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Practical considerations for heating logs prior to peeling

Coconut and other non-traditional forest resources for the manufacture of Engineered Wood Products (EWP)

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Executive Summary

This report discusses log heating methods in the context of veneer production. It is a component of the ACIAR-funded project "Coconut and other non-traditional forest resources for the manufacture of engineered wood products," activity 3.7- adhesive systems and manufacturing protocols.

Veneer production from logs has evolved historically, with modern technology making it more accessible and efficient. Veneer-based engineered wood products (EWPs) are popular for their versatility, value and sustainability.

This report explores log heating's benefits, which include increased veneer recovery, reduced defects, and improved quality due to decreased breakage and splitting. Despite these significant advantages, challenges like capital and operating costs and return on investment need to be considered before investing in log heating capacity.

The process of log heating softens the wood, relieving internal tension and stress. The glass transition temperature (Tg) determines this softening point and is affected by species, age, moisture content, and density. Saturated heating methods for billets are required to avoid drying the logs before peeling.

Log heating methods using water tube steam boilers are explored in this report. Two different approaches, including steam spraying and hot water immersion, are examined. Factors like mill capacity, energy source (natural gas, LPG, diesel), and boiler type influence system design and information about key considerations and where to start are provided in this report.

Biomass burners, or 'gasifiers,' present an alternative with potential circular economy benefits, utilising timber production waste as a fuel source. However, variations in biomass characteristics affect efficiency. Cleaning needs and automation further shape operating costs. Biomass's lower calorific value entails higher quantities for equivalent steam production in comparison to non-renewable sources. Challenges lie in moisture content, size uniformity, and sourcing. A custom design might enable biomass burners for water vat heating, but purpose-built biomass steam boilers were the only options considered in this report.

Four example scenarios illustrate system sizing for a hypothetical commercial practice, considering factors like production capacity, operating hours, billet dimensions, and heating time. The importance of engaging industry professionals, adhering to safety standards, and considering economic viability.

Comparing steam boiler configurations, a single 1250 KW water tube steam boiler fuelled by natural gas to heat a water vat and the 3 x 500 KW diesel-powered water tube steam boilers for both water vat and steam chamber revealed capital cost differences. While the larger single unit had higher annual maintenance costs, the aggregate expenses over time favoured the 3 x 500 KW boilers. Water consumption differed, with the steam chamber demanding more frequent steam replacement. Fuel costs dominated operations, with start-up duties reflecting similar expenses as extended operation. Natural gas was the most cost-effective fuel despite its lower calorific value.

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Introduction

This report has been conducted as part of the Australian Centre for International Agricultural Research (ACIAR) funded project (FST/2019/128) "*Coconut and other non-traditional forest resources for the manufacture of engineered wood products (EWPs)*" addressing activity *3.7 – Investigate adhesive systems and related manufacturing protocols*.

Veneer production from logs has been practised and utilised across the globe for centuries. Some examples of veneer inlays in furniture, and decorative objects have been observed in Egyptian artefacts as far as 5000 years ago, manufactured intricately by hand (Hughes 2015; Afifi and Youssef 2018). As technology has advanced over time, large scale manufacturing strategies make the production of veneer widely available and affordable. Veneer-based engineered wood products (EWPs hereafter) have gained significant popularity as high performing, versatile and renewable building materials (McGavin and Leggate 2019; Leggate et.al 2017).

Veneer can be produced by either slicing or rotary peeling. This review focuses only on preparing logs for rotary veneer production.

The processing and automation of technology has increased rapidly over the past 50 years and peeling logs in some instances is operated entirely by a workforce of varying skill levels. Despite the rapid technology expansion, very limited published information exists on log heating approaches and even less information exists to support decision making for wood processors in Australia and Fiji.

This report focuses on log heating methods that involve the use of water tube steam boilers and the associated capital and operating costs. There may be alternative heating and steam generation methods however this report is limited to water tube steam boilers to heat a water bath/vat or a steam chamber using a hypothetical commercial practice. Log heating is one of many components for a typical commercial veneer production system. The provided capital and operating costs do not consider pre-existing equipment or processes and all components of log heating have been investigated in isolation.

Why heat logs?

Some research has been published concerning the benefits of heating logs immediately prior to peeling. Some of the benefits described by Resch and Parker in 1979 include;

- increased veneer recovery and improved quality of recovered veneer due to decreased splitting and breakage during handling,
- reduced knife wear and pressure and reduced power consumption during peeling due to softened defects and less resistance, and
- improved veneer 'tightness' with shallower checks and less mechanically induced defects which can lessen adhesive consumption and provide higher performance products.

Despite the benefits, there can be disadvantages associated to heating logs including the capital and ongoing operating costs, time in the production system, and in some instances, over heating can cause undesired veneer colour changes, fuzzy or fluffy veneer surfaces and/or incorrect heating methods can induce end checking or splitting (Resch and Parker 1979).It is important to highlight that the process of heating logs in preparation for rotary peeling, must be undertaken in a manner that doesn't dry the log. For this reason, methods that use high humidity steam or hot water are traditionally favoured.

Why does log heating work?

Wood is a viscoelastic material that is made of building blocks including cellulose, hemicellulose, and lignin. The term viscoelastic describes a medium that behaves like a liquid and a solid material at the same time, and this is important when considering heating wood to change its material characteristics. Wood is also hygroscopic, meaning it can take on or lose moisture depending on the surrounding environment (Fredriksson 2019).

Log heating prior to peeling works by heating the peeler billet to the glass transition temperature (Kumar 2023). The glass transition temperature or T_g is the point at which the wood softens or plasticises and relieves any internal tension and growth stress (Kong et al. 2017). The point at which wood softens with heating is dependent on a range of factors most notably the timber species, taxonomy (hardwood/softwood), tree age, and moisture content (Dupleix et al. 2012). The glass transition temperature is reached sooner and at a lower temperature with a high moisture content and low density softwoods typically require a lower temperature and/or reach the respective T_g sooner than high density hardwoods (Dupleix et Al. 2012). Because the glass transition temperature is easier to reach with an elevated moisture content, logs are typically soaked or steamed whilst green and in close proximity to felling.

How can I heat my logs?

There are a number of strategies to heat logs including electric heating, microwaving, infrared technology and hot water pressure impregnation however the most commercially relevant and practical strategies are hot water soaking (usually a bath or vat) or saturated steam (insulated shed or vessel) (Kumar 2023). Both saturated steam based and hot water-based systems have the potential to be run in continuous systems described in Table 1. For the purpose of providing greater detail on costs and energy requirements, only two options are explored including steam spray at low/no pressure in a batch process and hot water immersion in a batch process (table 1) (figures 1 and 2). The heating options explored require a steam boiler for heat and steam generation.

Table 1: Methods for log conditioning (Resch and Parker 1979)

	Process	
Method	Batch	Continuous
Steam sprayed at low pressure or high pressure	Above ground chamber (drive-in vaults)	Above ground chamber (conveyor)

Spray or deluge with hot water below 90 ˚C or mixed with steam	Above ground or below ground chamber	Above ground chamber (conveyor)
Immersion in water heated by steam coils or live steam or external heat exchanger	Submerged, covered soaking vat	Feed-through soaking vats, above or below ground

Figure 1- Batch process stream spray on rails (method 1 above) (source – Windsor Engineering)

Figure 2 - Batch process - hot water vat (method 3 above) (source – Shutterstock)

Where do I start?

