Wood chip heating for a University Hall of Residence

Carrington College, University of Otago, Dunedin

Extended Case Study 7

ABSTRACT

An examination of the deployment of twin small-scale wood chip boilers to heat a University Hall of Residence, the Business Case, and the experience so far.

CONTENTS

1. BACKGROUND

The University of Otago has been blazing the trail for modern wood boilers in New Zealand for more than a decade now. Their energy manager, Hans Pietsch, is German, and when he arrived in New Zealand he saw the potential to use wood as a heating fuel for commercial buildings.

Hans has embarked on a progressive conversion programme, with three core objectives; clean air, low running costs and sustainability. The latest conversion from fossil fuels has been Jenkins House, an 83-bed residential hall of Carrington College.

From coal to what ?

Fig. 1: The 83 bedroom Jenkins House (part of Carrington College) now heated by wood chip.

Jenkins House had been heated primarily using a 330kW Hamilton Heatpack coal boiler closing in on its 40th birthday, backed up with an old diesel boiler, and both boilers were approaching end-of-life. Coal would not be considered as a replacement due to air quality issues, and the concern of an ever-rising carbon price.

The University already had New Zealand's largest fleet of wood boilers in the country (twelve, ranging in size from 20kW up to 1100kW) and so wood energy was already a well-understood and trusted solution. The question was how the extra cost of modern wood boiler equipment could be justified for Carrington, especially when compared to the significantly lower cost equipment needed for LPG, electricity or diesel. The case was not helped by the fact that the sustainability and the low-carbon merits of wood energy only recently gained more weight in the University's purchasing criteria.

2. THE BUSINESS CASE

Wood chip as a heating fuel has a much lower running cost than diesel, LPG, and electricity, but the high capital required for the wood-based system always represents a challenge for decision makers, especially finance managers. The holders of the purse-strings may be bound to operate within certain strict criteria, such as a three year payback, without any recognition that the asset may last ten times that, or attaching any value to sustainability.

The University has a Sustainability Framework that commits it to becoming 100% renewable in regards to energy consumption by 2030, but this was not introduced until 2017, so the sustainability merits of wood energy did not greatly influence the decision. At the time of the procurement decision in late 2015 National were in power, and looking well set for another term, and the price of carbon was below $10/Tonne.

So the business case needed to be strong to justify significant extra up-front costs, although ideally the 'soft' benefits should also be attributed some value. Hans and his off-sider, Mark Mason, began their analysis.

a. Wood boiler sizing

With wood boilers, **it is crucial to get the boiler sizing right**. The over-sizing that is common and acceptable in other boiler types will have a **disproportionately large negative impact on the capital, operational cost and longevity of a wood boiler**. So Step One with any potential wood boiler project is to verify the correct wood boiler sizing, and only then can any cost comparisons can be made.

Whereas fossil fuel boilers can easily turn on and off, wood boilers, though fully automatic, are not so well suited to this as they have a lot of refractory lining to enable them to combust the wood fuel which may be 20-35% water – or even up to 60% water in some wood fuels used in other boiler types. So it is best to try to **aim for continuous operation so the refractory lining can be kept hot** in order to perform its role optimally. This allows complete combustion (so minimises particulate emissions) and also reduces running costs by using less fuel, as it allows the wood boiler **to achieve better efficiency**. The refractory is also likely to last longer if not expanding and contracting excessively. Most coal boilers do not have much refractory (if any – see below) so this is not a problem.

Fig. 2: A cut-away of a Hamilton Heatpack coal boiler – there is very little refractory

Despite several over-sizing examples around New Zealand, it is still common for engineering consultants to be overly cautious, and this continues to result in wood boilers being incorrectly specified in Tender documents. This has resulted in sub-optimal performance at various high-profile sites. If the wood boiler is **in a hot water application**, **an accumulator tank should always be used** as it not only helps to smooth the load to prevent on/off cycling, but it also helps to meet peak loads which allows the boiler size to be minimised.

Another reason to try to prevent excessive on/off cycling is **to prevent the flue gases from cooling below the dew point** as they can be laden with chlorine from the wood. This can re-combine with the condensing water vapour to form hydrochloric acid on the heat exchange surface. This is also the reason that **wood boilers should always have a minimum return temperature** – to prevent condensation inside the boiler tubes. See section 3a, and Daring 4 for more detail.

The University's energy management team understand the importance of wood boiler sizing very, so conducted detailed modelling to identify the peak and average load of the building. The last three years of actual coal consumption at the hall were used. They concluded that the peak load was around 140kW.

With the new system destined to be the only heat source for 83 residents, reliability was paramount, so it was decided that a twin boiler system was the optimum way to go, and that **2 x 120kW boilers coupled to 3000 litres of accumulator tank capacity would be the optimal balance** between sizing and back-up.

An **alternative strategy to a twin wood boiler system** is to install a single wood boiler (plus buffer tank) to meet the majority or all of the load (just) and use a diesel or LPG boiler to meet the peaks if required, and to act as a back-up. This plays nicely to the relative strengths of wood energy (low variable cost) and LPG/diesel (low cost boilers). See the Extended Case Study 1 regarding West Otago Health's Tapanui Medical Centre for a good example of this. There are several other sites around New Zealand that have this arrangement, such as Invercargill's Splash Palace (840kW chip plus 600kW diesel), the Universities own College of Education (1100kW chip plus 400kW LPG) and Dunstan Hospital (500kW chip and 400kW diesel). Otago Polytechnic have deployed a twin boiler system at their Forth Street Energy centre (2 x 650kW coupled to a 15000litre buffer tank).

