then $16.26 per kWh thereafter. Battery storage may allow businesses to continue to operate, keeping lighting and point of sale (EFTPOS etc) working, decreasing the value of VOLL in the future. This may change the economics of traditional network options when exploring future business cases.

Over Voltage

Solar power has the potential to raise localised voltages above the regulated threshold. This effect can be mitigated by inverters set to volt/var mode if correctly configured, however Orion does not have a default requirement to enforce this on customers at present.

4.2.5 Low Voltage Network

Work being conducted by the University of Canterbury for the Green Grid forum has identified LV constraints within Orion's network for varying EV and PV uptake rates. Overhead and older feeders have been identified as at risk due to a higher impedance and customer infill. Figure 27 and Figure 28 show projected constraints within Orion's LV network from the uptake of emerging technologies.

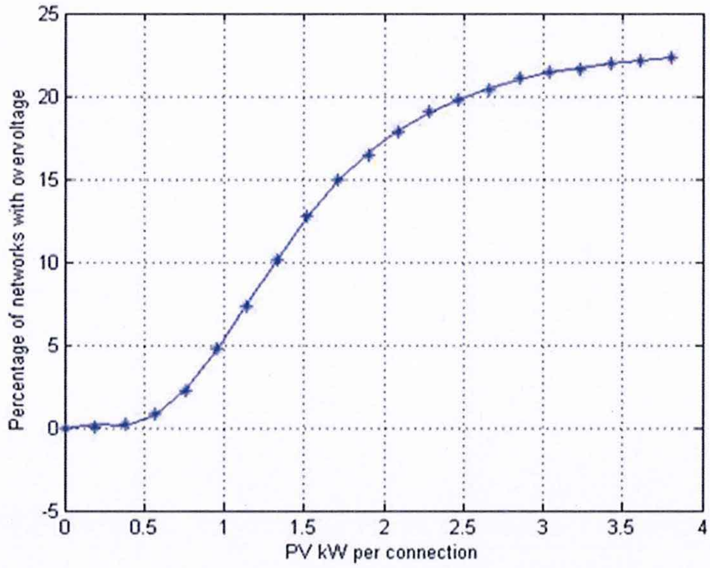


Figure 27: PVs effect on the low voltage network.

[42] Orion AMP 2015, Page 205.

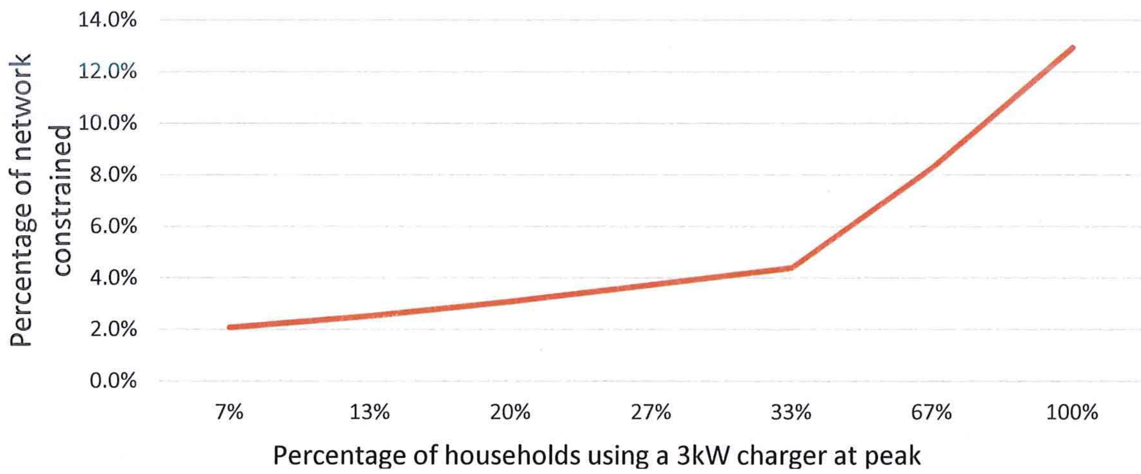


Figure 28: Residential Low Voltage constraints from the uptake of electric vehicles.

4.2.5 Micro Grids

Micro grids are localised grids that operate autonomously and are capable of being disconnected from the greater grid indefinitely, or as physical and economic conditions dictate. They feature distributed generation, battery storage, and control systems to match local generation to load.

It may become plausible for new subdivisions to put aside land and install community PV, diesel, battery storage and control systems, forming a micro grid. When members buy into the subdivision they could receive an allocated share of the distributed generation and storage as part of a house package. Alternatively embedded networks could become common place, with the developer choosing to own the network assets and have a single point of supply. This is the same concept that many shopping malls use now.

Scanpower recently announced plans to embed PV and diesel generation into its marginal rural assets to form micro grids from 2016. Both Scanpower[43] and Vector have expressed interest in becoming 'energy solutions providers' and Scanpower have commented "we are not confined to our own network".

[43] http://www.seanz.org.nz/News-Events/News/Scanpower-to-install-solar-diesel-micro-grids-next-year

4.3 Commercial Impact

4.3.1 Revenue and Price

An issue with customer PV installations is that they offset the variable component of transmission and distribution prices. This creates a cross-subsidisation environment where non-PV connections are subsidising PV installed connections. The New Zealand Institute for Economic Research found that by 2025 solar connected households would pay $250 less in lines charges per annum and those without solar $150 more per annum[44]. This is further exacerbated when distributed solar allows customers to migrate to the LUFC tariff. If this continues Orion will find it harder to collect the full amount of revenue allowable by the Commission from the variable portion of tariff charges. Another issue exists where retailers repackage cost reflective distribution pricing into their own pricing structures, diluting incentivised distribution pricing from the view of the consumer.

4.3.2 Return on Emerging Technology Investments

The power industry is seeking greater clarity around the demarcation between regulated (monopoly) investments and 'contestable investments' on the network fringe. The Commission held an emerging technologies workshop in December 2015 to discuss ownership and commercial scenarios. A final decision on any change to the Input Methodologies (IMs - rules) is expected in November 2016. The current IMs can be interpreted to allow emerging technologies beyond the meter to be included in the RAB where they can be shown to contribute to the role of providing 'Electricity Line Distribution services'. A change in the IMs could see a decision that future assets need to be ring fenced into a new un-regulated business.

Transpower Demand Response Programme

Transpower are seeking proposals for providers of demand response, offering a financial incentive for trial participants over a 5 year period. Transpower is giving emphasis to areas it has identified it has network congestion (Figure 29). Electricity Ashburton[45] is partaking in the trial with a 36 kWe, 143 kWh battery system it has ordered from Australia.

Locations:

- Oamaru;
- Otahuhu/Wiri;
- Timaru;
- Upper North Island (North of Huntly); and
- Upper South Island (North of Timaru, and specifically near Temuka.

Ideal Providers:

- Campuses (Hospital, University);
- Agribusiness (dairy, Irrigation, Coolstore);
- Battery based technology; and
- Aggregated residential buildings (same GXP).

Figure 29: Transpower demand response areas.

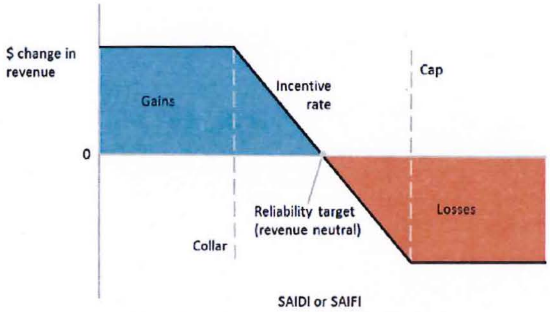
4.3.3 Regulatory Risk

Orion currently operates under a CPP which was granted in 2014 following the 2010 and 2011 Canterbury earthquakes. It is the first and only EDB to be managed under a CPP regime. Orion was granted a 1 year DPP to realign its regulatory period with the rest of the industry. Consideration is still

[44] http://www.energynews.co.nz/news-story/22691/pricing-could-prompt-5-billion-solar-overspend-ea
[45] http://www.energynews.co.nz/news-story/22999/alpine-trial-battery-demand-response

being given as to whether or not to apply for an additional CPP for 2020 onwards. A recommendation is expected by June 2016.

Table 29: *Changes in DDP methodology at last reset (1st April 2015)*

Changes[46]	Description
OPEX calculation	An underlying assumption of declining partial productivity (-0.25% per annum) of OPEX has been taken into consideration.
CAPEX calculation	A 20% limit increase in CAPEX relative to historic levels.
Revenue growth	A reduced assumption about future consumer electricity use per user, elasticity of revenue assumption for commercial and industrial users also reduced.
Incentive Scheme	The pass/fail quality incentive scheme has been replaced with a sliding scale (Figure X). The cap and collar are fixed at ±σ of SAIDI/SAIFI with a ±1% revenue cap.  *Figure 30: Quality incentive scheme.*
Cost of capital	Cost of Capital changed from 7.60% to 7.19% following the use of a lower estimate and a change to the 67th percentile from the 75th percentile estimate.
Compliance	An EDB will be deemed non-compliant if it breaches reliability standards in 2 out of 3 reporting periods.
Incentives to control expenditure	15% for every dollar of CAPEX saved as well as an approximate 35% for OPEX saved. Note this will not take effect until take effect until the 2020-2025 regulatory period.
Revenue compensation	In return for forgone revenue due to DSM an energy efficiency initiatives.
Neutralised incentive	For commissioning of assets based on asset life span. No longer penalised for investing in short-life assets if it is a more efficient outcome.

Fixed Photovoltaic export price: The government recently voted against a bill put before parliament to set a minimum PV export price, instead opting for a price driven by market forces.

Transmission Pricing Methodologies (TPM): Transpower allocates its transmission costs/charges (in a similar manner to EDBS) through its TPM. Proposed TPM changes dating back to 2009 have left the industry in a constant state of uncertainty with a multitude of discussion papers covering a varied range of substantial changes being proposed.