There are many important considerations when deciding to heat logs and these considerations can include;

Capital and operating costs: Designing, building and troubleshooting new log heating equipment could cost anywhere from (AUD) $100,000 to over (AUD) $1,000,000 depending on the design and desired operating capacity. Additionally, the majority of systems will demand ongoing electricity, water, diesel, natural gas and/or LPG running costs, accredited maintenance and operator costs. Capital and operating cost estimates are provided in example scenarios below.

Labour requirements and skilled operator capacity: Log heating equipment often requires labour for regular loading and unloading, regardless of the system. Skilled operators may be required for servicing and maintaining log heating equipment including high temperature water vats and steam-based systems. This could include high risk licencing and trades specific to the system installed.

Space, logistics and design on site: Log heating systems will occupy land on site and may occupy a significant area depending on the design and desired capacity. The system ideally would be in close proximity to the peeling process and allow safe loading and unloading in a low traffic zone, away from pedestrians. Additionally, close proximity will reduce temperature losses prior to peeling.

Access to power and water: Depending on the log heating system, access to consistent electricity/alternate power source and water will likely be required including automatic safety devices in the event of water or fuel supply inconsistency/deficiency.

Automation level: Typically, increased automation will increase capital costs whilst also reducing labour. A range of automation exists to support log sorting, conveying, and loading before and after log heating and this technology would be specific to the operation, log dimensions and desired throughput. At the time of writing no commercial automated log heating system was identified.

Mill output capacity requirements: The log heating system is required to be of sufficient capacity to not create bottlenecks in the production capacity of the mill. The system will need to accommodate batches large enough to satisfy production output or run a continuous system at a speed similar to the production line. Log heating can take anywhere from 3-24 hours, depending on multiple factors including (but not limited to) log species, billet diameter, and heating temperature.

Billet characteristics: Different species will reach its relative glass transition temperature at different times. It is important to group by species and/or similar densities, billet diameters and lengths to ensure uniform heating and ensure all billets reach the optimal temperature. It is also important that logs are not left to overheat or remain heated for extended periods of time as this may have a negative effect on veneer quality. It is recommended the glass transition temperature is determined to support decision making.

Certification: Steam-based systems (capable of holding pressure >100 kPa) in Australia require certification to *AS 2593:2021 Boilers – Safety management and supervision systems.* This standard includes the frequency of maintenance, inspection and servicing depending on the design as well as minimum supervision and minimum safety requirements. It is recommended that an industry professional is engaged to navigate the design, installation, maintenance, oversight and attendance (if required) of any boiler/steam-based system. Limited information could be found on a boiler certification standard in Fiji, however as a rule of thumb the practices outlined in the Australian standard could be adhered to. The Australian standard for steam boilers is one of the most demanding globally to achieve and maintain certification.

Steam boilers: The Australian standard *AS 2593:2021 Boilers – Safety management and supervision systems* also outlines the requirements for a boiler in operation and whether the system can operate attended (manned) or unattended (unmanned). Boilers manufactured as 'attended' boilers require a certified person to operate and oversee boiler operation at all times. Unattended boilers can operate with a skilled (but uncertified) operator and the system does not need to be attended. Generally, boilers up to a 500 KW capacity are typically designed to be unattended and can be operated by a skilled (but uncertified) operator. Systems over 1000 KW capacity are typically designed as attended boilers and require full time attendance whilst in operation (although there are exceptions to this). Generally, smaller boilers are capable of being regularly stopped and started, whilst larger boilers are designed to run continuously, only stopping for routine or emergency maintenance. Log heating processes are likely to follow a typical commercial work week operating approximately 260 days per year. This is important when considering the type of boiler required for log heating purposes. Note: a range of steam boilers can be purchased from many international suppliers with a wide range of costs. Many of the available boiler systems may not meet the Australian standard and each boiler would need to installed and tested for performance by qualified inspector before operation and certification. If the system does not meet the Australian standard, it may be unable to be efficiently retrofitted. Steam boilers that do not meet Australian Standards have not been investigated or considered in this report. Professional assistance is recommended before purchasing foreign equipment.

Steam boiler maintenance: Depending on the system and certifier, steam boilers in operation are required to undergo routine maintenance outlined in *AS 2593:2021 Boilers – Safety management and supervision systems.* Typically, unattended boilers <500 KW require quarterly (4 times per year) routine maintenance including an extensive annual maintenance. The maintenance needs to be performed by a qualified inspector and the cost is typically charged per boiler with prices increasing as the size of the boiler increases. Depending on the system, an additional qualified gas technician may be required for natural gas and LPG based systems. Depending on the system, quarterly routine maintenance will involve replacement of sight glasses/gauges, seals, valves and other identified issues. Annual maintenance requires replacement of feedwater pump safety valves, blowdown pipes and valves as well as most seals and gauges and any identified issues. For systems over 1000 KW, the routine maintenance is more frequent requiring qualified servicing every 5 weeks (11 times per year) including an extensive annual maintenance to remain certified. The costs of steam boiler maintenance will be explored in an example scenario below.

Safety: Hot water baths and steam-based systems could be classified as high risk and any incident has the potential to be fatal due to highly flammable fuel sources, high pressures and/or high temperatures. The location and design of any system will need to be equipped with appropriate safety measures to protect the safety of those onsite including protection of fuel sources, protection from pressure vessels, fences and exclusion zones for steam chambers and water baths including loading and unloading areas and any rail systems. Automatic safety stops and alarm systems may be required when water or other agent is at low levels in the system with automatic fire safety alerts. Regulatory authorities may impose additional requirements, such as design registration, boiler gas supply arrangements, water and sewerage arrangements, electrical arrangements, attendance and supervision by operators and training of operators. The safety and certificaiton component should not be overlooked when considering log heating and it is recommended that an industry professional be engaged early in the process.

Disposal: Depending on the system, hot water vats will need water replacement relatively frequently. This is to prevent build up of material, extractives and dissolved organic carbon in the system. Debarking/rounding before heating will reduce the frequency required for water replacement. The disposal/reuse of the water will need to take into account local or site specific regulations and also consider disposal of potential chemical waste including steam boiler condensate or other water pollutant.

Process and energy optimisation: It is worth considering renewable energy options to reduce the costs of operating a log heating process where possible. This could include solar power to reduce energy costs and replace other parts of the operating process that are powered by electricity or other non-renewable sources. Steam boilers have the potential to be powered by biomass and utilise existing onsite timber waste material. This has the potential to reduce energy costs, improve environmental credentials and create a self-sufficient system on site. Energy costs may also be reduced through efficient and modern steam boilers, regular maintenance, insulation, optimising boiler start – up and operating demand, automation, system monitoring and any heat recovery.