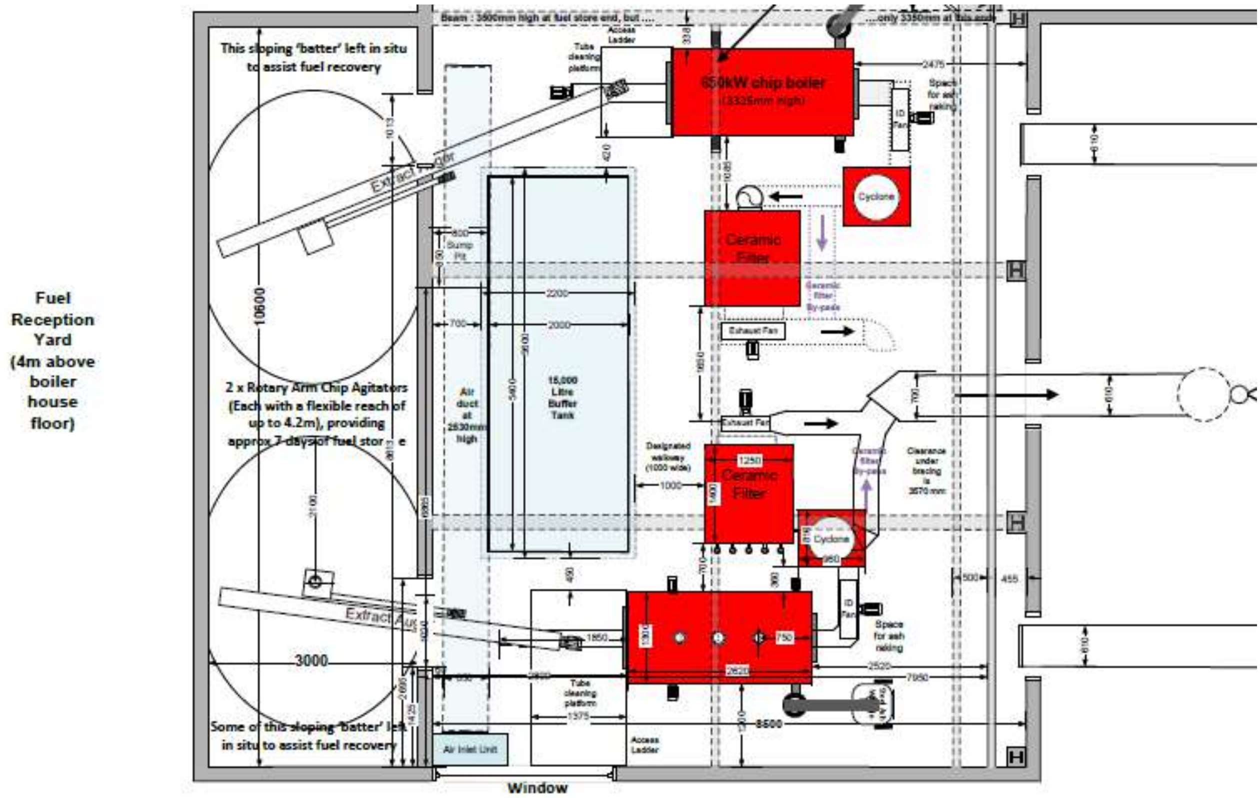


Fig. 3: Another example of a twin wood boiler site – the layout of Otago Polytechnic's 2 x 650kW wood chip boilers

Another alternative is **asymmetrical boiler sizing** – see Extended Case Study 8 (Zealandia Horticulture) where a 1.6MW and a 2.3MW boiler has been deployed. With a 20% turn-down capability, this gives an operational range of 300kW up to the full 4100kW, to suit the summer and winter loads.

The Carrington Hall site suited a step-down from a 330kW coal boiler to a 120kW wood chip boiler with accumulator tanks, so is another example of a **3:1 down-sizing ratio which is a surprisingly common statistic when the wood boiler is properly sized**. The typical annual coal usage indicates an average year-round load of only 5kW, again illustrating that the coal boiler was substantially under-utilised.

b. Projected capital costs

So the exercise began to cost the twin 120kW wood chip boilers and compare these to the more conventional alternatives.

The University, already having experience with a dozen wood boilers sourced from three European suppliers (two Austrian makes and HDG from Bavaria), have made a long-term decision to only use boilers from Hargassner GmbH. This standardises their fleet and allows the University to realise synergies from common parts, controls, support etc. So they had already negotiated a preferential arrangement with Hargassners New Zealand partners, and so could be quickly provided with accurate capital costs reflecting the agreed discount.

The two boilers and buffer tanks, including fuel extract system and controls cost around $95k plus shipping, so around $105k landed at Port Chalmers. On top of that, installation, piping, electrical and flue ducting, as well as altering the fuel store to better suit wood chip, was assessed as bringing the installed cost up to about $190k.

