Ripple Control of Hot Water in New Zealand

September 2020

EECA
TE TARI TIAKI PŪNGAO
ENERGY EFFICIENCY & CONSERVATION AUTHORITY

New Zealand Government

PSC
Specialist Consultants to the Electricity Industry

Front cover image: Auckland at night

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Acknowledgements

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About this report

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1.0

Executive summary

Ripple control is a network management tool for managing electricity demand. New Zealand's Electricity Distribution Businesses (EDBs) use ripple control to turn off consumers' electric hot water systems at times of peak demand. It has been New Zealand's most important demand management tool since the 1950s.

This report will help to inform future plans for managing demand for heating water and peak demand in general. The report describes the current state of ripple control infrastructure, its application by EDBs and the resulting benefits. The report also describes problems with ripple control, barriers to its effective use and its future role in the energy system in the context of emerging technologies. Research for this report included surveys with consumers, EDBs and electricians, and well as a review of existing published information.

All 29 EDBs in New Zealand own and operate ripple control plant which sends audio-frequency signals through the electricity network. These signals are detected by ripple relays at consumers' premises. The relays respond by switching off certain electrical appliances, mostly hot water systems. Ownership of ripple relays varies around New Zealand and is split between EDBs, electricity retailers and metering equipment providers (MEPs).

Ripple control continues to be widely used and well maintained. EDBs continue to invest in ripple control plant with over$16M capital expenditure planned for upgrades and replacements across New Zealand through to 2029. EDBs continue to maintain ripple control plant, and overall, it appears to be in good condition.

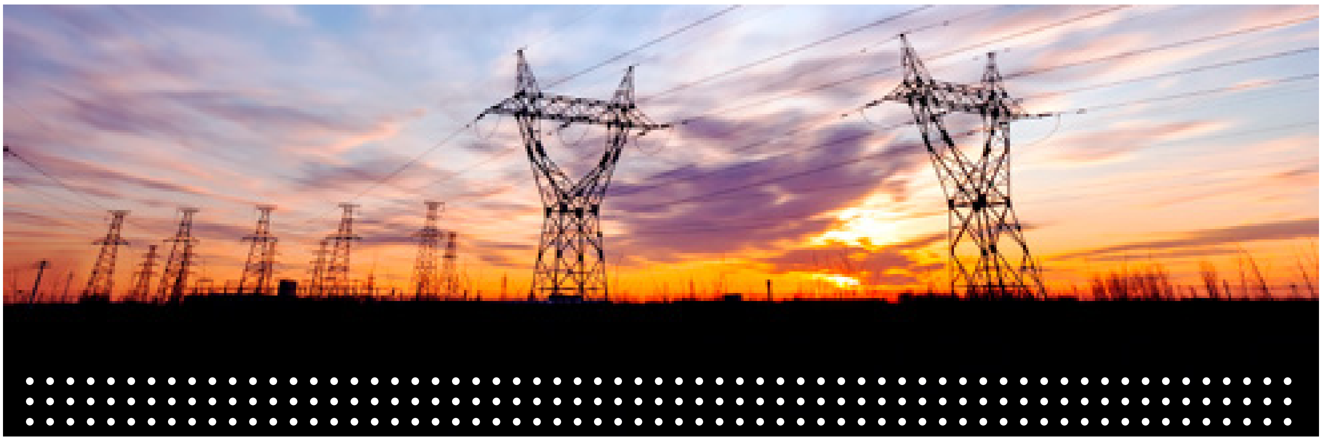
Most EDBs see ripple control as effective, reliable and low-cost technology with multiple benefits. It is estimated that just over half of electricity consumers have ripple control, most of which is connected to hot water systems. The load connected to ripple control equates to approximately 15% of New Zealand's annual peak demand. However, the proportion of consumers with ripple control is gradually declining due to removal of ripple relays by retailers and disconnection of water heating from ripple relays by solar panel installers, as well as the increasing uptake of alternate energy sources for water heating.

Ripple relays are currently the most expensive part of providing ripple control. Individual ripple control relays cost about$300 per ICP to supply and install or$10 per ICP per year assuming a 30 year life of a ripple relay. Costs that were disclosed indicate the total annual cost of providing ripple control ranges between$10 and$27 per kW of controllable load and between$10 and$19 per ICP compared to approximately$130 per kW per year to provide additional peak distribution capacity.

The most important use of ripple control is to control peak electricity demand. EDBs take different approaches to the use of ripple control. It is likely to be most useful in integrated networks typical of urban areas, and in areas with growing electricity demand. Most EDBs use ripple control in winter to maintain network demand within predetermined limits. This has several potential benefits, including:

- minimising the transmission charges that EDBs must pay to Transpower
- ensuring demand does not exceed network capacity, hence maintaining network security and reducing the risk of outages
- deferring expenditure on network upgrades, helping to keep customer bills lower.

Some EDBs use ripple control to manage consumers' electricity use in-line with their electricity tariff. For example, a consumer on a night-only tariff will have their water heated between 11pm and 7am. This use of ripple control permanently shifts demand away from morning and evening periods when peaks occur. In some regions ripple control is also used to switch off load in response to system low frequency events and other emergencies such as network failures.



EDBs highlight a lack of clear market incentives to use ripple control. Although ripple control reduces the cost of the electricity system, the benefits do not necessarily accrue to the consumers and industry participants who provide the service. EDBs continue to invest in ripple control for the benefit of their consumers, not because of direct business incentives. In fact, if they were to abandon ripple control and allow peak loads to rise, EDBs could upgrade their networks and increase their revenues. Consumers should receive reduced rates in return for ripple control, however, not all retailers structure their tariffs to align with consumers' consumption patterns and few retailers appear to actively promote the benefits of ripple control.

In the short term, (1-3 years) most EDBs see ripple control continuing as the best option for managing domestic hot water loads, despite uncertainties on the horizon. Industry participants recognise that the evolving electricity system will need new approaches to energy management beyond ripple control of hot water. The Electricity Authority's proposed 2021 introduction of Default Distributor Agreements adds uncertainty. Load control will become a contestable "related service" or "additional service", not a core distribution service. EDBs may no longer be able to mandate ripple control in their connection agreements. Further, from April 2023, the Electricity Authority is changing the way Transpower allocates and recovers transmission costs. The new cost-allocation method will no longer be related to the Regional Coincident Peak Demand. For some EDBs this change will remove a major incentive to deploy ripple control.

In the medium-term (5 years) the future of ripple control is uncertain. Greater adoption of technologies such as electric vehicles, solar power and home battery systems will increase the need to manage electricity demand, including at the level of individual households. There is currently no industry-wide strategy for ripple control or demand management. This leads to lack of clarity over responsibility for demand management and the pace of change. If change is gradual, ripple control may continue for decades, increasingly interacting with new technologies such as smart meters. However, with a more rapid transformation, ripple control will be superseded more quickly.

In the long-term (10 years), ripple control is likely to be displaced by a range of advanced technologies, including:

- advanced smart meters and home automation systems that can transmit two-way information on current consumption and send signals to consumers' appliances
- individual appliances that respond to load and price signals sent by smart meters
- software to handle monitoring, forecasting of energy and control of appliances
- alternative communication channels such as cellular networks and broadband.

These technologies will combine to monitor, forecast, control and coordinate energy generation, demand and storage. They will surpass ripple control in their ability to control consumer equipment according to market conditions and provide real-time data on consumption at the household level. Some retailers and EDBs in New Zealand are carrying out small trials of these technologies, however their introduction is slow and piecemeal.

2.0

Ripple control

2.1. Introduction to ripple control

Electricity grids must be constantly managed so that supply and demand are in balance. One way to achieve this balance is to reduce or shift electricity consumption – an approach known as demand management. Ripple control is a demand management technology that enables consumers' electrical equipment to be switched off and on using a remote signal. New Zealand's Electricity Distribution Businesses (EDBs) have relied on ripple control as their main demand management tool since the 1950s.

Ripple control involves control plant (Figure 1) sending an audio-frequency signal through the ordinary electricity network (Figure 2). This signal is detected by ripple relays located next to consumers' meters (Figure 3), or embedded in a modern smart meter. Relays respond by switching off the electricity supply to designated electrical appliances. When power demand falls, a second signal is sent to restart appliances. This report concerns the most common type of equipment under ripple control – domestic electric hot water heating systems.

Data included in this report described as ripple control includes an older and less common technology called pilot wire. Pilot wire is still used to control some domestic hot water heaters in older built-up areas in various locations around New Zealand. The difference with pilot wire is that the initial signal is sent to substations, not consumers. These substations then send a signal over a dedicated wire that is separate from the mains supply. Once the signal reaches a consumer, their hot water is switched on/off.

Figure 1 - Mangamaire 33 kV ripple injection plant. (Photograph courtesy of Powerco)

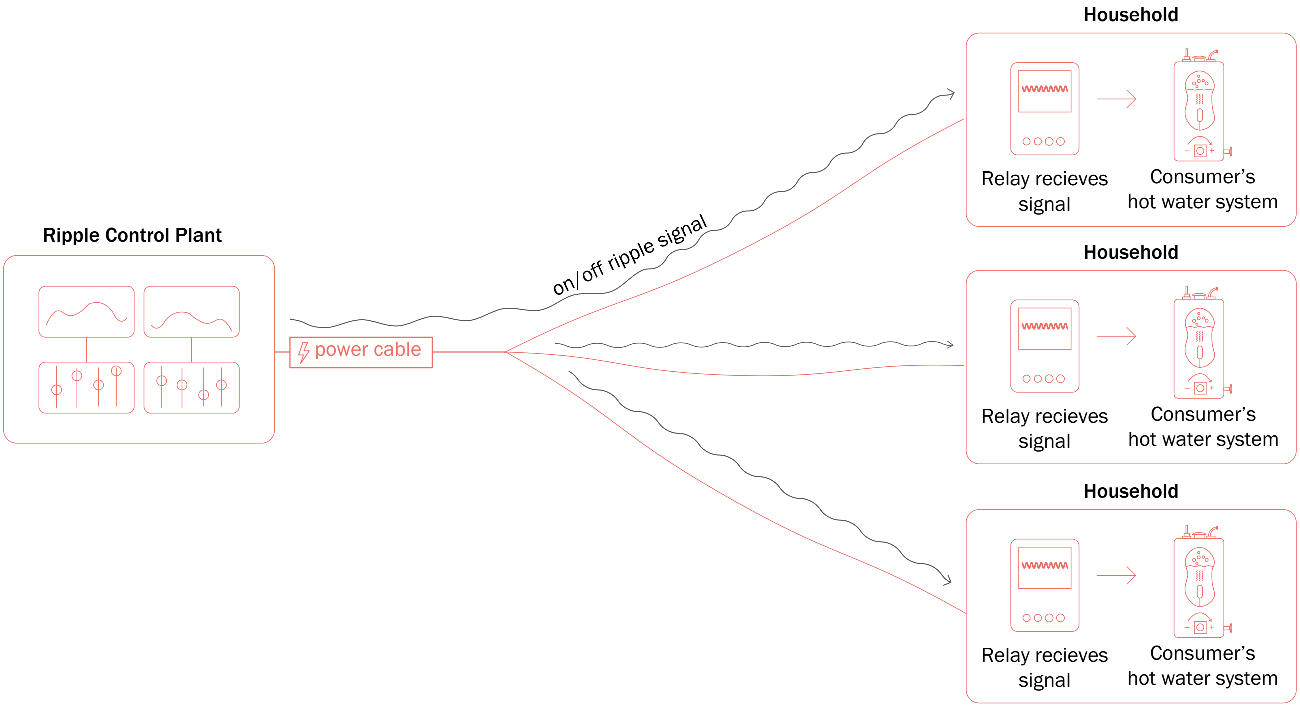


Figure 2 - Ripple control plants send signals to switch on/off thousands of hot water systems

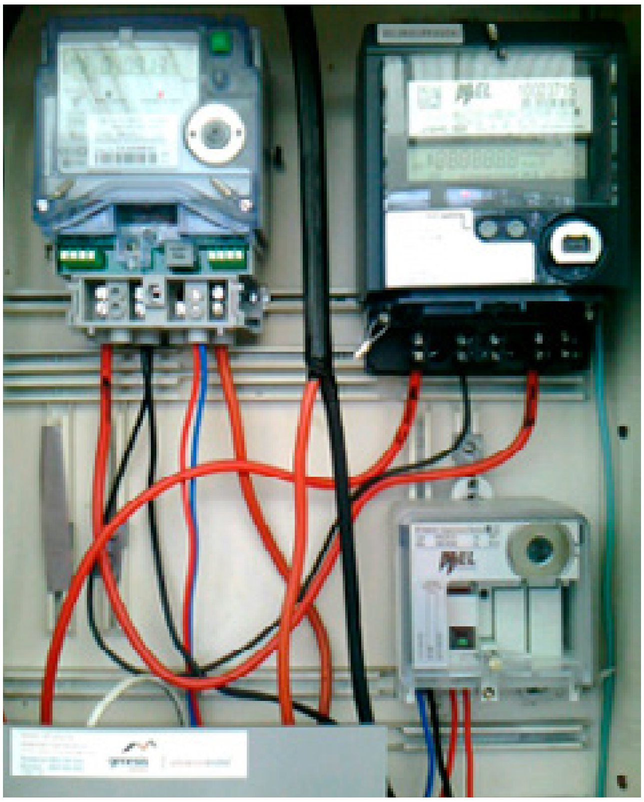


Figure 3 - A domestic meter board showing: upper left = retailer's meter; upper right = WEL Networks' meter of controlled hot water load; lower right = WEL Networks' ripple relay. *(Photograph courtesy of WEL Networks)*

This report focusses on the primary use of ripple control in New Zealand – reducing electricity demand at peak times. It also discusses some related uses of ripple control such as alleviating network constraints and managing consumers' electricity use to align with retailer tariffs.

Ripple signals are transmitted for several other reasons that are outside the scope of this report. For example, they are used to a lesser extent to control the operation of other equipment such as street lighting, night-storage heaters and irrigation pumps. They are also used to alert commercial and industrial consumers to periods of high electricity consumption and, in some parts of New Zealand, to trigger Tsunami warning sirens. These alternative uses for ripple control appear to be declining. For example, street lighting control is often being replaced with other control systems incorporating daylight sensors. Tsunami warnings are now mostly via mobile phone alert systems.

2.2. The benefits of ripple control – balancing the grid and reducing electricity costs

Ripple control of domestic electric hot water heating is one way of reducing demand. In New Zealand it is deployed at times of peak electricity use – usually winter mornings (8-9:30am) and evenings (5-8pm), largely due to greater use of electric hot water, heating and lighting. Figure 4 shows how, ripple control can enable a reduction in peaks of electricity demand.

Demand management techniques, such as ripple control, have several benefits that support the New Zealand Government's objectives for an energy system that is affordable, reliable and more sustainable.[1]

2.2.1. Ripple control reduces electricity costs

Ripple control can help deliver cheaper electricity for all consumers by reducing system costs, in several ways:

Lower network costs. Figure 5 from Orion suggests that typically 25% of an electricity network's capacity is used only during peak demand periods in winter that accounts for less than 10% of the year. Ripple control can flatten these peaks (Figure 4), improving asset utilisation and reducing the required capacity and overall cost of the transmission and distribution networks.

Lower generation costs. The cost of electricity usually rises when demand is high. At these peak times lower cost generation is already operating at maximum output so more expensive generators such as gas-fired power stations with a higher environmental impact are deployed. Also, transmission lines can reach their capacity, resulting in the dispatching of more expensive generation connected by different transmission lines with spare capacity. Ripple control reduces the reliance on expensive generation by reducing peak demand.

Reducing consumers' energy bills. Around half of New Zealand households have hot water systems under ripple control. These consumers often pay a reduced rate for energy in return for allowing network companies to control their hot water systems.

2.2.2. Ripple control supports the reliability of the electricity system

Occasionally electricity supply is unable to meet demand due to either insufficient generation or inadequate transmission capacity. A last-resort measure in these situations is to cut electricity supply to some consumers, causing sudden blackouts. The option of ripple control reduces the likelihood that this emergency response will be activated.

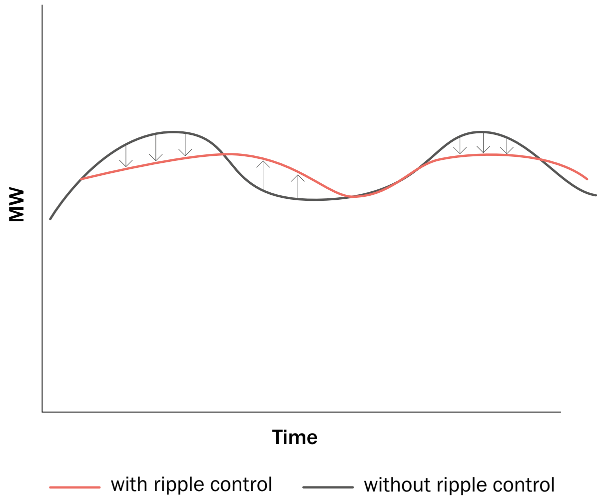


Figure 4 - Ripple control can help reduce peaks in electricity demand.

1. Ministry of Business, Innovation and Employment, Energy strategies for New Zealand. www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-strategies-for-new-zealand/

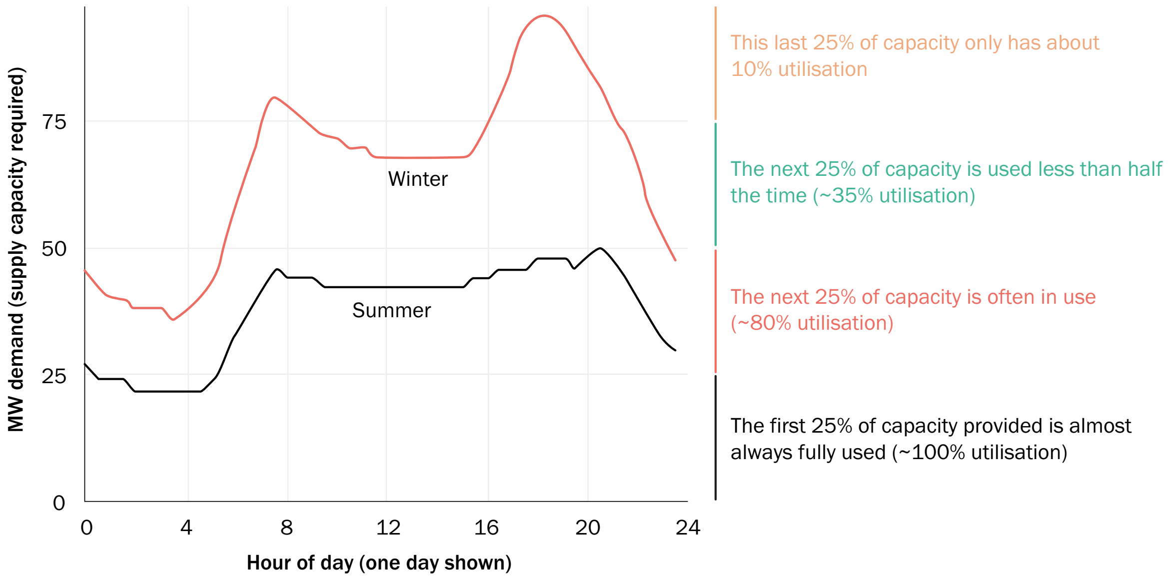


Figure 5 - About 25% of an electricity network's capacity is only used for 10% of the time – mostly during peak demand on winter evenings.

2.2.3. Ripple control supports power quality

A side effect of using ripple control to reduce network peaks is that it helps with network voltage control. On occasions the automatic ripple response of EDBs participating with Orion in the Upper South Island Load control scheme has assisted in maintaining voltage security in the Upper South Island. (See the Orion Case Study, Appendix C).

WEL Networks have ripple relays configured to respond to under-frequency events to help maintain the power system frequency. (See the WEL Networks Case Study, Appendix C).

2.2.4. Ripple control supports the integration of renewable energy sources

Demand management can also support New Zealand's emissions reduction targets, by facilitating the introduction of more wind and solar energy. The variable output of these technologies increases the value of systems that manage demand, including ripple control. The integration of renewable energy sources will also require greater electrification of transport and process heat, which, if not carefully managed could exacerbate spikes in demand. Hot water load management is one way to reduce these spikes. Demand management by shifting peak loads to off peak times is an opportunity to use the existing capacity of the power system more efficiently.

