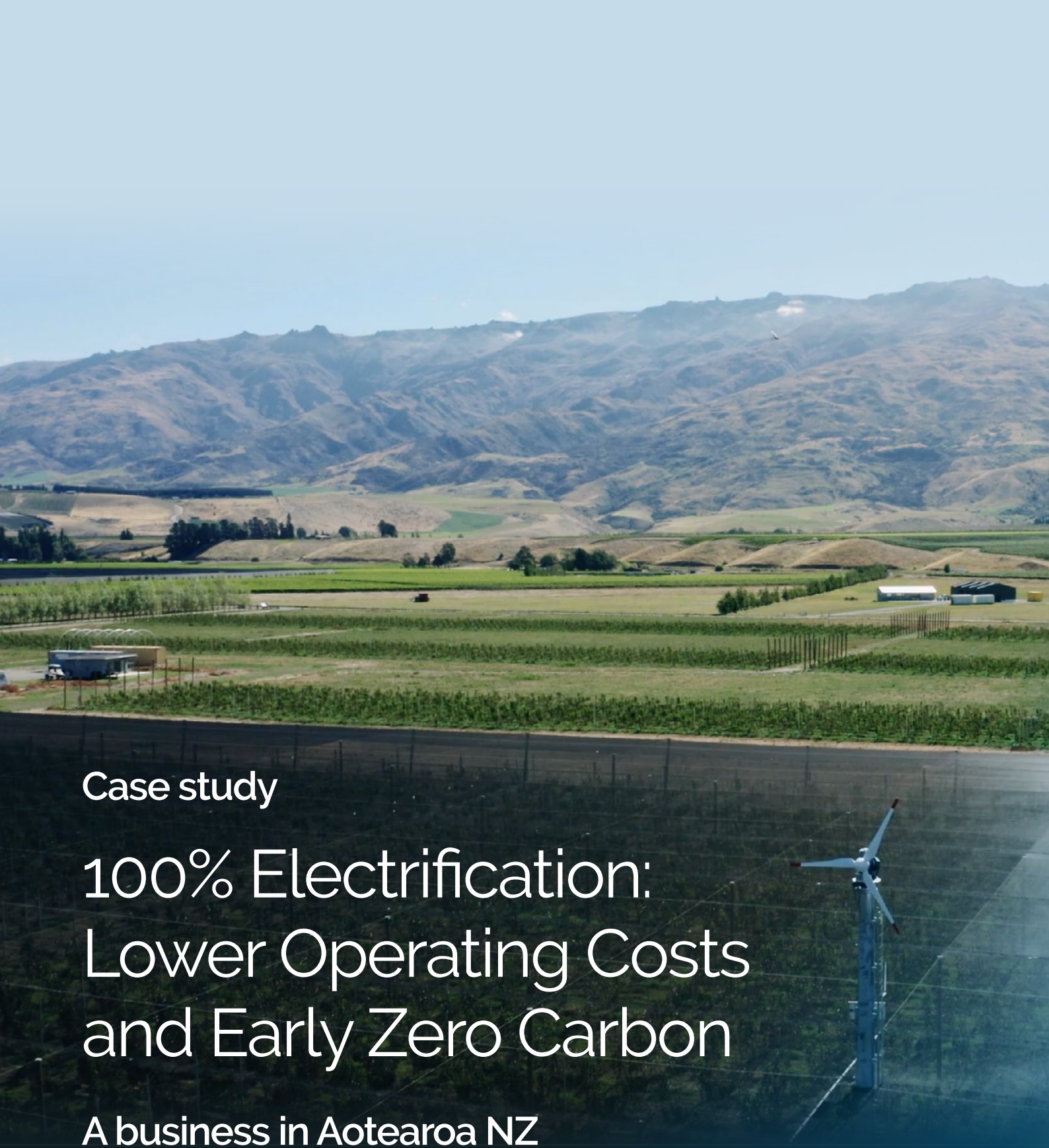

Case study

100% Electrification: Lower Operating Costs and Early Zero Carbon

A business in Aotearoa NZ making it happen

Sustainable Energy
Association New Zealand

Foreword

Climate change has created the absolute necessity of decarbonisation through electrification of the economy in Aotearoa NZ.