The boilers would be connected to 2 x 1,500l accumulator tanks. Generally only one boiler is running at a time, with rare cross-overs to meet only the highest peak loads. The 3000l of buffer tank capacity means the ratio of kW heating capacity to litres of hot water is 1:25. This is a good ratio, though still some way short of the optimum of 1:40 that is recommended in an ideal world.

Prices were sought for an LPG boiler as well as connecting the boiler-house to the town's gas reticulation network. This led to a total of $85k. Diesel was similar including a new bunded tank of sufficient size, as the old tank was underground and was required to be de-commissioned. An electricity-based heating system including controls and upgrading the power to the site was anticipated to cost about $10k more.

Table 1: Summary of the capital costs of possible Heating solutions

Heat Source	Capital Cost	Savings vs Wood Chip
Diesel	$85k	$105k
LPG	$85k	$105k
Electricity	$95k	$100k
Coal	Not considered for air quality reasons	
Wood chip	$195k	--

The University also considered 2 x 150kW wood chip units with 2 x 2000 litre tanks. The additional cost compared to 2 x 120kW units was over $50k, and this excluded up-sizing the pipework. This is another good reason not to over-size wood boilers: they are relatively expensive per kW of capacity, so **over-sizing also means spending significantly more than necessary upfront**, as well as on running costs.

Having established that the installed wood boiler system would cost around $100k more than the LPG, diesel and electric system, the energy team had to work out which heat source would offer the best 20 year NPV.

c. Were other wood fuels considered ?

For a facility of this size, only the modern European genre of small wood chip boilers is appropriate, considering the space constraints in the boiler-house and the nature of the existing coal fuel store. These small wood boilers can also use wood pellets but are not designed to consume hogged fuel, even if it was available locally.

The local wood chip fuel supply chain is well-established, with wood chip suppliers having fuel depots in the area. The University already has various boilers running on wood chip, and relationships with the existing suppliers, so can be confident of its ongoing supply.

Fig. 4: The wood fuel depot that supplies chip to the University's boilers

Wood pellets were not considered for this site as they are more expensive and so only necessary where there are either extreme access issues and/or a shortage of fuel storage volume. In this case there was already a below-ground coal bunker reasonably well suited to chip storage, albeit with some minor modifications. Pellets need a fuel store that is 100% dry, as any water ingress will quickly turn the pellets to a porridge-like mulch, which will block in feed systems and will not combust cleanly.

d. Projected running costs

The University's highly knowledgeable Energy Management team have a detailed understanding of all the components of the full cost of heating with different heat sources. With this specialist knowledge, they compiled the table below

Table 2: Summary of the variable costs of the current and possible future heating solutions					
Current pricing	**Coal**	**Chips**	**Diesel**	**LPG**	**Electric**
January	$ 900	$ 100	$ 60	$ 90	$ 3,300
February	$ 2,012	$ 1,421	$ 4,440	$ 3747	$ 5,825
March	$ 2,055	$ 1,471	$ 4,608	$ 3887	$ 5,922
April	$ 2,027	$ 1,438	$ 4,496	$ 3794	$ 5,858
May	$ 2,046	$ 1,461	$ 4,572	$ 3858	$ 5,901
June	$ 2,453	$ 1,944	$ 6,175	$ 5196	$ 6,826
July	$ 2,047	$ 1,461	$ 4,575	$ 3860	$ 5,903
August	$ 3,151	$ 2,773	$ 8,924	$ 7492	$ 8,410
September	$ 2,020	$ 1,430	$ 4,470	$ 3772	$ 5,843
October	$ 2,037	$ 1,450	$ 4,536	$ 3827	$ 5,881
November	$ 2,024	$ 1,435	$ 4,487	$ 3787	$ 5,853
December	$ 900	$ 100	$ 60	$ 90	$ 3,300
Total Annual Cost of Heat	**23,671**	**16,483**	**$ 51,404**	**$ 43,401**	**$ 68,820**

As can be seen, once all factors are correctly incorporated, including fixed charges, labour, ash disposal and line charges, **the variable cost of heating with wood chip is substantially less than all the other viable alternatives**. Coal was costing around $200/T for a Newvale/Ohai mix, but a significant portion of the total coal cost is the regular manual boiler checking/monitoring as well as the ash clean-out required. The student residents were trained and paid to do this at weekends, at minimum wage levels. If the building was to be heated with electricity then the site would incur additional fixed charges of around $3k per month for the incremental electricity supply, reflected in the table above.

e. Convert the coal boiler to wood ?

This has been done with both smaller and larger wood boilers. But the combustion properties of wood and coal are significantly different. This means if wood is combusted in a coal boiler, even if the boiler is adapted for fuel feed, air speed and air distribution, there are fundamental compromises that impact on the efficiency and the particulate emissions. See Case Study 8 (Zealandia Horticulture) examines this issue in more detail.

f. Decision time

As usual with a wood heating decision, the University had to decide whether to pay higher running costs for the next 20+ years, or whether to invest more capital up front to reduce those costs. In this case, an extra $105k of up-front capital would be needed to realise the savings.

From the table above it can be seen that wood chip would deliver savings of $27k per year against the closest alternative, LPG. So that would provide a payback on the incremental capital of 4 years. This looks worthwhile for an asset with a life of 20+ years. However the University normally requires a simple payback of less than 3 years.