[46] http://www.comcom.govt.nz/dmsdocument/12767

Input Methodologies (IMs): The Commerce Commission is currently undertaking an IM review with a set of draft decisions expected in mid-June 2016. Topics relating to EDBs being considered include[47]:

- Risk allocation mechanisms under price-quality paths, including the form of control for price-quality regulation of EDBs;
- Cost-effectiveness of the CPP requirements, and interactions between DPP and CPPs;
- Related party transactions;
- Incremental Rolling Incentive Scheme (IRIS) reimplementation;
- The future impact of emerging technologies in the energy sector; and
- Cost of capital issues.

Regulated Asset base (RAB)

There may be risk in the future that emerging technologies make some assets redundant. In such a scenario regulators may designate the redundant assets 'stranded', disallowing Orion to make a return on them. This would need to be widespread to occur, Red Zone assets have not been stranded even though they are no longer in use. A change in Orion's RAB would affect its CAPEX, OPEX and Revenue.

Optimised Deprival Value Review (ODV)

Optimised deprival value (ODV) is a methodology used by regulators to value EDBs assets irrespective of when they were built. The process involves pricing the costs associated with building an equivalent service using todays pricing, methods and technology. The last ODV occurred in 2004 and forms the basis of how Orion values its RAB. In 2010 the Commission stated they would not conduct another ODV, however if network utilisation were to reduce the Commission may come under pressure to revisit this statement. If an ODV was conducted today Orion's RAB would likely increase.

Default Contract between Distributors and Retailers

The Electricity Authority is currently planning a review looking into the efficiency of distribution pricing. The issue at hand is the complication for Retailers to analyse over 1000 different tariffs present in New Zealand, and how this stifles competition. The Authority (and Retailers) would like to see some level of standardisation across distribution networks in regards to tariff structures, and the creation of default contracts between EDBs and Retailers to reduce legal costs of new entrants. The ENA has formed the Distribution Standardisation Group[48] to provide an EDB perspective on this issue. This has the potential to limit Orion's flexibility in tariff structure, depending on its outcome.

Third party Approval of CAPEX Expenditure

Regulators of other jurisdictions (the closet being Australia) require EDBs to produce a document outlining planned CAPEX and OPEX spending, defending their expenditure. There is potential that New Zealand regulators could move in this direction in the future, however no changes can take place for at least 6 years.

[47] http://www.comcom.govt.nz/dmsdocument/13833
[48] http://www.electricity.org.nz/includes/download.aspx?ID=139097

5. Scenarios

Scenario analysis has been used as no single model can accurately capture the changing landscape of the electricity industry. This section builds on the five models developed by Third Horizon[49] projecting forward to the year 2040. Although the likelihood of three of the scenarios is low but plausible they have been included to cover all basis. The modelling included both the effects of the technology as well as increases in population and energy efficiency.

5.1 Probable

5.1.1 #1 Cost Reflective Pricing

Table 30: *Cost Reflective Pricing.*

EV	Storage	PV	EVs Charging at Peak	Peak Demand	Annual Energy	Network Prices	RAB Risk Reduction
30%	25%	5%	20%	-5%	5%	Similar	Low

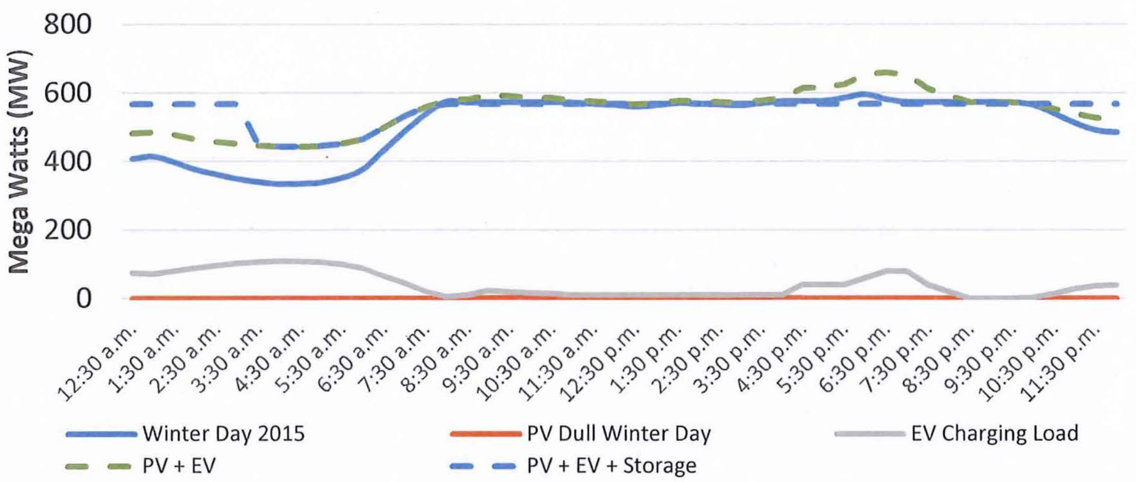


Figure 31: Cost reflecting pricing scenario peak load projection.

The cost reflective pricing scenario is the most probable of the scenarios investigated. The ability to 'game' the low user fixed charge tariff and disparity between PVs generation and network peak, which represents 50% of a networks asset base will lead to falling revenue under current pricing models. EDBs will correct this by rebalancing tariffs to time of use and peak pricing to fairly distribute costs across customers.

Under cost reflective pricing the uptake of battery storage would occur sooner, and be less correlated to the uptake of PV. This is attributed to the economic gain consumers can deploy through offsetting peak usage and taking advantage of off-peak pricing, while also increasing security of supply. The differential between non-peak and peak pricing (assuming the incentive is passed through by retailers) will also be a network controllable factor in the technologies uptake rate.

With annual energy consumption increasing there is a low probability of regulators reintroducing ODV or stranding assets.

[49] Third Horizon: Phase 2 Board presentation, Page 8

5.1.2 #2 Central Scenario (Status Quo)

Table 31: *Central scenario.*

EV	Storage	PV	EVs Charging at Peak	Peak Demand	Annual Energy	Network Prices	RAB Risk Reduction
35%	10%	30%	25%	6%	-1%	Similar	Low

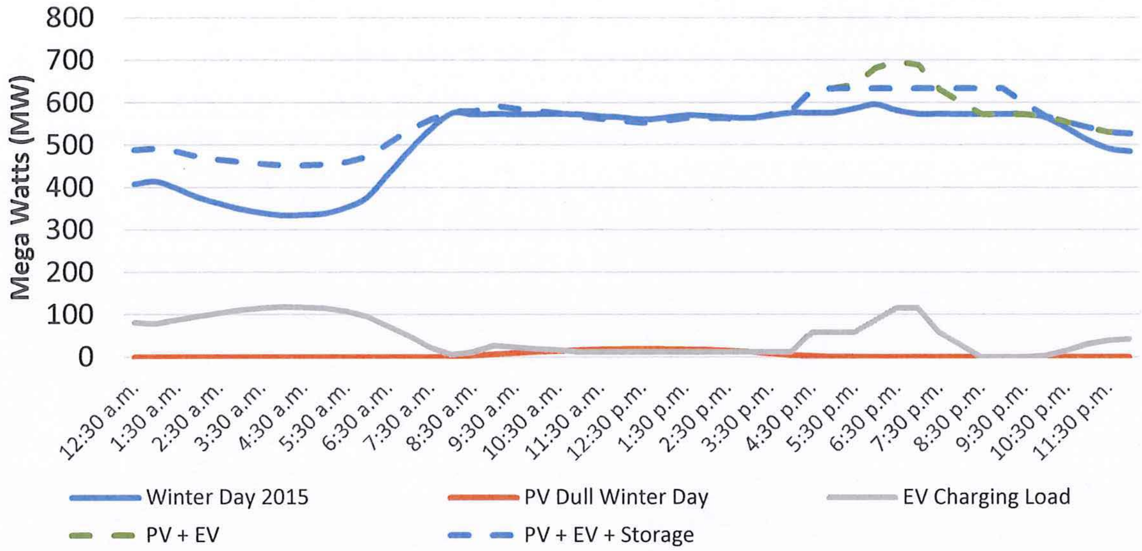


Figure 32: Central scenario peak load projection.

The central scenario is business as usual with no drastic market changes or unexpected new technologies. 2015 projections of emerging technology uptakes prove accurate and price parity between electric vehicles and ICE vehicles occurs in 2020-2025 as expected. Annual energy remains flat with energy efficiency gains and PV matching the introduced and the loads of electric vehicles and population growth.

With annual energy consumption flat and peak load increasing there is a low probability of regulators reintroducing ODV or stranding assets.

5.2 Plausible

5.2.1 #3 Extreme Electric Vehicle

Table 32: *Extreme uptake of Electric Vehicles scenario.*

EV	Storage	PV	EVs Charging at Peak	Peak Demand	Annual Energy	Network Prices	RAB Risk Reduction
80%	10%	30%	25%	31%	15%	+25%	Low

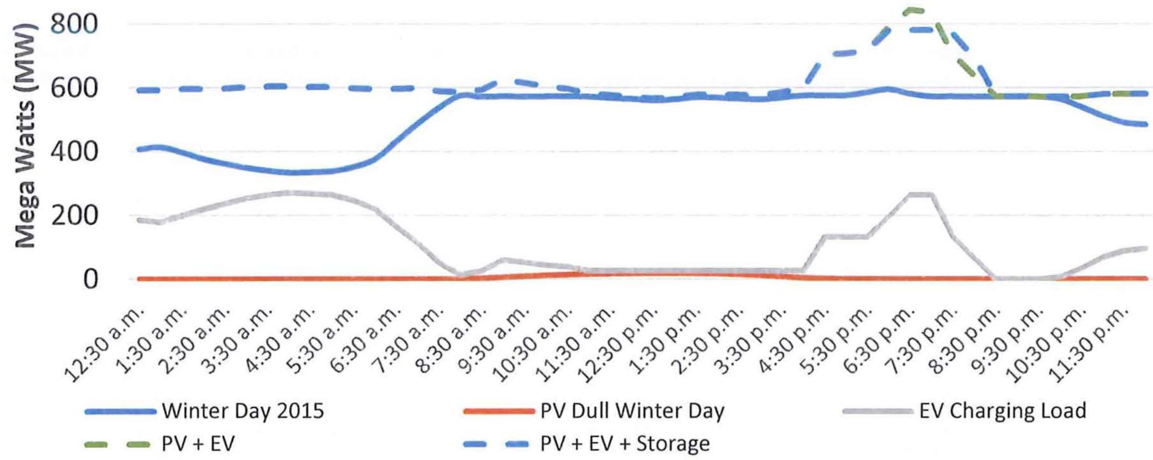


Figure 33: Extreme Electric Vehicle scenario peak load projection.