Leaders in business are actively engaged in making this happen. This is an analysis of one of those businesses. The owners vision was to achieve full decarbonisation through electrification, maximising on-site renewable generation and grid supply to electrify all required tools and technologies, replacing all fossil fuelled services, and incorporating electrical tools and appliances to operate the orchard farm.

This is a real-world example of reducing operating costs of a business, achieving decarbonisation and gaining other benefits on the journey.

The focus and outcomes are:

1. The cost savings achieved to electrify the orchard farm business far exceeds the finance and depreciation costs as well as the operational costs. It demonstrates that going 100% electric makes sound economic sense

2. The benefit and value of distributed energy resources (DER) with the flexibility market approach to electricity, to offset capital costs to achieve electrification and decarbonisation

As an operating model, the principles applied herein can be adopted to suit many other industries in Aotearoa New Zealand, especially in the primary industries.

Working with the electricity distributor and a willing retailer to create a flexibility model approach, using the farms DER (solar/battery/software smarts) arbitrage is utilised and the value of generation is acknowledged by reward for supply of electricity to the grid for consumers. The potential is significant across industry. Mike Casey, the owner has not only achieved the vision, he leads the way through innovation, creating value for the business, his industry and Aotearoa NZ.

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15th September, 2021

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This case study draws conclusions regarding the opportunities and challenges of electrification of food production based on the experience, circumstances and production practices of Forest Lodge Orchard. Understanding the extent of the opportunities and challenges requires an equivalent assessment of a larger sample of orchards and other food producers.

Imagery credit: Produced for Crux by Kim Bowden, shot and edited by James Haskard in partnership with Two Bearded Men using funding from NZ On Air

Forest Lodge Orchard

100% electrification means lower operating costs and early zero carbon

Forest Lodge Orchard is a newly established 6-hectare cherry orchard in Central Otago near Cromwell which aims to be the first large-scale food producer in the country to minimise the carbon emissions from food production by using renewable energy.

Forest Lodge will be 100% electric for its first commercial harvest in January 2022.

Electrification means Forest Lodge will avoid about 84t CO_2e a year.

Electrification means choosing electric equipment, having an appropriately sized network connection, and using the flexibility of solar with battery storage to manage energy costs

Forest Lodge is electrifying on-farm energy use wherever possible with electrification of irrigation pumps, frost fighting, farm equipment and off-farm light vehicles. The still-to-be-electrified list includes the electric (and autonomous) tractor which is arriving in Aotearoa New Zealand from California in April 2022.

Forest Lodge needed to invest in a larger network connection due to an increase in maximum power required.

Forest Lodge also invested in solar and battery storage to further reduce the carbon intensity of the orchard and to provide flexibility to manage energy costs.

Electric equipment is more expensive to buy...at the moment

Electric equipment for orchard operations – irrigation, frost fighting, farm equipment etc – cost $150,000 (or 45%) more than the conventional fossil-fuelled options.

Fewer electric options are available. The two 30kW electric frost fighting fans were imported from South Africa after an extensive global search provided a shortlist of one manufacturer.[1]
The electric tractor is coming from California after another extensive global search provided a shortlist of two manufacturers.

But far more cost effective to operate...

Electric equipment has lower operating costs, because electricity costs less than the liquid fuels to deliver the equivalent output.

[1] The purchase of the electric frost fans was supported by a grant from the Energy Efficiency and Conservation Authority.

Forest Lodge will reduce its energy costs by about $41,000 a year (about 85%) compared to an equivalent sized fossil-fuelled orchard.

Total savings are greater because electric equipment doesn't need refuelling (a time saving) and requires less maintenance, as electric motors are significantly less complex than their fossil-fuelled counterparts.