So the energy team assessed the Net Present Value over 20 years. The value of each heating option had to be assessed on current costs, with no assumed increase to the price of CO_2 emissions, and with no value apportioned to the merits of sustainability. Using a discount rate of 9% – rather higher than the Universities actual cost of capital – wood chip was shown to have a NPV of $325k, with LPG costing $475k. The 20 year saving of $150k was sufficient to gain approval for the project to go ahead, and so the order for the twin wood boilers was placed in October 2015.

3. EQUIPMENT SPECIFICATION & CONFIGURATION

a. Wood chip boiler specification

The selected Hargassner boilers were the ECO-HK 120 model. These boilers are amongst several advanced Austrian boiler types that offer full automation and high levels of control and reliability. The key technical features are as follows :

ECO-HK 120 Hargassner boiler technical features	
• Output range	33-120kW
• Fuel specification	Pellets or chip P16/P43 <W35 A1
• Weight	890kg plus 188kg of water
• Dimensions	L1500 x W745 x H1610
• Efficiency (partial/ full load)	94.3% / 93.3%
• Temperature range of water	70-85°C (with 95°C max permissible)

So it can be seen that, in common with similar Austrian boilers available in New Zealand (such as ETA, Frohling, Heizomat etc) this boiler is very efficient. The actual particulate emissions achieved in reality depend on the fuel and the operating conditions. A real-life test result done on site in New Zealand is more meaningful than laboratory-based tests which show a best case outcome, and is not necessarily realistic under actual field conditions. Nevertheless, most jurisdictions in New Zealand are imposing a stack particulate limit of 50mg/Nm^3 of PM10 in built-up areas, which these small boilers should easily achieve without any further flue-gas clean-up being required.

Because these two wood boilers are not within the boundaries of the main University Campus, there are no emissions requirements imposed on the boiler.

The diagram below shows a cut-away of the 120kW boiler. The automatic tube cleaning mechanism can be seen (the coiled 'turbulators' in the red heat exchange tubes) as can the ash removal auger feeding to the detachable ash bin.

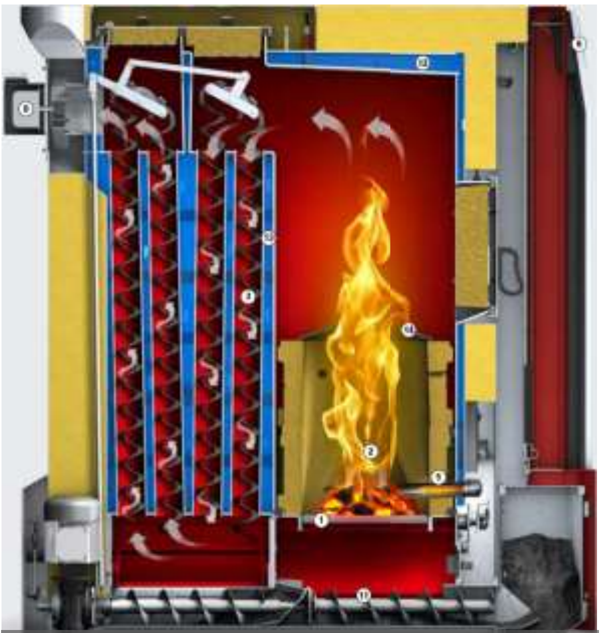


Fig. 5 : Cut-away showing the internal arrangement of the Hargassner boiler

As with all of this genre of sophisticated boilers, as well as automatic tube cleaning and ash removal, the boiler also comes complete with **touch screen controls**, automatic fuel feed and ignition, **lambda control** and automatic modulation to match the fuel and the heat load. **Flue gas recirculation** is an option that should be installed if a boiler is to switch to very dry fuels such as pellets, to prevent over-heating. The twin boilers are positioned side by side in the basement of the building.

Fig. 6: The twin ECI-HK 120 wood boilers from Hargassner in Austria

Unusually, the two wood boilers are both fed from one fuel store with one wood chip agitator. See section 6.c for more detail on the boiler layout and fuel recovery system.

There are certain other features that should be supplied with such boilers, including **burn-back control** which is sometimes done with a rotary valve (as shown below left), but is often achieved by the automatic release of water into the auger, triggered by a thermostatic valve (below right). On this project the University are using both systems, as a belts-and-braces approach.

Fig. 7 and 8 : Cut-away of the rotary valve and the thermostatic valve, both used for burn-back control

An **emergency heat exchanger** is also normally required to prevent over-heating in the event of a power failure. In such cases, without a power back-up, the pump would stop, and the stored energy in the burner's refractory lining can cause water to boil.

All wood chip or hog fuel boilers should have a mechanism to ensure a **minimum hot water return temperature** to the boiler, to prevent condensation on the heat exchange surfaces and potential corrosion. This is done via a return-loop and 3-way valve that mixes a percentage of the flow with the return to provide the required minimum. Hargassner and others now offer this 'back-end protection' loop as a pre-configured ex-factory option, which is more cost effective than doing the piping etc on site.

Fig. 9 and 10: The ex-factory back-end protection, and screen showing the set point for the min return temp

The appropriate minimum temperature depends upon the fuel moisture content, but, in any event, should not be less than 60ºC.