Ripple control is now competing with other, newer technologies that can enable demand management, such as advanced smart meters (Box 1). EDBs will have to make strategic decisions about their level of investment in ripple control compared to these alternative technologies. This report provides part of the evidence base for making those decisions.

2.3. Project background and purpose

The main objective of this research is to provide a better understanding of the current state of ripple control for domestic electric hot water heating in New Zealand. This understanding will help the Energy Efficiency and Conservation Authority (EECA) deliver new initiatives aimed at reducing peak electricity demand, using existing power system capacity more efficiently and increasing use of renewable energy.

EECA suspects that use of ripple control for domestic electric hot water heating is declining in parts of New Zealand. The report explores this issue, as well as looking to the future of managing domestic hot water heating loads. It addresses the following questions:

- To what extent is ripple control being used to manage electric hot water heating loads?
- Is ripple control being used effectively, and what are the problems with it?
- Are there adequate incentives for using ripple control?
- How much does it cost to install and maintain ripple control technology, and what are network companies' plans to invest in maintenance and upgrades?
- Are there better alternative technologies for managing electric hot water heating loads, and are these alternatives being explored by network companies?

To answer these questions, this research explores various new and existing evidence, including:

- Existing data and research such as network companies' Asset Management Plans, Commerce Commission data and academic reports.
- Surveys conducted for this report with network companies, electricians and electricity consumers.
- Case studies of four network companies developed through interviews conducted for this report.

2.4. The use of ripple control in New Zealand today

2.4.1. EDBs use of ripple control

Every EDB in New Zealand owns ripple control infrastructure which they can use to manage electricity demand in their area. This infrastructure includes multiple ripple control plants, each covering a different part of an EDB's network. These control plants send ripple control signals on different communication channels. Ripple relays at consumer sites are programmed to respond to one or more of these channels. This gives network companies the ability to control blocks of hot water systems according to different timetables or real-time needs.

It is estimated that just over half of New Zealand's electricity consumers have ripple control, most of which is connected to hot water. The total network load connected to ripple control is estimated to be approximately 15% of New Zealand's peak demand. This estimate is based on publicly available data on the extent of ripple control (Appendix A). The total load connected to ripple control cannot be determined exactly, but is estimated based on the changes in network load that EDBs observe in response to ripple control on and off signalling. The fragmented ownership of ripple relays between EDBs, electricity retailers and metering equipment providers (MEPs), and differing requirements across New Zealand in EDB connection contracts for mandatory and optional ripple control of water heating, add to the uncertainty of exactly what load is connected to ripple control.

Ripple control is a one-way communication system with no information sent back from consumers' sites. This means EDBs cannot detect if individual ripple relays receive a signal or if a hot water system is correctly turned on/off. EDBs can only estimate their controllable loads by monitoring the impact of ripple signals on their network load.

Ripple-controlled water heaters generally remain off for less than three hours, and occasionally up to five hours. Only in rare events, such as a system fault, will ripple control affect an individual consumer for over five hours. To minimise its impact, ripple control is sometimes rotated between consumers. Mostly it has very little or no impact on consumers, as the water remains hot in the tank for several hours while the heater is switched off.

Most EDBs see ripple control as an effective, reliable and low-cost technology with multiple benefits, as described below. Ripple control is likely to be most useful in integrated networks typical of urban areas, and in areas with growing electricity demand. This type of network presents greater opportunities to realise some of the benefits of ripple control, such as alleviating network constraints and maximising use of network assets (Section 2.5).

In sparsely populated rural networks, ripple control may be less useful as its use may lead to under-utilisation of network capacity. The case study on Eastland Networks (Appendix C) describes a rural network where distributed diesel generators are seen as a more effective alternative to ripple control alone. The diesel generators run at peak times to meet demand and are also available as back-up power supplies when there are transmission failures and an area within the network loses its connections to its normal sources of generation.

Table 1 - Quantification of ripple control in New Zealand

Quantification of ripple control in New Zealand	
Total network peak demand in New Zealand	6,617[2] MW
Network load connected to ripple control	987[3] MW
Total Installation Control Points (ICPs) in New Zealand	2,177,219[4]
Consumers (ICPs) with ripple control	1,134,301[3]
Typical frequency of use	
• Reducing peak demand	Weekdays in winter (1 to 4 month period)
• Managing off-peak rates (tariff switching)	5 weekdays per week (throughout the year)
• Emergency load-shedding	<5 times per year

2.4.2. Consumers' perspective

A short survey was conducted with 42 responses from domestic consumers located across 7 EDB network areas, from Vector in Auckland, to Orion in Christchurch. Responses are summarised below in Table 2 as a percentage of the respondents that the question applied to, i.e. some questions apply to only those with ripple controlled hot water and not those who answered the survey with no ripple control.

2. Commerce Commission electricity distributors information disclosure data 2018

3. Estimate from Commerce Commission Electricity Distribution Business Emerging Technology data 2018 plus estimate for Vector's load (not included in the Commerce Commission data).

4. Electricity Authority Market Information metering snapshot 30/6/2020

Table 2 - Consumer survey response summary

Before receiving this survey, were you aware of ripple control on domestic hot water systems?	Yes 90% No 10%
Do you have electric water heating?	Yes 62% No 38%
Is your water heating ripple controlled?	Yes 54% No 23% Don't know 23%
What benefit do you gain by having your hot water heating ripple controlled?	Reduced rates 43% Nothing 29% Not sure 28%
If ripple control of hot water heating in your area was optional would you choose to have it ripple controlled?	Yes 70% No 15% Don't know 15%
Do you ever run out of hot water where you think it may be because of ripple control?	Yes 21% No 79%
Have you had hot water faults where you have called an electrician or reported a fault to your retailer and the cause of the fault has been due to the ripple control?	Yes 7% No 93%
Do you have any other ripple controlled load such as Night Store heaters?	Yes 5% No 90% Don't know 5%
Do you suspect that ripple control interferes with any electrical appliances, devices or lighting that you have (e.g. buzzing or flickering lighting)?	Yes 2% No 98%

2.4.3. Electricians' perspective

An attempt was made to gather experiences and views of electricians on ripple control. A short survey was sent out to 37 electrical contractors spread across New Zealand from Northland to Southland, selected based on their website information indicating a focus on residential work.

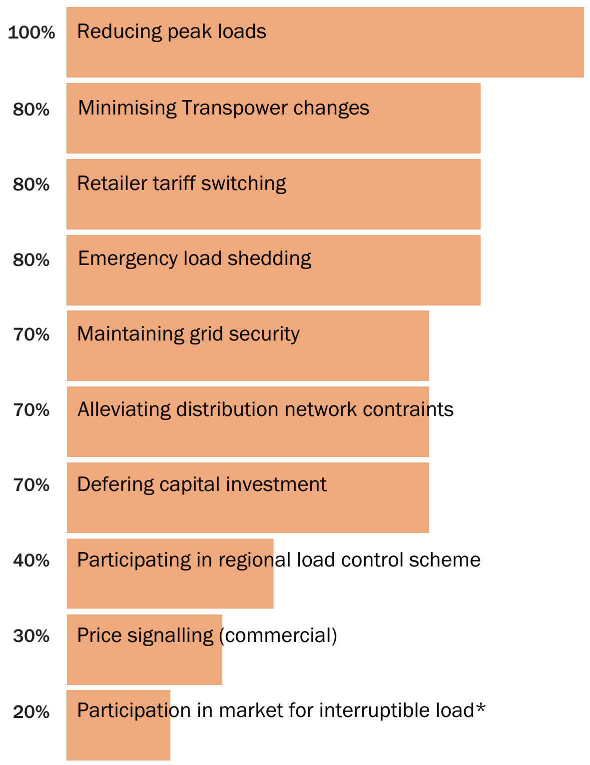
Only one response was received so there was insufficient information to draw any conclusions.

Once a ripple relay has been installed for a new build the terminal covers are sealed and from then on, work on ripple relays is restricted to authorised contractors of the ripple relay owners. Most residential focused electricians are not contractors to ripple relay owners and appear to have little interest in ripple control.

2.5. How and why is ripple control used?

This section describes how EDBs use ripple control, and their motivations for doing so (Figure 6). The sources of this information were:

- responses from 10 EDBs to a survey on ripple control
- interviews with the four EDBs for the case studies in Appendix C
- EDBs' Asset Management Plans.



**This was not specifically asked in survey, so may under-represent true number.*

Figure 6 - EDBs' reasons for using ripple control of hot water as percentage from 10 survey respondents

2.5.1. Ripple control for reducing peak demand

All 10 survey respondents reported using ripple control to reduce peak demand and maintain network loads within predetermined limits. EDBs anticipate when their limit is about to be exceeded and respond by sending ripple signals to turn off some of their hot water load (Figure 7). This requires careful management to ensure individual water heaters are not turned off for too long.

The use of ripple control to manage peak loads is most common on winter mornings and evenings. Some companies only use ripple control for between one and three months each year, as electricity demand tends not to approach the network limit outside winter.

There are several potential benefits from using ripple control to manage peak loads: minimising transmission charges; alleviating network constraints; maintaining grid security and deferring capital expenditure, as explained further below.

2.5.2. Minimising Transmission charges

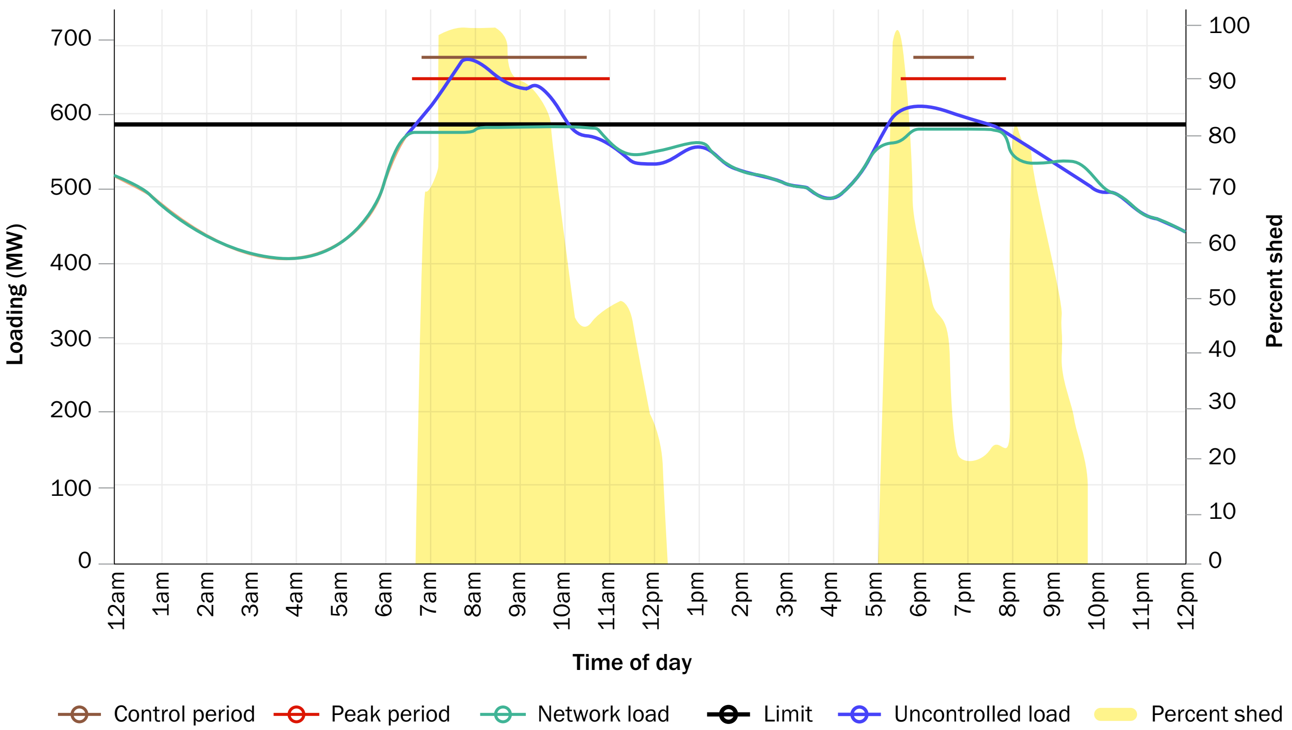
Transpower's allocation of transmission charges to EDBs is based partly on regional peak loads (Regional Coincident Peak Demand (RCPD)). By reducing peak loads, EDBs can sometimes reduce their transmission costs. Three case study participants reported passing these lower costs onto retailers, in the expectation that it would lead to lower bills for consumers. However, there is no obligation on retailers to pass lower costs onto consumers.

For some EDBs (including eight survey respondents) minimising transmission charges is a direct motivation for using ripple control. This includes the eight distribution companies that cooperate in a scheme to reduce the peak load of the upper South Island. Orion coordinates the Upper South Island Load Management Project by issuing participants with peak demand thresholds. The participants aim to keep demand below these thresholds, primarily through ripple control of domestic water heating. The project has successfully led to a reduction in transmission charges and the deferral of investment in new transmission capacity.

For some EDBs, lower transmission charges are not a direct motivation for managing peak loads, although they may be a beneficial side-effect. These companies do not explicitly set out to reduce their transmission charges because they consider their load is too small to have a significant effect on the peak load in their region.

Regulations allow EDBs to pass their transmission charges onto retailers, so there is no clear financial incentive to minimise them. Companies that do so are motivated by a desire to save money for consumers. Other companies are more comfortable passing transmission costs onto retailers, and therefore to consumers.

From April 2023, the Electricity Authority expects to



(Source: Orion Load Management Dashboard (https://online.oriongroup.co.nz/LoadManagement/)

Figure 7 - Ripple control can help contain electricity demand within network limits (Orion network load 6/6/2019)

The graph illustrates how ripple control of hot water (yellow shaded area) keeps network load (green line) below the network limit (black line). The purple line shows the estimated load in the absence of ripple control.

change the way Transpower allocates and recovers transmission costs[5]. The new cost-allocation method will no longer be related to the Regional Coincident Peak Demand. For some EDBs, particularly those without capacity constraints in their own networks, this change will remove a major incentive to deploy ripple control as ripple control will no longer reduce the transmission charges from Transpower that pass through to consumers.

2.5.3. Alleviating network constraints and maintaining grid security

If a network's capacity is exceeded, the result can be a power outage or a drop in the system voltage below agreed supply limits. EDBs continuously monitor their networks to ensure that loads remain within their capacity. Ripple control of hot water offers one way to protect a network that is close to capacity. This helps to reduce the likelihood of outages and maintain network security. Ripple control can also allow an EDB to carry out essential maintenance without interrupting the service to consumers. By alleviating network constraints with ripple control, EDBs maximise the use of their existing assets.

2.5.4. Deferring capital expenditure on network upgrades

Regulators determine expenditure on network upgrades according to peak demand. By using ripple control to reduce peak demand, EDBs can defer costly upgrades. Across New Zealand this reduces expenditure on network infrastructure by tens of millions of dollars every year, helping to keep consumer bills lower.

Ripple control enables the deferral of two types of upgrade. Firstly, it minimises peak loads at Transpower's substations – known as Grid Exit Points (GXPs)[6]. Without ripple control, EDBs could be required by Transpower to fund more frequent supply capacity increases at GXPs. Secondly, ripple control allows EDBs to reliably handle peak loads on sub-transmission networks that are close to their maximum capacity, also deferring the necessity of upgrades.

EDBs that aim to delay expenditure do so on behalf of their consumers, but have no direct financial incentive to do so. On the contrary, they may have a financial incentive to upgrade their networks as under current rules they are able to make a return on this investment and grow their revenue.

2.5.5. Retailer tariff switching

Some electricity consumers can select cheaper tariffs where appliances such as water cylinders and night-store heaters are operated outside peak periods. For example, on the night-only tariff, water heating occurs overnight, and is then off all day. Other tariffs include peak control; night-only with afternoon boost; night-only with weekend boost; and emergency control.

Some EDBs send fixed-time ripple control signals every weekday to support these tariffs. Some companies support the full range of tariffs, others support only the night-only tariff, while others do not support tariff switching at all. In general, EDBs are not incentivised by retailers to provide a tariff switching service.

This use of ripple control has the additional benefit of permanently shifting demand away from morning and evening periods when peaks occur. EDBs must balance this demand reduction with their obligations to achieve service level targets.

EDBs handle switching of consumers on different tariffs by using multiple ripple control channels. For this to work effectively, ripple relays must be correctly programmed to align with consumers' selected tariffs. Where an EDB does not own a ripple relay it must rely on the relay owner to correctly programme the relay to align with a consumer's selected tariff, which may not always occur.

5. https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/transmission-pricing-review/

6. Grid exit points (GXPs) are the points of connection (Transpower substations) where electricity flows out of the national grid to local networks or direct consumers.

2.5.6. Ripple control for emergency load shedding

In some networks ripple control is used to reduce load in grid emergencies – known as emergency load shedding. Grid emergencies can be due to a failure in the network, caused for example by damage to lines caused by storms or a high vehicle. Emergencies can also result from the sudden failure of a generating station. In such cases, Transpower may direct an EDB to reduce load. Using ripple control to limit demand is the preferred first response before taking more extreme action such as turning off all supply to consumers over wide areas. This helps prevent disruption to supply, including electricity outages, while the problem is fixed.

2.5.7. Using ripple control to participate in reserve market

When the network frequency falls below 49.2 Hz, the system needs to respond within seconds by reducing demand and/or increasing generation. Some EDBs use ripple relays to drop load in response to low-frequency events by having low frequency load shedding as a function programmed into ripple relays. This enables them to earn revenue in the reserve market for fast interruptible load. Low frequency activation typically only occurs a few times per year, and EDBs usually participate only outside the winter months, as 'ripple reserve' cannot be offered during periods when ripple control is already in use.

Some EDBs do not provide this service because the financial rewards are too small to justify the additional operational complexity and risk. Ripple control systems are too slow to respond by sending control signals within the time required by regulation. For companies that do provide this service an under-frequency detection function is programmed in the ripple relay and does not require a ripple signal to be transmitted over the network.

2.6. Costs of ripple control

EDB Commerce Commission information disclosures do not separately identify maintenance expenditure on ripple plant. Annual costs were requested in the EDB survey that was conducted for this report, however, some of the respondents to the survey did not provide any maintenance costs. Annual maintenance costs that were disclosed ranged between$10,000 and$80,000 per year. With this level of expenditure, the annual cost of maintenance is generally below$1 per ICP per year and below$1 per kW of controllable load per year.

Capital costs of ripple control are dominated by the cost of supplying and installing ripple control relays. EDBs responding to this survey that owned ripple relays stated the cost of supplying and installing stand-alone ripple relays (that is, not embedded in smart meters) was commonly about$300 but could be$500 or more for a rural installation. Assuming a ripple relay life of 30 years this gives cost of around$10 per year per ICP for an urban consumer ripple control installation

EDB cost information provided for this research is included in Appendix B. This shows the total annual cost of ripple control ranged between$10 and$27 per kW of controllable load and between$10 and$19 per ICP which compares favourably to approximately$130/kW/year for increased peak distribution capacity.

Capital costs of planned ripple control plant upgrades and replacements over the next 10 years have been extracted from EDB disclosures published in 2019 Asset Management Plans and tabulated in Appendix B. The planned total over all of New Zealand is$16.8M.

In general, EDBs consider ripple control as an inexpensive method of managing loads with positive financial benefits. Several EDBs reported that their financial benefit from ripple control is at least twice the costs. However, a couple of companies mentioned the anticipated costs of ripple plant replacements over the next decade provides an opportunity to evaluate the benefits of alternatives
to ripple control.

2.7. Requirements and incentives for load management

2.7.1. Consumers

Currently EDBs have the power to make ripple control mandatory for consumers with electric hot water heating. Most companies do not exercise this power, but some do, particularly in the upper South Island. Use of ripple control tends to be more extensive and effective in those areas where it is compulsory. Two large areas where ripple control is not compulsory, Auckland and Wellington, have comparatively low ripple-controlled load. Data from Auckland is unusual in that there is a substantial area that was served by a pilot wire system which is no longer in service because it has become unreliable. Vector is exploring different technologies, approaches and their costs, that may replace the services provided by the pilot wire system. The replacement should be adaptable such that it not only replaces the services from the pilot wire system but also addresses the uncertainty from a future with many distributed energy resources.