A larger network connection

Electrifying orchard operations at Forest Lodge required upgrading the network connection to 3-phase and 138kVA, plus internal electrical work to connect power to the frost fans and pumps. The connection and internal electrical work cost about $140,000, but these costs will vary according to the location and requirements.

Solar with battery storage reducing overall costs

The 23.1kW solar array and 60kWh battery storage cost $160,000, but reduces annual operating costs by a further $13,000 compared to a grid-only electrification by providing flexibility to manage energy costs.

Forest Lodge uses the solar and battery storage to put a ceiling on average electricity costs due to the flexibility to purchase power from the system when wholesale prices are low (and the electricity probably less carbon intensive) and use self-generated electricity when wholesale prices are high.

Because the local distributor, Aurora, charges for network use in part based on network capacity used by a customer,

Forest Lodge can use the solar and battery storage to reduce its network charges by minimising network use when Aurora provides a demand reduction signal.

Network operators will need to signal the value of flexibility before electrification accelerates

Making solar and battery storage part and parcel of electrification will provide network operators with more options to keep down the costs of electrification.

Electricity distribution and transmission network operators, along with the wider

electricity sector, including government and regulators, need to make sure that as people and businesses electrify, they are encouraged to consider the longer-term benefits from investing in solar and battery storage so that flexibility capability is available to provide a resilient and reliable network service and defer or avoid network upgrades and higher network charges in the future.

Additional detail on how Forest Lodge uses the network and the current and potential value to the network operator of the flexibility outcomes from the solar and battery storage is provided on page 16.

An off-the-shelf service is needed to support mass electrification

Electrification of Forest Lodge required considerable effort from the owner Mike Casey to integrate bespoke solutions. There was no off-the-shelf product or service available from the electricity sector or equipment manufacturers to maximise the value of electrification.

The lack of off-the-shelf services from the electricity sector means equipment suppliers and installers – particularly solar and battery suppliers – don't have the guidance or insight needed to design systems that maximise value for the customer.

Electrifying a cherry orchard

Forest Lodge Orchard was established in June 2019 with clear determination to minimise the carbon emissions from food production by using 100% renewable energy.

The orchard has about 9600 cherry trees. The first fossil-fuel free harvest in summer 2021/22 is bound for the domestic market. The fossil-fuel free 2022/23 harvest will be exported.

Electrification of Forest Lodge has been mostly about avoiding use of fossil fuels for on-and-off-farm transport, stationary pumps and motors and residential use.[2]

Forest Lodge has chosen to electrify everything – irrigation pumps, frost fighting fans, farm vehicles, farm equipment, light vehicles, and the household – all powered from the national electricity system supplemented by a 23.1kW solar array and 60kWh battery storage.

[2] The orchard residence was renovated to electrify household cooking, water and space heating. This involved replacing the gas hot water system, gas stove and oven, a gas fire and a diesel furnace for underfloor heating (using about 4000 litres of diesel a year – that's about 10t CO2-e!).

Electrification will avoid over 84t CO_2-e a year

Electric option	Fossil fuel not used	CO_2-e avoided a year
Electric Irrigation	2,400L diesel	6,500kg
Electric Frost Fighting	12,000L diesel	32,000kg
Electric Farm Equipment	2,000L diesel now 12,000L diesel from March 2022	5,000kg now 33,000kg from April 2022
Electric Light Vehicles	5,000L petrol	13,000kg

Source: Forest Lodge Orchard and CTQ Advisors

Electrification will avoid over 84t CO2-e a year

Forest Lodge will avoid over 84t CO2e a year compared to an equivalent fossil-fuelled operation by using electricity rather than diesel and petrol.

Electrification means Forest Lodge will emit no more than about 6.5t CO2-e a year from using power from the national electricity system.

Actual emissions will likely be less because Forest Lodge uses its solar and battery storage to lower its electricity costs by drawing on the grid when the spot price is low (when grid power likely has lower emissions) and using the sun when the spot price is high.

The 18.5kW electric irrigation pump was the start of the electrification process

Electrification of Forest Lodge started with an 18.5kW electric irrigation pump.

