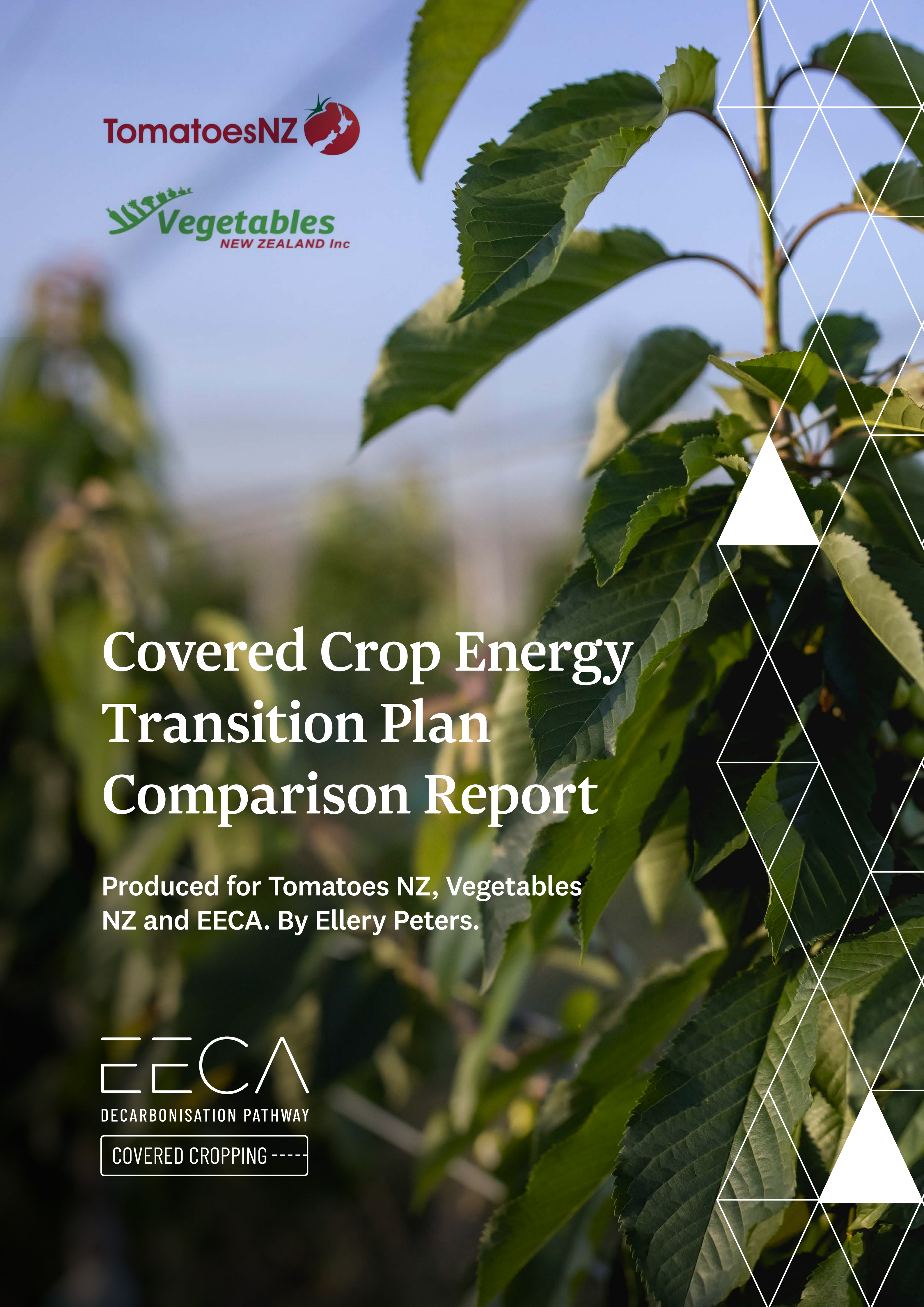

TomatoesNZ

Vegetables NEW ZEALAND Inc

Covered Crop Energy Transition Plan Comparison Report

Produced for Tomatoes NZ, Vegetables NZ and EECA. By Ellery Peters.

EECA

DECARBONISATION PATHWAY

COVERED CROPPING

Contents

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Executive Summary

This report compares six energy transition plans (ETPs) which were conducted for covered crop growers across New Zealand between 2022 and 2023. The key focus areas for these ETPs were the energy profiles, and demand reduction and fuel switching opportunities for growers.

Thermal energy profiles

The thermal energy profile of each site followed a very similar trend, with the highest energy use in the middle of winter with very little to no energy use during summer months. A breakdown of the energy profiles found that during peak energy demand of the winter months, four of the six boilers could be about half their size and still be able to provide the necessary heat. The remaining two boilers were found to be undersized due to being aging assets that had not grown with the expansion of the sites.

Demand reduction

The demand reduction opportunities discussed in the ETPs generally showed positive returns for certain growers and should be the first thing to consider when evaluating site efficiency. That said, certain demand reduction options should be considered on a site-by-site basis, as factors such as location, growing type, and site size can impact the overall return on investment.