Many consumers receive reduced rates for allowing their water heating to be controlled. This can happen in one of two ways:

- Some domestic installations with ripple control have one meter for water heating (or other controlled loads) and a second meter for all other appliances. This allows these consumers to receive a discounted rate for their water heating.
- Other consumers have a single meter and receive a discounted rate for all load in return for allowing water heating to be controlled.

In some areas, the extent of consumers' discounts depends on the degree of ripple control they allow, as determined by their chosen tariff (Section 2.5.5). However, some variable tariffs are not well-aligned with actual ripple control, or an EDB's use of ripple control does not support the range of tariffs offered by all retailers. Also, some retailers do not offer reductions for controlled load or offer flat rates which take limited account of controlled load. Ripple control is not well promoted by retailers and many consumers are unaware of its potential benefits or even of its presence in their house.

2.7.2. EDBs

There are no regulatory requirements for EDBs to maintain or use ripple control infrastructure. However, as outlined in Section 2.5, EDBs have several potential motivations for using ripple control, including: lower transmission charges; deferred expenditure; reducing consumer energy bills and participation in the reserve market. Except for participation in the reserve market, these are not direct financial incentives, but rely largely on EDBs' willingness to act responsibly. The EDBs interviewed for the case studies (Appendix C) stressed that regulatory and community expectations are a major incentive for them to use ripple control. This is particularly the case for community owned EDBs.

2.7.3. Retailers and meter owners

Engagement with retailers and meter equipment providers (MEPs) was not part of the research for this report. EDBs believe retailers or MEPs are not promoting ripple control to their consumers, which indicates they have few incentives to do so. On the one hand, retailers that are also generators may lose out from the use of ripple control because it undercuts profitable peak generation On the other hand where they have fixed price contracts to supply electricity, having the ability through load control to shift load from high price peak periods to low price off peak periods improves profitability of supply contracts. EDBs reported poor coordination of ripple control between themselves, retailers and MEPs.

2.8. The reliability of ripple control of hot water

EDBs report that they can control a large proportion of electric hot water systems using ripple control, with few technical problems. For example, WEL Networks indicated an annual failure rate of individual relays of less than 0.2%. Most hot water faults tend to be related to the consumers' equipment, not ripple control.

Often publicised in trade literature is the potential problem of adverse interaction between ripple control signalling and consumer equipment, such as causing some types of lighting to flicker. Neither the consumer nor the EDB surveys indicated that this is a common problem in New Zealand. Some industrial equipment has the potential to absorb ripple signalling power to the extent that ripple control signalling in the surrounding area becomes unreliable. This is mostly an issue for the older ripple control systems using the higher signalling frequencies, e.g. 1050 Hz, which are more prone to signal degradation. Powerco stated that their Network Connection Standard requires the installation of blocking filters to prevent consumer equipment interfering with ripple control signals.

Most ripple control plant is well-maintained and very reliable. However, their failure is the most serious potential technical problem with ripple control infrastructure. Several companies reported that their ripple control infrastructure is several decades old, and hence more likely to fail. The risk is compounded by difficultly of obtaining new parts for ripple control plant, and a lack of technicians with the skills to repair the older ripple control infrastructure.

Older ripple control plant uses a higher frequency (e.g. 1050 Hz) which has a greater risk of signal loss. Many newer installations have moved to a more reliable lower frequency range (200 to 400 Hz). Migration to lower-frequency signalling requires ripple relays to be replaced. This is a slow and costly process, especially where ripple relays are not owned by EDBs. Pilot wire is less reliable than ripple control and replacement parts even harder to source. For this reason, some EDBs are decommissioning pilot wire as part of scheduled renewal programmes.

Sometimes hot water control systems get stuck in the "off" position. This can happen, for example, when the "switch on" signal coincides with a network failure or maintenance. It can also be caused by failures in communication between the SCADA Master Station and the control plant, as well as operational mistakes. Generally, EDBs can overcome this problem quickly by re-sending the "switch on" signal. Newer ripple control relays can be programmed to switch themselves on if they do not receive an expected "on" signal after a pre-set time limit. Orion reported sending nightly confirmation signals to ensure hot water systems are turned back on. Some modern ripple relays revert to a pre-programmed timetable if they do not receive an expected ripple signal.

Ripple relays themselves sometimes fail and no longer respond to ripple control signals. If a relay fails in the "off" state, an EDB will not know until they receive a consumer's complaint about lack of hot water. If a relay fails in the "on" state it is likely to remain in this state indefinitely as the consumer will continue to have hot water and is unlikely to report a problem. Also, the relay owner is unlikely to discover the problem as regulations do not require regular condition assessments.

Some problems relate to the ownership of meters and ripple control relays by third parties. This means EDBs have a limited understanding of the status of relays in their area. For example, they may not know what ripple channels different relays are set to, and therefore can only determine how much load is controlled by a particular channel by observing the effect on their network by switching the channel on and off. It can also mean that that the control of a consumer's hot water system does not align with their chosen tariff. Sometimes retailers incorrectly wire the ripple relays when replacing consumers' meters. An EDB has no way of finding out about this unless a consumer reports a problem. This is unlikely however, as the consumer will still have hot water.

Split ownership of ripple relays also makes fault finding complicated and potentially time consuming, with multiple parties often involved. If a consumer has a problem with no hot water, EDBs prefer that the consumer contacts their retailer first to have the problem resolved. If a consumer is not aware of this, then they are just as likely to call a local electrician or plumber. If the electrician or plumber determines that the fault is related to the ripple control, then the consumer will have to make another call to their retailer. Another contractor, depending upon who owns the ripple relay, will need to attend the consumer's premise to undertake testing of the ripple control signal level and the ripple control relay. Potentially a consumer could have a period of time with no hot water and a call-out invoice from an electrician or plumber to claim back from their retailer.

2.9. Barriers to the more effective use of ripple control

Ripple control could be used more extensively and effectively than it is today. As indicated by Figure 6, not all EDBs extract the full range of benefits from ripple control. In fact, none of the survey respondents use ripple control to its full capability as a demand management tool, especially outside winter.

The fundamental barrier to greater use of ripple control is the lack of a national or industry-wide strategy on load control. Along with no effective strategy there is no effective market with financial incentives for the controllable load available via ripple control. This leads to uncertainty among EDBs about the future of ripple control, as well as a lack of coordination between market participants and even conflicting objectives. For example, some retailers aim to maximise the electricity delivered, while EDBs aim to maintain secure supply at minimum cost. This research revealed several specific problems that arise due to this lack of industry coordination, including:

- lack of understanding among EDBs about consumers' electricity use patterns
- EDBs' ripple control not coordinated with Transpower's demand management measures
- retailers' unnecessary removal of working ripple relays, without consulting EDB
- retailers or MEPs failing to program ripple relays correctly, and not consulting EDBs
- retailers not promoting the benefits of ripple control to consumers, or even offering tariff structures (such as flat rates) that discourage load control.
- the lack of clear business incentives for some EDBs to provide ripple control.

Part of EDBs' motivation for using and maintaining ripple is political and public expectation that they will run an efficient network. Fear of reputational damage may be the most common incentive for EDBs' continued investment in ripple control. But such an incentive could be eroded if one or more EDBs were to break ranks by abandoning ripple control. There is a greater risk of this among EDBs that reap fewer rewards from ripple control, such as those in rural areas. The case study on Eastland Networks (Appendix C) shows how, for some EDBs, distributed generators have business and operational advantages over load management. Some EDBs also point out there is a disincentive to providing ripple control because by allowing peak loads to rise, EDBs could upgrade their network and increase their revenues.

3.0

The future of hot water load control

3.1. Short-term outlook for ripple control

In general, ripple control infrastructure is well maintained and its level of deployment is roughly stable. Most EDBs consider ripple control to be the best option for managing domestic hot water loads, at least for the next few years. Nevertheless, the proportion of hot water systems in New Zealand connected to ripple control and pilot wire control is declining slowly (see Appendix A) due to:

- removal of ripple relays by retailers and MEPs
- increased use of alternative water heating systems, particularly gas-fired heaters
- installers of rooftop solar moving hot water systems to the main meter, disconnecting from ripple control.
- Vector's faulty pilot wire system being disabled between 2014 and 2015 and not replaced.

Impending regulatory changes may introduce new barriers to the use of ripple control:

- In 2021, the Electricity Authority is planning to introduce Default Distributor Agreements which will make load control a contestable "additional service" separate from the distribution service[7]. EDBs may lose the ability to make hot water load control mandatory in their connection agreements. One EDB reported that this change will remove a major incentive for continued investment in ripple control infrastructure. This company also believes that it will make coordination harder and that for ripple control to work well, it needs a central controller.
- From 2023 Transpower's Transmission Pricing Methodology will change[8]. Transmission charges to EDBs will no longer be related to the Regional Coincident Peak Demand (Section 2.5.2). For some EDBs this change will remove a financial incentive to deploy ripple control.

Even with these changes, many EDBs expect to continue to invest in ripple control, as it will continue to be useful for limiting peak demand, alleviating capacity constraints and deferring network expenditure.

7. https://www.ea.govt.nz/dmsdocument/25535-code-amendment-default-distributor-agreement-proposal
8. https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/transmission-pricing-review

3.2. Ripple control and the evolving electricity system

In the coming decades, New Zealand is likely to see the more widespread adoption of several technologies which could have a major impact on the electricity system. These include:

- new sources of consumer demand for electricity, particularly electric vehicles
- domestic rooftop solar panels and batteries
- grid-scale solar and wind energy which have variable output.

These technologies have the potential to make a positive contribution to a cleaner energy system and a reliable electricity grid. However, their large-scale deployment also creates new risks for the electricity system by increasing fluctuations in supply and demand. The importance of demand management is likely to grow to ensure successful integration of these technologies. This may mean ripple control retains its value as a load control option. Domestic hot water cylinders are a large reservoir of stored energy, which could be used to help balance the intermittent output of solar and wind energy in a similar way to batteries.

However, the future electricity system will need new approaches to energy management beyond ripple control of hot water. New capabilities will be required such as real-time monitoring and control of energy consumption and production at the household level. Ripple control is not well adapted to these new requirements as it can only signal to large blocks of hundreds or thousands of consumers. Also, as a one-way communication system, ripple control cannot report on consumers' use or production of energy. Therefore, as these new approaches to energy management and new capabilities evolve, control of electric water heating may transfer from ripple control to new systems.

3.3. The longer-term – distributed energy resource management systems

New Zealand's future energy system will need an enhanced ability to monitor, forecast, control and coordinate energy generation, consumption and storage. A system with these capabilities is sometimes called a Distributed Energy Resource Management System (DERMS). DERMS depend on a range of smart energy technologies including:

- smart meters that can transmit two-way information on current consumption and send signals to consumers' appliances (Box 1).
- individual appliances that respond to load and price signals sent by smart meters and home automation systems.
- software to handle monitoring, forecasting of energy demand and production, and control of appliances.
- alternative communication channels such as cellular networks and broadband.

DERMS also depend on reliable two-way communications. The risk of a failure in communication can be minimised by using multiple channels such as cellular networks, ripple signals, broadband and radio. A breakdown in one network could then automatically activate an alternative network.

There will be significant costs involved with fully implementing DERMS. For example, consumer meters may need replacing with more advanced devices as described in Box 1 with the data from these made readily available to EDBs. However, extensive application of DERMS is probably an essential component of New Zealand's future energy system. Eventually it could also negate the need for ripple control leading to avoided costs for both ripple relays and ripple control plant.

The advent of DERMS has been flagged for many years, and some EDBs are currently working with industry partners on DERMS trials. For example, Vector is carrying out trials of the demand management potential of home battery systems and electric vehicles. Some newer smart meters have embedded ripple relays (Box 1), although their ripple control functionality is constrained by one-way ripple control signalling. The adoption of smart energy management in New Zealand is slow and piecemeal. Barriers to faster progress include:

- Lack of an industry-wide strategy on demand management. For example, there are no plans or targets for the rollout of the type of advanced smart meter described in Box 1 that integrates metering and control functionality. This means industry participants are unclear about the direction and pace of change, and lack clear incentives to plan for, or invest in, demand management fit for the evolving energy system.
- The fragmented ownership of electricity infrastructure leads to uncertainty about responsibility for smart energy management. For example, some EDBs see it as retailers' responsibility.
- Limited incentives to try out new demand management technologies. For example, there is no scheme for equitable sharing of resulting cost reductions. Also, some EDBs believe they need to show that demand management solutions perform as reliably and predictably as traditional investments. This sets a high bar which deters investment and innovation.

Box 1 - Ripple control and smart meters

Over 70% of households and businesses in New Zealand have a smart meter which measures and records electricity consumption at 30-minute intervals. This data is transmitted to retailers using a radio or cell phone network. Some advanced smart meters have additional features that have implications for the future of ripple control. These features include:

- Embedded ripple relays that respond to ripple signals. This negates the need for a separate ripple relay at a consumer's premises, saving space on the meter board and reducing the cost and complexity of the ripple control system.
- Some smart meter ripple relays can limit the time water heater are switched off, or revert to a programmed timetable if they do not receive an expected ripple signal. These features improve the reliability of ripple control.
- Some smart meters can also be programmed to control water heating in line with a consumer's retail tariff (such as night-rate heating). This feature of smart meters could replace the need to use ripple control for tariff switching.
- Two-way communication between consumers and retailers/EDBs of real-time information on consumption and control capability at the individual household level.
- The ability to communicate with consumer's computing devices, home automation systems and electrical appliances.
- Bi-directional energy recording capability suitable for monitoring consumption of electricity (import) and production of electricity (export).

Advanced smart meters with these capabilities could play an important role in the future electricity system. Smart meter installations began in New Zealand in 2005. Types and models of meters installed vary, so not all meters that have been installed since 2005 have the additional features listed above.

3.4. Integration of ripple control and DERMS

Ripple control of hot water will continue to play an important role for some time. It is likely that EDBs will persist with ripple control of hot water, while more advanced technologies are gradually introduced to control electric vehicles, batteries and other modern equipment.

Even with universal application of DERMS, some EDBs see ripple control plants continuing to manage hot water loads by communicating with smart meters which have embedded ripple relays (Box 1). In fact, Orion has already carried out a small trial with a retailer using ripple control with DERMS. However, this will require DERMS that offer good control of hot water heating, which is not generally the case today.

With the right incentives, ripple control of hot water could be used more frequently to manage daily fluctuations in demand and supply. It could also be used to control the charging and discharging of electric vehicles and batteries and other appliances. Network Tasman is currently conducting a trial of ripple-controlled batteries.

Eventually DERMS technologies are likely to displace ripple control due to their greater capacity to control consumer equipment according to market conditions and provide real-time data on consumption at the household level. The timeline for widespread introduction of smart energy management is unclear. There is currently no industry-wide strategy for ripple control or demand management, and this creates uncertainty over responsibility for demand management and the pace of change. If change is gradual, ripple control may continue for decades, interacting with new technologies, for example, by communicating with smart meters with embedded ripple relays. However, with a more rapid transformation, ripple control could be superseded much more quickly.

4.0

Conclusions

Ripple control continues to be widely used, with assets well maintained and in good condition. Around half of New Zealand's electricity consumers have ripple control, most of which is connected to hot water systems. The load connected to ripple control equates to approximately 15% of national peak demand.

The proportion of consumers with ripple control is gradually declining due to the removal of ripple relays by retailers and installers of solar panels, as well as the increasing number of gas water heaters. Vector's removal from service of their faulty pilot wire system was a major contributor to the 11% decline in the total number of ICPs with ripple or pilot wire controlled hot water heating between 2014 and 2018.

Most EDBs continue to invest in ripple control and see it as an effective, reliable technology with multiple benefits. Capital investment in ripple control plant through to 2029 disclosed in EDB Asset Management Plans is in excess of$16 million across all of New Zealand. Operating and maintenance costs for ripple control are not disclosed by all EDBs. For those that did disclose these costs for this ripple control research, annual operational expenditure per EDB ranged up to$80,000 per EDB per year. The costs that were disclosed indicate the annual cost of providing ripple control ranges between$10 and$27 per kW of controllable load and between$10 and$19 per ICP.

Each EDB takes a different approach to the use of ripple control. It is likely to be most useful in integrated networks typical of urban areas, and in areas with growing electricity demand. Most EDBs use ripple control in winter to maintain network demand within predetermined limits. This has several potential benefits, including:

- minimising the transmission charges that EDBs must pay to Transpower
- ensuring demand does not exceed network capacity, hence maintaining network security and reducing the risk of outages
- deferring expenditure on network upgrades, helping to keep customer bills lower.

Some EDBs use ripple control to manage consumers' electricity use in-line with their electricity tariff. For example, a consumer on a night-only tariff will have their water heated between 11pm and 7am. This use of ripple control permanently shifts demand away from daytime periods when peaks occur. Some EDBs use ripple control to reduce demand in response to emergencies such as a failure in part of the network. Another application of ripple control to earn revenue in the reserve market for fast interruptible load.

EDBs highlight a lack of clear market incentives to use ripple control. Although ripple control reduces the cost of the electricity system, the benefits do not necessarily accrue to the consumers and industry participants who provide the service. EDBs continue to invest in ripple control for the benefit of end consumers, not because of direct business incentives. Consumers should receive a reduced rate in return for ripple control, however, not all retailers provide tariff options that compensate consumers for ripple-controlled load and few retailers appear to actively promote the benefits of ripple control.

Most EDBs see ripple control as the best option for managing domestic hot water loads, at least for the next few years. However, industry participants recognise that the evolving electricity system will need new approaches to energy management beyond ripple control of hot water. Greater adoption of technologies such as electric vehicles, solar power and home battery systems will increase the need to manage electricity demand, including at the level of individual households.

5.0

Glossary of terms

Coincident demand – The amount of demand at any given point in time. All possible loads are never all switched on at the same time so coincident demand varies throughout the day depending on several factors such as weather or the state of thermostats in water heater and space heaters.

Electricity demand – The amount of electricity required to satisfy all of the connected load.

Demand management – Being able to switch discretionary loads on and off to exercise some control over the demand of the electricity network both for quantity and time of use.

Distributed energy resource management system (DERMS) – A system used by an EDB to manage electricity resources distributed in their network such as storage batteries, roof top solar, standby diesel generators wind turbines.

Distribution – Transport of electricity in the low voltage distribution network owned by EDBs.

EDBs – Electricity Distribution Business. Also called lines companies, distribution companies or distributors, of which there are 29 in New Zealand.

EECA – The Energy Efficiency and Conservation Authority (EECA) is the government agency that works to improve the energy efficiency of New Zealand homes and businesses, and encourage the uptake of renewable energy.

Electricity Authority – The independent Crown entity which provides regulatory oversight of the New Zealand electricity sector.

Grid emergency – A grid emergency occurs when the system operator's ability to meet its principal performance objective (PPO) obligations is at risk, equipment or people are at risk or the system operator has to take urgent action to restore the power system to a stable operating state.

GXP – Grid Exit Point. A point of connection where electricity flows out of the national grid to local networks or direct consumers.

ICP –An Installation Control Point is a physical point of connection on a local network or an embedded network that the distributor nominates as the point at which a retailer will be deemed to supply electricity to a consumer.

Load – A device (e.g. water heater), or collection of devices (e.g. all electric appliances and devices in a house) that consume electricity.

Load control – Turning on or off loads in an electricity network.

Load diversity – The proportion of time that a load draws power compared to the amount of time that the load is connected and has power available.

Electric hot water cylinders include thermostats so even though they are connected to a power source if the water is hotter than the thermostat setting then the hot water cylinder will not draw any power. When ripple control switches off a group of hot water cylinders, some of them will already be off because of thermostat action so the amount of load control that occurs is always less than the total possible load.

Load shedding – The disconnection of load from a network, usually used in an emergency situation when the amount of electricity available is no longer sufficient to meet the all of the load.

Metering equipment providers (MEPs) –A metering equipment provider is a person who either: assumes responsibility for any metering installation or is appointed to be responsible for any metering installation.

Generally, MEPs own meters and meter reading infrastructure. An MEP may also own ripple switches.

Network maximum coincident demand – The highest measured demand in a network recorded over a specified period, often over a year.

Regional Coincident Peak Demand (RCPD) – An average peak demand figure used in Transpowers transmission pricing methodology defined as:

Average of the ‘n’ ½ hour net offtakes during the regional coincident peak periods for the region for a customer at a connection location during the capacity measurement period (CMP)

n=100 in Lower North and Lower South Island and n=100 in the Upper South Island and Upper South Island USI and UNI. For the North Island and Lower South Island the months between November and April are excluded from CMP.