At the same time the network connection was upgraded from single-phase to three-phase and the nearby transformer was upgraded to 41kVA. The upgrade took 18 months from start to finish, with most of the time spent on paperwork and approvals, and cost $26,000 (split 50:50 with a neighbour).

The larger connection and transformer served double duty by supporting maximum export from the 23.1kW solar array on the orchard shed roof.

Electric pumps cost about the same to purchase and install as diesel pumps. The main difference in cost is electric pumps may need a larger network connection and internal electrical works, increasing the upfront cost compared to a diesel alternative.

The electric pump is cheaper to run at about $0.90 an hour when supported by the solar and battery storage and about $2.80 an hour at typical commercial retail electricity prices, compared to about $5.60 an hour for a diesel pump.

Forest Lodge is saving about $2,800 a year in operating costs by electrifying its irrigation.

An unexpected benefit of electric frost fighting is reduced crop loss and a more productive operation.

The much lower operating costs of the electric frost fans makes it cost-effective to turn the fans on earlier resulting in less fruit being damaged when it gets frosty.

Electric frost fighting is lower cost and may improve crop productivity

The two 30kW electric frost fans were imported from South Africa after an extensive global search provided a shortlist of one manufacturer.

The installed cost of $170,000 was nearly 20% more expensive than the conventional diesel-powered option, though some of this was due to it being the first ever installation in Aotearoa.

The electric frost fans required an additional upgrade to the transformer at the network connection from 41kVA to 138kVA, plus internal electrical works.

The total cost of upsizing the network connection was about $100,000, though just over half was for moving from single-phase to three-phase. Many agricultural operations will already have a three-phase connection, potentially reducing the cost of upsizing.

Internal electrical works cost a total of $40,000. These costs will always be site-specific

Forest Lodge is saving about $15,000 a year by electrifying its frost fighting, due to the electric frost fans being cheaper to operate than equivalent diesel fuelled fans.

Electric farm equipment and electric vehicles

As a producing cherry orchard, Forest Lodge needs an array of equipment and vehicles.

Currently the orchard uses a modified golf cart, an electric mower, assorted electric (farm-grade) gardening equipment and two electric light vehicles.

The electric equipment and farm vehicles cost about 35% more to purchase than the equivalent fossil-fuelled options.

The electric tractor coming in March 2022 will be about $115,000 versus $75,000 for the conventional diesel-fuelled equivalent. The tractor was sourced from Monarch Tractors in California after due diligence on electric tractors.

Operating costs for the farm equipment will be about $25,000 less than the equivalent fossil-fuelled options.

No differences in operating capability or performance have been observed when compared to the conventional farm equipment. Charging of the equipment and vehicles is managed through the same system that manages the solar and battery storage.

Solar and battery storage combined further reduce energy costs and provide option value for the local network operator

The 23.1kW solar array and 60kWh battery storage were installed to match energy needs of the orchard over a year.

The solar array can produce about 90kWh of power a day during the spring and summer and about 20kWh a day in the autumn and winter.[3]

The orchard can operate off-grid for a few hours. Going completely off-grid was not plausible because relying solely on solar and battery storage to power the orchard operations would require a much greater investment. And most importantly, with no grid connection, there would be no opportunity to gain additional value and revenue through services to the electricity system now and in the future.

The solar and battery system investment of $160,000, represents about 20% of the total cost of electrifying Forest Lodge. The solar and battery system investment provides two key benefits.

[3] The Forest Lodge solar array generated 28.43MWh in February 2021 and 7.5MWh during July 2021.

Forest Lodge uses the solar array and battery storage to minimise its energy costs

They do this by using solar or energy from the battery on-site when spot prices are high and drawing from the national electricity system when the spot price is low.

Forest Lodge has a stretch goal of timing energy import and export from the grid to produce a net zero energy bill for the year.

"When the spot price is under $0.15, we know that power is likely to be renewable and abundant. Likewise, when the spot price goes above $0.40, it's likely that coal and gas are being used to supplement supply at that time, and that there is a shortage of power available."