- **Double skinned plastic greenhouses** are the best for heat loss; any greenhouses with single layer plastic skin should consider double-skinning as energy savings up to 60 percent can be achieved.
- **Thermal screens** provide high energy savings at a high capital cost. These provide the most payback in regions with colder climates.
- **Dehumidifiers** have greater return on investment for growers located in warmer, more humid climates in the North Island. They are also better suited to smaller sites due to the lower cost of infrastructure upgrades.
- **Distribution fans:** Distribution fans provided moderate savings at a low-cost to growers. These created a more even climate, reducing temperature stratification and risk of humidity related disease. The key for these was effective management to ensure they are being run as efficiently as possible.
- **Insulation:** Insulation is one of the best low-cost methods for reducing heat loss. Insulating any exposed hot water pipework outside the greenhouse will lead to energy savings.

It should be noted that hydroponic growers largely saw lower returns from the typical energy reduction methods. This is because hydroponics heat water which the produce sits in rather than heating the atmosphere like other growers. Hydroponic growers need to reduce heat loss from the water, which is done through smart insulation practices, rather than methods like dehumidifiers, screens and distribution fans.

Fuel switching

Four fuel switching options were discussed in the ETPs. The clearest take-away was that no fuel switching method was a one-sized-fits-all option. Most of the fuel switching opportunities were too expensive from either a capital or operational expense perspective except for coal to biomass conversions and heat pumps in certain contexts. Without price reductions or funding to help cover the cost of installing the new heat source or fuel, these options will be too cost-prohibitive for most growers in the current landscape. This may change over the course of the next few years due to the ETS price which is forecast to continue to increase over the coming years, and prices for alternative fuels may also begin to decrease as the infrastructure required to distribute these energy sources improves with improved availability.

- **Biomass boilers** of different types were discussed in each report as a common fuel switching option. For coal boilers, it was found that converting to wood pellets was the most cost-effective option for fuel switching. However, converting waste oil boilers to wood pellets was not as cost effective because of the extra investment needed to upgrade the fuel handling and storage infrastructure.
- **Electric boilers** were considered; however, the operating costs were generally too high to be feasible for the sites.
- **Air-source heat pumps** typically had low operating costs but high capital costs when compared to other methods. High capital costs were often due to the infrastructure upgrades that were required to get enough electricity on site. Heat pumps are generally more favourable for smaller sites. However, it is important to note that the cost assessments for a few of the sites appeared unreasonably high, so more investigation into these capital costs is needed.
- **Ground source heat pumps** have low operating costs, but typically the capital costs were very high which meant that the total cost of ownership was still too high. Another key issue for ground source heat pumps is a lack of research relating to geothermal mapping in New Zealand, which limits the ability to accurately price operating costs.

Introduction

This report compares key findings and recommendations from six ETPs conducted on six covered crop sites located in both the North and South Islands of New Zealand during 2022 and 2023. The key areas analysed in this report are the growers' energy profiles, emissions reduction opportunities and fuel switching opportunities. The growers involved in the studies grew crops such as tomatoes, capsicums, leafy greens, cucumbers, and chillies.

The purpose of this report is to summarise the key findings from the ETPs. These findings will then be used to help New Zealand cover crop growers understand the options that are available for reducing energy use and for fuel switching and make informed decisions about what to apply to their site.

Energy Profile Comparisons

In each ETP, the energy profiles of the businesses were analysed to fully understand:

- The fossil fuel used on site;
- How the energy is distributed across the year to identify the variance in usage;
- A cost evaluation of energy used on site; and
- The amount of carbon emissions emitted from th0e site.

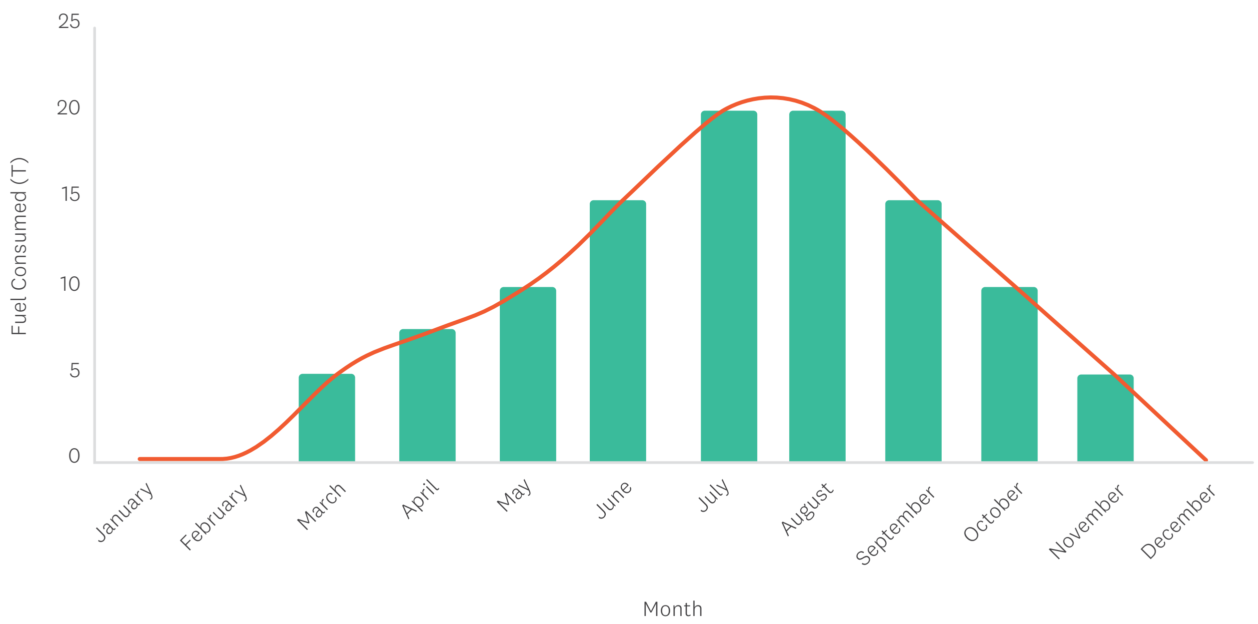
A summary of the findings of the six ETPs can be found in *Table 1* below.