Return on investment: Log heating can be costly for both capital and operating costs if designed and implemented inefficiently and could potentially not provide a suitable return on investment. It is important to consider if the species intending to be peeled, could be peeled to a satisfactory standard without the need for log heating. Most Australian hardwood species and Fijian coconut palm stems benefit (or demand) heating to successfully produce satisfactory veneer. Without log heating investment, these resource types will miss the opportunity to be manufactured into high value engineered wood products.

How do I estimate the size of the system I need?

It is recommended an industry professional is engaged to provide information and support. However, the theoretical size of the system you will need can be roughly calculated based on few factors. These include;

1. required production capacity (e.g m^3/year),
2. frequency of operation (e.g part week or 24/7)
3. size of billets (e.g 2.5 m x 0.3 m diameter)
4. size of batches (how many billets per batch)
5. size of chamber or vat and available space (volume)
6. initial temperature of logs/billets
7. target temperature of logs/billets
8. green timber density/species

Once this information is determined efforts can be made to approximate the energy requirements and size of components needed to support the log heating system. From here, a specialist or steam boiler sizing engineer can assist with calculations including structural heat losses, insulation requirements and environmental losses, heat, humidity and vapour losses, wood heating losses, opening chamber/vat or water replacement heat losses and ultimately the total energy requirements of the system. Professionals will also be able to provide detailed upfront costs and operating costs including maintenance by a qualified serviceman and certification to meet *AS 2593:2021 Boilers – Safety management and supervision systems.*

Example scenario

To provide an example of a typical log heating and veneer processing commercial practice, a few scenarios and options have been provided with estimates of their associated capital and operating costs. The information presented here has been provided through consultation with industry professionals. The author has made every effort to provide accurate information at the time of writing, however, costs and availability of presented options may vary. It is recommended an industry professional is engaged to develop site specific log heating options and capital and operating costs. The below information is generalised and is based on assumptions for a hypothetical commercial practice.

Using the below factors an example scenario can be developed;

1. **Required production capacity**

Using table 2 (below), a typical log peeling commercial operation of 15, 000 m^3/year (billet volume) is assumed.

2. **Frequency of operation**

Using Table 2 (below), a typical commercial operation of weekdays (Monday to Friday) totalling 260 days of operation per year is assumed. The operation will run for 8 hours a day from 8 am to 4 pm. It is assumed that log heating equipment is started at 6 pm on Sunday evenings and run continuously until Friday afternoon with log peeling occurring during business hours.

3. **Size of billets**

Billet dimensions are assumed to be an average of 2.5 m long and 0.3 m diameter (ranging from 0.25 -0.35 m). This totals a volume of 0.18 m^3 per billet. It is assumed the billets are uniform in dimension and have been debarked and rounded prior to heating.

4. **Size of batches**

Assuming 15,000 m^3/year (billet volume), operating weekdays (Monday to Friday) and totalling 260 days of operation running, 8 hours a day from 8 am to 4 pm and using table 2, the batch size needs to accommodate 58 m^3 of billets each day. Using the billet volume above (0.18 m^3), this equates to peeling approximately 323 billets per day.

5. **Size of chamber or vat and available space**

It is assumed that the operation has enough size to accommodate log heating processes including an insulated shed or large hot water vat, boilers, associated ancillary equipment and loading/unloading zones.

6. **Initial temperature of logs/billets**

It is assumed that the average initial temperature of the billets is 20° degrees Celsius at all times throughout the year.

7. Target temperature of logs/billets

It is assumed that the target temperature of the billets is 90° degrees Celsius.

8. Green timber density/species

It is assumed the operation will be managing a single species of green Australian hardwood at an average green density of 1000 kg/m^3. It is assumed that heating a billet from 20° degrees to 90° degrees will take 12 hours. It is assumed that heated logs can remain heated for up to 24 hours without any adverse effects on veneer quality.

Table 2: Production capacity per year

Options	**Capacity**	**Capacity 260 days**	**Capacity 365 days**	**Capacity 260 days**	**Capacity 365 days**	**Capacity 260 days**	**Capacity 365 days**	**Capacity 260 days**	**Capacity 365 days**
	(m^3/year)	(m^3/day)	(m^3/day)	(m^3/hr) (24 hours)	(m^3/hr) (24 hours)	(m^3/hr) (12 hours)	(m^3/hr) (12 hours)	(m^3/hr) (8 hours)	(m^3/hr) (8 hours)
1	5000	19.23	13.70	0.80	0.57	1.60	1.14	2.40	1.71
2	7500	28.85	20.55	1.20	0.86	2.40	1.71	3.61	2.57
3	10000	38.46	27.40	1.60	1.14	3.21	2.28	4.81	3.42
4	12500	48.08	34.25	2.00	1.43	4.01	2.85	6.01	4.28
5	**15000**	**57.69**	41.10	2.40	1.71	4.81	3.42	**7.21**	5.14
6	17500	67.31	47.95	2.80	2.00	5.61	4.00	8.41	5.99
7	20000	76.92	54.79	3.21	2.28	6.41	4.57	9.62	6.85
8	22500	86.54	61.64	3.61	2.57	7.21	5.14	10.82	7.71
9	25000	96.15	68.49	4.01	2.85	8.01	5.71	12.02	8.56
10	27500	105.77	75.34	4.41	3.14	8.81	6.28	13.22	9.42
11	30000	115.38	82.19	4.81	3.42	9.62	6.85	14.42	10.27

**highlighted cells indicate production capacity of focus (15,000 m^3/year), operating weekdays (260 days per year) between 8 am and 4 pm (8 hours a day) with a required throughput of approximately 58 m^3 per day or 7.25 m^3 per hour*.

Using the above outlined scenario, the production demands a design to accommodate the following things;

- the system needs to be capable of stopping and starting with log heating equipment started on Sunday evenings and operated continuously until Friday evening with log peeling occurring during business hours,
- the heating chamber (either an insulated shed or water vat) needs to be able to accommodate approximately 58 m^3 or 323 billets at a time,
- the boiler(s) need to be capable of the start up duty of 58 m^3 of material in addition to either the matched water or air volume whilst overcoming thermal losses,

- the log heating time is 12 hours, requiring logs to be heated overnight (ideally by an unattended boiler) and peeled during the day,
- operating weekdays, for 8 hours a day, requires peeling an average of 40 logs an hour,
- using an assumed location of Southern East Queensland, Australia, a supply of LPG, natural gas and diesel are readily available with a possibility of biomass,
- using an assumed location in Fiji, LPG and diesel are considered readily available with a possibility of biomass.