The hot water from the wood boilers can go either directly to the 2 x 1,500 litre accumulator tanks (below left), or to the 3 x 500 li calorifiers, or it can go directly to the network distribution header.

Fig. 11 and 12: The 2 x 1500 litre insulated accumulator tanks (left) and 3 x 500 li calorifier tanks

Boilers such as this also send a text to designated operators should an alarm occur. This allows a timely response. With the second boiler and the buffer tanks an urgent response is not vital.

b. Controls and HMI

The twin boilers come with a specialised "Cascade" control programme, which means that there is a primary and a secondary boiler (or lead and lag). The secondary boiler only kicks-in if the water Flow temperature drops below a certain level. In order to ensure equal life-times, the programme automatically rotates the role of primary and secondary boiler after a certain amount of run-hours.

Each boiler has its own colour touchscreen, which allows parameters to be easily changed, and shows the boiler status, run hours etc. There are password levels to prevent unauthorised adjustments of the settings.

Fig. 13: The Touch screen, which gives an instant Image of the boiler status

As can be seen, the boilers have Lambda (oxygen) control and is targeting a level of 7.7% O_2 in the flue gas, and achieving it at this time. The PLC also records the key outputs over the last 24 hours, and shows these on another screen.

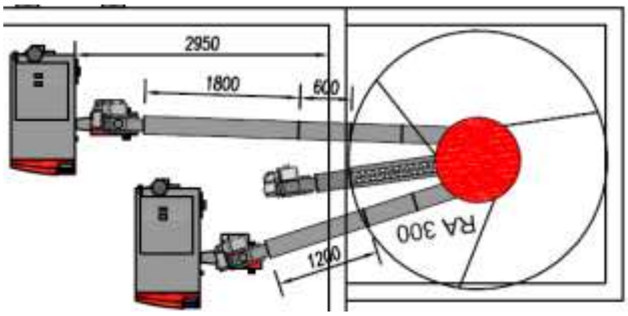
Fig. 14: The Trends over the last 24 hours are displayed

The "Filling level" refers to the amount of energy in the accumulator tanks. It can be seen that they were fully charged about 10 hours ago, so just before dawn ready for the spike in heating demand as students wake up and shower etc.

Other screens show the buffer tanks, the calorifiers, the run hours, the fuel feed settings etc.

c. Equipment arrangement

The equipment layout used on this project is somewhat unusual, because the twin boilers are both fed from one fuel store. This requires two extract augers to be fed by a single wood chip agitator, as shown below:



Fig, 15: Showing wood chip being fed to two boilers from a single wood chip agitator.

As can be seen, this requires a single drive shaft to rotate the agitator, driven by signals from both boilers. The 'sweep arm agitator' pushes the wood chip into the extract auger. The agitator and extract augers are on an angle so that they have sufficient elevation to drop the fuel into the rotary valve above the stoker auger.

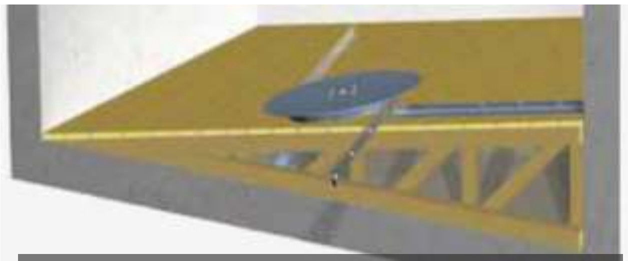


Fig. 16: Showing an angled extract auger and false floor – the latter not installed on this project

There is no need for the false floor, and this project avoided that cost. Another solution, arguably more elegant, is to have two different floor levels, allowing a flat agitator and auger, so preventing loss of chip, as below.

See Section 6 for more detail on the fuel storage and feed system.

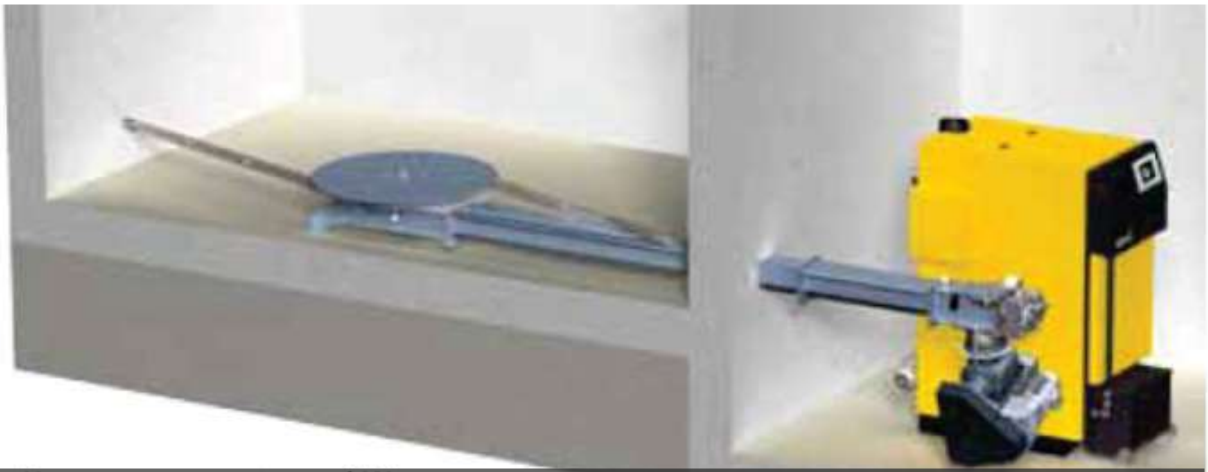


Fig. 17: Showing split level floors, enabling a flat agitator and extract auger

.