Retailers – A company that sells electricity to customers

Ripple control – A method of using the power lines to send signals to turn on and off consumer loads

Ripple (control) channel – A means of sending several different signals down the same powerline to control different consumer equipment according to different schedules and functions.

Ripple relay – A receiver for the ripple control signals which can switch loads on and off

SCADA – Supervisory Control and Data Acquisition. The systems used by networks to collect and display information on how their system is operating on a moment-by-moment basis. Provides the facilities to remotely control the electricity network from a central location.

Transmission – Transport of electricity in the high voltage transmission network (the national grid) owned by Transpower.

Transpower – The State-owned enterprise that owns the high voltage transmission network (the national grid) and acts as System Operator

Under frequency event– If the power system suddenly experiences a loss of power infeed, either because of a generator fault or loss of connection to a generation source, then the frequency falls. If load is not quickly disconnected or the remaining generation increased to restore balance between generation and load, then the frequency will fall further. In severe cases the power system can reach a state known as system collapse.

6.0

Appendix A - Summary of existing data on ripple control

In producing this report, PSC analysed the existing information on ripple control, including:

- EDB emerging technology data gathered by the Commerce Commission in 2018
- EDB information disclosure data collected each year by the Commerce Commission
- EDBs' Asset Management Plans
- Electricity Authority Market Information.

A.1 Commerce Commission data

In July 2018 the Commerce Commission surveyed all 29 network companies in New Zealand on the potential changes in peak demand from emerging technologies. The survey data, published on the Commerce Commission's website[9], includes the most detailed readily available information on the extent of ripple control assets in New Zealand. The survey included two metrics on ripple control for the period 2014-18 of interest for this report:

- estimated number of Installation Control Point (ICPs) with ripple control
- load under ripple control (MW).

Tables 1 to 5 present this data as well as other statistics calculated from the Commerce Commission data, including:

- average load of an ICP under ripple control
- percentage change in ICPs from 2014 to 2018
- percentage of customers under ripple control
- percentage of load under ripple control.

Table 3 and Table 4 list the ICPs across all EDBs and Table 5 shows that overall, 58% of ICPs in New Zealand in 2018 included load under ripple control. For most EDBs the percentage is higher than this, but the national averaged is skewed downwards by the largest EDB, Vector, with a sharp drop recorded in the number of ICPs with ripple control.

Two substantial discrepancies were found in the numbers of ICPs with ripple control as recorded in the Commerce Commission data compared to figures returned for the EDB survey conducted for this research. In Table 4 the entries for WEL Networks and Wellington Electricity use the ICP counts with ripple control as returned for the survey undertaken for this report. The number inserted for each year for these two EDBs is the number that was current for the end of 2019. The load under ripple control from the Commerce Commission data appeared to be a good match for the load figures provided by EDBs for the survey undertaken for this report.

Change from 2014 to 2018 (Commerce Commission data)

The average increase in ICPs from 2014 to 2018 was 4.6%, which compares to New Zealand population growth over the same period of around 5.3%[10]. Over the same period, the EDB information disclosures show a 10.5% fall in the number of ICPs with ripple control and a decline of 9.7% in the proportion of ICPs with ripple control. This decline was particularly large for the networks owned by Vector and Powerco. (Vector's large decline is due to no longer counting ICPs from pilot wire schemes that are no longer in use.)

9. Commerce Commission, Oct 2018, Electricity Distribution Businesses' emerging technology data. https://comcom.govt.nz/__data/assets/excel_doc/0014/100670/Electricity-distribution-businesses-emerging-technology-data-10-October-2018.xlsx

10. Statistics NZ, https://www.stats.govt.nz/topics/population

11. https://www.emi.ea.govt.nz/Retail/Reports/H3WIHL?RegionType=NWKP&MarketSegment=Ind&_si=_dr_DateTo|20171231,_dr_RegionType|NWKP,_dr_MarketSegment|All,v|4

According to EDBs, the main reasons for the decline are:

- retailers/MEPs removing ripple relays
- replacing of electric water heating with gas
- solar PV installers removing ripple control and the associated second meter for water heating.

Tables 3 to 7 with the summary graphs in figures 8 to 12 were compiled from the Commerce Commission Emerging Technology Data[9] and EA market information[11].

Note that Vector's "load under ripple control" is not shown in the Commerce Commission's Emerging Technology Data and Vector's survey response for this study did not include this information either. Consequently Table 6 uses a calculated value for Vector's load under ripple control based on their number of ICPs with ripple control multiplied by the average load per ICP from all other EDBs.

Table 3 - Ripple control statistics – Total ICPs

Network Company	2014	2015	2016	2017	2018	Change
Vector	542,043	547,551	553,214	560,326	567,584	4.7%
Powerco	314,981	318,312	322,002	326,493	330,278	4.9%
Orion	186,557	190,864	194,072	197,311	200,397	7.4%
Wellington Electricity	165,399	166,035	166,577	167,205	168,251	1.7%
Unison Networks	108,666	109,445	109,975	110,863	111,733	2.8%
WEL Networks	86,907	88,137	89,627	91,133	92,464	6.4%
Aurora Energy	85,267	86,093	87,407	88,733	90,175	5.8%
Northpower	55,368	56,051	56,918	57,859	58,724	6.1%
Electra	43,419	43,679	44,068	44,528	44,912	3.4%
Counties Power	39,064	40,028	41,092	41,925	42,776	9.5%
Network Tasman	37,973	38,393	38,893	39,438	39,960	5.2%
MainPower NZ	37,026	37,627	38,328	39,047	39,843	7.6%
The Power Company	35,383	35,536	35,598	35,813	36,082	2.0%
Alpine Energy	31,721	31,947	32,163	32,444	32,634	2.9%
Top Energy	30,908	31,185	31,471	31,861	32,314	4.5%
Waipa Networks	24,801	25,250	25,784	26,269	26,776	8.0%
Marlborough Lines	24,760	24,958	25,194	25,448	25,717	3.9%
Eastland Network	25,418	25,469	25,436	25,569	25,644	0.9%
Horizon Energy	24,411	24,435	24,544	24,644	24,726	1.3%
The Lines Company	23,058	23,269	23,439	23,557	23,613	2.4%
Electricity Ashburton	18,534	18,882	19,067	19,283	19,515	5.3%
Electricity Invercargill	17,358	17,407	17,390	17,445	17,443	0.5%
OtagoNet JV	14,805	14,879	14,907	14,985	15,054	1.7%
Westpower	13,319	13,392	13,456	13,528	13,627	2.3%
Network Waitaki	12,558	12,676	12,747	12,873	12,981	3.4%
Nelson Electricity	9,092	9,109	9,114	9,140	9,166	0.8%
Centralines	8,133	8,173	8,196	8,248	8,318	2.3%
Scanpower	6,716	6,709	6,691	6,680	6,680	-0.5%
Buller Electricity	4,599	4,625	4,594	4,651	4,686	1.9%
North Island	**1,499,292**	**1,513,728**	**1,529,034**	**1,547,160**	**1,564,793**	**4.4%**
South Island	**528,952**	**536,388**	**542,930**	**550,139**	**557,280**	**5.4%**
New Zealand	**2,028,244**	**2,050,116**	**2,071,964**	**2,097,299**	**2,122,073**	**4.6%**

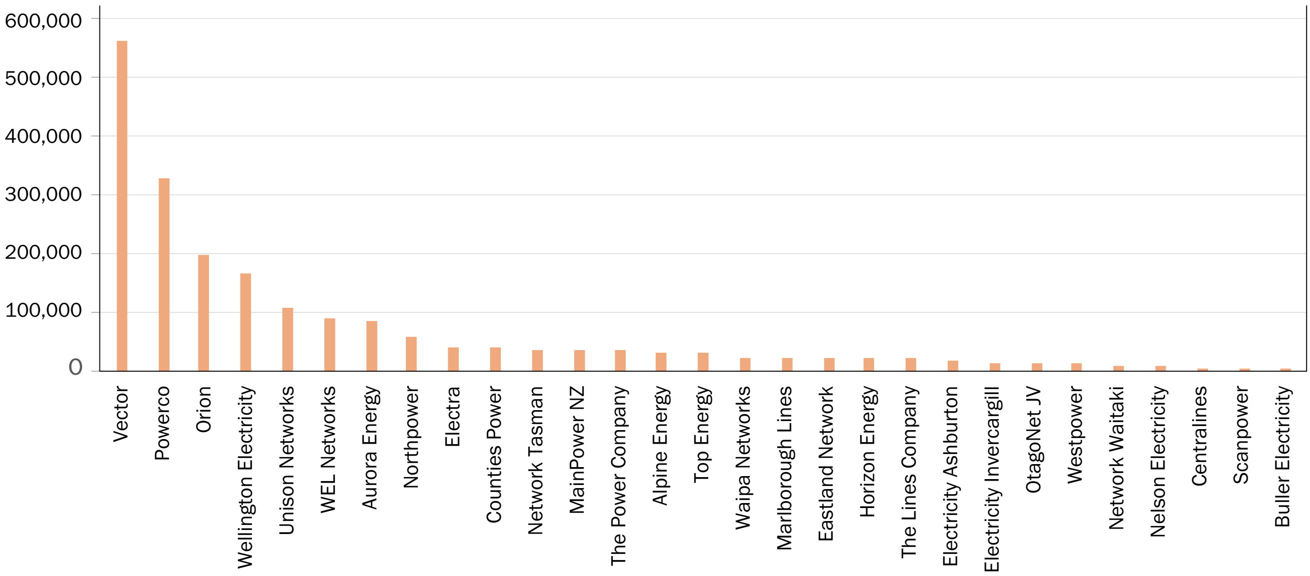


Figure 8 - Ripple control statistics - Total ICPs by EDB

Table 4 - Ripple control statistics - ICPs with ripple control

Network Company	2014	2015	2016	2017	2018	Change
Vector	388,413	221,483	220,938	219,999	214,690	-44.7%
Powerco	206,510	190,721	184,423	186,634	178,516	-13.6%
Orion	155,331	157,268	159,984	162,252	164,321	5.8%
Wellington Electricity	80,000	80,000	80,000	80,000	80,000	0.0%
Unison Networks	81,891	80,825	79,477	78,995	78,870	-3.7%
Aurora Energy	66,114	66,441	66,589	66,898	67,170	1.6%
WEL Networks	53,479	53,479	53,479	53,479	53,479	0.0%
Northpower	32,900	33,600	34,300	35,000	35,700	8.5%
Network Tasman	32,161	32,441	32,731	33,036	33,336	3.7%
Counties Power	29,653	30,247	30,852	31,470	32,100	8.3%
MainPower NZ	28,712	29,366	29,798	30,287	30,647	6.7%
Electra	30,072	30,072	29,015	30,605	29,791	-0.9%
Top Energy	22,677	22,760	22,873	22,917	22,960	1.2%
Alpine Energy	21,817	22,037	22,260	22,485	22,712	4.1%
The Power Company		22,079	21,808	21,543	21,027	-4.8%
Horizon Energy	18,480	18,557	18,650	20,231	20,332	10.0%
Marlborough Lines	19,122	19,146	18,999	18,979	18,956	-0.9%
Waipa Networks	17,759	17,956	18,238	18,406	18,577	4.6%
The Lines Company	17,138	16,808	16,824	16,976	17,467	1.9%
Eastland Network	15,220	15,192	14,908	14,429	14,430	-5.2%
Electricity Invercargill		12,805	12,628	12,468	12,137	-5.2%
Electricity Ashburton	11,373	11,581	11,804	11,938	12,083	6.2%
Network Waitaki	9,454	9,504	9,464	9,361	9,345	-1.2%
Westpower	9,300	9,300	9,300	9,300	9,300	0.0%
Nelson Electricity	7,411	7,402	7,351	7,335	7,300	-1.5%
OtagoNet JV		5,887	6,198	6,129	6,461	9.8%
Scanpower	4,761	4,761	4,761	4,761	4,761	0.0%
Centralines	4,286	4,286	4,373	4,417	4,422	3.2%
Buller Electricity	3,442	3,300	3,318	3,374	3,362	-2.3%
North Island	**1,003,239**	**820,747**	**813,111**	**818,318**	**806,095**	**-19.7%**
South Island	**364,237**	**408,557**	**412,232**	**415,385**	**418,157**	**14.8%**
New Zealand	**1,367,476**	**1,229,305**	**1,225,343**	**1,233,703**	**1,224,252**	**-10.5%**

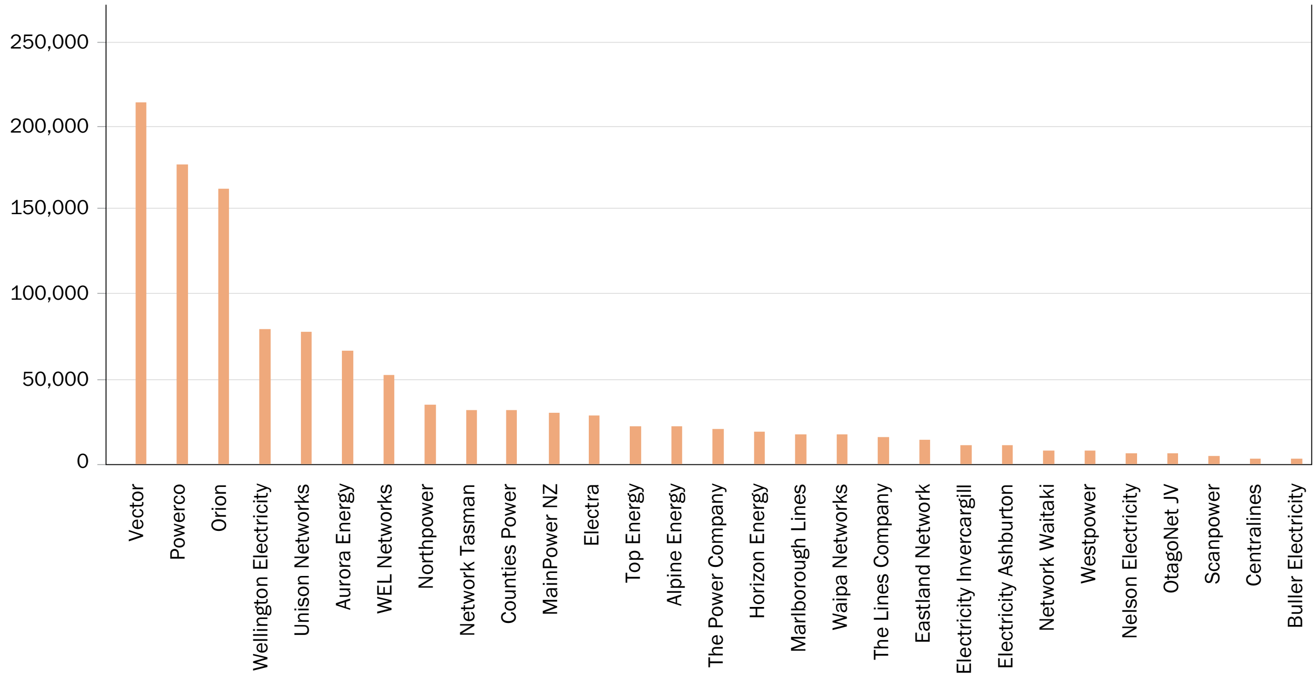


Figure 9 - Ripple control statistics - ICPs with ripple control by EDB

Table 5 - Ripple control statistics - % ICPs with ripple control

Network Company	2014	2015	2016	2017	2018	Change
Network Tasman	85%	84%	84%	84%	83%	-1.3%
Horizon Energy	76%	76%	76%	82%	82%	6.5%
Orion	83%	82%	82%	82%	82%	-1.3%
Nelson Electricity	82%	81%	81%	80%	80%	-1.9%
MainPower NZ	78%	78%	78%	78%	77%	-0.6%
Counties Power	76%	76%	75%	75%	75%	-0.9%
Aurora Energy	78%	77%	76%	75%	74%	-3.0%
The Lines Company	74%	72%	72%	72%	74%	-0.4%
Marlborough Lines	77%	77%	75%	75%	74%	-3.5%
Network Waitaki	75%	75%	74%	73%	72%	-3.3%
Buller Electricity	75%	71%	72%	73%	72%	-3.1%
Scanpower	71%	71%	71%	71%	71%	0.4%
Top Energy	73%	73%	73%	72%	71%	-2.3%
Unison Networks	75%	74%	72%	71%	71%	-4.8%
Alpine Energy	69%	69%	69%	69%	70%	0.8%
Electricity Invercargill		74%	73%	71%	70%	-4.0%
Waipa Networks	72%	71%	71%	70%	69%	-2.2%
Westpower	70%	69%	69%	69%	68%	-1.6%
Electra	69%	69%	66%	69%	66%	-2.9%
Electricity Ashburton	61%	61%	62%	62%	62%	0.6%
Northpower	59%	60%	60%	60%	61%	1.4%
The Power Company		62%	61%	60%	58%	-3.9%
WEL Networks	62%	61%	60%	59%	58%	-3.7%
Eastland Network	60%	60%	59%	56%	56%	-3.6%
Powerco	66%	60%	57%	57%	54%	-11.5%
Centralines	53%	52%	53%	54%	53%	0.5%
Wellington Electricity	48%	48%	48%	48%	48%	-0.8%
OtagoNet JV		40%	42%	41%	43%	3.4%
Vector	72%	40%	40%	39%	38%	-33.8%
North Island	**67%**	**54%**	**53%**	**53%**	**52%**	**-15.4%**
South Island	**69%**	**76%**	**76%**	**76%**	**75%**	**6.2%**
New Zealand	**67%**	**60%**	**59%**	**59%**	**58%**	**-9.7%**