Fuel source and efficiency

A range of options are available to power steam boilers including natural gas, LPG, diesel, electricity, biomass and in some scenarios hydrogen (see table 3). Not all energy options may be available in the location where billets are to be heated and may not represent the most cost-effective option depending on geographic location and desired operating capacity. Typically, electrically powered steam boilers are not recommended for commercial operations due to the demand on the local power grid, lower capacity and operating cost

Table 3: Steam boiler fuel source options

Fuel source	Australia	Fiji
Natural Gas	Available in some locations	Not available
LPG	Available	Available
Diesel	Available	Available
Electricity	Available but not for recommended for commercial operations	Available but not for recommended for commercial operations
Biomass	Potentially available with reliable free/cheap feedstock	Potentially available with reliable free/cheap feedstock
Hydrogen	Not available – estimated 10 years until Australian certification	Not available

The available fuel sources have differing heating efficiencies (see table 4) and different boiler sizes and manufacturers will achieve varying efficiencies with the fuel sources based on design and other factors. The efficiencies for each fuel type will also vary depending on the proportions of gaseous hydrocarbons present. Natural gas is typically methane and LPG (liquefied petroleum gas) is propane or butane or a mix of both. Each require different operating pressures and is why natural gas can be delivered via pipeline (lower pressure) and LPG is sold in gas bottle/cylinders/tanks (higher pressure). Differing fuel sources offer different calorific values with diesel having the highest calorific value or efficiency at 38 MJ per litre, followed by LPG at 25.5 MJ per litre (or 95 MJ per m^3 for comparison), natural gas at 38.9 MJ per m^3 followed by biomass (see table 4). This means to operate a steam boiler, more litres or cubic meters of a relatively low calorific fuel source is required to achieve the same output compared to using a high calorific fuel source. Steam based systems can be operated by natural gas, LPG or diesel (or potentially biomass) with relatively uniform capital pricing across systems. Geographic location, gas/energy suppliers, fuel source mix efficiencies, purchasing quantities, boiler specifications and global price fluctuations will dramatically influence the long-term operating costs for log heating fuel sources and each system should be considered and designed with the guidance of a professional.

Table 4: Fuel Source Efficiency and Price

Fuel source	Efficiency	Price per unit (Australia)
Natural Gas* (gas)	38.9 MJ per m^3 / 50,000 kj/kg	$18.59 per GJ** ($485.88 m^3)
LPG* (gas and liquid)	95 MJ per m^3 / 25.5 MJ per litre	$1.00 per litre* (price unknown in Fiji)
Diesel* (liquid)	38 MJ per litre	$1.00 - 1.50 per litre* (price unknown in Fiji)
Biomass*** (solid)	3,000 MJ per m^3 (30% MC woodchips at 250 kg/m^3) – 11,000 MJ per m^3 (10% MC wood pellets at 650 kg/m^3) or approx. 19,000 kj/kg (max)	Unknown (potentially free)

**Information provided by East Coast Steam, Brisbane, Australia. All prices are subject to energy/gas supplier, individual boiler efficiency, individual fuel mix components, purchasing quantity and highly variable price fluctuations. Prices also accommodate supply arrangements and do not require upfront costs.*

***https://www.aer.gov.au/wholesale-markets/wholesale-statistics/gas-market-prices*

**** Biomass efficiency is highly variable depending on form, density and moisture content. https://www.forestresearch.gov.uk/tools-and-resources/fthr/biomass-energy-resources/reference-biomass/facts-figures/typical-calorific-values-of-fuels/ Figures presented may vary depending on species (Telmo and Lousada 2011).*

As a rule of thumb, regardless of fuel source, 30 MJ of energy is required to produce 1 kg of steam per hour. This will vary depending on the efficiency of the steam boiler and manufacturer. The required kilograms of steam per hour (kg/h) or kilowatts (kW) are used to estimate the size of the steam boiler system required for the desired production capacity.

Using the above scenario outlined in table 2, a steam boiler size was estimated, accounting for the factors outlined in table 5 (below). These factors will vary depending on individual manufacturers and boiler design.

The estimated size can be divided into the start-up duty and operating duty. The start-up duty is the energy required for heating to overcome any thermal losses, heating of cold coils, getting water to the target temperature, and all equipment associated with log heating. The operating duty refers to the upkeep or maintenance of the target temperature and the energy required to do so. The operating duty requirement should be less than the start-up duty. Across all surveyed steam boiler providers, the operating duty for a water vat/water bath system is considered significantly lower (less fuel demand) than a steam chamber. This is due to the thermal holding capacity of liquid water as opposed to steam.

Table 5: Start up duty and operating duty factors used in steam boiler size estimation for a water vat (courtesy of Tomlinson Energy) *(calculations were not provided and are subject to each boiler type and manufacturer*).

START UP DUTY:	
Tank volume	m^3
Volume of logs	m^3
Mass of water per tank @1000kg/m3	kg
Mass of wood logs	kg
Cold temperature	°C
Enthalpy of water at cold temp	kJ/kg
Hot temperature	°C
Enthalpy of water at hot temp	kJ/kg
Heat to raise water temperature	kJ
Specific heat of wood logs	kJ/kg/°C
Heat to raise wood logs temperature	kJ
Heating time (for water with logs in it)	Hours
Heating power per tank	kW
Overall heat transfer coefficient for coils	$kW/m^2°C$
Steam pressure	Bar
Saturated steam temperature	°C
LMTD (logarithmic average of temperature difference between hot and cold feeds at each end of the double pipe exchanger) - (delTin - DelTout) / ln (delTin / delTout)	°C
Heating surface required per tank	m^2
Heating coil pipe OD	mm
Pipe length required	m
Heating pipe length per flow	m
Number of loops per flow	m
Pitch of heating pipes	mm
Enthalpy of saturated steam	kJ/kg
Enthalpy of saturated water	kJ/kg
Starting steam flow per tank	kg/h
Density of saturated steam	kg/m^3
Volume flow of steam	m^3/s
Supply pipe/header ID	mm
Velocity of steam in supply pipe	m/s
Heating Pipe ID	mm
Number of steam flows in parallel heating pipes	

Velocity of steam in heating pipe	m/s
Number of tanks to heat up simultaneously	
Total heat input from steam	kW
Total steam flow required	kg/h
LPG input based on 80% boiler efficiency	MJ/h
OPERATING DUTY:	
Heat loss through insulated walls	W/m^2
Insulated surface area of tank	m^2
Heat loss from water surface	W/m^2
Water surface area	m^2
Heat loss	kW
Tank volume	m^3
Mass of water per tank @1000kg/m^3	kg
Mass of wood logs	kg
Cold temperature	°C
Enthalpy of water at cold temp	kJ/kg
Hot temperature	°C
Enthalpy of water at hot temp	kJ/kg
Heat to raise water temperature	kJ
Heat to raise wood logs temperature	kJ
Heating time	hours
Heating power per tank	kW
Overall heat transfer coefficient for coils	$kW/m^2°C$
Steam pressure	Bar
Saturated steam temperature	°C
LMTD (logarithmic average of temperature difference between hot and cold feeds at each end of the double pipe exchanger) -$\frac{\Delta T_{in}-\Delta T_{out}}{\ln\left(\frac{\Delta T_{in}}{\Delta T_{out}}\right)}$	°C
Heating surface required per tank	m^2
Enthalpy of saturated steam	kJ/kg
Enthalpy of saturated water	kJ/kg
Maintaining steam flow per tank	kg/h
Density of saturated steam	kg/m3
Volume flow of steam	m^3/s
Heating pipe ID	mm
Number of steam flows in parallel heating pipes	
Velocity of steam in heating pipe	m/s
Number of tanks to heat up simultaneously	
Total heat input from steam	kW
Total steam flow required	kg/h
LPG input based on 80% boiler efficiency	MJ/h

The operating duty (lower fuel requirements) can be maximised in a water bath/vat system only requiring energy to maintain/upkeep the target water temperature. A summary (table 6 – below) shows the start-up duty fuel requirement (MJ/h) is a magnitude of approximately 20 times higher (for a period of 3 hours) than the operating duty. The operating duty for a water bath/vat is approximately 4% of the start-up duty. A steam chamber, as opposed to a water bath/vat, is approximated to be operating at 10-15% of the systems start-up duty (highly dependent on insulation and opening frequency of steam chamber door).