Table 1: Summary of the energy profiles discussed in the six ETPs

Grower	Greenhouse Area (m^2)	Boiler Size (kW)	Maximum heat demand (kW)	Fuel Source	Carbon Emissions (TCO_2e/ year)	Region
1	1,600	130	240	Coal	49	Southland
2	5,000	634	336	LPG	195	Waikato
3	2,200	750	800	Coal	336	Otago
4	9,815	1,800	765	Waste Oil	520	Auckland
5	12,000	2,500	1,000	Coal	1,717	Canterbury
6	16,440	3,800	2,000	Waste oil	1,101	Canterbury

All growers have similar annual heating profiles, peaking in the middle of winter, with minimal to no use over the summer periods. This is consistent for every region and every crop type. The typical monthly energy profile is shown in *Figure 1* below. Note: this is a generic profile which has been developed to show the general trend and is not related to any specific case.

Figure 1: Graph of a typical yearly fossil fuel usage profile for a covered crop grower



In most cases, the boilers were found to be significantly oversized. When comparing the current boiler sizes to the actual peak energy demand used by the growers, the analysis found that the boiler size and output were considerably higher than what was required to meet peak demand. This is important when looking at fuel switching options available, as new equipment with higher output tends to come at a higher price. The peak energy demand can further be reduced by implementing the recommended energy reduction methods before fuel switching and would further reduce the capital costs involved with fuel switching.

Overall, a key finding for future energy assessments is knowing the peak heat demand required by the site to correctly size fuel switching methods. The costs for fuel switching can be estimated before and after energy reduction strategies to see how this affects the capital cost.

Demand Reduction Opportunities

The six ETPs highlighted several options for reducing emissions by lowering the energy usage of each site. These options ranged in price from $5,000 to $300,000 and the amount of energy savings generated fell anywhere from between two and 50 percent of the site's total energy bill. The different growing techniques demonstrated that there is not a one size fits all approach. A full breakdown of the different emission reduction opportunities is found in *Appendix 1*.

Thermal Screens

Thermal screens for covered cropping are agricultural technologies designed to regulate and control the temperature within greenhouse or covered growing environments. These screens are typically made from specialised materials that can either reflect, diffuse, or absorb sunlight and infrared radiation, helping to manage the internal climate of the growing area. *Table 2* (below) displays the different ETPs which explored thermal screens as an energy reduction method.

Table 2: table of the capital cost and operating costs of thermal screens in the various ETPs

Grower	Capital Cost ($)	Operating Savings ($/yr)	Energy Reduction (%)	Payback (yrs)
1	$130,000	1,669	13%	77.9
2	$200,000	24,989	26%	8.0
3	$50,000	4,975	26%	10.1
4	$260,878	17,996	6%	14.5
5	$244,860	24,989	30%	15

Thermal screens were commonly explored for energy reduction in greenhouses which did not have them installed already. Growers 2, 3 and 4 showed that it was possible to achieve a 26 to 30 percent reduction in fossil fuel usage by installing them. Although very good energy reduction is achieved from thermal screens, the ETPs highlight a long payback period which may be an obstacle for growers. The high upfront cost of around $200,000 would take on average over 10 years to pay back at the current cost of energy, with the lowest payback period being around eight years for Grower 2.

However, in practice, some growers in the South Island who have thermal screens installed have reported payback periods of between three to four years. Though these growers were not assessed in these ETPs, it suggests shorter payback periods are possible. These shorter periods are due to the screen providing both shading and heat to provide year-round efficiency gains.

Dehumidifiers

Dehumidifiers are specialised devices used in agricultural settings, particularly in greenhouses or indoor growing environments, to control and manage humidity levels. These devices are designed to extract excess moisture from the air, helping to create a balanced and optimal atmosphere for plant growth.