The extreme electric vehicle scenario is the same as the central scenario in every aspect apart from the factors behind the uptake of electric vehicles. It poses the highest threat of the scenarios considered. Rising petrol prices (and potentially governmental incentives) coupled with falling electric vehicle prices lead to an increased uptake rate of electric vehicles, drastically increasing the network peak and annual energy consumption. It should be noted that this model uses an uptake rate above the standard turnover of vehicles. Orion could mitigate the effect of charging through a better DSM initiative or installing grid level storage.

With a considerably higher peak load network prices will need to increase to manage network upgrades. New peaks and increased annual energy consumption will make it extremely unlikely that regulators will strand assets.

5.2.2 #4 Hydrogen Cars

Table 33: *High uptake of Hydrogen Cars scenario.*

EV	Storage	PV	EVs Charging at Peak	Peak Demand	Annual Energy	Network Prices	RAB Risk Reduction
10%	30%	60%	5%	-11%	-19%	+15%	Medium

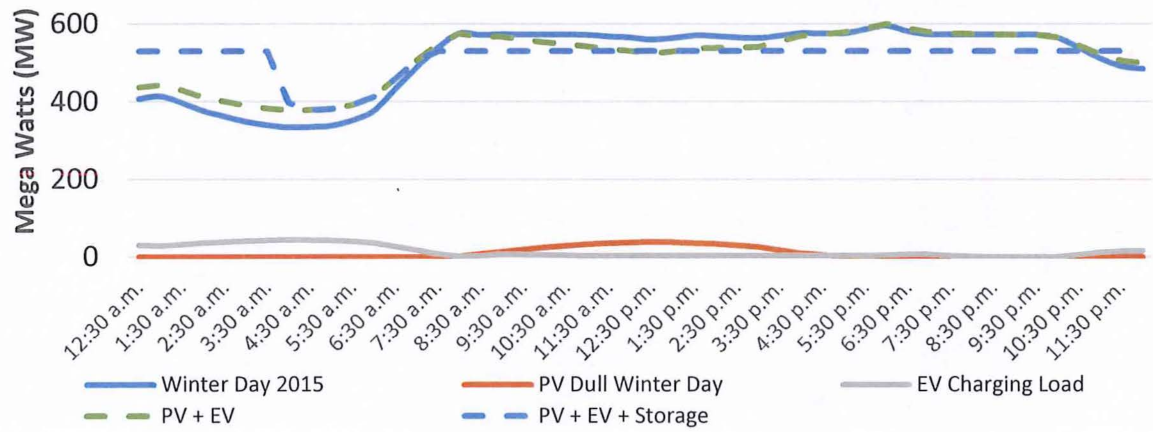


Figure 34: Hydrogen Car scenario peak load projection.

Competitors offer solutions to manage customer's systems to offer the best value. These include home energy management systems, energy audits, solar installation and battery storage. The uptake of electric vehicles stalls due to competition from hydrogen fuel celled vehicles. The growth from an increase in population is more than offset by developments in energy efficiency and solar generation, leading to a dramatic fall in annual demand. Lower demand coupled with a high uptake of battery storage contributes to a large fall in peak demand.

With a considerable reduction in annual energy consumption and peak load it is plausible that regulators would look to reintroducing ODV and stranding assets. Additionally network pricing would need to rise to ensure revenue targets are met.

5.2.3 #5 Spiralling

Table 34: *Spiraling cost scenario.*

EV	Storage	PV	EVs Charging at Peak	Peak Demand	Annual Energy	Network Prices	RAB Risk Reduction
45%	60%	80%	80%	13%	-13%	+25%	High

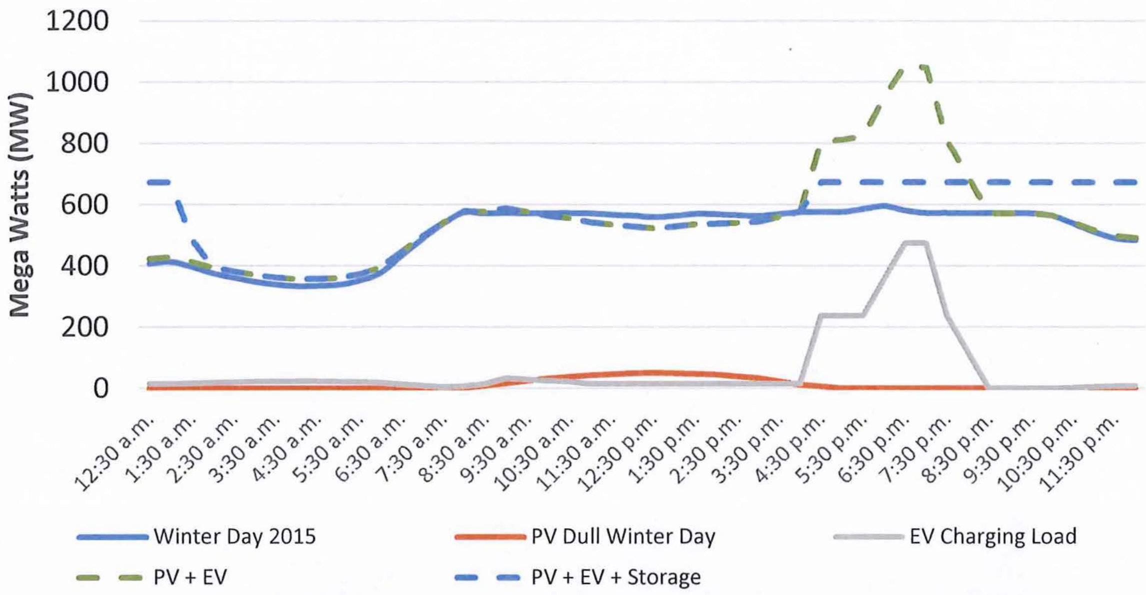


Figure 35: Spiralling scenario peak load projection.

The spiralling scenario poses the second largest negative impact to Orion's business. A cost effective form of winter generation when coupled with solar and battery storage allows consumers to go 'off-grid'. The continuation of this trend leads to higher network costs for those still connected, further incentivising the exodus of customers to off-gridding. This leads to a large uptake in emerging technologies. It will begin with customers leaving for ideological reasons, and increase drastically at the inflection point between the cost of a grid connection compared with going off-grid.

Under such an environment regulators may relax the security of supply requirement imposed on networks at present. This would give customers choice between a less reliable cheaper network and a network + battery system. Long term it is plausible that once the cost of off-gridding becomes a viable alternative to a network connection regulators could deregulate EDBs.

Under such a scenario there is a high probability of an ODV review by regulators which would see Orion's RAB reduced. A reduction in annual demand and increase in peak demand will see considerable rising of network charges to meet revenue targets.

5.3 Scenario Summary

Table 35: *Scenario Summary.*

Attribute	Scenario #1	Scenario #2	Scenario #3	Scenario #4	Scenario #5
EV	30%	35%	80%	10%	45%
Storage	25%	10%	25%	30%	60%
PV	5%	30%	5%	60%	80%
EVs Charging at Peak	20%	25%	20%	5%	80%
Peak Demand	-5%	6%	31%	-11%	13%
Annual Energy	5%	-1%	15%	-19%	-13%
Network Prices	Similar	Similar	+25%	+15%	+25%
RAB Reduction Risk	Low	Low	Low	Medium	High

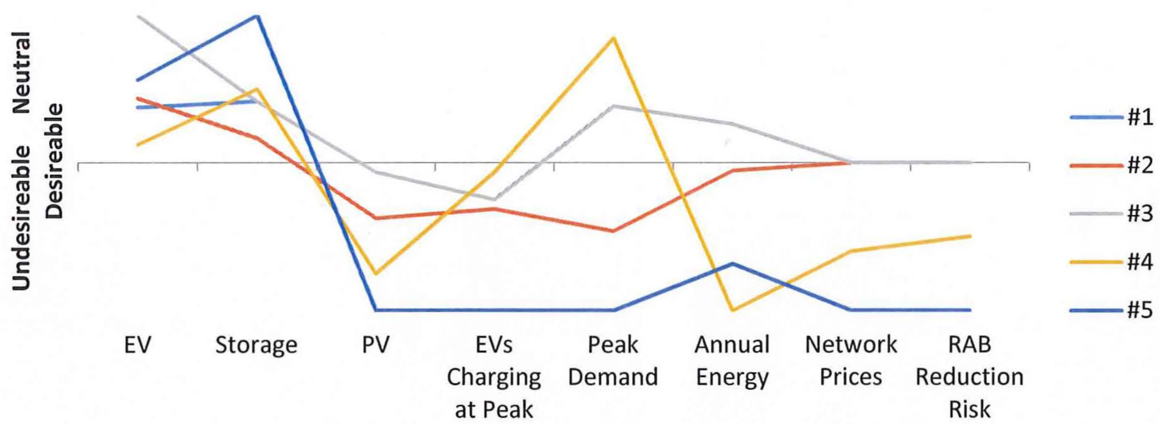


Figure 36: Normalised scenario comparison.