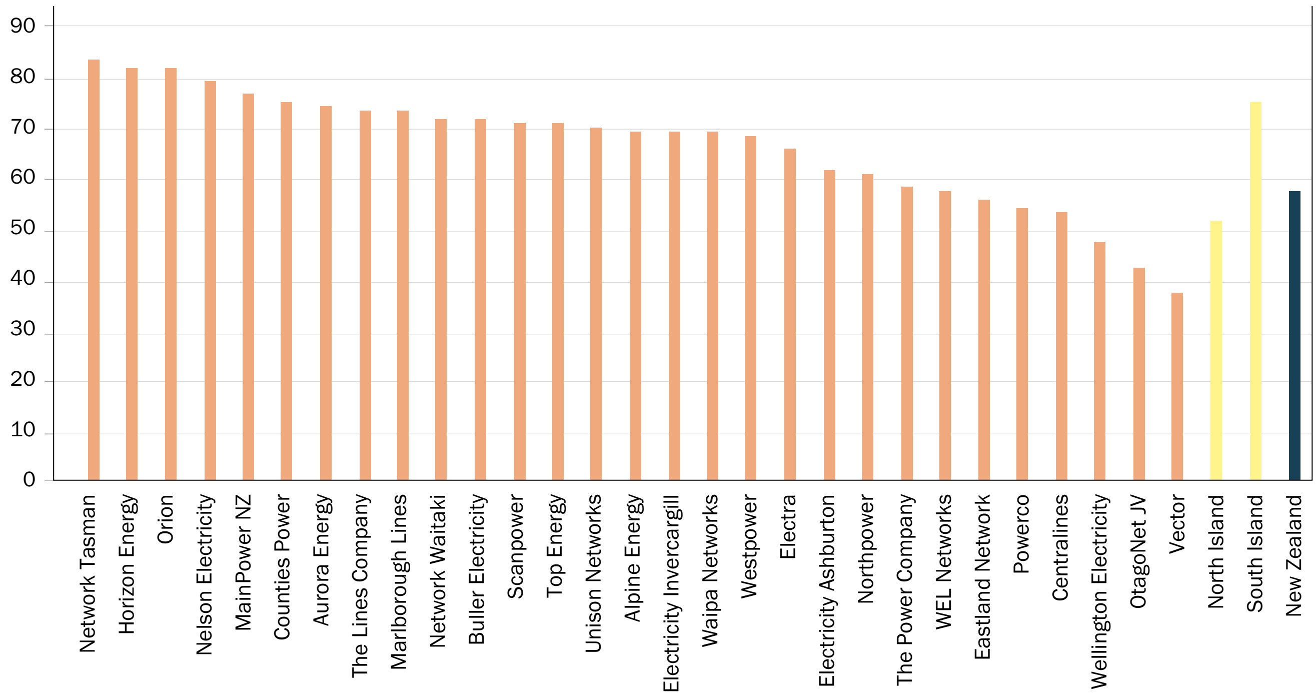


Figure 10 - Ripple control statistics - % ICPs with ripple control

Table 6 - Ripple control statistics - MW load under ripple control

	Load under Ripple Control (MW)							
Network Company	2014	2015	2016	2017	2018	Change	Maximum network demand 2018 (MW)	% Maximum demand under ripple control 2018
Alpine Energy	55.5	56.0	56.6	57.2	57.7	4.1%	140.5	41%
Electra	24.1	24.1	23.2	24.5	23.8	-0.9%	59.0	40%
Electricity Invercargill		25.6	25.3	24.9	24.3	-5.2%	60.6	40%
Buller Electricity	3.8	3.8	3.8	3.8	3.8	0.0%	11.0	35%
The Power Company		44.2	43.6	43.1	42.1	-4.8%	138.6	30%
The Lines Company	15.5	15.3	17.4	19.5	18.3	17.9%	67.8	27%
Orion	150.0	150.0	150.0	150.0	150.0	0.0%	607.7	25%
Waipa Networks	16.9	17.2	17.5	17.7	18.0	6.5%	75.0	24%
Counties Power	23.7	24.2	24.7	25.2	25.7	8.3%	116.5	22%
Scanpower	3.0	3.0	3.0	3.0	3.0	0.0%	14.0	21%
OtagoNet JV		11.8	12.4	12.3	12.9	9.8%	62.0	21%
Powerco	206.5	190.7	184.4	186.6	178.5	-13.6%	896.9	20%
Top Energy	12.0	12.0	12.0	12.0	12.0	0.0%	69.0	17%
WEL Networks	46.4	46.0	45.0	45.1	47.0	1.3%	271.2	17%
Electricity Ashburton	15.2	15.5	15.8	16.0	16.1	6.2%	104.0	16%
MainPower NZ	14.4	14.7	14.9	15.1	15.3	6.7%	113.0	14%
Aurora Energy	37.9	38.1	38.2	38.3	38.5	1.6%	299.7	13%
Marlborough Lines	9.3	9.3	9.3	9.3	9.2	-0.9%	73.0	13%
Network Waitaki	7.1	7.1	7.1	7.1	7.1	0.0%	61.0	12%
Network Tasman	14.5	14.6	14.7	14.9	15.0	3.4%	139.0	11%
Eastland Network	18.0	18.0	18.0	18.0	18.0	0.0%	181.1	10%
Westpower	4.0	4.0	4.0	4.0	4.0	0.0%	42.4	9%
Vector	283.5	161.7	161.3	160.6	156.7	-44.7%	1,768.0	9%
Nelson Electricity	3.0	3.0	3.0	3.0	3.0	0.0%	34.0	9%
Northpower	14.1	14.4	14.7	15.0	15.3	8.5%	173.6	9%
Wellington Electricity	50.0	50.0	50.0	50.0	50.0	0.0%	575.0	9%
Horizon Energy	5.5	5.6	5.6	6.1	6.1	10.0%	93.0	7%
Centralines	1.0	1.0	1.0	1.0	1.0	0.0%	21.1	5%
Unison Networks	14.0	14.0	14.0	14.0	14.0	0.0%	349.0	4%
North Island	**734.3**	**597.1**	**591.9**	**598.3**	**587.5**	**-20.0%**	**4730.2**	**12%**
South Island	**314.6**	**397.6**	**398.5**	**398.9**	**399.1**	**26.8%**	**1886.5**	**21%**
New Zealand	**1048.9**	**994.7**	**990.4**	**997.2**	**986.5**	**-5.9%**	**6,616.7**	**15%**

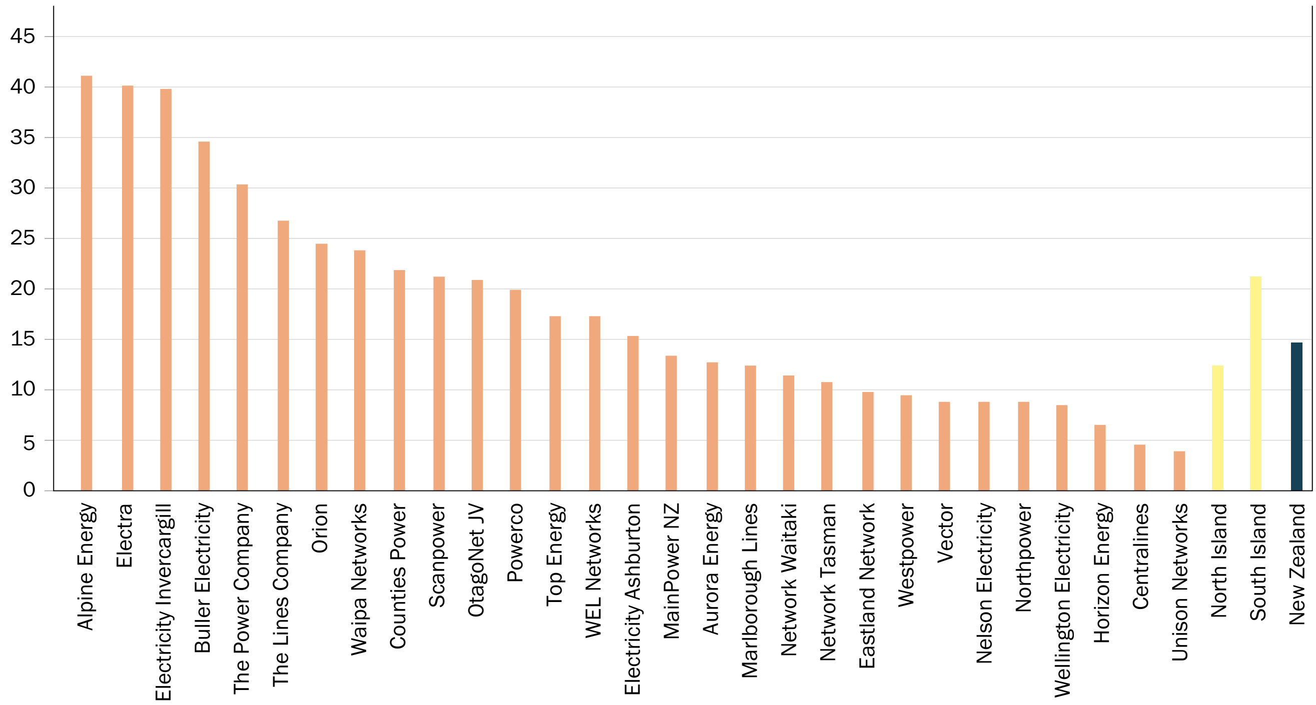


Figure 11 - Ripple control statistics - Load under ripple control as % of the EDB's maximum demand

Table 7 - Ripple control statistics - average load under ripple control per ICP with ripple control

Network Company	2014	2015	2016	2017	2018	Change
Alpine Energy	2.54	2.54	2.54	2.54	2.54	0.0%
Electricity Invercargill		2.00	2.00	2.00	2.00	0.0%
OtagoNet JV		2.00	2.00	2.00	2.00	0.0%
The Power Company		2.00	2.00	2.00	2.00	0.0%
Electricity Ashburton	1.34	1.34	1.34	1.34	1.34	0.0%
Eastland Network	1.18	1.19	1.21	1.25	1.25	5.5%
Buller Electricity	1.10	1.15	1.15	1.13	1.13	2.4%
The Lines Company	0.90	0.91	1.04	1.15	1.05	15.7%
Powerco	1.00	1.00	1.00	1.00	1.00	0.0%
Waipa Networks	0.95	0.96	0.96	0.96	0.97	1.8%
Orion New Zealand	0.97	0.95	0.94	0.92	0.91	-5.5%
WEL Networks	0.87	0.86	0.84	0.84	0.88	0.7%
Counties Power	0.80	0.80	0.80	0.80	0.80	0.0%
Electra	0.80	0.80	0.80	0.80	0.80	0.0%
Network Waitaki	0.75	0.75	0.75	0.76	0.76	1.2%
Vector	0.73	0.73	0.73	0.73	0.73	0.0%
Scanpower	0.63	0.63	0.63	0.63	0.630	0.0%
Wellington Electricity	0.63	0.63	0.63	0.63	0.625	0.0%
Aurora Energy	0.57	0.57	0.57	0.57	0.57	0.0%
Top Energy	0.53	0.53	0.52	0.52	0.52	-1.2%
MainPower NZ	0.50	0.50	0.50	0.50	0.50	0.0%
Marlborough Lines	0.49	0.49	0.49	0.49	0.49	0.0%
Network Tasman	0.45	0.45	0.45	0.45	0.45	-0.2%
Westpower	0.43	0.43	0.43	0.43	0.43	0.0%
Northpower	0.43	0.43	0.43	0.43	0.43	0.0%
Nelson Electricity	0.40	0.41	0.41	0.41	0.41	1.5%
Horizon Energy	0.30	0.30	0.30	0.30	0.30	0.0%
Centralines	0.23	0.23	0.23	0.23	0.23	-3.1%
Unison Networks	0.17	0.17	0.18	0.18	0.18	3.8%
North Island	**0.80**	**0.82**	**0.82**	**0.82**	**0.82**	**2.0%**
South Island	**0.86**	**0.97**	**0.97**	**0.96**	**0.95**	**10.5%**
New Zealand	**0.82**	**0.87**	**0.87**	**0.87**	**0.87**	**5.9%**

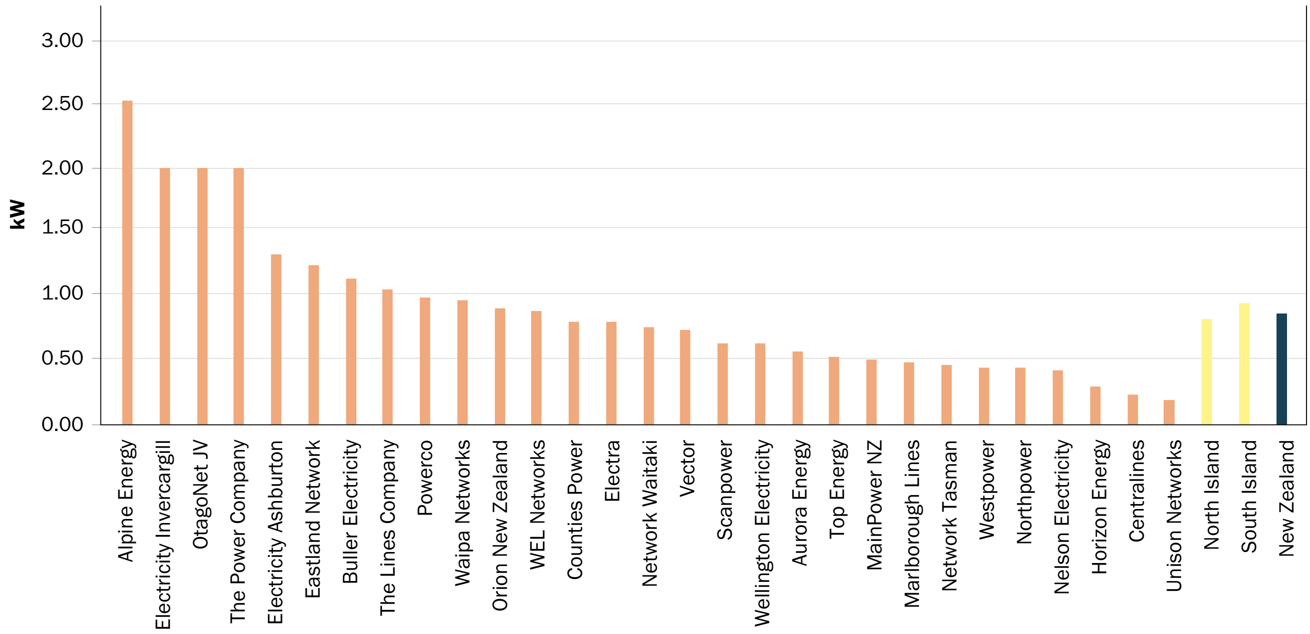


Figure 12 - Ripple control statistics - average load under ripple control per ICP with ripple control

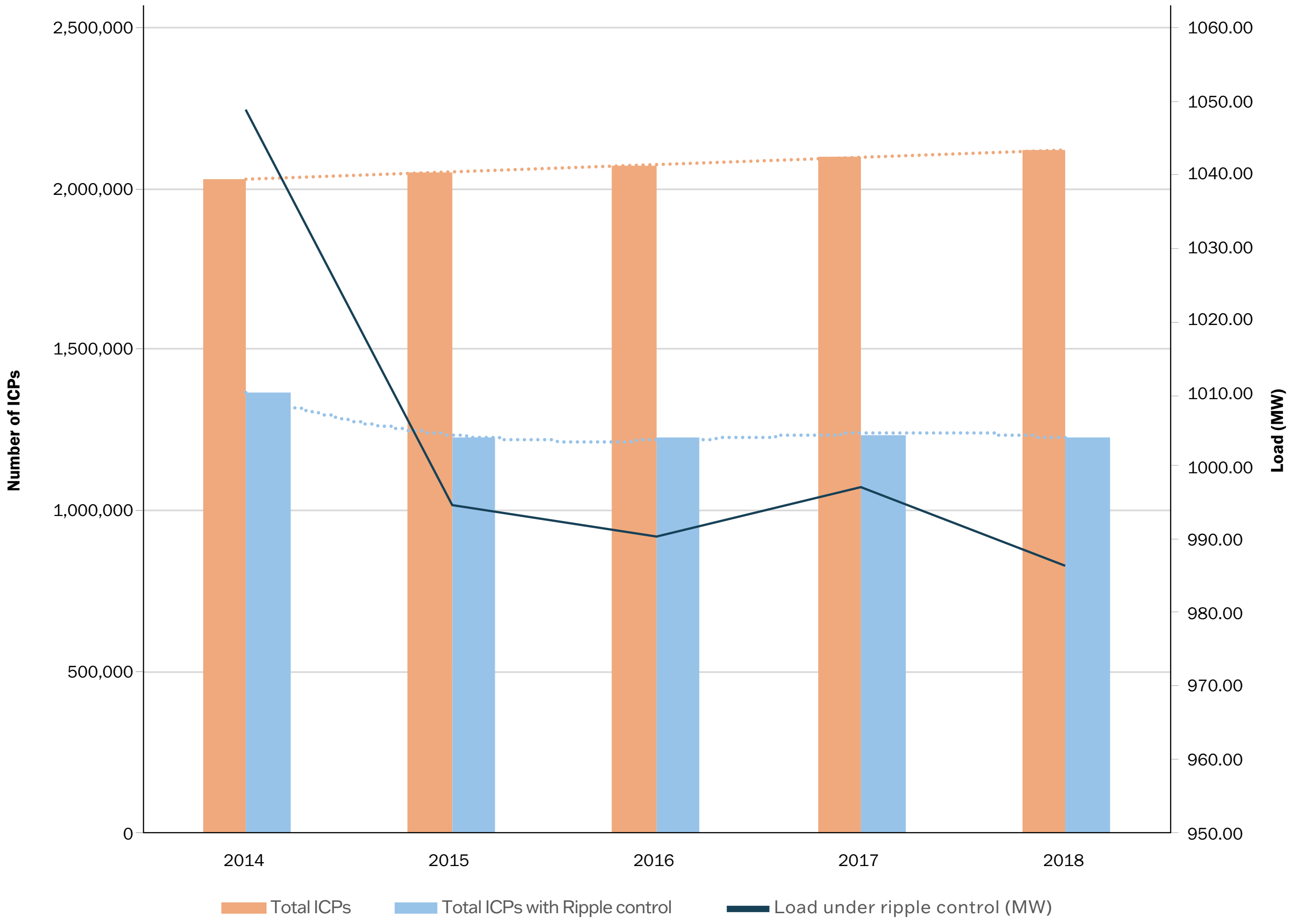


Figure 13 - Summary of ICPs and ripple controlled load

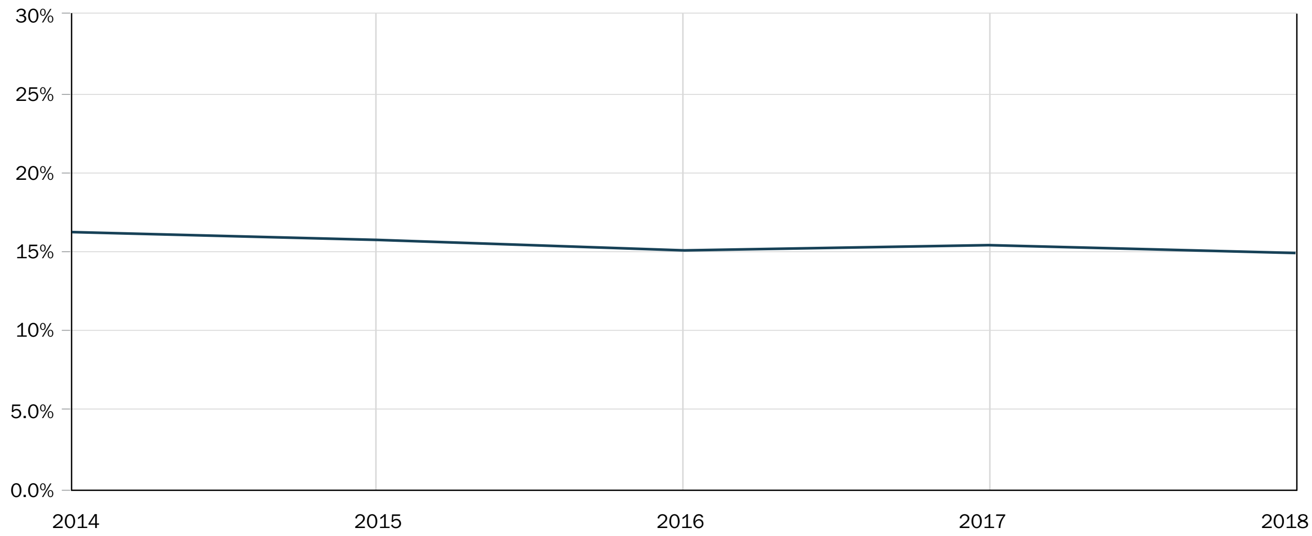


Figure 14 - Summary of NZ total ripple controlled load as percentage of peak demand

Evaluation of Commerce Commission data

In Table 6 the “Load under ripple control (MW)” is a very approximate figure, normally an estimate provided by EDBs based on operational experience. It is highly variable and subject to seasonal variation. It is not directly measurable for existing installations, but its effects are observed by monitoring total network demand as ripple control channels are switched on and off. From time to time some EDBs carry out drop load testing by switching ripple channels off and on to determine the approximate amount of controllable load that is responding to ripple control.

The data summarised in Table 6 show EDBs have significant ability to manage peak loads, with an average of 15% of peak demand connected to ripple control. This average conceals a wide spread with several EDBs reporting under 10% and several others apparently able to control 30-41% of load.

These large variations may reflect differences in what is being reported. Some EDBs may have recorded their total theoretical load under ripple control whereas others recorded the actual amount available at any one moment. These two figures differ because the amount of load that can be switched off or on depends on the state of each water heater’s thermostat at the moment of ripple control activation. A third possibility is that EDBs reported the additional network capacity that would be needed in the absence of any load management capabilities. Orion explicitly stated that this is what their response (150 MW) relates to. Orion provided an additional note to their response to the Commerce Commission which suggests a lack of clarity about the data sought.

This difference in reporting may also explain the disparity in average size of each ICP load under ripple control – from 0.2 kW to 2.5 kW. This may be partly explained by different types of equipment under ripple control – for example domestic vs commercial and industrial. The high average loads of some EDBs may also be partially explained by larger commercial loads being under ripple control. The average controlled load per ICP listed in Table 7 is the after diversity effect of switching off ripple controlled load averaged over the number of ICPs with ripple control. Whenever ripple-controlled load is switched off, some of the connected load will already be switched off due to thermostat action. This means that the average load listed in Table 7 will always be less than the average rated value of the connect hot water heater elements. Commonly today, hot water heater elements are rated at 3 kW with older elements rated at 2 kW or occasionally less, depending on the size of the cylinder. For the top 4 EDBs in Table 7 with an average load of 2 kW and above, it is likely that the number of ICPs with ripple control recorded in Table 4 from the Commerce Commission data is under reported. The calculated average load for these 4 EDBs is well above the calculated national average. These 4 EDBs did not provide returns for this report so the authors have no better data to substitute for the Commerce Commission figures here.