4. SO WHAT ACTUALLY HAPPENED ?

a. Actual capital costs

Although the boilers were ordered in Q4 2015 and arrived from Austria in early 2016, the implementation was held up by new building consent requirements regarding fire isolation and emergency lighting. The Council had certain requirements which they wanted addressing at the same time as the boiler installation. So unfortunately the boilers sat in storage for 1½ years.

The actual costs of implementing the project were in-line with the predictions, with a small blow-out on the flue gas ducting and controls adding about 10% to the expected $190k costs. Given the time delay, the cost increase can be partially attributed to inflationary effects between the budget being compiled and the work being done. So overall, apart from the delays, the installation went well, capably supervised by the Universities experienced team who had already installed and commissioned a dozen wood boilers.

One unfortunate side-effect of the delay was that the coal boiler, on its last legs anyway, did not receive the loving care and attention normally heaped upon it, so the coal usage in the last year ballooned out by around 40% compared to most years. This corroborates the energy team's policy of paying ample attention to correct boiler tuning.

b. Actual running costs

The anticipated annual heating costs using wood chip, was $16.5k. Unfortunately, due to the delayed implementation, there are only 4 months of actual chip usage data available at the time of writing[1]. However, comparing the first 4 months usage, and comparing that to the actual monthly 3 year average GJ used in the same period, it looks like the actuals are track to be at or near the total annual projected costs.

Fig. 18: The chip being supplied from the depot at Three Mile Hill

In making their calculations the energy team had assumed that the wood boiler would have a net efficiency of 90% compared to the coal boiler at 73% - an improvement of 23%. So far, this is looking accurate.

.

5. SENSITIVITY ANALYSIS

a. Actual payback

Assuming the actual wood heating costs come in as forecast, as looks likely, then the payback will be negatively influenced only by the $20k increase in capital expenditure. That means that the extra cost of implementing the wood boiler project was actually $120k, compared to LPG.

Wood Energy was forecast to cost $27k per year less than LPG, so it will theoretically take about 9 months extra to achieve payback.

Of course the actual payback is also sensitive to the projected savings, which are dependent on the assumptions used at the time the Business Case was compiled. In Dunedin the pricing of LPG, the next best alternative to wood chip in this case, is relatively stable as it is reticulated and is all sourced from within New Zealand. So LPG in this case, and somewhat unusually, is not subject to revisions driven by fluctuations in the Saudi Index.

The diagram below is from the University's 2017 Sustainability Framework. This project delivers on various themes, so potentially similar projects may benefit in the future from these new objectives.

[1] *This case Study will be revisited and revised once a full year of data has been collected.*

Fig. 19: The 2017 Sustainability Framework

b. Future savings

The cost of LPG has remained reasonably consistent over the 2½ years since the boilers were ordered, with only the normal small inflationary increases since the Business Case.

For most sites the annual cost of heating with LPG (or diesel) could reasonably have been expected to fluctuate significantly over any extended period, and certainly over the life of the asset. Wood fuel, on the other hand, is much less prone to international shocks and exchange rate variations, making it far less volatile, so much more predictable.

The **relative price stability offered by wood energy** is another positive risk management feature, and provides another big tick in the wood energy box, further vindicating the drive by the Energy Team of the University to convert to a locally sourced, sustainable and consistently priced heat source wherever possible.

6. RISK ANALYSIS

There are various potential risks that come with any heating solution, and there are wood-specific ones that, even with experienced wood chip boiler suppliers, need to be recognised and eliminated or mitigated.

a. Boiler reliability risk

A widely held perception that is hopefully changing now that there are several dozen European boilers operating around New Zealand, is that wood chip boilers are unreliable. In reality these boilers are extremely reliable, with **typical availability over 98%.** Problems with the boiler operation will nearly always be attributable to wood fuel quality, which may lead to a blockage and an interruption in fuel feed to the boilers. This also can flow through to potential maintenance issues if the fuel has large amounts of contaminants which are more abrasive, can cause damage and will need more manual clean-out time.

Many sites will chose to ensure uninterrupted heat supply by implementing one wood boiler with a low cost diesel or LPG back-up boiler. That was the case at West Otago's Tapanui Medical Centre, where the installed a diesel boiler to back-up the wood boiler. Both boilers are shown below.

Fig. 20 and 21: An 88kW ETA Hack wood boiler and a 93kW diesel back-up

The installed cost of the small diesel boiler above was around $15k including the 250 litre diesel tank. So this is a very cost effective risk mitigation strategy, providing 100% back-up for just 5% of the total project cost.