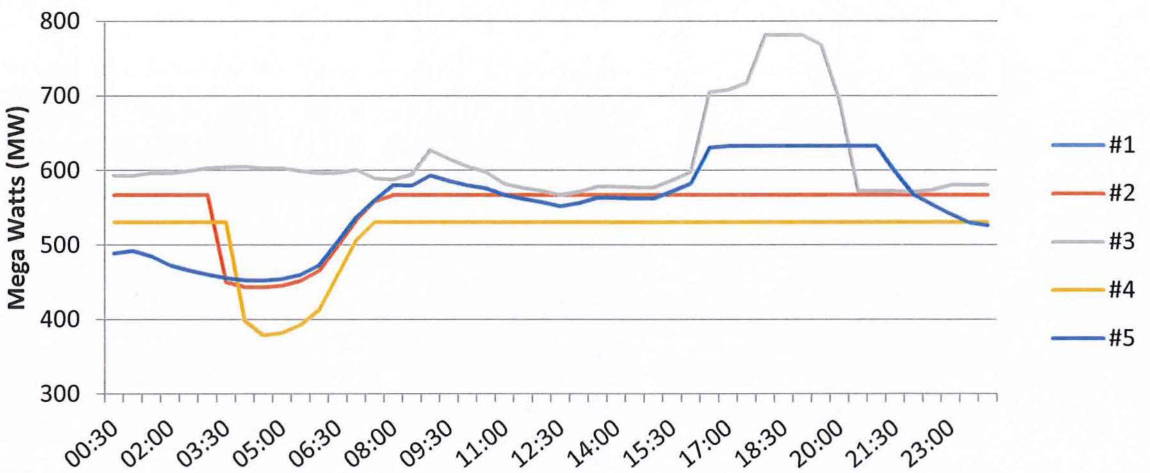


Figure 37: Scenario daily load comparison.

6. Business Growth (Opportunities)

Orion's strategy depends on its appetite for risk. Although the company still has time it will need to decide at some point what business strategy it intends to follow in terms of emerging technologies. A spectrum of business strategies is outlined in Table 36.

Table 36: *Business Strategy Types.*

Type	Characteristics
Reactor	• Inward focus, no proactive strategy. • Change when forced by external environment. • May have strategy, not clearly articulated or incorrect business structure to pursue.
Optimiser	• Internally focused, improvement through operation efficiency. • Stability key, seeks to protect market. • Structure: centralised, formalised and standardised, business units have moderate to low autonomy.
Analyser	• Follow into adjacent markets once proven. • Monitors industry closely. • Mix of exploitation and exploration. • Structure: moderately decentralised.
Prospector	• Outwardly orientated risk taker • Constantly seeking to innovate with new markets and products. • Fast deciding and acting. • Structure: individual business units with high autonomy.
Ambidextrous	A combination of OPTIMISER and PROSPECTOR.

Historically Orion has covered all aspects of the business spectrum, but has focused on being an optimiser, implementing new technologies and strategies in an attempt to increase network efficiency, reliability and utilisation while also decreasing the cost to serve to its customers.

6.1 Acquisitions (Optimiser)

The fastest method of growth available to Orion is through the targeted acquisition of existing assets. Recent examples include the purchase of the Springston and Bromley GXPs from Transpower. Historically Orion has also made a healthy return of large purchases including a $170 million return on the purchase and sale of Enaco, a North Island gas network. Potential assets to acquire include the Hororata 33kV and Islington 33kV zone substations from Transpower, embedded networks or other networks in their entirety, if the opportunity presents itself and the price is right.

6.2 Operational Services (Analyser)

Being the third largest network by customer numbers Orion has reached an economy of scale that allows for the efficient utilisation of back-end systems. Orion could offer to smaller networks (which start at 6,000 ICPs), its back end systems, 24 hour control room and 24 hour call centre as a service so that they may capitalise on the benefit of scale.

6.3 Local System Operator (Analyser)

Potential exists for Orion to further its collaboration and coordination with other networks and Transpower for potential services Orion could offer in the future. An example would be extending Orion's USI load management system to the rest of New Zealand, or supplying other networks with the outcomes and experiences gained from conducting an emerging technologies trial.

6.4 Beyond the Meter (Prospector)

Many market segments are tailored to emerging technologies including:

- Solar Sales and Installation
- Charging Infrastructure
- Smart Meters
- Storage Sales and Installation
- HEMS
- Inverter Sales and Installation
- Electric Vehicle Sales
- Energy Audit
- Embedded Networks

None of these areas could be considered 'blue ocean' as various companies are trading in each business segment, including other distribution networks. An advantage for distribution networks that do partake in these business segments is a direct contact by default with the customer at the point of sale/installation. This gives the network influence over the type of emerging technologies being installed, which could be tailored towards the mutual benefit of the grid and customers.

7. No Regrets Actions (Recommendations)

No regrets actions are recommended actions Orion can take now that are likely to have a net benefit regardless of which of the scenarios identified (or alternatives) eventuate.

7.1 Regulatory Influence

Orion has maintained and independent voice when putting forward submissions on regulatory discussion, and is not afraid to stray from the ENA opinion. Other contributors with equally deep pockets and different business models may try to sway regulators to an unfavourable position. It is paramount that Orion continues to voice its opinion on emerging technology discussion for the mutual benefit of its customers, shareholders and the industry.

7.2 Promotion of Electric Vehicles

As a source of new load that also has the added benefit of lower CO_2 emissions value would be gained from facilitating its uptake. The current chicken and egg scenario due to range anxiety and charging infrastructure is being overcome through the likes of EDBs, drive.net and the Christchurch EV forum with the rollout of charging infrastructure. Orion could further advertise the benefits of electric vehicles by partnering with others in the industry to take its EVelocity event nationwide. This could be achieved at a relatively low cost to Orion and would be mutually beneficial to the industry.

7.3 Getting Closer to the Customer

Orion's recent rebranding is the first step in a process towards better customer engagement. The next step involves re-establishing the word Orion with the network as the first thought of reference for customers. Besides the traditional advertising and sponsorship Orion could work with its contractors to get a 'working with' area on their vehicles, displaying Orion's logo.

Orion currently maintains an outage page on its website which could be extended to an app to give customers real time updates during an outage. With greater clarity customers would be able to make well informed decisions on how best to react, and better minimise the economic costs associated with an outage.

Potential features and information include:

- About Orion;
- Tree guidelines and report a tree;
- Videos explaining how the system works;
- Push notification for outages;
- Flashlight;
- Phone numbers (report an outage, emergency numbers);
- Projected restoration time; and
- Safety information for outages.

As well as an app other forms of social media like Twitter and Facebook could be used as a cost effective method to inform customers of larger outages affecting the network, or other Orion information in general.

7.4 Business Structure and Resources

As the workload associated with monitoring and managing emerging technologies starts to become more prominent, Orion should consider the structure and need for any dedicated resources it requires to effectively manage their uptake. Monitoring will be required to ensure Orion is best placed to react to any changes.

Additionally resources need to be allocated to building and maintaining relationships with suppliers of emerging technologies, to ensure that their technologies are compatible with Orion's back end systems, so that mutual benefits can be derived.

As Orion operates in a monopolistic regulated environment it has historically allocated resources to influence regulators on issues relating to the company's continued operation. With a new emphasis on customer interaction and relations a decision will need to be made in terms of the size of the resources allocated, to determine the ratio between regulator and customer interaction.

7.5 Technology Trial

To best understand emerging technologies first-hand experience is required. In terms of value for money Orion will likely derive more benefit from investing in backend systems to manage customers emerging technologies, than putting the technologies in the hands of the customer. This is due to the scalability a fixed cost investment in backend systems can provide and has the added benefit of allowing Orion access to capital supplied by others. It also allows all customers to benefit, not just a few.

7.6 Replacing Uneconomical Lines with Emerging Technologies

Orion should conduct cost benefit analysis and produce a business case around the credibility of subsidising the off-gridding of customers deemed to be connected through uneconomical lines. Such investment, if it benefits all customers by lowering the cost to serve can put on Orion's RAB. The process, if undertaken, would also give Orion first-hand experience in off-gridding, which may become invaluable knowledge in the future.

8. Triggers

Along with constant monitoring Orion needs to establish trigger points with corresponding action plans so that it is ready which ever scenario eventuates. How Orion defines each trigger will require more research however a non-exhaustive list could include:

- Market share;
- Uptake rate;
- Technology cost vs alternatives;
- Technology capabilities vs alternatives;
- Clustering;
- New game-changing technology; and
- Competitors' actions.

8. Conclusion

Observation of overseas markets has shown emerging technologies are likely to become established within New Zealand's wider power system. Although Orion has some time before the impacts of emerging technologies will be felt, it is important to consider the consumer, and the decisions being made today. If Orion reacts too quickly it may find itself locked into the wrong technology. Too late, and customers who purchase these technologies now may find there economic assessment unfounded.

Under all of the scenarios considered Orion will still be needed in some capacity. The company has some influence as to how technologies are embedded and controlled within the network, which if exerted efficiently could benefit Orion under any outcome. The impacts each technology will have are well understood, it is just the uptake that is uncertain. Orion needs to monitor the advancement of these technologies to effectively capitalise on their potential, for the benefit of stakeholders, the industry and its customers.