The Commerce Commission data does not separate domestic ICPs from other types of connection. While Electricity Authority’s registry identifies residential ICPs, many EDB’s do not appear to keep ripple control load data for commercial and residential installations separate. Data provided by EDBs for this research was generally aggregated residential and commercial totals. It is reasonable to assume that the majority of ICPs are domestic connections, but the proportion is unknown. Similarly, the data collates all equipment under ripple control and does not reveal the proportion connected to domestic hot water heating systems. In many regions most controlled load is likely to be domestic hot water, but some networks have a large proportion of other equipment under ripple control. For example, some rural areas have a substantial load from irrigation pumps.

In summary, Commerce Commission data for ICP counts with ripple control appears questionable for six of the EDBs. Data reported for load size has some uncertainty due to lack of clarity over how the load size has been determined. Overall, there is reasonable confidence that around 50% of customers nationwide have ripple controlled hot water heating. If anything, this proportion may be under reported. The proportion is over 70% in several regions – often those where ripple control of electric hot water is a condition of service.

7.0

Appendix B - Costs of ripple control

Every year all 29 network companies in New Zealand must meet Commerce Commission information disclosure requirements by publishing financial, technical and pricing information. Technical information is published in Asset Management Plans containing statutory information disclosures which the Commerce Commission consolidates into a spreadsheet published on the Commerce Commission's website[12].

Forecast operational expenditure for load control is not separately reported in the EDB disclosures preventing comparisons of the cost of providing ripple control across all of New Zealand. EDB Asset Management Plans include forecast expenditure for "significant" load control replacement and renewal projects.

Load control replacement and renewal costs found in the EDB 2019 Asset Management Plans have been extracted and shown in Table 8. The costs for Orion are not directly comparable to other EDBs listed in the table as the Orion costs include replacement of load control SCADA systems used in the Orion network and for the Upper South Island load control scheme. Other EDBs planning to replace load control SCADA systems such as Wellington Electricity listed the SCADA replacement separately. For some others, costs for load control and network SCADA are reported as a single combined figure. The 10-year forecast total capital expenditure from Table 8 totals$16.8M. This equates to$0.79 per year per ICP or$1.70 per year per kW of controllable load.

Operations and maintenance costs for ripple control only, are not able to be identified from expenditure disclosure made by most EDBs. The PSC survey of EDBs requested an estimate of the annual cost of providing ripple control, i.e. capital expenditure and maintenance, excluding the cost of ripple relays. This produced the spread of results shown in Table 9. To supply and install standalone ripple relays costs approximately$300 which assuming a life of 30 years is$10/year. Adding this to the costs in Table 9 gives indicative cost ranges for providing ripple control of:

- $10/ICP/year to$19/ICP/year or
- $10/kW/year to$27/kW/year.

The alternative to load management to meet peak demand is increased peak capacity for distribution. At present the peak distribution charges for Vector, Orion and Wellington Electricity average at approximately$130/kW/year[13] compared to a mid-point of$18.50/kW/year for ripple control.

12. Commerce Commission, Nov 2019, Electricity distributor's information disclosure data 2013-2019
https://comcom.govt.nz/__data/assets/excel_doc/0022/155047/Electricity-distributors-information-disclosure-data-2013-2019.xlsm

13. https://blob-static.vector.co.nz/blob/vector/media/vector-regulatory-disclosures/180201_price-schedule-1_apr-2018.pdf
https://www.welectricity.co.nz/disclosures/pricing/2020/document/206
http://www.oriongroup.co.nz/assets/Company/Corporate-publications/ScheduleOfDeliveryPrices.pdf

Table 8 - Capital expenditure for ripple control plant replacements and upgrades (from Asset Management Plans)

Network company	2020 $000	2021 $000	2022 $000	2023 $000	2024 $000	2025 $000	2026 $000	2027 $000	2028 $000	2029 $000	Totals $000
Vector Lines	$2,990	$1,200	$60	$700	$30	$30	$30	$30	$30	$30	$ 5,130
Orion NZ	$140	$140	$1,140	$890	$190	$620	$190	$190	$190	$190	$ 3,880
Powerco		$780	$780		$780						$ 2,340
Network Tasman					$450		$350				$ 800
Top Energy				$74	$708						$ 782
Unison Networks	$720										$ 720
OtagoNet	$603										$603
Counties Power	$300							$200			$500
Wellington Electricity		$40	$60	$60	$60	$60	$60	$60	$80		$480
Alpine Energy					$400						$ 400
Northpower		$100	$100	$100	$100						$ 400
EA Networks	$9						$388				$397
Horizon Energy				$259							$259
The Power Company	$72										$72
Aurora Energy											$ -
Buller Electricity											$ -
Centralines											$ -
Eastland Network											$ -
Electra											$ -
Electricity Invercargill											$ -
Mainpower											$ -
Malborough Lines											$ -
Nelson Electricity											$ -
Network Waitaki											$ -
Scanpower											$ -
The Lines Company											$ -
Waipa Networks											$ -
WEL Networks											$ -
Westpower											$ -
Total	$4,834	$2,260	$2,140	$2,083	$2,718	$710	$1,018	$480	$300	$220	$16,763

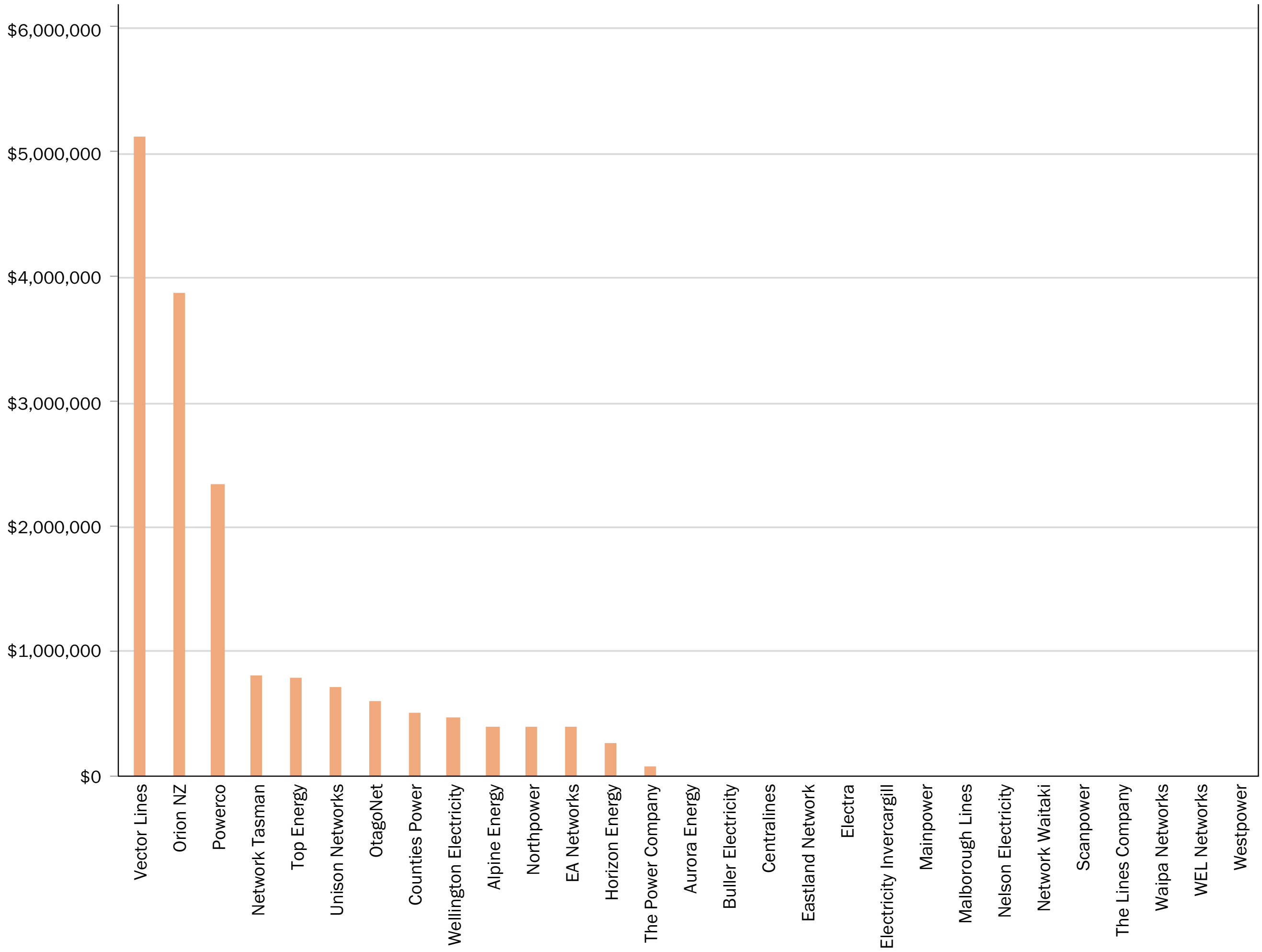


Figure 15 - Planned capital expenditure on ripple control plant upgrades and replacements from 2020 to 2029

Table 9 - Annualised cost estimates to provide ripple control excluding ripple relays

Network Company	Load (MW)	ICP	Cost/yr	Cost/ICP/yr	Cost/kW/yr
Eastland Networks	18.02	14,430	$20,000	$1.39	$1.11
Marlborough Lines	9.23	18,956	$30,000	$1.58	$3.25
Network Tasman	15.00	33,336	$250,000	$7.50	$16.67
Northpower	15.30	35,700	$86,000	$2.41	$5.62
Orion	150.00	164,321			
Powerco	178.52	178,516	$930,000	$5.21	$5.21
Scanpower	3.00	4,761	$20,000	$4.20	$6.67
Vector	156.72	214,690			
WEL Networks	47.00	53,479	$500,000	$9.35	$10.64
Wellington Electricity	50.00	80,000	$15,000	$0.19	$0.30

8.0

Appendix C - EDB Case studies

Case study 1 - Eastland Network

Introduction to Eastland Network

Eastland Network distributes electricity to approximately 19,600 domestic consumers and 6,000 non-domestic consumers in Gisborne, Wairoa and the east coast. Eastland owns and maintains the poles, wires and underground cabling as well as, since March 2015, the towers and poles that connect the region to the national grid.

Electricity demand in the Eastland region has been steady in recent years, with small declines in rural demand offset by small increases in towns. Eastland services no large industrial loads.

Eastland Network is part of Eastland Group, wholly owned by the Eastland Community Trust, that also owns Eastland Port, Gisborne Airport and Eastland Generation, which produces electricity from hydro, diesel and geothermal plants.

Ripple control capability and condition

Eastland estimates it has approximately 18 MW of load connected to ripple control. (The exact figure is uncertain as the extent of ripple was last accurately assessed in 2000.) The vast majority (at least 95%) of connected load is domestic hot water. Eastland estimates that around one quarter of domestic hot water is not connected to ripple control, most of which is thought to be gas heating.

Eastland owns all ripple relays in its network outside Wairoa, accounting for about 73 % of relays at customers' sites. Ripple relays in the Wairoa area are owned by third parties. In recent years many relays have been removed by retailers as they install smart meters, especially in Gisborne area. Only around 50% of Gisborne. Wairoa and East Coast properties have a smart meter, the lowest penetration In New Zealand.

Table 10 - Ripple control capability of Eastland Network

Total network peak demand (maximum coincident demand[14])	59 MW
Total network load connected to ripple control	18 MW (figures from 2000)
Network maximum coincident domestic demand	47 MW
Network domestic water heating load connected to ripple control	Eastland cannot differentiate between domestic and commercial water heating control.
Network total domestic water heating load not connected to ripple control	6 MW (estimate)
Load in your region can be reduced using ripple control	2.6 MW (Gisborne- 2 MW; Wairoa - 0.6 MW)
Domestic hot water heating as proportion of network ripple control	95%
Total number of Installation Connection Points (ICPs)	25,569
Total ICPs with ripple control	18,628
Total domestic ICPs	19,555
Domestic ICPs with ripple-controlled water heating	17,254

14. Maximum coincident demand is the peak load that has been recorded during a reporting period – usually 12 months. This is less than the maximum possible load because everything in the network is never drawing power at the same time.

Box 2 - Eastland's ripple control plant – Asset Health Indicators

Network companies report on the health of their assets in their information disclosures according to the Electricity Engineers Association (EEA) Asset Health Indicator Guide (AHI 2016). The guide is intended to help network companies identify assets that need replacing and plan upgrades.

Eastland's ripple control plant is fully working but is end of life with lack of readily available spares. All of Eastland's controlled water heating load is dependent on end of life ripple plant.

Note that this health assessment covers the central ripple control plant owned by Eastland Networks not the ripple relays located at customer premises, some of which are owned by others (i.e. retailers and Metering Equipment Providers).

Table 11 - Eastland Networks central ripple control plant health assessment

Asset Health Indicator		% of ripple control central plant
H5	As new condition – no drivers for replacement	0%
H4	Asset serviceable - no drivers for replacement, normal in-service deterioration	0%
H3	End-of-life drivers for replacement present, increasing asset related risk	0%
H2	End-of-life drivers for replacement present, high asset related risk	100%
H1	Replacement recommended	0%

Current application of ripple control

Eastland uses ripple control of hot water on weekdays for 2 to 3 months during winter, with maximum use in August. On these days the load control system turns off 40% of the Gisborne relays at around 4:30 pm to reduce fast-building demand. The company always limits off periods for heating water to 3 hours in the morning and 3 hours in the evening. Eastland estimates, based on the visual projection of load graphs, it can reduce peak loads by around 2.6 MW using ripple control (2 MW in Gisborne and 0.6 MW in Wairoa). This represents less than 5% of peak loads – a lower proportion than many other network companies. The ripple control systems turn hot water systems on and off in large blocks of roughly 1 MW.

For about one month during winter, network load management is via ripple control and diesel generators. Eastland Generation owns several 1 MW diesel generators around the Tairawhiti and Wairoa regions, which are used mostly to manage peak loads in winter. These diesel generators are turned on automatically when the load reaches a pre-determined threshold and run for at least 2 to 4 hours.

Diesel generators are designed to run at maximum output, not partial loads. Eastland therefore deploys ripple control for 20 to 30 minutes while its generators are ramping up and for a similar period while they are ramping down. Ripple control reduces the periods when this diesel generation is required. Without ripple control the diesel generators would be required throughout winter.

The overriding motivation for Eastland to deploy ripple control is to manage winter peak loads. Eastland does not use ripple control for many of the reasons cited by other network companies, such as maintaining network security, alleviating distribution network constraints, deferring capital investment, emergency load management or supporting retailer tariff schemes.

Eastland's use of ripple control does reduce its transmission charges – but as a side-effect rather than a direct motivation. Transpower's method of allocating charges to distribution companies (based on Regional Coincident Peak Demand) is not a sufficient incentive for Eastland to reduce loads, because it contributes only a small amount to the regional load. In any case, Eastland is able to pass transmission charges onto the retailers (and therefore electricity customers).

About once every two years, Eastland is asked to carry out emergency load shedding to relieve transmission constraints. However, it uses its diesel generators to support this load shedding rather than ripple control. Ripple control would only be useful during an emergency if it coincided with a period when many customers were heating water, which isn't always the case.

From 2003 to 2005, as part of a national drive to conserve energy, Eastland used ripple control to switch off water heaters for two 3-hour periods per day. Eastland considers that this measure only saved energy to the extent that customers' water was not as hot as normal.

Does ripple control deliver its potential benefits?

Section 2.2 of this report outlines six potential benefits of using ripple control. Table 3 summarises whether each of these benefits is achieved in the case of Eastland Network.

Table 12 - The benefits of Eastland's use of ripple control

Potential benefit	Benefit delivered?
Reducing network costs	No. Used only to manage winter peaks in conjunction with embedded diesel generation
Reducing domestic energy bills	Yes. To the extent that reduces transmission charges that Eastland passes onto retailers.
Reducing generation costs	Yes. Without ripple control embedded diesel generators would be used for longer periods.
Supporting reliability of the electricity system	No.
Power quality support	No.
Supporting the clean energy transition	Yes. Without ripple control embedded diesel generators would be used for longer periods.

Technical problems with ripple control

When retailers replace consumers' meters there have been issues with incorrectly wired ripple relays. In cases where consumers pay an electrician to fix this problem, Eastland reimburses the consumer and bills the retailer. There is a lack of skills in the Eastland region to maintain and repair ripple control infrastructure, meaning Eastland would struggle to resolve any major technical problems.

Ripple control rarely causes problems where ripple control interacts with Eastland consumers' equipment in undesirable ways. The only major technical problems with ripple control occurred more than a decade ago. For example, in 2000, Eastland briefly used ripple control in Mahia to enable a retailer to carry out time-shifting. Load fluctuation then caused the system to trip, so Eastland discontinued the time shifting and stopped using load control in Mahia. In 2001, weak signalling issues in the Mahia area prompted Trustpower to remove all their ripple relays.

Barriers to the more effective use of ripple control

Eastland has very little financial incentive to continue maintaining and investing in ripple control. Eastland's existing dispatch system for ripple control and diesel generation does not anticipate load changes correctly and would need additional investment to make software improvements. Its main incentive is to meet government and regulators' expectations that network companies operate efficiently. Eastland believes that abandoning load control could harm the company's image. Without this motivation, Eastland might stop investing in ripple control altogether.

Even so, load control is becoming less important for Eastland. The company has found diesel generators to be a more flexible alternative for managing peak demand. The generators also reduce Eastland's transmission charges.

Diesel generators provide back up if a line goes down and can reduce the need to upgrade or build new lines. In Wairoa, Eastland has found the 5 MW embedded hydropower plant to be more effective at managing loads than ripple control.

Eastland does not work with retailers to maximise benefits from ripple and has no incentives or requests to do so. One barrier to using ripple control for time of use tariffs is that it requires Eastland to reprogram individual relays at a cost of$100 to$200 per relay.

Future approaches to ripple control and demand management

Use of ripple control is slowly declining due to removal by retailers as well as increasing installations of rooftop solar. Solar installers often move the hot water system to the main meter, disconnecting it from ripple control.

In future Eastland hopes to see responsibility for load control move to retailers. Retailers will use energy management systems involving smart meters and individual appliances that respond to load and price signals. This may replace the need for traditional ripple control, as Eastland believe it makes no sense to have two load control systems operating simultaneously. Ripple signals may still be useful as the means of communicating with smart appliances.

However, Eastland says smart demand management has been promised for several years without any real progress. This leaves Eastland in an uncertain position regarding the future of ripple control.

A few years ago, Eastland explored the option of setting up a company to install smart meters and providing energy management services to individual customers. However, the initiative was abandoned and Eastland now believes its best option is to continue managing loads using small generators.

Case Study 2 - Orion Group

Introduction to Orion

Orion owns and operates the electricity distribution network that provides power to central Canterbury from the Waimakariri River in the north to the Rakaia River in the south. Orion distributes electricity to more than 200,000 homes and businesses. In 2019 total energy distributed across Orion's network was 3,317 GWh, an increase of 8 GWh on 2018.

Orion is a community-owned entity with two key shareholders – Christchurch City Council and Selwyn District Council.

Ripple control capability and condition

The vast majority of residential water heating load in Orion's region can be turned on and off by ripple control. This gives Orion significant capability to reduce peak demand by turning off hot water systems. Domestic water heating accounts for 90% of Orion's controllable load.

The total amount of electrical load that Orion can control varies throughout the day, week and year. Controllable load peaks at about 57 MW on cold winter mornings. Domestic water heating can be turned off using ripple control for up to 4 hours and equates to about 10% of demand (Table 13). Orion also has 190 MW of load connected to ripple control for the purposes of switching on appliances (mostly hot water) during low tariff periods at night.

Orion operates two ripple coding systems:

- Telenerg, based on 11 kV injectors using a 175 Hz carrier frequency which operates mainly in the urban Christchurch and Lyttelton areas, and
- Decabit, based mainly on 33 kV injectors using a 317 Hz carrier frequency which operates in the rural Canterbury and Banks Peninsula areas.