Table 6: summary of sizing estimate for a water vat

START-UP DUTY*:	7500 m^3/year → → → 20000 m^3/year										
Tank volume	m^3	18	27	36	46	55	64	**73**	**82**	91	100
Volume of logs per day	m^3	14	21	27	34	41	48	**55**	**62**	69	75
Total heat input from steam	kW	293	439	586	732	879	1025	1172	1318	1465	1611
Total steam flow required	kg/h	506	759	1011	1264	1517	1770	**2023**	**2276**	2528	2781
LPG input based on 80% boiler efficiency	MJ/h	1318	1977	2636	3296	3955	4614	5273	5932	6591	7250
OPERATING DUTY*:	7500 m^3/year → → → 20000 m^3/year										
Total heat input from steam	kW	14	19	25	30	35	41	46	52	57	63
Total steam flow required	kg/h	24	33	42	52	61	71	**80**	**90**	99	108
LPG input based on 80% boiler efficiency	MJ/h	61	86	111	135	160	184	209	233	258	283

**summary of factors used to calculate system size. This information has been provided in consultation with Tomlinson energy. Calculations will vary depending on boiler manufacturer and system.*

Using the above calculations including the:

- required production capacity of 15,000 m^3/year, operating weekdays (Monday to Friday) totalling 260 days a year and running 8 hours a day from 8 am to 4 pm,
- an average of 2.5 m long and 0.3 m diameter billets (ranging from 0.25 -0.35 m) with an average volume of 0.18 m^3 per billet,
- with a throughput of 58 m^3 of material or 323 billets a day,
- in a batch process water vat (with a volume of 80 m^3) starting at 20^o C and achieving 90^{o}C,
- and factoring in temperature increase of 70^0, thermal losses, the start-up duty of 3 hours and the operating duty,

the estimated size of the system required needs approximately 2200 kg/h steam. Whilst variable on boiler design efficiency and manufacturer, this roughly equates to a boiler rating of 1500 KW or 150WT for a water-tube boiler (see appendix table 13).

Capital and operating costs

The information contained herein is subject to change without notice. The Queensland Government shall not be liable for technical or other errors or omissions contained herein. The reader/user accepts all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from using this information. Pricing has been sourced for information purposes only. The Queensland Government makes no recommendations or endorsements for any equipment or company that is described below. Professional assistance is recommended to develop site specific information. All costs are presented in AUD and/or have been converted to AUD using the relevant exchange rate at the time of writing.

To gauge capital costs, industry consultation and quotes have been sourced using the above estimated boiler requirement of 2200 kg/h steam and/or 1500 KW or 150 VWT. Water tube boilers were preferred by industry professionals consulted because of the target kg/h requirement and purpose. Therefore water-tube boilers, associated equipment and maintenance are explored for price comparisons. Capital costs and operating costs will be presented by potential options and compared in a summary.

Example 1 – 1250 KW unattended boiler and a water bath/vat

Table 7: Quoted cost of a 1,250 KW unattended boiler and estimated cost of water bath/vat (courtesy of Simons)

Capital costs	Details	Cost (ex. GST)
Steam Boiler	1 x 1,250 KW unattended steam boiler (slightly below intended target however can be compensated by longer start-up duty time), meets *AS 2593:2021*	$140,000.00
Feedwater tank	1000 L feedwater tank, condensate coil, break tank, insulation and cladding, galvanised stand	$14,000.00
Blowdown Tank	440 L blowdown tank	$4,800.00
Water softener	Timer controlled with brine tank	$2,400.00
Chemical dosing pump	60 L chemical dosing pump	$1,800.00
Freight to site	Site dependant – likely to vary	$5,000.00
Commissioning	Site dependant – likely to vary	$4,000.00
Concrete water bath/vat	Reinforced concrete, waterproofing, labour, embedded heating manifolds, heating manifold protection system, plumping, drainage, bunding and insulation to house 80 m^3 of water	$100,000.00
Custom piping and inspection	Connection of fuel source to boiler gas/fuel, inspector and certification to meet *AS/NZS5601.1:2010 Gas installations, Part 1 General installations* (site specific)	Additional

	(quote 1: $200 an hour, quote 2: $32,400)	
Log retrieval system to and from water	crane, gantry, log grab attachment or steel cradles with lifting attachment	Additional
General site preparation for boilers, water bath, loading zone and fuel source	leveling, concrete, weather protection, connection to power, water and fuel source	Additional
	Total capital cost (ex. GST) (not including additional items)	$272,000.00

Table 8: Calculated annual operating costs of a 1250 KW unattended boiler and water bath/vat (steam boiler maintenance provided courtesy of Simons)

Operating costs	Details	Cost (annually)
Steam boiler maintenance and inspections	1 x 1,250 KW unattended steam boiler (11 inspections annually-$1,500 per inspection) with consumables (gauges, seals etc.), blowdown valve, feedwater pump safety value and other items averaging at $4,000 per year. (11 x $1500) + $4000 = $20,500.00 annually	$20,500.00
Water*	80,000 L (water bath/vat volume), required twice weekly and upkeep of steam at 2000 kg/h (10 kilolitres weekly) (80 kilolitres x 2) + 10 kilolitres = 170 kilolitres weekly 170 kilolitres x $3.371* = $573.07 weekly $573.07 x 52 weeks = $29,799.64 annually	$29,799.64
System designed for natural gas	5625 MJ/h required for start-up duty for 10 hours a week $18.59 per GJ 130 MJ/h required for operating duty for remaining 110 hours week at $18.59 per GJ $18.59 GJ/1000 = $0.01859 per MJ Start-up (5625 MJ/h x $0.01859) x 10 = $1045.69 weekly Operating (130 MJ/h x $0.01859) x 110= $265.84 weekly ($1045.69 + 265.84) x 52 weeks = $68,199.56 annually	$68,199.56
Wastewater disposal	Disposal of treated water used in steam boilers and/or other wastewater. Information and pricing is specific to local council trade waste definitions and facilities driven by the *Environmental Protection Act 1994* and the *Water (Safety and Reliability) Act 2008*	Additional
	Total annual operating cost (ex. GST)	$118,499.20

https://www.business.qld.gov.au/industries/mining-energy-water/water/industry-infrastructure/pricing/bulk-water/prices-seq

Example 1 has an estimated capital cost of A$272,000.00 with an annual operating cost of A$118,499.20. There may unexpected or unaccounted for expenses in the capital and operating costs, however, all figures used are conservative. Prices may be subject to change. Labour and/or project management requirements to design and oversee installation were not included in calculations. Labour requirements for operating log heating equipment, depreciation, additional costs and GST were also not included.