"We need to cover a $0.23 spread to break even on arbitrage. This takes into account battery wear and tear, power loss from inverting, and Contact Energy's cut on our export."

The solar array and battery storage provides Forest Lodge with flexibility to 'modify its generation and consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system'.

The Forest Lodge solar array and battery storage is well suited to providing flexibility services and happens to be in a location where Aurora is actively procuring flexibility services in the Upper Clutha and Wanaka area to defer network upgrades.

This flexibility service has value to the local network operator – Aurora - and to the wider power system.

The solar array and battery storage allow Forest Lodge to reduce its use of the network when Aurora says doing so would help avoid network costs.

The benefit for responding to the demand reduction signal from Aurora is a reduction to the demand-based component of the network charges paid by Forest Lodge.

By managing its use of the network at specific times, Aurora has set Forest Lodge a chargeable demand of 0.5kVA for the coming year compared to the 'standard' of 35.5kVA for an operation with equivalent electricity use. The ability to reduce the chargeable demand represents a reduction on the network charges paid by Forest Lodge of nearly $9000 a year.

More value is likely to be available in the future from the flexibility of the solar array and battery storage

Forest Lodge could have electrified without incurring the 'extra' capital investment in solar and battery storage.

By minimising the energy costs and reducing network costs, the solar with battery storage is expected to reduce annual operating costs by another $13,000 compared with pursuing a grid-only electrification.

Solar and battery storage will provide longer-term and as-yet realised value to network operators as mass electrification accelerates by providing flexibility on tap to use to defer or avoid extra network investment needed to cope with increased pressure on the network from electrification (particularly on the same feeder).

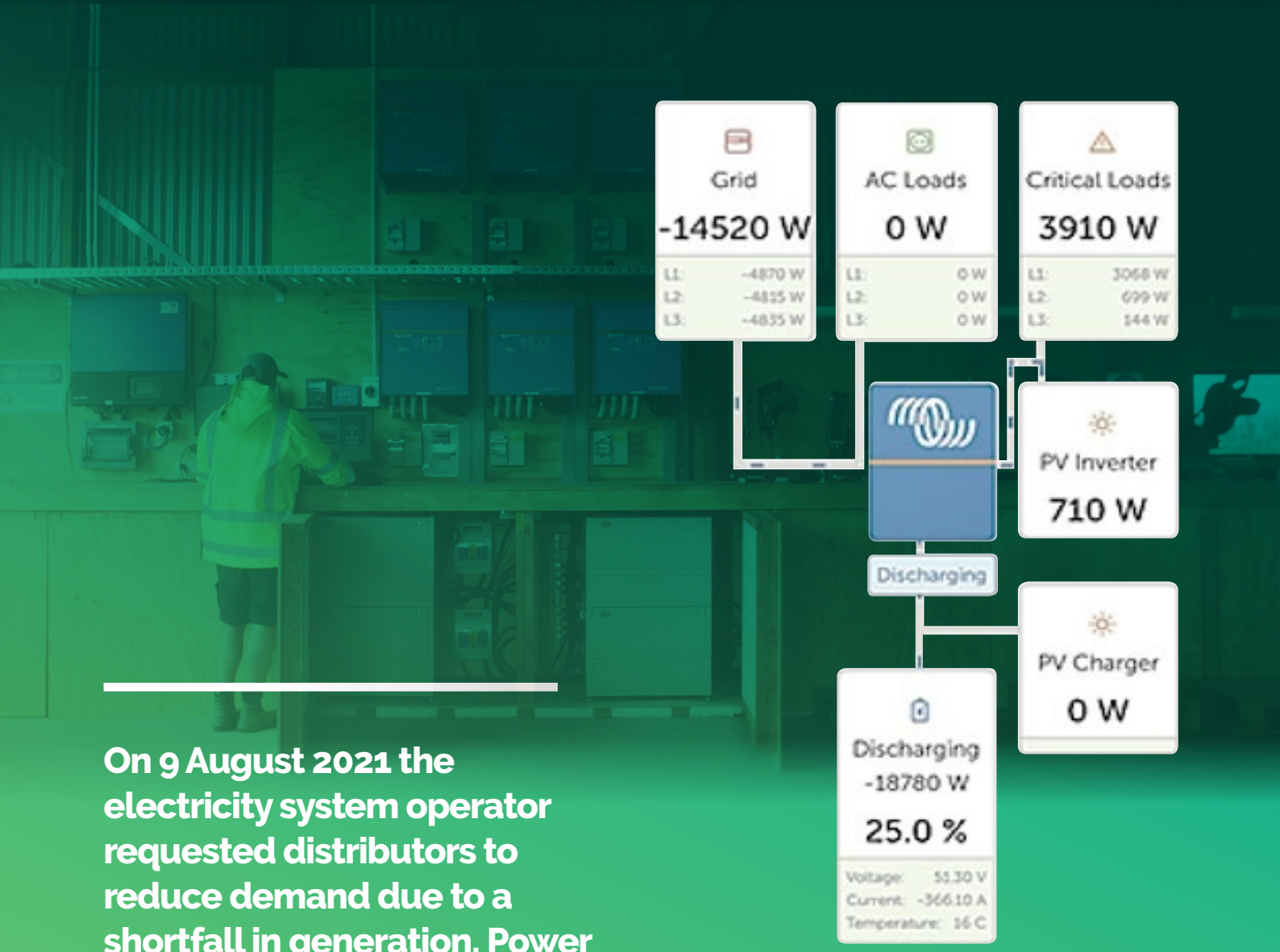
Solar and battery storage could be particularly valuable in rural areas where electricity is supplied by longer network circuits to small numbers of customers.