This plant is generally in a good condition (Box 3) and present few technical problems. Each plant communicates with a few thousand consumers, though specific channels could be used to reach just a few hundred consumers. The timetables for ripple control for tariff switching are programmed into the ripple control plant and reassessed every year.
The timetables can also be switched by the Orion SCADA system.

Orion believes that the success of its ripple control systems relies just as much on its people and processes, as it does on hardware and software.

Ripple control ownership

Orion owns and operates its ripple injection plant. Ripple relays at consumers' sites are all owned by either retailers or Metering Equipment Providers (MEPs). Most dwellings have two electricity meters – one for hot water and one for all other appliances. A few years ago, without consultation, a retailer removed 6,000 ripple relays from Orion's network as part of a program installing new meters. Ownership of meters at the sites where these relays were removed has changed again since the removal. Orion does not know if the ripple relays have been replaced but in the absence of clear incentives for retailer to use load control it is unlikely.

Table 13 - Ripple control capability of Orion Network

Total network peak demand (maximum coincident demand[15])	610 MW
Total network load connected to ripple control, and load that can be reduced using ripple control (A simple figure for load reduction is not available. All loads are not necessarily available at the same time and have seasonal and weather dependencies.)	250 MW made up of: • Residential water heating: 57 MW connected; most of which is available to reduce peak loads • Business water heating: 3 MW connected; most of which is available to reduce peak loads • Night load tariff switching: 190 MW in total. If this load was not controlled, it would add approx. 73 MW to load • Emergency control: All above load can be switched off in an emergency. Effectiveness depends on the time of occurrence of the emergency as some load may already be switched off due to normal ripple control action.
Network maximum coincident domestic demand)	Orion cannot separate domestic component of peak demand.
Network total domestic water heating load not connected to ripple control	10%
Domestic hot water heating as proportion of network ripple control	90%
Total number of Installation Connection Points (ICPs)	207,521
Total ICPs with ripple control	169,000
Total number of domestic ICPs	178,000
Domestic ICPs with ripple controlled water heating	160,000

15. Maximum coincident demand is the peak load that has been recorded during a reporting period – usually 12 months. This is less than the maximum possible load because everything in the network is never drawing power at the same time.

Box 3 - Orion’s ripple control plant – Asset Health Indicators

EDBs report on the health of their assets in their information disclosures in accordance with the Electricity Engineers Association (EEA) Asset Health Indicator Guide (AHI 2016). The guide is intended to help electricity network companies identify assets that need replacing and plan upgrades.

Orion’s asset health disclosure shows most of its ripple control plant to be in good condition, although 16% are nearing end of life (Table 14). As ripple control is an important part of Orion’s network management strategy, the company will continue to invest in replacement of end of life ripple control equipment.

Note that this health assessment covers the central ripple control plant owned by Orion not the ripple relays located at consumer premises which are owned by retailers and MEPs.

Table 14 - Orion Group central ripple control plant health assessment

Asset Health Indicator		% of ripple control central plant
H5	As new condition – no drivers for replacement	9%
H4	Asset serviceable - no drivers for replacement, normal in-service deterioration	75%
H3	End-of-life drivers for replacement present, increasing asset related risk	16%
H2	End-of-life drivers for replacement present, high asset related risk	0%
H1	Replacement recommended	0%

Current application of ripple control

Orion operates the Upper South Island Load Management (USILM) Project, a collaboration between eight EDBs to manage the peak loads on the transmission grid. During periods of high electricity demand, these companies use ripple control to manage domestic water heating throughout the region. In a grid emergency[16], the system can also reduce water heating load rapidly to help avoid power outages. The USILM Project has led to a reduction in transmission charges and the deferral of investment in new transmission capacity.

Orion uses ripple control of domestic hot water to reduce peak load on about 30 days per year, mostly in winter. Orion also uses ripple control for tariff switching, emergency control and high consumption signalling.

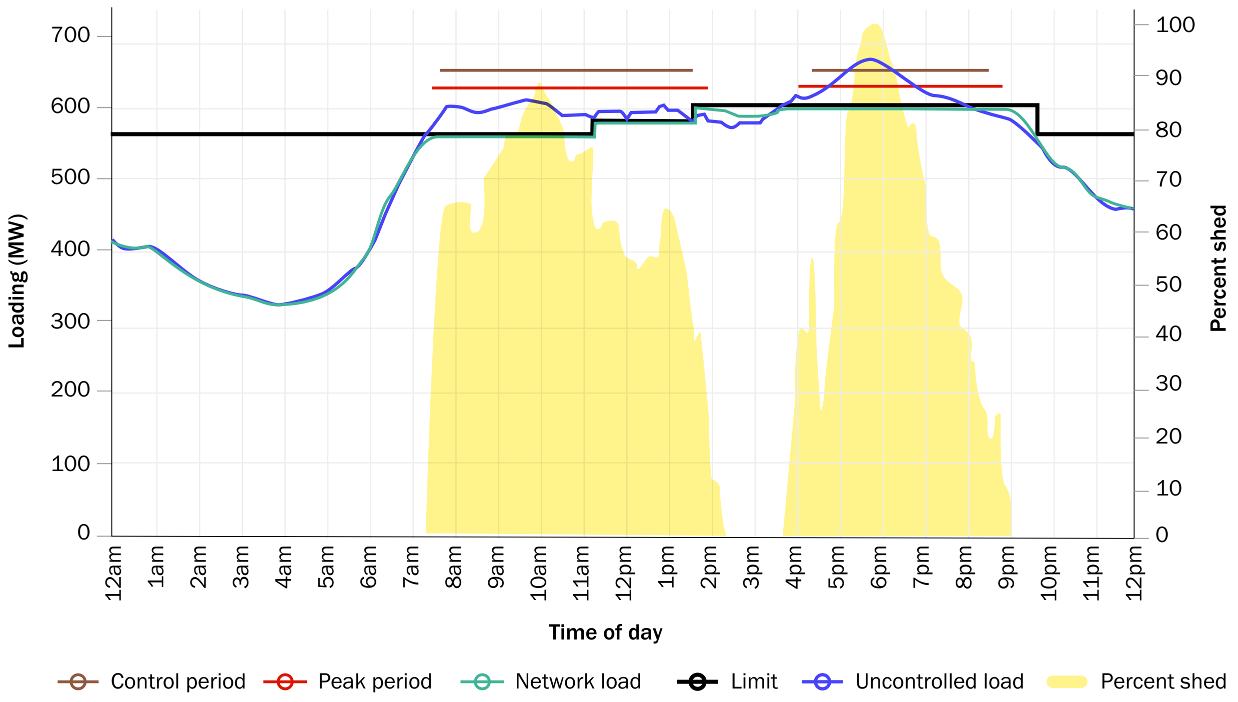
By using ripple control, Orion can maintain reliability of supply and keep consumer bills lower. Orion considers that its use of ripple control provides a major benefit to its consumers and the electricity system. Orion says that benefitting consumers, who are the ultimate owners of the company, is their main incentive for deploying ripple control.

Ripple control for reducing peak load. Orion aims to keep total load below a network limit of 580 MW. This limit is reviewed frequently and may change based on its effectiveness. When the load approaches this level, Orion sends ripple control signals to switch off hot water heaters. For example, if an excess load of 2 MW is expected, the system will send an "off" signal that it estimates will reduce the load by 2 MW. Once load levels start to fall, appliances are switched on again. Orion has about 57 MW of residential water heating connected to ripple control (Table 13) and can reduce peaks by just under this amount. In addition, Orion can turn off approximately 3 MW of business water heating.

On days of high energy use, water heaters are often switched off for up to four hours during the morning or evening, with four hours for re-heating in between. Orion aims to limit the time domestic water heaters are turned off to no more than four hours in any eight-hour period to minimise impact on the consumers' availability of hot water. Business water heaters are turned off for only two hours. During peaks that last longer than four hours, Orion rotates through the ripple channels at least every 10 minutes so that the accumulated off time of each water heater is not too long.

Figure 16 shows Orion's peak load on 1 July 2020, a particularly cold winter's day with high consumption throughout the day. The red line shows what would have occurred in the absence of control. The green line is what actually happened – both morning and evening peaks were flattened using control measures, including ripple control of domestic hot water. With ripple control being active over approximately 12 hours of the day the load limit
was adjusted while ripple control was in use and ripple channels were cycled to avoid individual
water heaters being turned off for excessive
periods of time.

16. Transpower may declare a Grid Emergency when problems arise and it believes it is unable to continue to keep the power system operating in the required stable state. Transpower may then request EDBs to assist by quickly reducing load.



(Source: Orion Load Management Dashboard (https://online.oriongroup.co.nz/LoadManagement/)

Figure 16 - Orion network load and load management on a winter's day (1/7/2020).

Ripple control to align with off-peak tariffs. Residential electricity consumers can choose cheaper electricity tariffs where appliances such as water cylinders and night store heaters are operated outside peak periods. For example, on the most common night-only tariff, heating occurs overnight, and is then off all day. (Other tariffs are peak control; night only with afternoon boost; night only with weekend boost; and emergency control.)

Orion sends fixed-time ripple control signals every day to support these tariffs. This permanently shifts load away from the daytime periods when peaks occur. Without night control of hot water, Orion estimates the coincident network peak would be 73 MW higher. Orion uses ripple control to stagger the switching times for night heating of hot water to limit the step sizes of load change across its network.

Orion receives no incentives from retailers for providing this service. Orion aims to limit load without breaching service level targets agreed
with electricity retailers and Transpower. This involves a challenging trade-off between costs
and service quality.

Emergency control. Orion also uses ripple control for emergency load shedding[17] on a small but growing number of domestic water heaters. Consumers signed up to the emergency control option account for less than 1 MW of load (Table 13). Orion only interrupts water heating supply to these consumers to prevent or limit outages during emergency capacity shortages. Residential consumers can expect fewer than two emergency events per year, lasting up to two hours. Retailers offer no discounts for the emergency control option, and it is the closest Orion offer to continuous water heating.

High consumption signalling. Orion use ripple control to signal higher network energy consumption periods to some commercial consumers. These consumers then have the option to use their own load control systems to minimise their electricity costs. Their responses to high consumption signals include load reduction, load shifting and starting up on-site diesel generators. The cumulative impact of these responses varies but is approximately 25 MW. High consumption signalling using ripple control occurs on fewer than 30 days per years. High
energy consumption links to increased transmission and distribution costs and but not directly to
energy prices.

Orion does not use ripple control to participate in the reserve market for fast interruptible load response, as any ripple control system is too slow[18]. Orion also uses ripple control for street lighting, industrial price signalling and irrigation load control (emergency only).

Does ripple control deliver its potential benefits?

Section 2.2 of the main report outlines six potential benefits of using ripple control. Table 15 summarises whether each of these benefits is achieved in the case of Orion.

Table 15 - The benefits of Orion's use of ripple control

Potential benefit	Benefit delivered?
Reducing network costs	Yes. Ripple control reduces network costs and defers investment in distribution and transmission upgrades.
Reducing domestic energy bills	Yes, because Orion charges less due to ripple control but Orion cannot be sure that savings flow through to the consumers whose hot water is controlled and not also those with uncontrolled electric water heating.
Reducing generation costs	Yes, as required peak generation reduces. The company believes current spot prices do not always reflect generation cost or actual loads.
Supporting reliability of the electricity system	Yes. Improves reliability and n-1 security.* This benefit is linked to use of ripple control by all EDB participants in the Upper South Island Load Management Project
Power quality support	On occasion automatic ripple response has kept system within voltage stability limits. This benefit is linked to use of ripple control by all EDB participants in the Upper South Island Load Management Project
Supporting the clean energy transition	Ripple control supports the clean energy transition allowing control of the peak demand contribution from hot water to help match the variable output of clean energy sources embedded in the network such as roof top solar power.

*N-1 security means the electricity system is in a secure state, and for any one credible contingency event, it would move to a satisfactory state.

17. Emergency load shedding is a deliberate action taken to selectively reduce load in a network when a power supply problem arises. Without emergency load shedding power supply problems may cause more widespread and indiscriminate power cuts which take longer to recover from.

18. In some other NZ regions pilot wire water heating control has been used for interruptible load control as it has faster signalling than ripple control. See also WEL Networks case study for their method of participating in the reserve market.

Technical problems with ripple control

Orion has few technical problems with ripple control. Orion's ripple injection plants send nightly confirmation signals to ensure hot water systems are turned back on. Additional confirmation signals can also be sent when problems arise. There are occasional problems during maintenance of the distribution network when ripple signals must reach further through the network.

Sometimes ripple relays fail, or difficulties arise when a consumer's hot water needs change. Consumers often contact Orion with these issues, but Orion refers consumers to their retailer as it is the responsibility of the ripple relay owners to fix. In rare cases where the problem does relate to network signalling, Orion compensates the consumer for any electrical work they have paid for.

Barriers to the more effective use of ripple control

It is a condition of Orion's delivery service that its consumers with electric hot water heating have a ripple relay installed. This requirement applies to all new connections and to all existing connections that already have ripple control. Nevertheless, the size of controllable domestic hot water load is slowly declining. As mentioned above, there have been instances of retailers removing ripple relays from Orion's network. Also, the installation of rooftop solar is often accompanied with switching the hot water system to the main meter, by-passing ripple control.

Orion has very few business incentives to use and maintain ripple control, as network savings are passed onto retailers (and hopefully consumers). In fact, there is a disincentive, as without ripple control Orion would need to upgrade its network and could make a return on this investment and grow its business. Orion avoids this approach as it would be to the detriment of its consumers.

In the absence of any national or industry-wide strategy for load management, there is a lack of alignment about how to apply ripple control of hot water. Ripple control favours some market participants and disadvantages others, such as generators. Increasingly, electricity retailers' pricing plans fail to reward consumers for ripple control of their water heating. For example, some retailers offer power at a flat rate, giving the consumer no incentive to avoid heating water at peak times.

In 2021, the Electricity Authority is planning to introduce default distributor agreements under which access to controllable loads will be opened up to a competitive market. This will reduce Orion's ability to control loads and retailers may switch consumers onto uncontrolled load to avoid the cost of maintaining ripple relays. Orion believes that for load control, including ripple control, to work well, it needs a central controller. Furthermore, if Orion loses central control of load management it would remove a major incentive for continued investment in its ripple control infrastructure.

Future approaches to ripple control and demand management

Ripple control of hot water is a simple, low-cost technology that works well for Orion and its consumers. It probably already operates close to its maximum potential in terms of managing Orion's peak loads.

However, as more New Zealanders adopt technologies such as roof top solar and electric vehicles, it will become more important to manage the electricity consumption and production at the level of individual consumers so that the aggregated effect can be properly controlled. Ripple control does not currently provide this level of control. However, in the future, Orion sees ripple signals interacting with distributed energy resource management systems (DERMS), and the company has already carried out a small trial with a retailer using ripple control with DERMS.

Ripple control could also support the integration of more variable renewable energy into the grid. Domestic hot water tanks represent a large reservoir of energy, which could be used to balance the intermittent output of solar and wind energy. However, this will require DERMS that offer good control of hot water heating. The systems Orion has explored so far are not able to provide this

One drawback of ripple control is that it is one-way communication: Orion does not know if signals are received by individual relays and cannot diagnose problems. A future demand management system should involve two-way communications. Orion does not regard the Internet as a suitable alternative as they observed it to be less reliable than ripple control signals during the Christchurch earthquake emergency situations.

Orion believes that a successful future for ripple control of hot water depends on an industry-wide strategy and supportive regulatory system. This system would set appropriate incentives for all market participants and leave overall control in the hands of distribution companies.

Case study 3 - Powerco

Introduction to Powerco

Powerco distributes electricity to more than 340,000 urban and rural households, businesses and major industrial and commercial sites in New Zealand's North Island. Powerco's networks are in the Taranaki, Wanganui, Rangitikei, Manawatu and Wairarapa regions, including the urban centres of New Plymouth, Wanganui, Palmerston North and Masterton, as well as Tauranga and the surrounding rural areas and the eastern and southern Waikato, Thames and Coromandel regions.

Powerco is New Zealand's largest electricity distributor in terms of network length (28,000km) and has the second largest number of electricity connections. Total energy distributed across Powerco's electricity networks was 5,099 GWh in 2019, up from 4,809 GWh on 2017.

Powerco is a privately owned network company which also operates a gas distribution network.

Ripple control capability and condition

Powerco has significant capability to reduce peak demand using ripple control connected to domestic hot water. Powerco estimates the maximum connected load for water heating as 280 MW (Table 16). The vast majority (about 95%) of this load is domestic. Ripple control provides fast response (under 10 seconds) and is extremely reliable and effective.

The meter registry indicates that 194,000 consumers in Powerco's network have controllable load (Table 16). The actual number is lower as not all these consumers are currently connected to ripple control. Powerco cannot quantify these unconnected consumers as the meter registry does not differentiate between controlled and uncontrolled domestic water heating. There is also no mechanism for reporting the removal of a ripple relays or the replacement of an electric water heater with another type of system. Table 16 presents Powerco's
estimate of its total controllable load as 155 MW - an estimate based on assuming an average of 0.8 kW for all 194,000 consumers recorded as having controllable load.

For night-rate heating, Powerco's estimated controllable load is 10 to 15 MW, which includes both space heating (night storage) and larger domestic water heating systems. Powerco uses different ripple control signalling channels for tariff switching and peak demand control.

Ripple control ownership

Powerco owns and operates 26 ripple injection plants (audio frequency load control transmitters) located close to their related Grid Exit Points (GXP)[19]. (The exception is Waverley GXP, which has no load control signalling capability.)

Powerco has installed dual frequency systems to accommodate older ripple relays. The company uses four signalling frequencies (217, 283, 317 and 383 Hz) which have all proven to be reliable in a 50 Hz power system. Powerco transmits signals using the DECABIT, Semagyr S50a and S52, and Rythmatic formats. Powerco is planning to migrate all ripple signalling to DECABIT as Powerco has found it to be the most secure, fast, reliable and flexible format in their network.

The majority of ripple relays on Powerco's network are owned by third parties, mostly Metering Equipment Providers (MEPs). Powerco owns some pilot wire circuits, along with a small number of ripple relays at the control points of these circuits. These relays mostly contain multi-channel receivers with separate channels for street lighting control and hot water pilot wire control. Additional interposing relays are installed on some consumers meter boards and are owned by MEPs.

19. A Grid Exit Point (GXP) is defined in the Electricity Industry Participation Code as any point of connection on the grid at which electricity predominantly flows out of the grid. Typically, a GXP is the point of connection in a Transpower substation for a cable or transmission line feeding power to a network belonging to an Electricity Distribution Business.

Table 16 - Ripple control capability of Powerco

Total network peak demand (maximum coincident demand)[20]	812 MW
Total network load connected to ripple control	280 MW
Network maximum coincident domestic demand	Powerco cannot separate domestic component of peak demand.21
Network domestic water heating load connected to ripple control	Powerco does not differentiate between domestic water heating control and other categories of load control.
Network total domestic water heating load not connected to ripple control	Unknown
Load in region that can be reduced using ripple control	155 MW (estimate)
Domestic hot water heating as proportion of network ripple control	95% (estimate)
Total number of Installation Connection Points (ICPs)	344,708
Total ICPs with ripple control	194,790 (according to meter registry data)
Total domestic ICPs	280,233
Domestic ICPs with ripple-controlled water heating	184,789 (according to meter registry data)

20. Maximum coincident demand is the peak load that has been recorded during a reporting period – usually 12 months. This is less than the maximum possible load because everything in the network is never drawing power at the same time.

21. It could be done by analysing a significant quantity of data from Advanced Meters, though retailers are reluctant to divulge this information.

Box 4 - Powerco’s ripple control plant – Asset Health Indicators

Network companies report on the health of their assets in their information disclosures in accordance with the Electricity Engineers Association (EEA) Asset Health Indicator Guide (AHI 2016). The guide is intended to help electricity companies identify assets that need replacing and plan upgrades.

Over the last 11 years, Powerco has focused on modernising and upgrading the older technology Injection plants that were identified in previous Asset Management Plans as outdated, overloaded and presenting a high risk of failure with a lack of availability of technical support. This renewal programme has resulted in a system that, while still containing some older technology plants, is supported with readily available spares and technical support contracts. The overall health of Powerco’s ripple control assets is of a high standard.