Over 10 years, a 1250 KW system operating on natural gas to heat 80 000 L would cost an estimated A$1,456,992.00

Example 2 – 3 x 500 KW unattended boilers and a water bath/vat

Table 9: Quoted cost of 3 x 500 KW unattended boiler and water bath/vat (courtesy of Simons)

Capital costs	Details	Cost (ex. GST)
Steam Boiler	3 x 500 KW unattended steam boilers in tandem to meet *AS 2593:2021*	$211,500.00
Feedwater tank	Custom feedwater tank, ball level water control, isolating valves and galvanised stand	$19,000.00
Blowdown Tank	Blowdown vessel	$6,200.00
Water softener	Timer controlled with brine tank	$6,200.00
Chemical dosing pump	60 L chemical dosing pump	$3,600.00
Freight to site	Site dependant – likely to vary	$8,000.00
Commissioning	Site dependant – likely to vary	$4,000.00
Concrete water bath/vat	Reinforced concrete, waterproofing, labour, embedded heating manifolds, heating manifold protection system, plumping, drainage and insulation to house 80 m^3 of water	$100,000.00
Custom piping and inspection	Connection of fuel source to boiler, gas/fuel inspector and certification to meet *AS/NZS5601.1:2010 Gas installations, Part 1 General installations* (site specific) (quote 1: $200 an hour, quote 2: $32,400)	Additional
Log retrieval system to and from water	crane, gantry, log grab attachment or steel cradles with lifting attachment	Additional
General site preparation for boilers, water bath, loading zone and fuel source	leveling, concrete, weather protection, connection to power, water and fuel source	Additional

	Total capital cost (ex. GST) (not including additional items)	$358,500.00

Table 10: Calculated annual operating costs of 3 x 500 KW unattended boiler and water bath/vat (steam boiler maintenance provided courtesy of Simons)

Operating costs	Details	Cost (annually)
Steam boiler maintenance and inspections	3 x 500 KW unattended steam boiler (4 inspections annually -$1200 per inspection) with consumables (gauges, seals), blowdown valve, feedwater pump safety value and other items averaging at $2500 per boiler per year. (4 x $1200) + (3 x $2500) $4800 + $7500 = $12,300 annually	$12,300.00
Water*	80,000 L (water bath/vat volume), required twice weekly and upkeep of steam at 2000 kg/h (10 kilolitres weekly) (80 kilolitres x 2) + 10 kilolitres = 170 kilolitres weekly 170 kilolitres x $3.371* = $573.07 weekly $573.07 x 52 weeks = $29,799.64 annually	$29,799.64
System designed for diesel	2250 MJ/h required for start-up duty for 6 hours a week at $1.25 per L at an efficiency of 38 MJ per litre 85 MJ/h required for operating duty for remaining 110 hours week at $1.25 per L at an efficiency of 38 MJ per litre Start-up ((2250 MJ/h / 38 MJ/L) x $1.25) x 6 h = $444.07 weekly Operating ((85 MJ/h / 38 MJ/L) x $1.25) x 114= $318.75 weekly ($444.07 + $318.75) x 52 weeks = $39,666.64 annually	$39,666.64
Wastewater disposal	Disposal of treated water used in steam boilers and/or other wastewater. Information and pricing is specific to local council trade waste definitions and facilities driven by the *Environmental Protection Act 1994* and the *Water (Safety and Reliability) Act 2008*	Additional
	Total annual operating cost (ex. GST)	$81,766.28

**https://www.business.qld.gov.au/industries/mining-energy-water/water/industry-infrastructure/pricing/bulk-water/prices-seq*

Example 2 has an estimated capital cost of A$358,500.00 with an annual operating cost of A$81,766.28. There may be unexpected or unaccounted for expenses in the capital and operating costs, however, all figures used are conservative. Prices may be subject to change. Labour and/or project management requirements to design and oversee installation were not included in calculations. Labour requirements for operating log heating equipment, depreciation, additional costs and GST were also not included.

Over 10 years, a 3 x 500 KW system operating on diesel to heat 80,000 L would cost an estimated A$1,176,162.80.

Example 3 – 3 x 500 KW unattended boilers and a steam chamber

Table 10: Quoted cost of 3 x 500 KW unattended boiler and steam chamber (courtesy of Simons)

Capital costs	Details	Cost (ex. GST)
Steam Boiler	3 x 500 KW unattended steam boilers in tandem to meet *AS 2593:2021*	$211,500.00
Feedwater tank	feedwater tank, ball level water control, isolating valves and galvanised stand	$19,000.00
Blowdown Tank	Blowdown vessel	$6,200.00
Water softener	Timer controlled with brine tank	$6,200.00
Chemical dosing pump	60 L chemical dosing pump	$3,600.00
Freight to site	Site dependant – likely to vary	$8,000.00
Commissioning	Site dependant – likely to vary	$4,000.00
Steam chamber	Well insulated shed, waterproofing, labour, steam spray manifolds, plumping, bunding, drainage and insulation to house 58 m^3 of logs.	$100,000.00
Custom piping and inspection	Connection of fuel source to boiler, gas/fuel inspector and certification to meet *AS/NZS5601.1:2010 Gas installations, Part 1 General installations* (site dependent) (quote 1: $200 an hour, quote 2: $32,400)	Additional
Log retrieval system to and from steam chamber	Forklift with steel cradles or rails with log carriages	Additional
General site preparation for boilers, water bath, loading zone and fuel source	leveling, concrete, weather protection connection to power, water and fuel source	Additional
	Total capital cost (ex. GST) (not including additional items)	$358,500.00

Table 10: calculated annual operating costs of 3 x 500 KW unattended boiler and water bath/vat (steam boiler maintenance provided courtesy of Simons)

Operating costs	Details	Cost (annually)
Steam boiler maintenance and inspections	3 x 500 KW unattended steam boiler (4 inspections annually -$1200 per inspection) with consumables (gauges, seals), blowdown valve, feedwater pump safety value and other items averaging at $2500 per boiler per year. (4 x $1200) + (3 x $2500) $4800 + $7500 = $12,300 annually	$12,300.00
Water*	Start -up (21600 kg/h x 10 hours) = 216 kilolitres Operating (2160 kg/h x 110 hours) = 237.6 kilolitres 216 + 237.6 = 453.6 kilolitres 453.6 kilolitres x $3.371* = $1529.10 weekly $1529.10 x 52 weeks = $79,512.45 annually	$79,512.45
System designed for diesel	21600 MJ/h required for start-up duty for 10 hours a week at $1.25 per L at efficiency of 38 MJ per litre 2160 MJ/h required for operating duty for remaining 110 hours week at $1.25 per L at efficiency of 38 MJ per litre Start-up ((21600 MJ/h / 38 MJ/L) x $1.25) x 6 h = $4263.16 Operating ((2160 MJ/h / 38 MJ/L) x $1.25) x 114 = $8100 weekly ($4,263.16 + $8100.00) x 52 weeks = $642,884.21 annually	$642,884.21
Wastewater disposal	Disposal of treated water used in steam boilers and/or other wastewater. Information and pricing is specific to local council trade waste definitions and facilities driven by the *Environmental Protection Act 1994* and the *Water (Safety and Reliability) Act 2008*	Additional
	Total annual operating cost (ex. GST)	$734,696.66

******https://www.business.qld.gov.au/industries/mining-energy-water/water/industry-infrastructure/pricing/bulk-water/prices-seq*

Example 3 has an estimated capital cost of A$358,500.00 with an annual operating cost of A$734,696.66. There may be unexpected or unaccounted for expenses in the capital and operating costs, however, all figures used are conservative. Prices may be subject to change. Labour and/or project management requirements to design and oversee installation were not included in calculations. Labour requirements for operating log heating equipment, depreciation, additional costs and GST were also not included.