Other advantages of dehumidifiers are that they can improve crop health and energy efficiency by providing exhaust heating, reducing fungal disease, and boosting air circulation. The main disadvantages of dehumidifiers are that they can substantially increase site electricity costs and may require the site to undertake electrical infrastructure upgrades.

Three ETPs highlighted the great benefits of dehumidifiers. However, these benefits were better realised for North Island growers rather than those of the South Island. This was due to greater energy savings in areas with higher humidity, with North Island growers seeing a 36 percent reduction compared to six percent for South Island growers. The three growers where dehumidifiers are recommended are shown in *Table 3* below.

Table 3: Financial information of the dehumidifiers recommended in the various ETPs

Grower	Capital Cost ($)	Operating Savings ($/yr)	Energy Reduction (%)	Payback (yrs)
2	$356,100	$47,481	34%	7.5
4	$533,292	$59,649	36%	8.9
6	$583,000	$15,000	8%	38.9

The capital cost for dehumidifiers was the highest of the emission reduction opportunities provided in the ETPs. For example, Growers 4 and 6 had 9,800m² to 16,000m² of greenhouses, this cost between $500,000 and $600,000 to install dehumidifiers into these greenhouses. The key barrier for this technology was the long payback periods paired with the expected product lifespan of 10 years.

The ETPs estimated for a South Island grower the payback period would be 39 years, and for two North Island growers a period of seven to eight years, both of which are too high to be feasible. However, it is worth noting that Drygair, the manufacturer of the dehumidifiers, suggests a two to four year payback, while other analysis of a site in Auckland provided a payback of three to six years which indicated the estimates in the ETPs may be too conservative.

Based on the reports it is difficult to justify dehumidifiers for larger sites because of the high additional costs. The most suitable sites would be around the 2,000 to 5,000m² in size, as they would only need one to three dehumidifiers. This is approximately one dehumidifier per 1,500m², but varies from site to site.

In the right context, dehumidifiers can provide moderate energy reductions for small to medium sites in warmer climates, such as the upper North Island. Dehumidifiers can become a financially attractive demand reduction option because of their energy savings and the additional advantages creating a healthier, more productive crop. These cost savings haven't considered other plant health factors such as reduction in infection (and thus better yield) that dehumidifiers provide, so realistically growers may see greater cost savings.

Distributions fans

Distribution fans are vertical or horizontal fans which are used to circulate air throughout a greenhouse to promote uniform air movement and temperature distribution within a greenhouse.

A good option for growers was air distribution fans. The capital cost for air distribution fans ranges from $4,000 to $10,000 for greenhouses from 1600m² to 3500m² in size.[1] This is shown in table 4 below.

Table 4: Financial Information of air distribution fans identified in the various ETPs

Grower	Capital Cost ($)	Operating Savings ($/yr)	Energy Reduction (%)	Payback (yrs)
1	$7,000	-$1,292	7%	N/A
3	$4,315	$401	8%	10.8
5	$10,000	$13,000	9%	0.8

If the heating system is set up to encourage temperature stratification[2], it is highly recommended air distribution fans are considered as they will:

- improve the consistency of the temperature throughout the greenhouse;
- drive moisture away from plants;
- eliminate cold/damp spots; and
- reduce the need for ventilation, improving CO_2 retention.

1 All prices for equipment in this report were found in 2022, please note these may have changed at the time of reading.
2 Radiative pipework not located on the bottom of the greenhouse or hot air blowers blowing air above the plant line.

These disadvantages mainly revolve around the ability to help keep the plants healthy and limiting bacterial/fungal infections in the plant. It should be noted that savings could also be generated through a reduction in lost crop; this cost saving hasn't been accounted for and if it is something growers struggle with then air distribution fans should be considered.

It is important to note that air distribution fans increase electrical operating costs and the savings obtained are dependent on how the heating system is set up. Effective management of fans are crucial to ensure that savings outweigh the cost of operation. Effective management varies between sites, but this means being smart when using your distribution fans to get maximum return, such as only running them during heating periods and when humidity is high to get an even distribution of heat and an even climate to reduce micro-climates.

Other options

The ETPs also recommended other minor changes for reducing energy demand. These included process changes to use heat more efficiently and insulating practices and for multiple sites, offered great return on investment.

Insulation was recommended for multiple different sites. Insulating bare pipes, boilers and other areas that leak heat is one of the first options to combat heat loss. Insulation is relatively cheap and provides good savings. One site looking to insulate 215 metres of large diameter pipework had a capital cost of $21,000 with operational savings of $5,000 providing a payback period of just over four years.

Other options to reduce heat loss centred on limiting the heat lost through the greenhouse walls. The ETPs highlighted that greenhouse materials have a notable impact on how much heat is lost through the walls. Double skinned plastic was almost always recommended because of the excellent insulation properties. Though expensive, re-skinning greenhouses can provide significant savings. In one example for Grower 4, the price for a 9000m2 total area is around $315,000 with energy savings of around $44,000.