Powerco continues to operate ten phase distortion CycloControl transmitters on the Huirangi and Stratford networks. (CycloControl is an outmoded signalling method with similar functions to ripple control.) Technical support and spare parts are no longer available for these transmitters, so they are being run until they fail. The network area with the CycloControl system has been overlaid by a modern system which now provides reliable and supportable load control in this network area. Any CycloControl receivers found by MEPs during routine meter replacements etc are replaced with modern ripple control receivers with DECABIT coding.

Note - This health assessment covers only the central ripple control plant owned by Powerco and not the ripple relays located at consumer premises which are owned by MEPs. Powerco has been able to influence MEPs to upgrade ripple relays as part of meter replacement programmes.

Table 17 - Powerco's central ripple control plant health assessment

Asset Health Indicator		% of ripple control central plant
H5	As new condition – no drivers for replacement	58%
H4	Asset serviceable - no drivers for replacement, normal in-service deterioration	42%
H3	End-of-life drivers for replacement present, increasing asset related risk	0%
H2	End-of-life drivers for replacement present, high asset related risk	0%
H1	Replacement recommended	0%

Current application of ripple control

Powerco's application and maintenance of ripple control is motivated largely by a desire to be a responsible participant in New Zealand's electricity system. The main objectives for Powerco's activation of ripple control are described below.

Minimising peak loads to alleviate network constraints. Powerco uses ripple control on about 20 days each year to reduce peak demand. Occasionally Powerco uses ripple control of hot water in response to a direct request from Transpower in order to maintain network security and reliability. It is also deployed to meet any demands from the Electricity Authority or other legislative bodies to limit demand during events such as electricity shortages or low frequency events.

Using ripple control to reduce peak loads helps maintain network security (at n-1 level) and so reduces the likelihood of outages assisting with meeting supply reliability obligations. It also helps Powerco carry out essential maintenance without interrupting the service to consumers.

Ripple control of domestic hot water to control peak demand normally occurs during winter. (Outside of winter, Powerco sometimes uses ripple control to manage demand from dairy farms on GXPs with a high proportion of dairy farm load.) It would be unusual for Powerco to use ripple control in the morning and afternoon of the same day. Ripple control of domestic hot water is available and operates over the entire Powerco network area.

Ripple control allows Powerco to reliably handle peak load on sub-transmission networks that are close to their maximum capacity. This has allowed the company to defer upgrades potentially costing tens of millions of dollars, thus reducing costs passed on to consumers.

The estimated size of the hot water load to be shed or restored is determined by a load control algorithm. This algorithm takes account of factors including current load, time of day, season, time on since last off time, time off during the current time period and social behaviour patterns such as school holidays. Powerco believes consumers should not notice any impacts from ripple control so limits its use to a total of 3 to 4 hours off time per consumer per day.

Aligning with off-peak tariffs. Powerco also uses ripple control every day to align with retailers' discounted tariffs for consumers with night-rate controlled loads. This ensures consumers' controlled loads (which may include water heating) can only be operated between 11pm and 7am to coincide with lower night-rate tariffs. Some off-peak tariffs also include a "boost" period during the early afternoon intended for water heating.

In the past, retailers paid Powerco to turn off hot water during peak demand periods. Powerco considered that some of these 'off' periods were too long, and the company now receives no incentives from retailers to deploy ripple control.

Reducing Transpower's charges is not an objective of Powerco's use of ripple control. This is partly because Powerco consider their load as too small to have a large effect on the peak load in the Lower North Island region (the basis for Powerco's transmission charges).

Powerco used to deploy ripple control to participate in the fast interruptible reserve market. However, the company has decided that the potential revenue from this market does not justify the risks and technical complications of participation.

Does ripple control deliver its potential benefits?

Section 2.2 outlines six potential benefits of using ripple control. Table 18 summarises whether each of these benefits is achieved in the case of Powerco.

Table 18 - The benefits of Powerco's use of ripple control

Potential benefit	Benefit delivered?
Reducing network costs	Yes – by improving asset utilisation and deferring investment in both transmission and distribution networks.
Reducing domestic energy bills	Yes – by enabling night-rate tariffs. (Though modern meters could also do this without ripple control).
Reducing generation costs	Yes – this is likely to be an indirect benefit of Powerco's use of ripple control, through lower use of peaking generation plants.
Supporting reliability of the electricity system	Yes – when responding to requests from Transpower and to enable network maintenance.
Power quality support	No. Although may indirectly reduce risk of voltage problems. Ripple control could be used to correct under-frequency problems, but this would require MEPs to program ripple relays differently.
Supporting the clean energy transition	Not deliberately, but ripple control can play a supporting role by using loads with suitable energy storage to lower peak demands to assist matching to the variable output of clean energy sources such as rooftop solar generation, e.g. hot water systems as a source of thermal energy storage, or irrigation schemes where the energy is stored as moisture in the soil.
Supporting the clean energy transition	Ripple control supports the clean energy transition allowing control of the peak demand contribution from hot water to help match the variable output of clean energy sources embedded in the network such as roof top solar power.

Technical problems with ripple control

Sometimes ripple control problems arise on Powerco's network when loads are turned off and require manual intervention to restore. These problems are more often due to operational missteps rather than faulty equipment. A busy operator could set controls and then forget to reset them. Occasionally there may be failures in the communication system between the SCADA Master Station and the injection plant controller.

Most of these issues are addressed by monitoring of the channel status at the injection plants. With loss of signal over a pre-set time, algorithms in newer ripple relays can be set to return output switches to the 'on' state or revert to timetable mode, thus further enhancing monitoring of system operations and reducing outage times to a minimum.

Pilot wires can cause reliability problems that are unrelated to ripple control. These problems include faulty joints, conductor clashing and incorrect fuses. Pilot wires also limit the functionality of load control, and Powerco believes that pilot wire unreliability may contribute to negative attitudes towards ripple control. Powerco is decommissioning pilot wire as part of its scheduled renewal programmes.

There are few problems related to the interaction of consumer equipment with ripple control within Powerco's network. Powerco has standardised ripple frequencies to within the 200 to 400Hz range, making them less susceptible to such problems. Powerco's Network Connection Standard requires the installation of blocking filters on the network side of any consumer loads that may otherwise absorb or interfere with ripple control signals.

Powerco takes no responsibility for faulty ripple relays as it does not own them. Powerco believes retailers and MEPs rarely check the health of their relays, which can be set to incorrect channels as a result of unreported changes in consumers' loads, or shorted out, or stuck in the 'on' position. It is widely recognised within the industry that such problems resulting in a control being always on are seldom reported.

When consumers do report a problem, their retailer will lodge a fault call with Powerco. If the fault is thought to be network related, Powerco sends a faults contractor to investigate and resolve it at no cost to the consumer or their retailer.

Industry fragmentation makes fault finding complicated. EDBs, retailers and receiver owners each have their own field contractors. Determining the underlying cause of a hot water complaint is often frustrating, involving several attempts by different parties to resolve. Powerco has a process for handling hot water complaints but it has never been formally adopted by retailers or MEPs.

Barriers to the more effective use of ripple control

The energy sector reforms of the 1990s introduced split ownership of ripple control systems with no clear business incentives to undertake load control. In Powerco's opinion, this has led to a lack of investment in ripple control and uncertainty about responsibility for load management. For example, Powerco lacks good information about the ripple relays in its area and the loads to which they are connected. Because of these changes, Powerco believes New Zealand's ripple control systems have degraded and are less effective than they were.

Powerco sees the main barrier to the more effective use of ripple control as a lack of strategic oversight and clarity. For example, while the Electricity Authority recognises that load control delivers a more secure electricity system at lower cost, it has no strategy for ripple control. Instead, it believes that demand response measures should be driven by market incentives such as consumers' willingness to pay.

Fragmented ownership and lack of strategy contribute to several barriers to the more effective use of ripple control, including:

- retailers' failure to promote and incentivise load control

- lack of understanding at Powerco about consumers' electricity use patterns
- conflicting incentives between network companies and retailers (e.g. EDBs aim to meet peak demand (kVA) and reliability obligations at minimum cost, while retailers aim to maximise the electrical energy (kWh) delivered)
- the unnecessary removal of functioning ripple relays at consumer sites.

The future of ripple control and demand management

Powerco sees ripple control of domestic hot water as a fast, reliable and effective service which can continue to play an important role in the electricity system. In particular, Powerco considers ripple control to be highly effective at reducing demands at peak times and shifting consumption to lower-demand periods. Powerco is investing in two new ripple control plants on existing networks, and a third ripple control plant as part of a new GXP. Despite these investments and the benefits of ripple control, its usage is slowly declining on the Powerco network due to:

- the lack of recognition of the benefits obtained from an effective means of demand management
- unauthorised removal of ripple relays
- an increase in alternate forms of water heating.

Powerco believes that ripple control of hot water can be modernised to meet the needs of the evolving electricity system. Newer relays can provide more flexible control which will make load-switching less noticeable to consumers. Advanced metering units have in-built load control functionality and monitoring functionality. This improves electricity network operational visibility and allows load switching to be scheduled, so that, for example they turn hot water back on at an appropriate time even when the ripple control system fails.

However, to fulfil the potential of ripple control, Powerco believes there needs to be a clear national strategy for load control. This strategy would describe how load control can support New Zealand's sustainable energy future. One of its key aims should be effective collaboration between the relevant stakeholders (ripple relay owners, EDBs, retailers and consumers), an equitable sharing of benefits between all stakeholders and the removal of conflicting business drivers. Powerco considers that useful regulatory changes would include:

- sharing transmission cost savings among stakeholders including consumers
- requirements to audit the health of ripple relays at consumers' sites
- introduction of standards for acceptable levels of "off" duration (with appropriate incentives and disincentives).

Powerco is monitoring developments of emerging alternative technology for managing loads, electric hot water and other thermal storage devices. Powerco is also in the early stages of planning a pilot of smart control on a small part of its network, although the details and technologies involved are still being worked out.

Case study 4 - WEL Networks

Introduction to WEL Networks

WEL Networks Limited (WEL) is the fifth largest electricity distribution company in New Zealand, covering Hamilton and the northern and central Waikato region. WEL distributes electricity to over 160,000 people through 91,000 installation connection points and 6,796 km of lines. In 2019, the total energy distributed across WEL's network was 1,285 GWh.

WEL is 100% owned by the community through its sole shareholder, WEL Energy Trust.

Ripple control capability and condition

WEL has significant capability to reduce peak demand using ripple control connected to domestic hot water. About two-thirds of WEL's domestic customers have a ripple control relay connected to their electric hot water systems. This allows WEL to reduce their network load by 40 to 60 MW – more than 10% of peak demand (Table 19). Ripple control is very effective at managing WEL's loads.

Each ripple injection signals affects around 2,000 to 3,000 customers, or about 2 MW of load.

WEL used to be able to control smaller numbers of customers at the substation level but it was decided that the few cases when this was used did not justify the complexity of maintaining multiple coding schemes and complicated inventory management. Customers on any given ripple control channel are not clustered but distributed across WEL's network, to avoid large swings in demand in particular areas.

Ripple control ownership

WEL owns the ripple control plant and all of the ripple control relays in its area. WEL owns and operates 5 ripple injection plants (33kV and 11kV) which send ripple signals at a frequency of 283 Hz. These systems are in good condition (Box 5) and present few technical problems.

WEL also owns and operates smart meters at two-thirds of its customer sites. These meters are mostly additional to the revenue meters that are installed at all sites. For controlled tariff consumers, WEL's smart meters contain ripple relays which have the capacity to control customer appliances. However, in most cases, WEL does not generally use its smart meters for ripple control because this would interfere with the operation of the main revenue meters. WEL does use its smart meters for several other purposes such as detecting network problems.

Table 19 - Ripple control capability of WEL Network

Total network peak demand (maximum coincident demand[22])	278 MW
Total network load connected to ripple control	100 MW
Network maximum coincident domestic demand	WEL cannot separate domestic component of peak demand.
Network domestic water heating load connected to ripple control	95 MW (estimate)
Network total domestic water heating load not connected to ripple control	5 MW (estimate)
Potential load reduction using ripple control	40 to 60 MW (estimate)
Domestic hot water heating as proportion of network ripple control	95%
Total number of Installation Connection Points (ICPs)	94,217
Total ICPs with ripple control	56,765
Total number of domestic ICPs	81,402
Domestic ICPs with ripple-controlled water heating	53,479

22. Maximum coincident demand is the peak load that has been recorded during a reporting period – usually 12 months. This is less than the maximum possible load because everything in the network is never drawing power at the same time.

Box 5 - WEL's ripple control plant – Asset Health Indicators

Network companies report on the health of their assets in their information disclosures according to the Electricity Engineers Association (EEA) Asset Health Indicator Guide (AHI 2016).[23] The guide is intended to help network companies identify assets that need replacing and plan upgrades.

WEL's asset health disclosure shows its ripple control plant to be in very good condition. Note that this health assessment covers the central ripple control plant owned by WEL Networks. Some of the ripple relays located at customer premises is owned by others (i.e. retailers and Metering Equipment Providers).

Table 20 - WEL Network's central ripple control plant health assessment

Asset Health Indicator		Load under ripple control (MW)	% of load that is domestic water heating
H5	As new condition – no drivers for replacement	50	95%
H4	Asset serviceable - no drivers for replacement, normal in service deterioration	50	95%
H3	End-of-life drivers for replacement present, increasing asset related risk	0	0%
H2	End-of-life drivers for replacement present, high asset related risk	0	0%
H1	Replacement recommended	0	0%

23. https://www.eea.co.nz/Site/news-events/news/Archive-2017/January-2017/asset-health-indicator-guide.aspx

Current application of ripple control

Last year WEL employed ripple control on 94 days, most of which were in winter. Although WEL has the capability to reduce peak demand by 40 to 60 MW, ripple control is not always deployed to its fullest extent or across every part of WEL's network. WEL aims to limit the time appliances are turned off to 7 hours per day – 3.5 hours in the morning and 3.5 hours in the evening.

WEL considers that it uses ripple control effectively, and that both the company and its customers benefit from its application. WEL receives an annual financial benefit of roughly$2 to 5 million from its ripple control capability, compared to a cost of around$0.5 million.

The main incentives and objectives for WEL's activation of ripple control are described below, in order of importance:

1. **Minimising transmission costs.**Transpower's method of allocating charges to distribution companies is based partly on regional peak loads (Regional Coincident Peak Demand (RCPD)). WEL minimises its transmission charges by minimising network load during coincident peak demand periods. This is the main reason the company activates ripple control.

   WEL passes these savings in transmission costs onto retailers in its network charge in the expectation that the savings are reflected in consumers' bills. WEL does this as a good corporate citizen, not because it is required by regulation. WEL could choose to pay higher charges to Transpower and then pass the costs onto retailers. In this sense WEL has no direct financial incentive to reduce the fees it pays to Transpower.

   (The Electricity Authority is changing the way Transpower charges distribution companies, and from April 2023, RCPD will no longer be part of transmission pricing methodology. This change will remove a major incentive for WEL to activate ripple control.)

2. **Alleviating network constraints.** WEL uses ripple control to minimise peak load at Transpower's substations – known as Grid Exit Points (GXPs).[24] This allows WEL to defer capital expenditure on network upgrades – a major secondary benefit of ripple control. If ripple control was not available to WEL, it could be required by Transpower to fund more frequent supply capacity increases at GXPs. WEL also uses ripple control to relieve more localised network constraints.

   Alleviating network constraints also helps WEL maintain grid security, reducing the likelihood of outages. WEL occasionally uses ripple control to reduce network load while it carries out maintenance on a substation. Use of ripple control indirectly reduces the risk of network voltage problems.

3. **Participating in reserve market**. WEL earns money from participating in the reserve market for fast interruptible load. This involves providing a service to instantly reduce demand when the network frequency falls below 49.2 Hz. The response is triggered by an under-frequency detection in the relay and does not require a ripple signal. WEL uses ripple control to participate in this reserve market for much of the year. It does this outside the winter months, as it cannot offer a fast interruptible load response during periods when it is already using ripple control on a daily basis.

24. Grid exit points (GXPs) are the points of connection (Transpower substations) where electricity flows out of the national grid to local networks or direct consumers.

WEL's use of ripple control is not timed to coincide with retailers' tariffs schemes and retailers give WEL no incentive to do this. In the past, the retailer Genesis paid WEL to control hot water to align with its cost drivers, but this agreement is no longer in place. (Note: WEL cannot control customers' load according to their retailer, so the agreement with Genesis affected all customers regardless of retailer.)

WEL does not use ripple control for emergency load shedding. During rare emergencies when the frequency drops below 48 Hz, special relays in WEL's substations automatically drop load by shedding feeders, but ripple control is not involved.

Does ripple control deliver its potential benefits?

Section 2.2 of this report outlines six potential benefits of using ripple control. Table 21 summarises whether each of these benefits is achieved in the case of WEL.

Table 21 - The benefits of WEL's use of ripple control

Potential benefit	Benefit delivered?
Reducing network costs	Yes. Using ripple control reduces network costs by millions of dollars a year through deferral of expenditure on network upgrades and minimising Transpower's peak demand transmission costs. WEL also earns revenue from the reserve market.
Reducing domestic energy bills	Yes – assuming that lower transmission charges are passed onto customers by retailers.
Reducing generation costs	WEL is not aware of the impact on generation costs. (Although it is likely that by reducing peak loads, WEL reduces generation costs.)
Supporting reliability of the electricity system	Yes. Ripple control helps maintain grid security (at N-1 level*) and reduces the risk of outages. It also helps WEL carry out network maintenance.
Power quality support	Yes – by supporting frequency control in the reserve market for fast interruptible load, which also indirectly reduces risk of voltage problems.
Supporting the clean energy transition	No. Demand management could increase use of distributed renewables, but this would require a finer level of control than offered by ripple control.

**N-1 security means the electricity system is in a secure state, and for any one credible contingency event, it would move to a satisfactory state.*

Technical problems with ripple control

WEL has few technical problems with the effective use of ripple control. In the last year the company responded to 380 reports of problems with electric water heater. Of these problems, WEL estimates that less than 25% are related to ripple control, indicating an annual failure rate of less than 0.2%. The most serious problem WEL encounters is the rare failure of injection plant components which can be hard to replace.

The company has measured the effectiveness of ripple control by collecting smart meter data while transmitting ‘off’ and ‘on’ signals. The data indicated a very high proportion of hot water systems were successfully controlled.

When a customer reports a hot water problem directly to WEL, the company first establishes the source of the problem. If it relates to ripple control, WEL fixes the problem at its own expense. However, if a customer first calls an electrician, WEL usually compensates the customer if the source of the problems turns out to be ripple control.

Problems caused by the interaction of ripple control and consumer equipment, such as flickering lights, are very rare in the WEL network. Where they do occur, WEL normally investigates at their own cost.

The future of ripple control and demand management

WEL considers that for network-wide control of electric hot water, ripple control is still the best option. Despite this, WEL does not foresee much greater potential for ripple control. In fact, once the RCPD component of transmission cost allocation ceases from April 2023, WEL’s largest incentive to operate ripple control will disappear.

WEL’s strategy with regard to ripple control is to maintain its current approach and level of infrastructure. The company’s injection plants and relays are relatively new, so there are no short-term plans to invest further in ripple control.

WEL’s use of ripple control is slowly declining due to the gradual increase in the proportion of hot water heating powered by gas. Many new homes have gas hot water heating installed because it saves space and is perceived as more convenient. Some householders have replaced electric hot water with gas systems.

WEL is planning for expected changes to the electricity system, including the more widespread adoption of technologies such as rooftop solar PV, batteries and electric vehicles. To successfully manage the integration of these technologies into the grid will require a greater degree of control at the level of individual customers.

Ripple control does not support this small-scale level of control, so WEL is exploring new approaches to demand management. For example, the charging and discharging of batteries and electric vehicles could be controlled via the Internet, allowing consumers to be rewarded for providing grid support.

WEL is currently scoping a trial to explore techniques for managing demand of appliances such as electric hot water, solar PV, electric vehicles and batteries. As part of this research WEL is talking to Horizon Power about their trials of distributed intelligent microgrids in Western Australia. New approaches are likely to consider innovative business models, such as aggregated demand response services.

WEL is carrying out these investigations as part of its internal strategy, with some assistance from research institutes. Neither the NZ Government nor Transpower provides WEL with any incentives to plan for demand management in an evolving system. Nor is there any coordinated national or regional strategy for ripple control or demand management.