Having solar and battery storage in place will help to avoid higher network charges needed to pay for network upgrades as more economic activity and agricultural production electrifies.

From this perspective, investing in solar and battery storage as part of the electrification process will help to reduce the cost of electrification by avoiding or delaying major network upgrades to provide the capacity to support increased use of electricity in the future.

Electricity distribution and transmission network operators, along with the wider electricity sector, including government and regulators, need to make sure that as people and businesses electrify, they are encouraged to consider the longer-term benefits from investing in solar and battery storage so that flexibility capability is available to provide a resilient and reliable network service and defer or avoid network upgrades and higher network charges in the future.

The opportunity of flexibility – both available and missed – is suggested at in the response by Forest Lodge to the grid emergency on 9 August 2021.



On 9 August 2021 the electricity system operator requested distributors to reduce demand due to a shortfall in generation. Power was cut to about 35,000 homes.

Forest Lodge was able to export about 14kWh to the local network during the emergency – sufficient to supply about 3-4 homes.

"We believe it was our civic duty to export, and we could have exported much more if there had been a protocol in place to request us to do so. We believe that being available to support the grid at the right time and place should be financially rewarded in the same way generators are paid to generate power. DER could become a significant revenue stream for businesses and encourage more companies to install batteries and export capability."

Extra detail on how Forest Lodge uses the network

Extra detail on how Forest Lodge uses the network and the potential value to the network operator of the flexibility from the solar and battery storage is provided on page 16.

An off-the-shelf service is needed to support mass electrification

Electrification of Forest Lodge required considerable effort from the owner Mike Casey to package up several bespoke solutions. There was no off-the-shelf product or service available from the electricity sector or equipment manufacturers to maximise the value of electrification.

Forest Lodge has needed to source equipment, including bespoke fabrication and importing gear, work out how to adapt conventional farming practices, manage energy use and production to maximise value (ie, lower energy costs as much as possible), and find people to work with that could make it all happen.

Much of the equipment and technology integration was done in-house by Forest Lodge. The arbitrage between grid and solar power occurs via a self-written algorithm run using a RasberryPi which decides how much to export based on the spot price at the Cromwell grid export point.

Interactions with the electricity sector started with requesting a network connection which matched the expected electricity requirements of an electrified orchard.