Redirecting pipework was suggested to use heating more efficiently. This was a unique solution for a specific site which had its heating pipes about mid-height up the plant and around the walls of the greenhouse. By redirecting the pipework directly underneath the plants, the heat will be applied more directly to the plants. This meant that less heat will be used to heat the surrounding air instead of the plant itself, and allows the heat to be used more efficiently with a great return on investment. For example, from the site analyses of Grower 6 it would cost $5,000 to redirect the pipework to the preferred solution and it would generate $6,000 in savings every year.

Fuel Switching Opportunities

Each report provided similar options for fuel switching methods. The options discussed were:

1. Biomass boilers (both conversions and new installation)
2. Electric boilers
3. Air source heat pumps
4. Ground source heat pumps

The ETPs determined the peak heat demand required for each site, this was then used to size the fuel switching method exactly to what the site demanded. It is important to note that they did not consider the impact of energy reduction methods on the size of the required fuel switching option in their calculations. If energy reduction steps were taken before fuel switching, the peak energy demand would be reduced allowing for much lower fuel switching costs.

A comparison of the fuel switching opportunities across the six sites can be found in *Appendix 2*.

Biomass boilers

Biomass boilers are a type of renewable energy technology that uses plant-based materials, typically wood, to generate industrial heat. Switching to a biomass boiler has many advantages such as:

- Environmentally friendly, carbon neutral source of fuel for heat, which means it's not captured under the NZ ETS.
- Reduces ash waste significantly, and the ash produced is biodegradable meaning it can be disposed of outside in any garden setting. The ash produced is 10 times less than what coal produces.
- Cleaner air quality from burning biomass. No heavy metals or other contaminants are released from biomass, the only contaminant which needs to be managed is particulate matter which can simply be filtered out.

Each ETP discussed a range of different biomass boilers options and considered fuel type (wood pellet, kiln dried wood chip) and whether it was more beneficial to convert the current boiler or purchase a new one.

This section highlights that:

- **Converting from coal to biomass is the cheapest option**, though this typically comes with higher operational costs because of the increased volumes of wood that would be required compared to coal.
- **Waste oil boilers are much more expensive to convert to biomass** because of the extra steps required.
- **New wood pellet boilers are typically the cheapest new biomass boiler**, at the current cost of wood pellets compared to coal they still show higher operational cost, this will change as units under the NZ ETS increase in price.
- **For larger sites, wood chip is recommended** because of the lower operational costs achieved.

Boiler conversion

The conversion of the coal boilers all recommended wood pellets or kiln dried wood chip (12 percent moisture content) to ensure the boiler would produce enough energy for the site.

The coal conversions ranged in price from $250,000 for Grower 3 (750kW) to around $400,000 for a Grower 5 (2500 kW). Grower 5's ETP showed that converting the boiler to use kiln dried wood chip cost about $50,000 more than converting to use wood pellet for the same 2.5MW boiler. Converting to kiln dried woodchip was the only option which had a positive net present value because over the course of its lifetime the savings from the reduction in operating costs would have paid back the capital cost of the piece of equipment and will be continue generating savings beyond this point as it is cheaper to run than coal.

The conversion of Grower 6's waste oil boiler to wood chip was discussed, though the capital cost for this was significantly higher being priced at $2.1 million for a 3800 kW boiler. The higher costs for waste oil conversions are due to the extra fuel handling equipment that needs to be installed, as coal conversions can use the existing fuel handling equipment.

Table 5: Financial information of the boiler conversions discussed in the ETPs

Fuel Switching Opportunity	Grower	Capital cost ($)	Operating Costs ($)	NPV ($)
Convert existing coal boiler to use wood pellet fuel (10-15%)	3	$253,144.00	-$36,050.00	-$304,000.00
	5	$337,000.00	-$81,755.00	-$652,000.00
Convert existing coal boiler to use kiln dried wood chip (12% moisture)	5	$394,000.00	$541.00	$120,000.00
Convert existing boiler to use wood chip (30% moisture)	6	$2,114,000.00	$4,000.00	-$1,079,000

Although these conversions had the lowest capital cost, the financial analysis was still quite unfavourable for most of them providing a negative net present value (NPV)[3], the lowest being

-$300,000. The low payback was because most of the boilers were either near or at their end of asset life illustrating the importance of timing in equipment conversion and replacement.

Only one conversion achieved a positive NPV which was the use of kiln dried woodchip. However, this was ruled out due to the lack of access to a supply of kiln dried woodchip as fuel source.

3 Net Present Value describes what the value of the asset will be in the future, basically what this means is that a positive NPV means you will obtain savings from the new asset, while a negative NPV means the asset will not recoup its initial investment.

New boiler installation

Installing new off-the-shelf wood pellet boilers was suggested at four of the sites. However, these also presented negative NPV for growers due to an increase in operational cost. For boilers sized between 240kW and 800kW the capital cost was between $350,000 and $900,000.