Over 10 years, a 3 x 500 KW system operating on diesel to heat a steam chamber would cost an estimated A$7,705,466.60.

Comparison of examples (natural gas, LPG and diesel)

From the provided examples, a 1250 KW water tube steam boiler powered by natural gas for a water vat, 3 x 500 KW water tube steam boilers powered by diesel for a water vat and 3 x 500 KW water tube steam boilers powered by diesel for a steam chamber were detailed for capital and operating costs.

Capital costs were the highest for the steam system that used 3 x 500 KW units in comparison to a single 1250 WT steam boiler. The annual inspections and maintenance costs for the larger single unit were larger than the 3 x 500 KW steam boiler units. Over time, this annual difference potentially makes the 3 x 500 KW more cost effective than the single larger unit, despite the capital cost.

Water consumption for the steam chamber was higher than water required for the water bath. The steam chamber requires the steam boiler to produce and use the steam as the heating source in contact with the logs and is consistently needed to be replaced. In a water vat, the steam enters into heating manifolds where the heat is transferred through coils within the water vat (see figure 8 appendix). This then is condensed and collected and can be recycled continuously. Any opportunity for water use efficiencies (where possible) will reduce operating costs.

Fuel pricing and consumption is the largest operating cost and accounts for the majority of the operating expense for most scenarios. There are significant differences in fuel requirements between the start up duty and the operating duty for each system. Typically, the start up duty for 6-10 hours a week, cost approximately the same as the operating for 110-114 hours. A steam chamber requires the most significant start up duty, which is reflected in fuel consumption and operating costs in comparison to the water bath (see table 11). Not considered in these calculations is the need to continuously open a steam chamber to access logs for peeling throughout the day. Losing all of the heated steam will require a new 'start up' requiring greater fuel consumption and water consumption than has been accounted for. Design strategies or efficiencies in operating methods and insulation to retain generated heat will reduce the operating costs for steam chambers and water baths.

There are significant differences in the operating costs for differing fuel sources with natural gas providing the lowest operating cost, followed by diesel, then LPG. This is despite natural gas having the lowest calorific value. The prices used in calculations are highly subject to variation and would significantly alter the annual operating costs and long-term costs. Additionally, the fuel pricing is subject to supply volumes and geographic location which will significantly change the price per unit for a commercial business. It is recommended to estimate fuel pricing specific to the production system and account for any pre-existing fuel supply arrangements. Outside of capital and operating costs, it is also important to consider the long-term environmental credentials of each fuel source.

Overall, the most cost-effective option (considering the long term operating cost) is the 3 x 500 KW water-tube steam boiler system powered by natural gas (where possible), LPG or diesel for a water vat. For this reason, a biomass based option will explore powering a trio of 500 KW boilers with a water vat for a capital and operating pricing comparison.

Table 11: comparison table of options and costs using differing fuel sources in a water vat or steam chamber

Opt.	Fuel Source	Boiler	Heating	Capital	Operating (annual)	10 year (cap. + operating)
1.1	Nat.Gas	1 x 1250 KW	Water vat	$272,000.00	$118,499.20	$1,456,992.00
1.2	LPG	1 x 1250 KW	Water vat	$272,000.00	$194,166.31	$2,213,663.07
1.3	Diesel	1 x 1250 KW	Water vat	$272,000.00	$170,977.27	$1,981,772.72
2.1	**Nat.Gas**	**3 x 500 KW**	**Water vat**	**$358,500.00**	**$64,516.95**	**$1,003,669.49**
2.2	**LPG**	**3 x 500 KW**	**Water vat**	**$358,500.00**	**$89,389.05**	**$1,252,390.52**
2.3	**Diesel**	**3 x 500 KW**	**Water vat**	**$358,500.00**	**$81,184.40**	**$1,170,344.00**
1a	Nat.Gas	1 x 1250 KW	Steam*	$272,000.00	$538,498.50	$5,656,984.98
1b	LPG	1 x 1250 KW	Steam*	$272,000.00	$1,025,000.69	$10,522,006.85
1c	Diesel	1 x 1250 KW	Steam*	$272,000.00	$875,907.19	$9,031,071.87
2a	Nat.Gas	3 x 500 KW	Steam	$358,500.00	$455,129.46	$4,909,794.61
2b	LPG	3 x 500 KW	Steam	$358,500.00	$858,231.27	$8,940,812.74
2c	Diesel	3 x 500 KW	Steam	$358,500.00	$734,696.66	$7,705,466.61

**capacity greater than 1 x 1250 KW system is recommended for presented example steam chamber*

Example 4 – Gasifier (or biomass burner)

Biomass burners, also known as 'gasifiers', involve biomass to be burnt in place of other fuel sources. This requires differing equipment than traditional steam boilers which will influence the capital and operating costs. Reliable and consistent information on biomass boilers was unable to be sourced however a preliminary example scenario can be developed from different sources.

Biomass is an attractive fuel source for a range of reasons, most notably the potential to use existing waste from the production system. In a veneer production or sawmilling context, this could include using peeler cores, veneer waste/scraps, sawlog offcuts, saw dust or material that doesn't meet the quality target. In some business, this material may be considered a waste product and/or need to pay to have this material disposed of. Utilising biomass also has benefits from a circular economy perspective, utilising as much of the processed material as possible and potentially reducing energy costs on site.

Biomass burning also has limitations. Biomass comes in variety of forms, sizes, taxonomy (hardwood/softwood), densities, calorific values and moisture contents. These factors significantly impact the efficiency of the fuel source. Additionally, in comparison to diesel, LPG and natural gas, biomass has a significantly lower calorific value (see table 4 above), meaning that more material is required to achieve the same kg/h steam output. Biomass is also heavy and takes up volume, which if a site exceeds its own waste production may require 'introducing' and potentially paying for biomass (and transport) from other sources.

Another consideration is that most consistent biomass forms (woodchips for example) already have a competitive global market and may be sought after for a fuel source, for producing pulp, gardening, landscaping, and animal bedding for example.

The moisture content and size uniformity are important considerations for biomass. The heating value capable of being produced is lower for higher moisture content biomass material and differently sized material will burn at different rates and produce non uniform heat fluxes, which can affect the operation and consistency of a steam boiler.

Biomass based boilers will require regular cleaning due to the build up of ash, slag and other debris. This requires the system to be taken off line during cleaning as well as labour operating costs. Depending on the system and manufacturer, systems will likely require attendance for both functional oversight (air control, smoke and flame monitoring) and potentially manual biomass loading.