Appendix A: Solar Cell Efficiency

Source: http://costofsolar.com/most-efficient-solar-panels-which-ones/

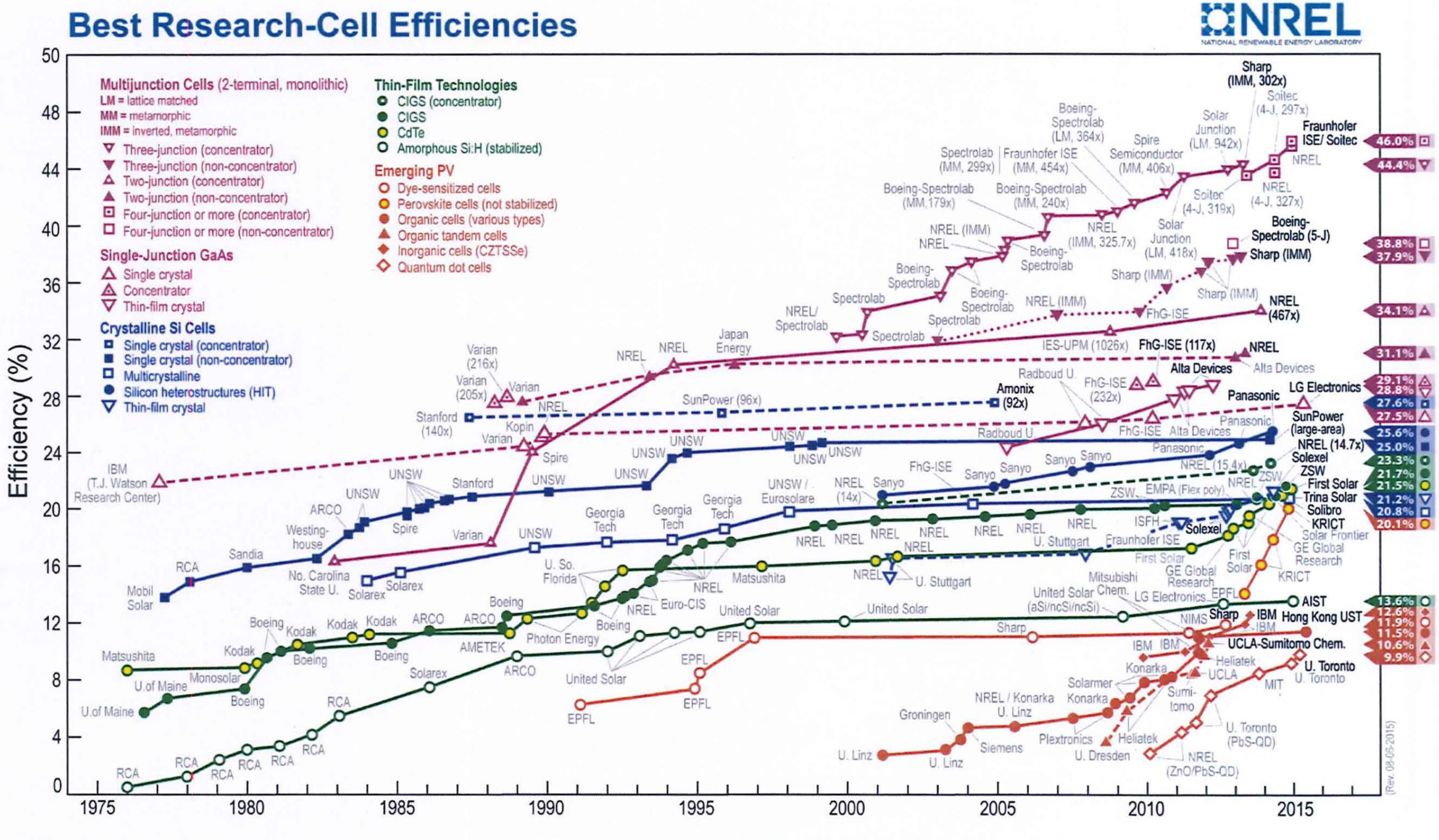


Figure 38: Development of the solar cell.

Appendix B: Charge.Net Charging Infrastructure

Source: https://charge.net.nz/charging-map/ [17/02/2016]

Appendix B

Literature Review

Assembled by:

Blake Burgess

February 2016

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1. Purpose

On commencement of the project a literature review was undertaken to establish a background understanding of major aspects of the project and electricity industry. The review looked into topics including:

- The structure of the electricity industry;
- Customer profiles and expectations;
- Emerging technologies to the electricity system; and
- Business models for entities active in the electricity industry.

2. Industry Structure

2.1 Regulators

Electricity Networks Association (ENA)

Represents the 29 electricity distribution companies (EDBs) operating in New Zealand. Facilitates industry working groups focusing on common areas of interest and provides a unified voice to industry and regulators [1].

Ministry for Business, Innovation and Employment (MBIE)

Used by regulators to commission reports and studies into the electricity sector. Produces a quarterly and annual energy modelling outlook which includes industry statistics and projections [2].

Electricity Authority

Responsible for regulation of the New Zealand electricity market [3]. The primary mechanism in which it does this is through the Participation Code (2010). The Code sets out the Authority's duties and participant's roles and responsibilities in relation to:

- System security
- Metering
- Billing
- Information management
- Quality of supply
- Trading arrangements
- System agreements
- Quality of security
- Reconciliation
- Distributed generation

Commerce Commission

Promotes competitive markets by setting economic regulation in regards to pricing, quantities and quality of service which are in the long term interest of consumers [4]. The Commission governs under the Fair Trading Act (1986) and the Commerce Act (1986), setting EDB pricing and quality constraints through its Default and Customised Price-Quality determinations based on a predetermined set of rules (Input Methodologies).

2.1.1 Consideration

Being a natural monopoly distributors are heavily regulated to emulate competition. This can stifle innovation in the sector as regulation written for one purpose inadvertently prevents a new idea/technology from meeting compliance. There can also be a lag between new technologies becoming available and how they are regulated. This can create 'hangovers' for businesses that choose to pursue a path of action only to have regulation ruin the economics of what was just undertaken in retrospect. How regulators decide to manage emerging technologies will determine whether they are regulated or unregulated assets. Even with the trade-offs regulation is still vital to protect customers from being abused by an incumbent monopoly.

2.2 Orion's Structure

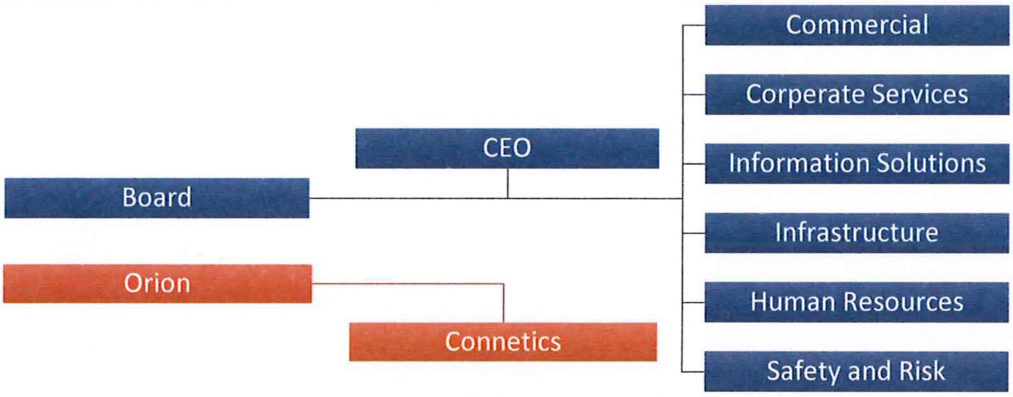


Figure 1: Overarching organisational structure of Orion and its subsidiaries.

2.2.1 Consideration

The team (Strategic Planning) at Orion currently working with emerging technologies comes under the Infrastructure section of the business (three levels deep). As uptake of the technology increases the need for cross section cooperation will increase. This may require Orion to elevate the prominence of emerging technology within the business to its own department.

2.3 Industry Participants

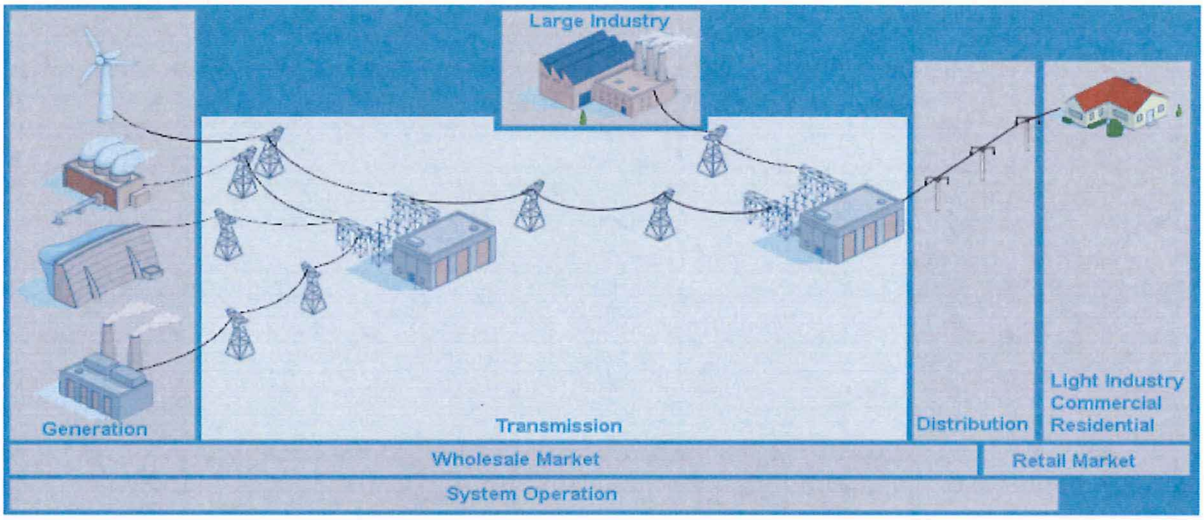


Figure 2: Overview of New Zealand's electricity industry [5].

System Operator (Transpower)

The system operator (Transpower) is responsible for the integrity and operation of the overall power system and electricity markets. Real time scheduling and dispatching of generation is used to match supply to customer demand, ensuring system stability. Additionally the system operator is active in the co-ordination of transmission or generation outages, facilitating the commissioning of new generating plant, and the procurement of ancillary services to support power system operation. Most of the System Operators revenue is received via a contract with the Electricity Authority.

Generation

Generators bid to produce electricity on the wholesale market based on a lowest cost first dispatch methodology. A clearing house matches retail consumption to the proportion of power generated during each 30 minute pricing period, with Retailers providing payment for the generation output.

Large generators maintain three types of generating assets including base load (geothermal and some gas), variable (hydro), peaking (gas, thermal, diesel) and intermittent (wind and solar). They are also typically integrated with a retail unit as a form of natural hedge for pricing variability between dry and wet years. Six major generators operate in New Zealand representing 90% of generation.