The next step was finding a retailer. Simply Energy, a subsidiary of Contact Energy, now provides a bespoke retail service where customers buy power from the grid at the spot price and sell their power, for example when Forest Lodge has surplus solar power or chooses to discharge its battery.

Finding Simply Energy was not straightforward, requiring lots of ringing around to find an electricity retailer able and willing to do what Forest Lodge wanted.

Simply Energy is now working on adding an additional bespoke flexibility trading service. This would allow Forest Lodge to participate in the Aurora Upper Clutha Non-Network Alternative project which uses the flexibility services from distributed energy resources to defer network upgrades.

The lack of off-the-shelf services from the electricity sector means equipment suppliers and installers – particularly solar and battery suppliers – don't have the guidance or insight needed to design systems that maximise value for the customer.

Much of the equipment and technology integration was done in-house by Forest Lodge. The arbitrage between grid and solar power occurs via a self-written algorithm.

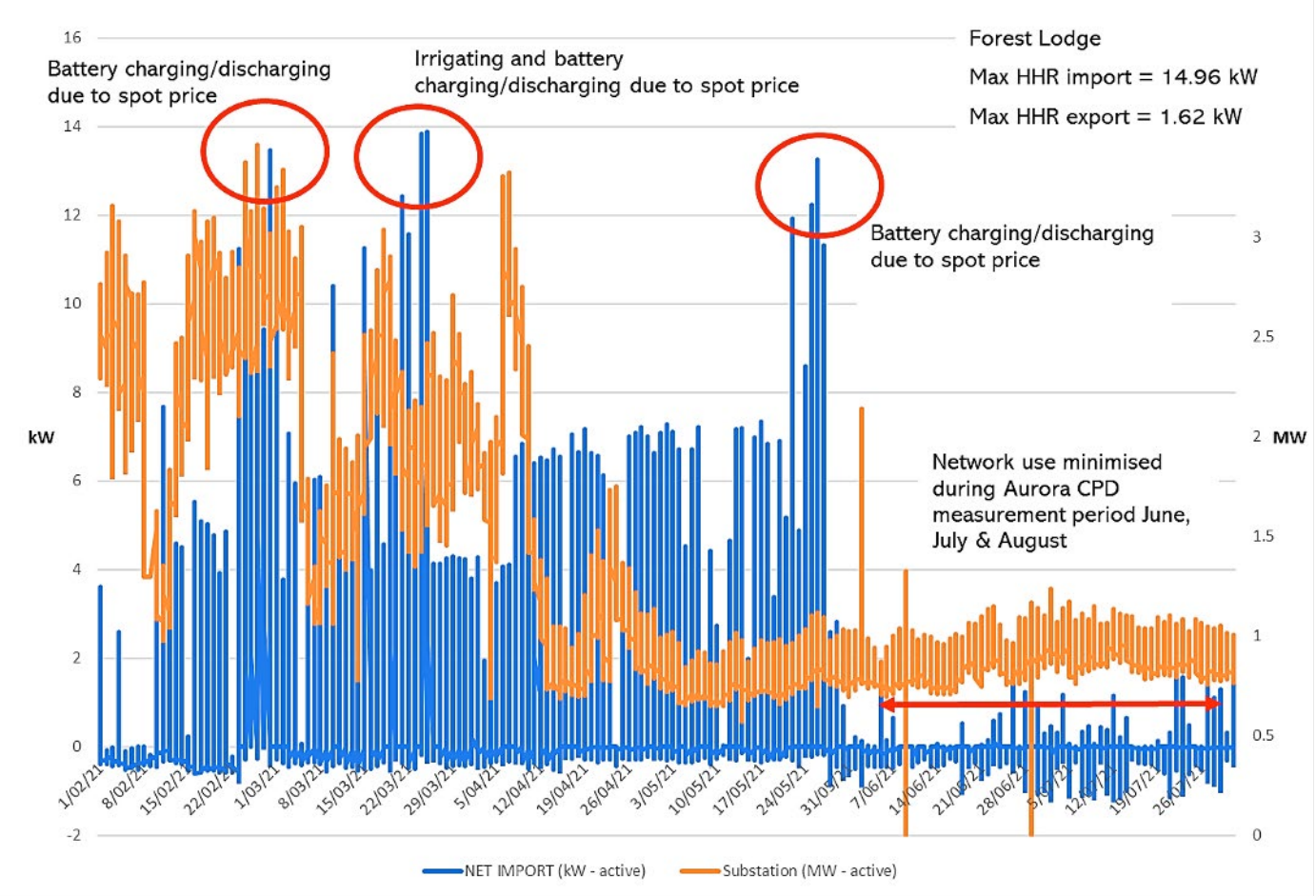
Extra detail on how Forest Lodge uses the network