In the case of Carrington College, setting up a safe fuel store for LPG or diesel would have been problematic, especially with new in-house regulations imposing strict rules regarding diesel tanks. The incremental cost of the second wood boiler was not as significant as may be thought : the fuel store would be modified anyway, buffer tanks would be installed anyway, piping and flue gas ducting re-arranged etc. Overall, with the peak loads expected to be supplied from the 2^{nd} boiler, the extra cost of diesel or LPG as a peaking fuel pushed the decision towards a 100% wood fuel solution, with the attractive benefit of near 100% redundancy.

b. Capital cost risk

The Energy team has a lot of experience with wood boiler projects. The cost of the boiler and ancillary equipment was locked-in, and the cost of the installation work was well understood. Overall the team managed the project within a 10% variance of a 2-year old budget, so the capital risk was well managed.

c. Fuel supply risk – and the reality

Normally a key concern for any adopter of wood energy is that the wood chip supply will not be reliable and/or the price will rapidly increase. This can especially be the case where the supply chains are perceived as immature. In this case there are two very active and professional suppliers servicing the various wood chip boilers in the Dunedin region. The University has an ongoing relationship with Pioneer Energy, who supply all of the Universities wood chip boilers under a five year arrangement, as well as electricity.

Several years ago Pioneer purchased Energy for Industry (EfI) as well as its specialist wood fuel subsidiary company Wood Energy New Zealand (WENZ), who were, and remain the selected wood chip supplier. Spark Energy are the other active local suppliers, whose wood chip subsidiary is called Lumbr.

A common risk management strategy is to seek a long-term arrangement for wood chip supply. This provides certainty to the heat user as well as allowing a good planning window for investments by the wood chip supplier.

The University have a 5-year chip supply arrangement with Pioneer Energy.

d. Fuel supply risk – and the reality

There are various methods that can be used to get the wood fuel from the delivery truck into the fuel store.

On projects of this size, this sometimes involves a fuel reception trough that on-feeds to an elevating auger that ejects the wood fuel at speed high-up into an above-ground fuel store, ensuring good filling. This is shown below:

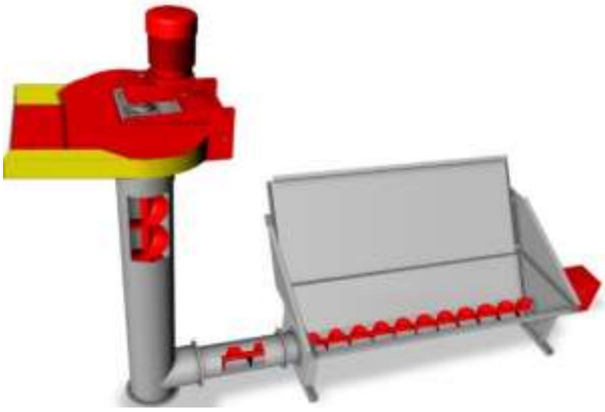


Fig. 22 and 23: One of various wood fuel reception troughs available

Whilst such equipment is reliable and effective, any machinery between the truck and the fuel store is best avoided.

Fortunately this site has an old tip-in coal store – now the wood chip store – as shown below.

Fig. 24: The old coal store at Jenkins House, now the wood chip store

The fuel store has a solid water-tight lid with a robust winch mechanism designed when there was clearly no shortage of steel. This was designed as a coal store, so it may be worth retro-fitting some air-movement ventilators to allow air flow, important to prevent water build-up on the inside walls and roof of the fuel store.

Wood chip trucks are larger than coal delivery trucks, as would be expected from the relative energy density of the fuels. So access for wood chip trucks to sites that have converted to wood energy can be problematic. This site presented just that problem.

Modifications were required to smooth the entrance and remove a nib wall (below top), so that the larger chip truck (below bottom) could manoeuvre to gain access to the chip store. This was a welcome modification, saving the wall regularly damaging the lower panels of unsuspecting cars.

Fig. 25 and 26: The modified entrance, to allow better truck access for the wood chip truck (bottom)

At this site, to gain access to the fuel store through a car park that is busy in the day, the deliveries need to be made after 7.30pm. This is an inconvenience for the fuel supplier which could be reflected in an increased wood chip price, though not in this instance because of the larger umbrella chip supply agreement.

e. Fuel storage risk

A small fuel store will result in frequent deliveries being required, as well as the need to run the store very low before deliveries, thus increasing the risk of a supply interruption.

This is often the enforced situation with conversion of coal boilers, which have much smaller stores than 'new-build' sites, as coal can have an energy density of up to 10 times wood chip. This store is approximately L3m x W3.5m x 3m, so has a theoretical gross volume of 31m^3. However, due to the back-wall (on the left below) in reality only around 20m^3 could be delivered even on the first delivery when some volume is lost forever under the agitator.

Fig. 27: fuel store, with a volume-limiting back wall – not important when it was coal

The actual volume of recoverable wood chip in this store is around 17m^3. This represents about 10 day's usage, which is actually well above average. However, the delivery needs to be done when the store is nearly empty, to allow 16-17m^3 to be delivered, and this is with a diligent driver who shovels fuel under the ledge at the front and back of the store, so that he can squeeze in an extra 2-3 cubic metres.

So the volume of the fuel store is not ideal, as it does not allow a full truck to be delivered, which can compromise supply logistics. However in this case, because the fuel depot is reasonably close and the remaining load could be delivered to another site that needs late night deliveries, there is no significant impact on efficiencies.