Transmission (Transpower)

Transpower owns and operates the majority of the national transmission grid assets (220kV, 110kV, 66kV) which form the basis of the national grid. It also owns 33kV and 11kV assets at the distributor interface although a recent trend has been to divest these assets to EDBs. It interfaces to EDBs through GXPs and generators through grid entry points (GEPs). Transpower also maintains the HVDC link that connects the North and South Islands. The company receives revenue from generators, distributors and direct connect customers.

Distribution

Distribution companies are responsible for taking electricity from Transpower's GXPs and distributing it to consumers dispersed over large geographical areas. Lines charges are set through the numerous tariff structures networks operate and are generally collected from the consumer by the retailer on behalf of the network. Large consumers (dairy processing, timber mills...) are directly billed by distribution networks. Distributed generation may also be present within a network.

Retail

Retailers are the industry interface to consumers, providing electricity pricing and billing. Retailers purchase electricity from the spot market and repackage all costs associated with the electricity supply chain into a single product, which they market to the consumer. New business models are emerging, for example Flick Electric, which communicates all industry costs straight through to the consumer directly (including the spot price), adding a margin on top.

Consumer

Both residential and business consumers are provided access to the grid through their local distribution network, and purchase electricity from a retailer. Some consumers own distributed generation to offset internal consumption, and export excess generation back into the grid.

2.3.1 Consideration

The power system involves many players each with defined goods or services, often by regulation. Since emerging technologies (currently unregulated) can transcend different segments of the power system, the roles businesses operate in may become blurred, creating vertical competition where before there was only horizontal. Retailers may find themselves competing with distribution networks and vice versa.

3. Customer

3.1 Diffusion of Innovations Theory

"A hypothesis outlining how new technological and other advancements spread throughout societies and cultures, from introduction to wider-adoption [5]". The theory defines customers' willingness to purchase/use a technology into one of five customer ideologies, which are outlined in Table 1.

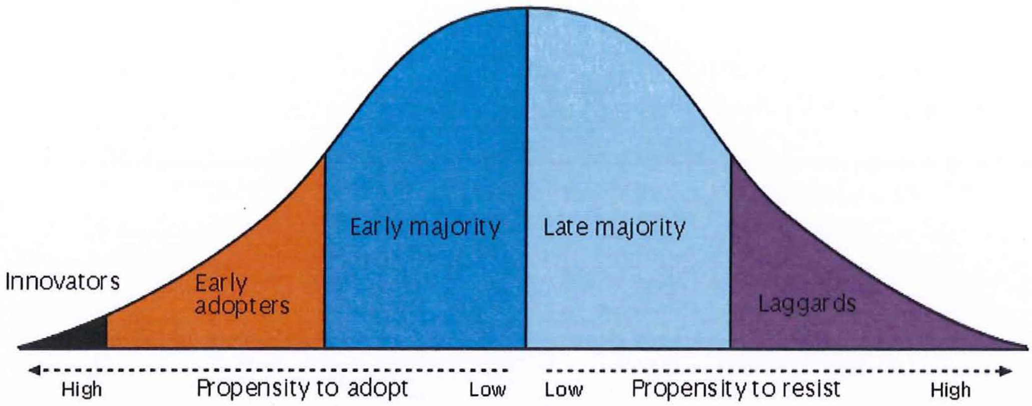


Figure 3: Technology uptake curve [6].

Table 1: *User segments of a market [6].*

Profile	Proportion	Explanation
Innovators	2.5%	Forward thinkers who see potential in new technologies even though they have yet to be fully developed. Are willing to take risks on unproven/unfinished technologies and get enjoyment from their use.
Early Adopters	13.5%	Have time and money to invest, like to be leaders in business and life. Slightly more reserved than Innovators.
Early Majority	34%	Adopt technology when it has been refined and proven to work. Often have contact with innovators and early adopters.
Late Majority	34%	Approach innovation with a high degree of scepticism. Will adopt a new technology only once it has been proven in the marketplace (by the early majority).
Laggards	16%	Typically last to adopt new technologies, have an aversion to change and will only use a technology if necessary or restricted financially.

The accumulated uptake of the technology curve generally resembles Figure 4, with slow uptake initially, exponential growth after a 25% uptake and then a tapering down after 75% uptake (approximates). Work conducted by *Fisher and Pry* concluded that once a new technology has reached a 5% market share the dynamics of the substitution process are likely to be well established [7]. Work by *Geoffrey Moore* found that marketing needed to change based on what profile the market uptake was currently in, and the transition over the 'chasm' (early adopters to early majority boundary) was the point that would make or break a technologies uptake [9].

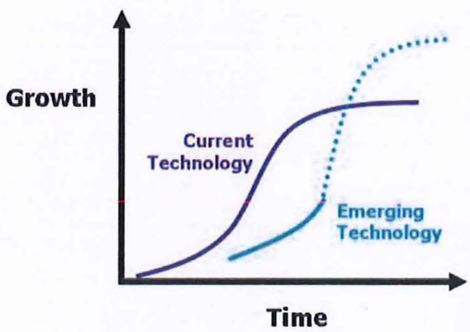


Figure 4: Technology uptake 'S-Curve' [8].

3.1.1 Consideration

Many of these 'emerging technologies' have in fact been around for years, some outdating the incumbent technologies themselves. Now that they are projected to become competitive they have been labelled 'emerging'. In the case of the incumbent technology the ideal customer are the Laggards.

3.2 Changing Customer Expectations and Future Profiles

New technologies will bring with them new expectations from the customer. Even though the majority of customers are currently happy with the level of service provided, the thought of a better offering, even if still uneconomic, will raise their expectations long term. Tables 2 and 3 outline current and future expectations customers may have.

Table 2: *Current expectations of customers* [11].

Expectation	Explanation
Prices Affordable and fair	Network connection costs and prices are not considered excessive and costs are allocated fairly between different customer groups.
Reliability	The power stays on with few interruptions.
Security	Power is restored quickly following failures on the network.
Safety	No harm comes to the customer or those operating and maintaining the network.
Resilience	The network is built and operated in a manner that ensures an appropriate resilience to major events (snow storms, earthquakes, etc.) and to changing customer needs.
Someone to talk to	All communication is simple, prompt, accurate and personalised to the customer.
To be informed	Of all impacts the network may have on a customer's daily life (loss of power, road works).
Hassle free	Interaction with the network is simple with a fast turnaround (new connections...).

Table 3: *Emerging expectations of customers* [11].

Expectation	Explanation
Additional Services	Beyond the delivery of electricity customers may desire energy audits and energy management systems to identify and reduce their energy usage.
New Technologies	The ability to connect and use complementary technologies alongside a network connection.
Independence	Customers may seek energy independence from the network for economic or ideological reasons.
Environmental Concerns	Customers may wish to contribute to reducing their impact on the environment. An example would be distributed generation offsetting the need for distribution infrastructure or large scale generation.
Social Acceptance	Of the technologies and methods used by networks (information privacy...).

Work conducted by the Commonwealth Scientific and Industrial Research Organisation identified four future mind-sets of customers including based on their changing mind sets [10]:

ACTIVELY INVOLVED **Innovators, Early Adopters** Actively involved customers will take full control of their energy usage and actively match demand to price signals. They are likely to be prosumers (consumers who also produce electricity) and will be more likely to take up emerging technologies.	OFF GRID **Innovators, Early Adopters** The lowering cost of new technologies will allow at least some customers to substitute their network connections for an off grid system. Under a traditional model these households and businesses would no longer be a customer, and will become the customer of off grid solution providers.
SET AND FORGET **Early Majority, Late Majority** Set and forget customers will after an initial investigation period hand over some control of power usage to their local utility or an energy management system. These customers will determine a level of control that suites them and be rewarded for the flexibility with a cheaper electricity rate or lower energy usage.	BUSINESS AS USUAL **Laggards** Traditional customers who are happy with what the local network has to offer and have no desire to install emerging technologies on their side of the meter.

3.2.1 Consideration

An electricity connection too many people is out of sight out of mind until something goes wrong. The service itself has not changed for a century, it has just incrementally gotten better. Now that there is an alternative solution attention is again being drawn to physical connections. Even though emerging technologies are more expensive the freedom they offer is raising expectations of the customer, wanting the same service from a physical connection. A customer's ability to pay may be the deciding factor (in general) on which future mind set a customer falls into.

4. Emerging Technologies

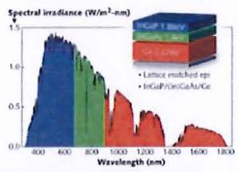
Although there are many emerging technologies relating to the electricity industry the three projected to have the largest impact on the industry include photovoltaics (PV), battery storage and electric vehicles (EV).

4.1 Photovoltaic

Photovoltaic (solar) power converts solar irradiation from a primary source (the Sun) into another form of energy, mainly electricity or heat.

Current state of the technology

Table 4: *Current PV technologies and capabilities.*

Type	Profile	Properties
Solar Thermal		Doesn't produce electricity but harnesses rooftop heat which is piped to a hot water cylinder, swimming pool or underfloor heating. The process is more efficient than electricity generation at 50-75% [13].
Crystalline	 Mono  Poly	Crystalline PV cells are wafers embedded with impurities, and then fitted with conducting circuitry and housing. They are the most efficient and expensive of the single junction technologies. Two types exist including mono and poly crystal, with mono being the more efficient and expensive option [14].
Amorphous Thin Film	 Amorphous	Amorphous (non-crystalline) panels are the simplest, cheapest and least efficient of the solar cells currently on the market. They have the benefit of being flexible and require no rare earth materials or heavy metals [14].
Multijunction		Multijunction cells [14] are single cells (usually crystalline) of alternate composition stacked on top of each other to capture different ranges of the solar spectrum. They are the most efficient cells overall but are considerably more complex and expensive.
Solar Windows		Still in their infancy solar windows have been in development since 2013 and are 1% efficient. The technology couples glass with transparent cells and is intended to replace traditional windows in high rise buildings [13].