Table 6: Financial information of new biomass boilers discussed in the ETPs

Fuel Switching Opportunity	Grower	Capital cost ($)	Operating Costs ($)	NPV ($)
Install new wood Pellet Boiler	1	$350,000.00	-$3,194.00	-$323,200.00
	2	$630,602.00	-$14,957.00	-$358,561.00
	3	$703,548.00	-$27,338.00	-$317,300.00
	4	$892,509.00	-$46,218.00	-$1,501,406.00
Install new wood chip boiler	3	$775,544.00	-$12,564.00	-$437,700.00
	5	$1,113,000.00	$64,723.00	$191,000.00
	6	$2,911,000.00	$70,000.00	-$1,845,000

When comparing Growers 3 and 4, both were recommended new wood pellet boilers of roughly the same size (765 kW compared to 800 kW). When the costing for the new wood pellet boilers was provided for these sites, Grower 4's boiler was almost $200,000 more expensive. This is an example of how significantly prices for fuel switching can vary between sites due to the difference in infrastructure that can be required. Storage requirements, new foundations for the storage facility and electrical upgrades for the boiler system are just a few examples of things which can affect cost.

New woodchip boilers were proposed for three sites. For the larger sites (Growers 5 and 6) using woodchip provided a reduction in operating costs when compared to coal and waste oil. However, for Grower 3 woodchips were more expensive than coal. The capital cost for the new woodchip boilers ranged from $775,500 for the smallest wood chip boiler to upwards of $2,911,000 for the most expensive.

Overall, for larger sites such as Growers 5 and 6 with boilers larger than 2,000 kW, wood chip was recommended because of the lower operating costs that would be achieved. This is because the large volumes required for big sites benefit from the lower operating costs obtained by wood chip when compared to smaller sites which need lower volumes so they see better operating costs from utilising wood pellets which have a lower volume requirement but higher operating costs. Wood pellet boilers are cheaper; however, they still produce lower savings than simply continuing to use coal because of the higher fuel cost of wood pellets.

As the price of coal continues to rise due to the increasing carbon price on the New Zealand Emissions Trading Scheme (ETS), wood pellets will become a better option for the small to medium growers because of their simpler management, lower storage requirements and a lower capital cost. For wood pellets to become viable at the current price the price of carbon would need to reach around $100/tonne.

Electric boilers

Electric boilers use electricity to heat water directly. This is normally through a heating element, typically made of resistance wires or heating rods. An electrical current will pass through these elements which generates heat through electrical resistance. This heat passes to water surrounding the heating element. The advantages of an electric boiler are:

- They are very compact and space-efficient;
- They are modular in design, this means they can operate anywhere from 10% to 100% at high efficiencies and multiple units can be installed in parallel easily to meet higher heating demands;
- They have no emissions related to the boiler unit itself;
- They are typically very safe and have very low maintenance costs.

Electric boilers of varying sizes were discussed in four of the ETPs. In every ETP, electric boilers were deemed as being too expensive from both a capital and operation cost perspective. The high capital cost was due to significant infrastructure upgrades being required to supply enough electricity to power the boilers, which would not be feasible for most sites. A basis for the capital cost of electricity infrastructure upgrades is around $1000/kW of upgraded infrastructure, meaning a 500kW increase in electricity demand could mean a $500,000 capital cost increase. This is extremely site dependant though and needs to be investigated with an electrician and the regional electricity provider to get accurate values.

From an operational perspective, these costs were too high due to electric boilers being unable to achieve the high enough heating efficiency compared to other technologies such as heat pumps. Although electric boilers are generally 99 percent efficient at converting electricity into heat, air source heat pumps can get two to three times more heat out of the electricity they use. Even in their own right, electric boilers are operationally too expensive due to the comparatively high cost of electricity. *Table* 7 (below) highlights the financial information of the electric boilers discussed in ETPs.

Table 7: Financial information of electric boilers identified in the ETPs

Fuel Switching Opportunity	Grower	Capital cost ($)	Operating Costs ($)	NPV ($)
New Electric Boiler	1	$230,000.00	-$2,860.00	-$246,500.00
	3	$430,560.00	-$19,723.00	-$545,400.00
	4	$1,035,318.00	-$310,363.00	-$5,360,260.00
	6	$3,626,000.00	-$250,000.00	-$10,430,000.00

Air-source heat pumps

Air source heat pumps are heating and cooling systems which use the atmosphere to efficiently transfer heat between the outdoor and indoor environments. They do this by extracting heat from the outside air (even when it is cold) and transfer it inside to be used for heating, the heat is extracted using a special type of refrigerant which has properties that allow it to become a gas below 0°C making it able to extract heat from very low outside temperatures once compressed using a compressor (which is what the electricity is needed for). This is also what makes air source heat pumps so efficient because the heat isn't being created directly by electricity, it is being taken from the air instead.

Air-source heat pumps have a coefficient of performance (COP)[4] of two to three which makes them an efficient means of space heating for covered crop growers. Other advantages of air source heat pumps are that they are very clean and easy to run, and they are able to be used for cooling.