For an example of an ideal wood chip fuel store for a small boiler, see the Extended Case Study No. 7 – West Otago Health's Tapanui Medical Centre. Their fuel store is shown below :

Fig. 28: Tapanui Medical Centre's purpose-built tip-in wood chip fuel store

This store can quickly receive a 35m^3 truck load whilst still having 2 weeks energy in the store.

This allows logistics to be optimised, which is particularly important given the 100km haulage to the relatively remote township.

f. Fuel recovery risk

Fortunately technology has progressed well past the days of manual stoking of boilers, as seen on trains and ships of the last century. Wood chip boilers are fed entirely automatically, with no manual intervention between emptying the delivery truck and taking the ash out of the boiler house – and even that is automated on larger boilers.

Once the wood fuel is in the store, the fuel is automatically 'recovered' (or 'reclaimed') with specially designed equipment. On larger boilers this may be done with walking floor systems, or overhead grabs, or more recently the Toploader rake system, but on a small system such as this, it is normal for a wood chip 'agitator' to be used to scrape the fuel to an extract auger that feeds the chip to the boilers stoker auger. See Section 3.c for detail.

On this project, they are finding that the wood chip is bridging more than normal – not helped by the suspended back wall of the old coal store – so the University is going to extend the arms of the agitator to get further into the corners. The wood fuel in the corners can be hard to recover, and sometimes it is best to consider this as 'reserve' fuel. There are various devices that can be used to get the bridging to collapse, such as inflatable 'mushrooms', sonic shock-waves, 'dongers' and vibrating devices. It is still relatively early days for this project, and the University is going to examine the possibilities.

The agitator and extract auger only runs when the burners send a signal that fuel is required. The fuel size specification in this case is based on the European Standard P43 sizing, which is a medium grade chip. The Hargassner boiler, as well as the extract and stoker auger are designed for this, and sized accordingly. The boiler will also accept the smaller P16 chip sizes too.

On slightly larger boilers the agitator and down-stream augers can be sized for larger fuel, up to a P63 chip (the old G100 category). This provides slightly greater fuel flexibility, and greater tolerance of over-sized particles, at the cost of larger motors and gearbox's, with the augers having a larger diameter (up to 330mm, compared to 140mm here).

Occasionally longer 'strands' of wood fuel may sneak into the mix, and these have the potential to hang-up at the exit end of the extract auger. The industry has responded to this by providing easily-opened hatches, with appropriate cut-off devices – see the cable running to a cut-off switch in the photo below left. Special prongs are also fitted to the auger shaft to encourage the strands to fall into the rotary valve – seen below bottom.

Fig. 29 and 30: The flap to allow 'strands' of wood to be removed, and the special design at the top of the auger shaft to knock these strands down

There is potential for a blockage in any such fuel recovery system, but again, this would normally be caused by fuel quality issues, such as a large stone or bolt being in the fuel. Wood chip quality is important in this genre of boilers, hence they require a 'premium grade' wood chip. Suppliers should have appropriate chippers with in-0built or separate screening mechanisms, and should ideally operate in yards that are fully concrete-sealed to avoid stone contamination.

Risk Summary Overall it can be seen that the various potential risks associated with wood energy can all be eliminated or managed to a minimum with good planning and good design, especially if the budget and payback period is realistic.

The mechanical risks are well-understood by the wood chip boiler industry, and specialised equipment has been refined over many years to reduce these to very rare realities. Strategies can be put in place, for instance a large fuel store or a low cost diesel burner, which reduce the risk to near zero – as low as any fossil fuel heating system.

7. SUMMARY – THE RIGHT CHOICE !

Although still relatively early days in the life of this project[2] this installation is already a good example of a successful conversion of an old coal boiler site to a modern wood chip boiler. Having a second wood boiler as back-up and occasional 'peaker' adds particular interest.

There have been no mechanical issues to date, and zero fossil fuels are now used at the site, with quality hydronic and domestic hot water heating that is supplied effortlessly and cleanly.

The student residents are missing their extra spending money, but not the coal dust.

The caretaker, used to carting bucket loads of coal up the steps every week, is so delighted that he has now decided that he can hove into retirement after over 30 years looking after dirty coal boilers.

In the 4 months of running so far, just two half-buckets of wood ash have been extracted by the ash augers and have left the boiler house.

The ash is sitting in storage buckets just outside, ready for distribution on the gardens of Carrington College – which will, no doubt, help to grow more biomass.

Fig. 31: Four months of wood ash in half-full storage buckets

The service received from Pioneer Energy to date has been excellent, and the quality of wood fuel has allowed the system to run very smoothly, despite a somewhat compromised fuel store.

The University's Energy Management Team of Hans and Mark had to be patient to see this latest project reach fruition, but they have now successfully transitioned yet another facility to a clean, locally-sourced and sustainable heat source, bringing their wood boiler fleet up to the grand total of fourteen, and helping the University towards its commitment of consuming 100% renewable energy by 2030.

Parting Comment Hans Pietsch, the Energy Manager said "Wood fuel is the way forward without a doubt" The project is a classic example of perseverance and long term thinking driving an outcome that is best for the pocket as well as the planet. We will keep a tally to watch their wood boiler fleet grow still large.

[2] *Note: This Case Study will be updated at the end of a full heating season and re-published with the actual heat usage data as well as any further learnings. Contact info@livingenergy.co.nz if you would like to receive an updated copy.*