Forest Lodge is connected via circuit QB2423 to the Queensbury substation and Cromwell grid exit point.

The Queensbury substation is summer peaking, along with the Lindis Crossing and Camphill (Hawea) substations, mainly due to irrigation. Aurora is observing localised summer peaking network congestion at the Queensbury and Lindis Crossing substations (these substations provide each other back-up). Aurora is observing emerging network congestion in the wider Upper Clutha region, mainly due to household space heating.

The Forest Lodge and Queensbury substation active power flows for each half hour between February and July 2021 are contrasted in the chart. The chart indicates Forest Lodge makes minimal use of the network during June and July, and by routinely exporting power probably helps to alleviate the winter congestion problem affecting the wider Upper Clutha area.

Forest Lodge Orchard & Queensbury substation profile 1 February 2021 to 31 July 2021



Additional detail on the electrification numbers

Annual Energy Costs

Conventional (fossil)	Electric (grid)	Electric (grid + solar/battery
$49,000	$20,000	$7,000

Source: Forest Lodge Orchard & CTQ Advisors. Note: All costs are exclusive of GST. Conventional (fossil) energy costs calculated based on 32,000 litres of diesel and petrol a year and a $1,000 network charge. Electric (grid) costs calculated based on 51,000kWh a year and a $12,500 network charge. Electric (grid + solar/battery) costs calculated based on the same power use and a $4000 network charge.

Capital costs

Conventional (fossil)	Electric (grid)	Electric (grid + solar/battery
$340,000	$630,000	$790,000

Source: Forest Lodge Orchard & CTQ Advisors. Note: All costs are exclusive of GST. Capital costs of Electric (grid) and Electric (grid + solar/battery) scenarios would reduce by $55,000 if Forest Lodge had started with a 3-phase connection.

Annual energy cost savings relative to incremental capital cost of electrification

	Electric (grid)	Electric (grid + solar/battery)
Current fossil fuel prices	9.7%	9.0%
Scenario: 15% increase to fossil fuel prices	12.1%	10.6%

Source: Forest Lodge Orchard & CTQ Advisors. Incremental capital cost of electrification calculated as the difference between the $790,000 capital costs of electrification (grid + solar/batter), the $630,000 capital costs grid-only electrification, and the $340,000 capital cost of the conventional (fossil) alternative, giving an incremental cost of electrification of $450,000 and $180,000 respectively. Current fossil fuel prices based MBIE fuel price monitoring data and assume an average price of $1.40L (ex GST) for diesel and $2.00L (ex GST) for petrol.

Annual carbon emissions (tonnes CO2-e)

Conventional (fossil)	Electric (grid)	Electric (grid + solar/battery
84t	6.5t	<6.5t

Source: Forest Lodge Orchard & CTQ Advisors. Note: CO2-e estimated using https://tools.genless.govt.nz/businesses/wood-energy-calculators/co2-emission-calculator/ based on 32,000 litres diesel and petrol a year for the Conventional scenario and 51,000kWh a year for the Electric (grid) scenario. No estimate is made of carbon emissions for the Electric (grid + solar/battery) scenario as it depends on the timing of use of the grid. Forest Lodge practice is to draw on the grid when the spot price is low (suggesting more renewable generation).

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