Due to these advantages, air source heat pumps were discussed in five of the six ETPS. In three of the ETPs, the operating costs were lower than current fuel costs. For Grower 5 (who has a heating demand of 1,100kW) the operating savings were estimated at $70,000, while for Grower 2's smaller system at 336kW the operating savings were $43,000. However, the favourable operating costs were not enough to offset the high capital cost. Only one ETP provided a positive NPV for this technology. Like electric boilers, there is a high cost to upgrade electrical infrastructure to get sufficient electricity on site. Although air-source heat pumps have a lower electricity demand due to their high efficiency, the cost of these upgrades is still prohibitive.

4 Coefficient of performance is a measure of how efficient a heat pump system is, a COP of 3 means that for every 1kW of electricity used by a heat pump, 3kW of heat will be generated by it.

Overall, air source heat pumps are a solution which could be viable for a large range of sites. This is because of their ability to obtain very low operating costs, which will remain consistently low for growers when compared to biomass and coal, as these fuels have the capacity to fluctuate significantly. If the capital cost of air source heat pumps can be reduced through funding or some other means, air source heat pumps should be considered as a viable option for fuel switching. It should be noted that the capital cost for some of these sites seemed unreasonably high, so more investigation would need to be conducted if pursuing air source heat pumps because of the need to keep the capital cost lower.

Table 8: Financial information of Air source heat pumps identified in the ETP's

Fuel Switching Opportunity	Grower	Capital cost ($)	Operating Costs ($)	NPV ($)
Air Source Heat Pump	1	$980,000.00	-$2,279.00	-$938,400.00
	2	$504,566.00	$43,084.00	$138,808.00
	3	$1,768,700.00	$12,904.00	-$1,160,300.00
	4	$1,050,400.00	-$51,993.00	-$1,733,171.00
	5	$2,215,000.00	$69,484.00	-$616,000.00

Ground Source heat pumps

Ground source heat pumps operate in a very similar way to air source heat pumps, the main difference being that they use the ground as the main heat source rather than the atmosphere. The principle is still the same, a refrigerant with a low boiling point is cycled through a pipeline which takes heat from the ground and is compressed to high temperatures to be used in a greenhouse. The advantages of ground source heat pumps are the same as air source heat pumps, just with a significantly higher efficiency (discussed further below) and significantly higher capital costs. They also have a reasonable amount of longevity compared to other heat pump systems, meaning they can take advantage of the low operating costs.

The analysis of ground-source heat pumps found similar conclusions to air-source heat pumps whereby they offered low operating costs but significantly higher capital cost. Overall, with the exception of Grower 2, the NPV of the installation of ground source heat pumps meant that they were cost prohibitive. In the case of Grower 2, it was feasible due to the more reasonable capital cost of $654,566, so even though initially the operating costs were greater than if the grower continued with fossil fuel, in the next few years that would change as the price of fossil fuel increased while electricity stayed the same. This means the ground source heat pump would begin to make savings which would pay off the capital cost within a reasonable time frame.

Table 9: Ground Source heat pump financial information pulled from the ETP's

Fuel Switching Opportunity	Grower	Capital cost ($)	Operating Costs ($)	NPV ($)
Ground Source Heat Pump	1	$1,510,000.00	$3,406	-$1,388,900.00
	2	$654,566.00	-$55,567.00	175,394.00
	5	$2,689,000.00	$93,340.00	-$606,000.00
	6	$4,602,000.00	-$6,000	-8,110,000.00

Using the ground as a heat source offers a greater COP of between five and seven because of their ability to use the ground or a surrounding body of water as a heat source, which generally remains at higher temperatures than the atmosphere. Thus, the operating cost would be very low when compared to other traditional forms of heating.

A key consideration is that ground-source heat pumps currently suffer from a lack of research in New Zealand which hinders the ability for accurate pricing. The cause of the inaccurate pricing is that the cost will vary depending on the location and the understanding of the geology surrounding the site. Low temperature resources are not well mapped in New Zealand and therefore accurate mapping of geothermal hotspots is required to give a better understanding of the application of ground-source heat pumps.

GNS Science have the tools available to progress with widespread mapping, but currently lack the funding to continue with this research. GNS and Vegetables New Zealand are currenlty collaborating in a two-year plan aimed at obtaining funding to develop ground-source heat pumps as a more widespread technology.