Commercial panels currently on the market typically operate with 15%-20% efficiency. The most efficient panel (created in a lab) has an efficiency of 46.0% [17]. SolarCity, a solar financing company in the United States and top installer of panels in the American market recently unveiled a 22.04% efficient [13] panel which it claims will be the most efficient sold commercially. On an economic basis solar generation is currently priced between 16.9 c/kWh and 41.0 c/kWh [18] installed compared the average price consumers' pay of 28.86 c/kWh [19].

Current uptake of the technology

Table 5: *Number of PV installations* [20].

Area	Connections	Residential	Commercial	PV Penetration
Orion	190,833	843	9	0.44%
New Zealand	2,060,005	7,460	91	0.37%

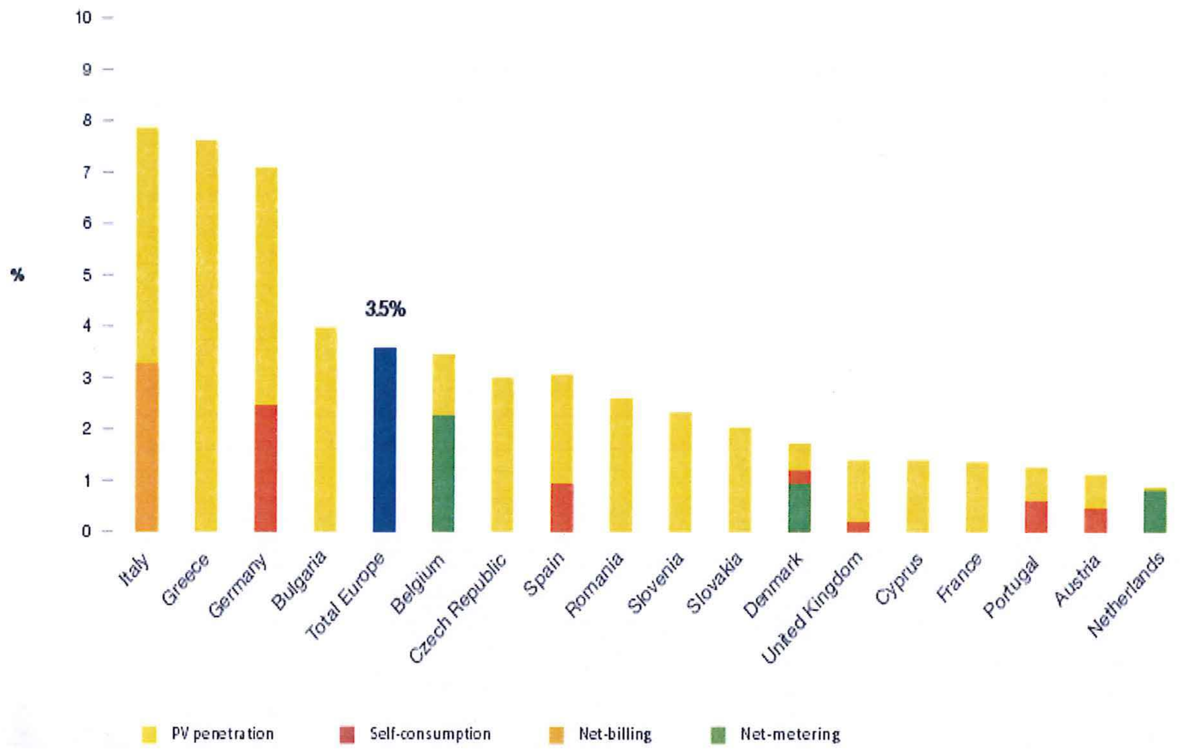


Figure 5: European uptake of PV [19].

To date (worldwide) Italy has the highest uptake rate (7.8%) of PV based on total generation. Other major markets including the USA, India and China all have less than a 1% uptake of PV [21]. Most jurisdictions with high uptakes of PV have had governmental incentives and/or high energy prices.

4.1.1 Consideration

Since PV offsets internal consumption it has an advantage over the grid in that it only needs to compete with electricity deliverance costs (28.86 c/kWh), and not generation costs (~8c/kWh). PV has yet to cross the chasm in any market however it has strong uptake rates underpinning its growth. Regulation and a lack of incentives have kept New Zealand's uptake to date relatively mild. New Zealand's generation is already mostly renewable (~80%) which has reduced the country's need for PV.

4.2 Battery Storage

Battery storage allows for the short term storage of energy as either a method to increase security of supply or shift supply off peak. It comes in a wide range of sizes including residential, commercial and network scale.

Current state of the technology

Numerous battery technologies have been developed over the years, each with their own pros and cons. Common battery types include Lithium-Ion, Sodium Sulphur (NaS), Redox Flow, Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH) and Lead–Acid. Table 6 identifies what characteristics of batteries are important, and Table 7 compares different battery chemistries against each other.

Table 6: *Desirable characteristics of battery technologies.*	
Characteristic	**Explanation**
High specific energy	Storage capacity per unit mass (weight to storage ratio).
High specific power	Ability to output power (rate at which stored energy can be discharged).
Affordable	Cost per kWh and number of cycles.
High cycles	The rated number of charge/discharge cycles under warrantee.
High round trip efficiency	The ratio of energy output to that input through a full charge-discharge cycle.
Long shelf life	Degradation of a battery over time while not in use.
High safety	Some battery chemistries are prone to fire, while also posing a shock hazard if improperly managed (dangerous elements, pressurised…).
Wide operating range	Some battery cycle management systems limit the depth of discharge in which a cycle can operate to extend the life of the battery. This band can be initially inhibited and then increased to keep a similar performance over the battery's lifetime. Other chemistries see considerable drops in performance once a discharge threshold has been reached. Additionally a wide operating temperature range is desirable.
Non-toxic	Depending on the chemistry toxic compounds may be used. Can determine the ability to recycle.
Fast charging	The time taken to charge a battery between 0-80 percent.
Low self-discharge	If left alone battery's will self-discharge over time.
Life cycle	Technologies with adequate end of life contingencies (recyclability, reuse).
Response time	How fast the battery can react to a change in demand.

Table 7: *Comparison of different battery chemistries (indicative only)* [19].

Property	Li-Ion	NaS	Flow	NiCd	NiMH	Lead-Acid
Specific energy	Green	Green	Green/Orange	Red	Orange	Red
Specific power	Green	Red	Green	Red	Green	Red
Cost	Red	Red	Orange	Red	Orange	Green
Number of cycles	Green	Orange	Green	Orange	Orange	Red
Round trip efficiency	Green/Orange	Orange	Red	Red	Black	Green/Orange/Red
Lifetime	Orange	Orange	Green	Orange	Green	Orange/Red
Safety	Red	Red	Green/Orange	Green	Green/Orange	Orange
Operating range	Orange	Green	Green	Orange	Orange	Green
Non-toxic	Green	Orange	Green	Red	Green	Red
Fast charging	Green	Red	Green	Green/Orange	Orange	Red
Self-discharge	Orange	Red	Red	Red	Red	Green
Form factor	Green	Red	Orange	Green	Green	Green
Shelf Life	Orange	Orange	Black	Red	Green	Green
Year commercialised	1992	1960	1993	1956	1990	1881

***Key:** [Green: Desirable, Orange: Neutral, Red: Poor, Black: Data Unavailable]*

There are many companies offering batteries including Tesla, LG Chem and Panasonic to name a few. The cheapest battery storage currently being marketed (by Tesla) costs NZ $630 per kWh [23] of storage excluding installation and an inverter. Typical batteries span 1.8 to 20 kWh of capacity, are capable of 2000 or more cycles and require an inverter in order to be connected to the grid [24]. Figure 6 shows the current maturity of different battery chemistries.

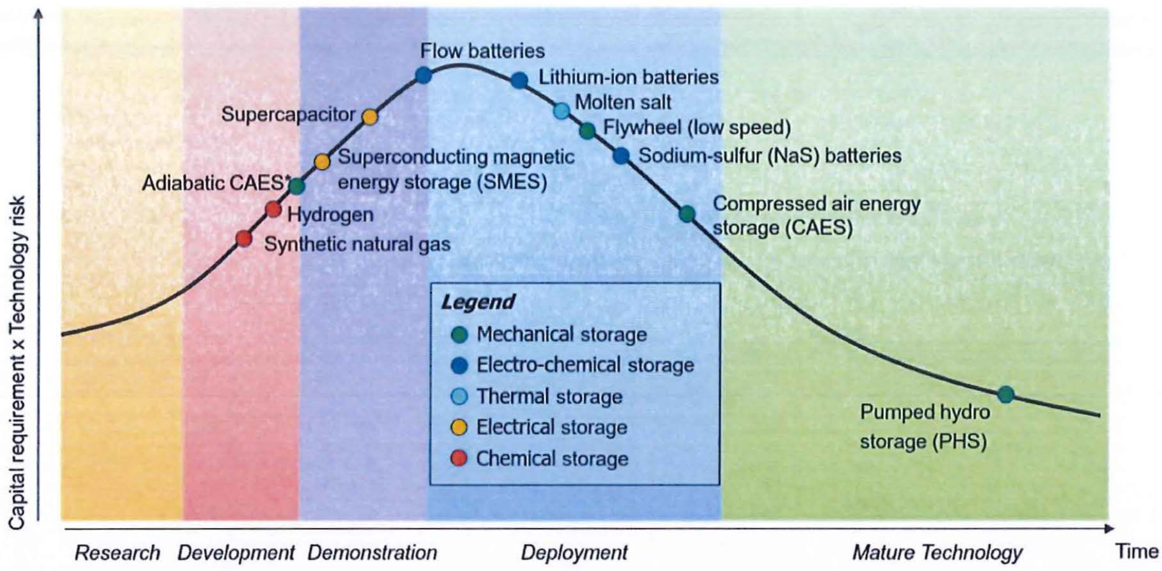


Figure 6: Energy storage technology maturity curve [23].

Current uptake of the technology

It is unknown at this time how many batteries are embedded within Orion's network or the New Zealand power system. It is not currently a requirement to for customers to declare the installation of a battery (like it is for solar), preventing a reliable uptake number from being available.