Appendix 1

Comparison of the demand reduction opportunities found in the six energy transition plans

Demand Reduction Opportunity	Heating Type	Capital cost ($)	Operating Savings ($)	Carbon Emissions Reduction (t/yr)	Simple Payback (yr)	MAC ($/$tCO_2$e)
Improve air distribution by installing air distribution fans	Radiative Pipework	$10,000.00	$13,000.00	128	0.8	-$6.00
	Radiative Pipework	$4,315.00	$401.00	26	10.8	$21.00
	Heating Nutrient Tanks	$7,000.00	-$1,292.00	4	N/A	$303.00
Insulation	Radiative Pipework	$209,000.00	$37,000.00	197	5.6	-$26.00
	Radiative Pipework	$2,288.00	$105.00	1	21.8	$81.00
Install modulating control	Radiative Pipework	$138,000.00	$16,000.00	85	8.6	$22.00
Install a hot water buffer tank	Radiative Pipework	$133,000	$10,639	13	41.2	$191.00
Install Thermal screens	Radiative Pipework	$50,000.00	$4,975.00	44	10.1	$14.00
	Heating Nutrient Tanks	$130,000.00	$1,669.00	15	77.9	$398.00
	Radiative Pipework	$260,878.00	$17,996.00	134.1	14.5	-$2.00
	Radiative Pipework	$244,860.00	$16,838.00	89	15	$170.00
	Hot Air Blowers	$200,000.00	$24,989.00	54	8.0	$-124.00
Install dehumidifiers	Hot Air Blowers	$356,100.00	$47,481	62	7.5	-$222.00
	Radiative Pipework	$583,000	$15,000	115	38.9	-$71.00
	Radiative Pipework	$533,292.00	$59,649.00	115	8.9	$108.00
Redirect pipework for better heating of crops	Radiative Pipework	$5,000.00	$6,000.00	22	0.8	-$152
LED Upgrades	Radiative Pipework	$11,000.00	$4,000.00	N/A	2.8	N/A
Reduce infiltration	Radiative Pipework	$10,000.00	$4,000.00	14	2.5	-$133
Heat Loss Through Greenhouse Walls	Radiative Pipework	$316,682.00	$43,943.00	327.4	7.2	-$39
Heat Loss Through water circulating pumps and greenhouse walls	Radiative Pipework	Low	Low	1-2%		
Heat Loss Through broken greenhouse walls	Radiative Pipework	Low	Low	1-2%		

Note: Current figures may vary from what is shown above, this is because these were conducted in 2022 and no changes have been made in relation to rising costs and prices

Appendix 2

Comparison of the fuel switching opportunities found in the six energy transition plans

Fuel Switching Opportunity	Heating Type	Boiler Size by Consultant	Capital cost ($)	Operating Costs ($)	NPV ($)
Convert existing coal boiler to use wood pellet fuel (10-15%)	Radiative Pipework	2.5 MW	$337,000.00	-$81,755.00	-$652,000.00
	Radiative Pipework	750 kW	$253,144.00	-$36,050.00	-$304,000.00
Convert existing coal boiler to use kiln dried wood chip (12% moisture)	Radiative Pipework	2.5 MW	$394,000.00	$541.00	$120,000.00
Convert existing boiler to use wood chip (30% moisture)	Radiative Pipework	3.8 MW	$2,114,000.00	$4,000.00	-$1,079,000
Install new wood Pellet Boiler	Radiative Pipework	240 kW	$350,000.00	-$3,194.00	-$323,200.00
	Hot Air Blowers	336 kW	$630,602.00	-$14,957.00	-$358,561.00
	Radiative Pipework	3x256 kW Boilers	$892,509.00	-$46,218.00	-$1,501,406.00
	Radiative Pipework	800 kW	$703,548.00	-$27,338.00	-$317,300.00
Install new wood chip boiler	Radiative Pipework	800-1100 MW	$1,113,000.00	$64,723.00	$191,000.00
	Radiative/Hot air	2 x 0.9MW boilers	$2,911,000.00	$70,000.00	-$1,845,000
	Radiative Pipework	800 kW	$775,544.00	-$12,564.00	-$437,700.00
Install new electric boiler	Radiative Pipework/Air Blower	2 MW	$3,623,000.00	-$250,000.00	-$6,499,000.00
	Radiative Pipework	800 kW	$430,560.00	-$19,723.00	-$545,400.00
	Radiative Pipework	765 kW	$1,035,318.00	-$310,363.00	-$5,360,260.00
	Heating Nutrient Tanks	240 kW	$230,000.00	-$2,860.00	-$246,500.00
Air-Source Heat pump	Radiative Pipework	800 kW	$1,768,700.00	$12,904.00	-$1,160,300.00
	Heating Nutrient Tanks	240 kW	$980,000.00	-$2,279.00	-$938,400.00
	Radiative Pipework	800-1100 MW	$2,215,000.00	$69,484.00	-$616,000.00
	Radiative Pipework	732.2 kW	$1,050,400.00	-$51,993.00	-$1,733,171.00
	Hot Air Blowers	336 kW	$504,566.00	$43,084.00	$138,808.00
Ground-source heat pump	Hot Air Blowers	336 kW	$654,566.00	-$55,567.00	$175,394.00
	Radiative Pipework	2 MW	$4,602,000.00	-$6,000.00	-$4,180,000.00
	Radiative Pipework	800-1100 MW	$2,689,000.00	$93,340.00	-$606,000.00
	Heating Nutrient Tanks	240 kW	$1,510,000.00	$3,406.00	-$1,388,900.00

Note: Current figures may vary from what is shown above, this is because these were conducted in 2022 and no changes have been made in relation to rising costs and prices