Of the energy storage installed worldwide 99% of it is pumped hydro. The remaining 1% is deployed as follows [26]:

- Compressed Air 44.8%
- Lithium Ion 11%
- Nickel-Cadmium 2.7%
- Redox Flow 1%
- Sodium Sulphur 31%
- Lead Acid 7%
- Flywheel 2.5%

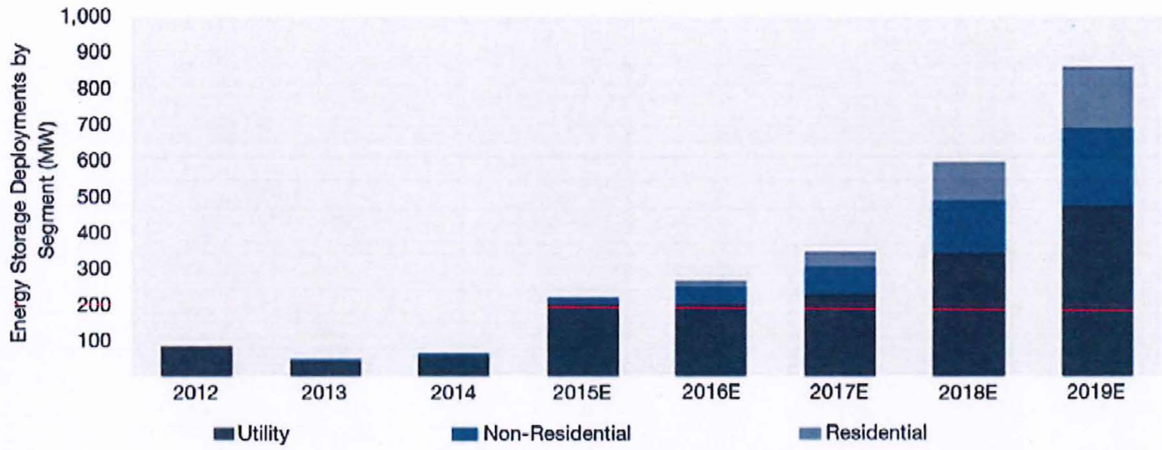


Figure 7: Energy storage deployment in the USA [19].

4.2.1 Consideration

Battery storages unique selling point is its size .The incumbent technology, pumped hydro, requires large capital expenditure, economies of scale and a reliable source of water to use. This constrains it to grid level applications. New Zealand's lack of reporting standards on battery installation may hinder innovation in the control systems that grids may implement to make better use of the technology.

4.3 Electric Vehicles

Electric vehicles (EV) are a direct substitute for internal combustion engine (ICE) vehicles that run on fossil fuels. The unique proposition of EVs are their ability to run of clean energy (depending on its source), and an inherently simpler design. They come in many varieties including:

- (BEV) Battery electric vehicle;
- (PEV) Plug in electric vehicle;
- (HEV) Hybrid electric vehicle; and
- (PHEV) Plug in hybrid electric vehicle.

Current state of the technology

Four factors have limited EVs uptake to date, and are outlined in Table 8.

Table 8: *Electric vehicles uptake constraints.*

Constraint	Description
Cost	The cheapest EV currently on the market, the Nissan Leaf costs $40,000 compared to $31,000 for an equivalent ICE vehicle (Toyota Corolla). An electric-combustion vehicle cost parody of US$ 150 kWh of battery storage is expected to be reached in 2020-2025 (US $300 kWh presently) [27].
Charging Time	EVs currently use three charging modes being *Quick Charge* (15-30 minutes, 80%), *Normal Charge* (7-8 Hours, 80%) and *Trickle Charge* (14 Hours, 100%) for the 120 km range 26 kWh batter used in the Nissan leaf. Specialised charging stations are required for quick charging, with a household plug being adequate for normal and trickle charging. This is in stark contrast to the instant refuelling capability of ICE and hydrogen vehicles.
Range	The average New Zealand driver travels 39 km a day. Entry level EVs have a theoretical range of 170 km (Nissan Leaf), with the top of the line Tesla capable of traveling 320 km on a single charge. Tesla's CEO stated in an interview he expects EVs to be capable of 1,200 km on a single charge by 2020 and to increase at a rate of 5-10% per annum [28].
Choice	In 2015 only one model of EV (Nissan leaf) was available for sale in New Zealand, with a further seven hybrids available. Many manufacturers are now manufacturing completely electric vehicles including Nissan, BMW and Chevrolet, to list but a few [29].

Current uptake of the technology

Table 9: *Factors contributing to the uptake rate of electric vehicles.*

Factor	Explanation
Incentives	Currently EV owners do not need to pay road user charges until 2020 equating to an average saving of $66.80 per 1000km [28]. Other countries allow electric vehicles to occupy bus lanes, car pool lanes, and subsidise their purchase.
Charging Infrastructure	The rate of charging infrastructure installation will help alleviate range anxiety.
Business Fleets	To foster the uptake of EVs the EECA has launched a '*Vehicle total cost of ownership*' [31] website allowing businesses the ability to compare their fleet needs against cars registered for sale in New Zealand. Meridian Energy and Air New Zealand have publically stated they intend to replace their commercial fleet vehicles with electric equivalents where appropriate, with more companies likely to follow. Orion currently has one all electric vehicle and seven hybrids in its fleet and plans to acquire more hybrids as vehicles come up for replacement.
Second Hand Vehicles	The majority of New Zealand's vehicles are bought second hand (54%) [31]. This creates a lag behind other countries while an import market is established. The average age of a vehicle in New Zealand in 14 years [31].
Hydrogen Vehicles	Hydrogen fuel cell powered vehicles are an alternative technology that could challenge ICE for dominance. Hydrogen is more expensive than electricity with a lower total efficiency however it can be refuelled instantly like ICE vehicles if the hydrogen infrastructure is put in place.
Hybrids	To some extent plug-in hybrids (PHEV), electric vehicles that also contain an ICE to charge the battery and add performance, are enabling the market transition from ICE vehicles to EVs while battery technology reaches an economical level.
Autonomy	Automakers have incorporated into EV design road sensing technologies, capable of hands free parallel parking and lane changing. Over air updates are expected to make these vehicles self-driving in the future. Tesla's CEO stated in a 2015 interview that vehicles would be technically capable of being autonomous by 2018, but would likely be restricted by regulation [33].

Table 10: *Snapshot of light vehicle fleet* [33].

Location	Diesel	Petrol	Electric	Hybrid
Christchurch	~66,000	~484,000	64	41
New Zealand	571,699	2,780,892	782	644

New Zealand's EV uptake at 0.043% [33] has lagged other countries, with Norway having the highest penetration at 12.5% [32].

4.3.1 Consideration

New Zealand and Norway are similar markets in terms of renewable energy output and population but differ in location, yet differ in the uptake rates of EVs. This in a large part can be attributed to Norway's incentive scheme it has used to drive uptake of the technology. A chicken and egg scenario has occurred where EV sales are needed to warrant the roll out of charging infrastructure, however more EVs are needed for charging infrastructure to make commercial sense to install.

5. Business Models

Although the industry calls these technologies emerging they have been around for some time. As such there are no longer 'blue sky' segments of the electricity industry that can be entered. Table 11 outlines business segments that other companies with New Zealand operations are present in. Business segments relating to emerging technologies include:

Sales

- Photovoltaic;
- Battery storage;
- Electric vehicle;
- Charging infrastructure;
- Home energy management systems;
- Smart meters; and
- Inverters.

Services

- PV installation;
- Battery storage installation;
- Charging infrastructure installation;
- Home energy management installation;
- Smart meter installation;
- Inverter installation; and
- Energy audits.

Table 11: *Companies and associated business segments (includes subsidiaries).*

Company	PV	Storage	Electric Vehicles	Charging	HEMS	Energy Audit	Smart Meters	Inverter
Vector	Green	Green		Green			Red	Green
Main Power					Green	Green	Green	
Mighty River Power	Green							Green
Genesis Energy		Green						Green
SolarCity	Red	Green						Green
EnaSolar					Red			Red
Enphase		Red						Red
Charge.net				Red				

Green: Sales, Red: Manufacture and Sales.

Orion does not operate in any of the emerging technology business segments identified. International companies that operate in these business segments are identified in Figure 8.

Figure 8: Companies active in the US market [19].

5.1 Consideration

The only market segment identified not dominated by a large company in New Zealand is EV sales. This segment is considered to be the furthest from traditional power business models and falls into the domain of car dealerships. Worldwide there are many companies in each business segment that will likely introduce their product into the New Zealand market over time. Potential exists to partner with these companies and handle the rollout of their technologies in the local market, should a company choose to do so. This is the approach Vector and Tesla have taken with their battery technology.

6. Conclusion

A review of the electricity industry, in particular distribution has identified the electricity industry's structure, customer profiles and perspectives, emerging technologies capabilities and market position, and the business models associated with emerging technologies. Conclusions drawn from this literature review include:

- Distributors' heavy regulation may stifle its ability to make attractive offers to customers under the umbrella of its current business. This may force distributors to create non-regulated arm's length businesses if they choose to operate in the space.
- As the prevalence of emerging technologies becomes more apparent Orion may need to change its organisational structure to best manage the deployment of emerging technologies throughout its network.
- The well-defined roles of different sectors of the electricity system may become blurred with the introduction of emerging technologies, allowing for vertical competition throughout the sector where before there was minimal.
- Customers have historically been content with their physical connection for the past century, however the emergence of a new (more expensive) alternative will drive a desire for a better level of service.
- At 7.6% photovoltaics uptake in Italy is on its way to approaching the chasm. With a lower uptake rate New Zealand is in a position to observe the effects of PVs uptake, and learn from any mistakes made in other jurisdictions.
- New Zealand might miss out on the full potential of battery storage if it continues to not record the technologies uptake.
- Charging infrastructure needs to be installed throughout New Zealand to facilitate the uptake of EVs.
- No 'blue ocean' opportunities exist as current emerging technologies have been around for a long time.

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