Biomass systems with some level of automation (e.g control panel) still require an alternate fuel source (likely electricity).

Biomass material costs, collection, processing, and drying has not been explored, however, should be considered on a site and production specific basis.

Can I use a biomass burner to directly heat my water vat?

This may be possible through a custom design, however, it is recommended by industry professionals to use a purpose built biomass steam boiler to safely control steam and heat flux requirements to achieve the target temperature for log heating (without overheating). Purpose built steam boilers also offer greater control over start up duty times.

Table 12: Quoted Gasifier burner/boiler (courtesy of Tomlinson) (ancillary information courtesy of Simons)

Capital costs	Details	Cost (ex. GST)
Biomass Boiler	3 x gasifier (requiring small 8-12 % MC pellets), control unit and automatic conveyor ($70,000 paired with 3 x 500 KW steam boilers (3 x $60,000)	$250,000.00
Wood pelletiser	Commercial wood pelletiser ($10,000 - $100,000)	$50,000
Feedwater tank	Feedwater tank, ball level water control, isolating valves and galvanised stand	$19,000.00
Blowdown Tank	Blowdown vessel	$6,200.00
Water softener	Timer controlled with brine tank	$6,200.00
Chemical dosing pump	60 L chemical dosing pump	$3,600.00
Freight to site	Site dependant – likely to vary 3 x 500 KW boilers ($8,000) Gasifier and conveyor ($8,000) Wood pelletiser ($10,000)	$26,000.00
Commissioning	Site dependant – likely to vary	$20,000.00

Concrete water bath/vat	Reinforced concrete, waterproofing, labour, embedded heating manifolds, heating manifold protection system, plumping, drainage and insulation to house 80 m^3 of water	$100,000.00
Custom piping and inspection	Connection of fuel source to boiler, gas/fuel inspector and certification to meet *AS/NZS5601.1:2010 Gas installations, Part 1 General installations* (site dependent) (quote 1: $200 an hour, quote 2: $32,400)	Additional
Log retrieval system to and from water	crane, gantry, log grab attachment or steel cradles with lifting attachment	Additional
General site preparation for boilers, water bath, loading zone and fuel source	leveling, concrete, weather protection connection to power, water and fuel source	Additional
	Total capital cost (ex. GST) (not including additional items)	$481,500.00

Table 13: calculated annual operating costs of 3 x 500 KW boiler and water bath/vat (steam boiler maintenance provided courtesy of Simons)

Operating costs	Details	Cost (annually)
Steam boiler maintenance and inspections	3 x 500 KW unattended steam boiler (4 inspections annually -$1200 per inspection) with consumables (gauges, seals), blowdown valve, feedwater pump safety value and other items averaging at $2500 per boiler per year. (4 x $1200) + (3 x $2500) $4800 + $7500 = $12,300 annually	$12,300.00
Gasifier and conveyor	Gasifier and conveyor maintenance, labour, cleaning, attendance.	Additional
Wood pelletiser	Wood pelletiser maintenance, consumables, and labour	Additional
Water*	80,000 L (water bath/vat volume), required twice weekly and upkeep of steam at 2000 kg/h (10 kilolitres weekly) (80 kilolitres x 2) + 10 kilolitres = 170 kilolitres weekly 170 kilolitres x $3.371* = $573.07 weekly $573.07 x 52 weeks = $29,799.64 annually	$29,799.64
Biomass*	Assuming dry (10% MC) softwood wood pellets (650 kg/m^3) with efficiency 16'000 kj/kg (maximum efficiency) 115 kg/hour per boiler** 3 x 115 kg/h = 345 kg/h 345 kg/h x 120 operating hours = 41,400 kg weekly	Additional/ free
Wastewater disposal	Disposal of treated water used in steam boilers and/or other wastewater. Information and pricing is specific to local council trade waste definitions and facilities driven by the *Environmental Protection Act 1994* and the *Water (Safety and Reliability) Act 2008*	Additional
	Total annual operating cost (ex. GST) (potentially significant additional costs not included)	$42,099.64

**(Telmo and Lousada 2011) **estimate provided by Tomlinson Energy*

Example 4 has an estimated capital cost of A$481,500.00 with an annual operating cost of A$42,099.64. There may be unexpected or unaccounted expenses in the capital and operating costs, however, all figures used are conservative. Prices may be subject to change. Labour and/or project management requirements to design and oversee installation were not included in calculations. Labour requirements for operating log heating equipment, depreciation, additional costs and GST were also not included.

Over 10 years, 3 x 500 KW system operating on biomass to heat a water vat would cost an estimated A$902,496.4.

Discussion

Four examples have been provided to compare capital and operating costs of log heating for the production of veneer at a production capacity of 15,000 m^3 a year. Using table 11 and examples 1-3, the most favourable options identified that 3 x 500 KW water-tube boilers powered by either natural gas, LPG or diesel for a water vat was the most cost-effective strategy for heating logs long term.

Using these best options (3 x 500 KW and water vat), a biomass option (gasifier) was compared for cost effectiveness. The capital cost for a quoted biomass option was significantly more than the capital costs associated for a traditionally fuelled boiler due to additional specialist equipment. However, over 10 years, the reduced cost/removal of traditional fuel makes the biomass option (assuming the biomass is available at no cost) appears to be comparable to the natural gas system option.

The information provided regarding biomass capital and operating is limited and further investigation is required to identify all additional costs (both capital and operating) which could significantly change the long-term cost of operating log heating equipment.

Best bet options for an Australian production

Based on capital and operating costs, availability, certification to Australian standards and ease of use, 3 x 500 KW natural gas, diesel or LPG steam boilers connected to a large water vat may be considered a favourable option.

Best bet options for a Fijian production

Based on capital and operating costs, 3 x 500 KW steam boilers powered by a gasifier (biomass fuelled) connected to a large water vat may be considered a favourable option.

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Appendix

Table 13: Sizing of vertical water tube boilers provided courtesy of Thermotech and Tomlinson

THERMOTECH INDUSTRIAL BOILERS

Price Lis

BOILER MODEL	RATING (KW)	RATING (hp)	EVAPORATION kg/hr	INPUT mj/hr
VERTICAL WATERTUBE BOILERS:				
6VWT	60	6	92	270
10VWT	100	10	154	450
15VWT	150	15	232	675
20VWT	200	20	309	900
25VWT	250	25	386	1125
30VWT	300	30	463	1350
35VWT	350	35	539	1575
40VWT	400	40	616	1800
50VWT	500	50	773	2250
60VWT	600	60	928	2700
75VWT	750	75	1160	3375
100VWT	1000	100	1547	4500
125VWT	1250	125	1933	5625
150WT	1500	150	2347	6750
200WT	2000	200	3130	9000
250WT	2500	250	3910	11250
300WT	3000	300	4694	13500
350WT	3500	350	5474	15750
400WT	4000	400	6260	18000
500WT	5000	500	7825	22500
600WT	6000	600	9389	27000
700WT	7000	700	10955	31500
750WT	7500	750	11740	33750
800WT	8000	800	12520	33750
900WT	9000	900	14084	40500
1000WT	10000	1000	15650	45000

Figure 3- Image of 2 x 500 KW tandem boilers

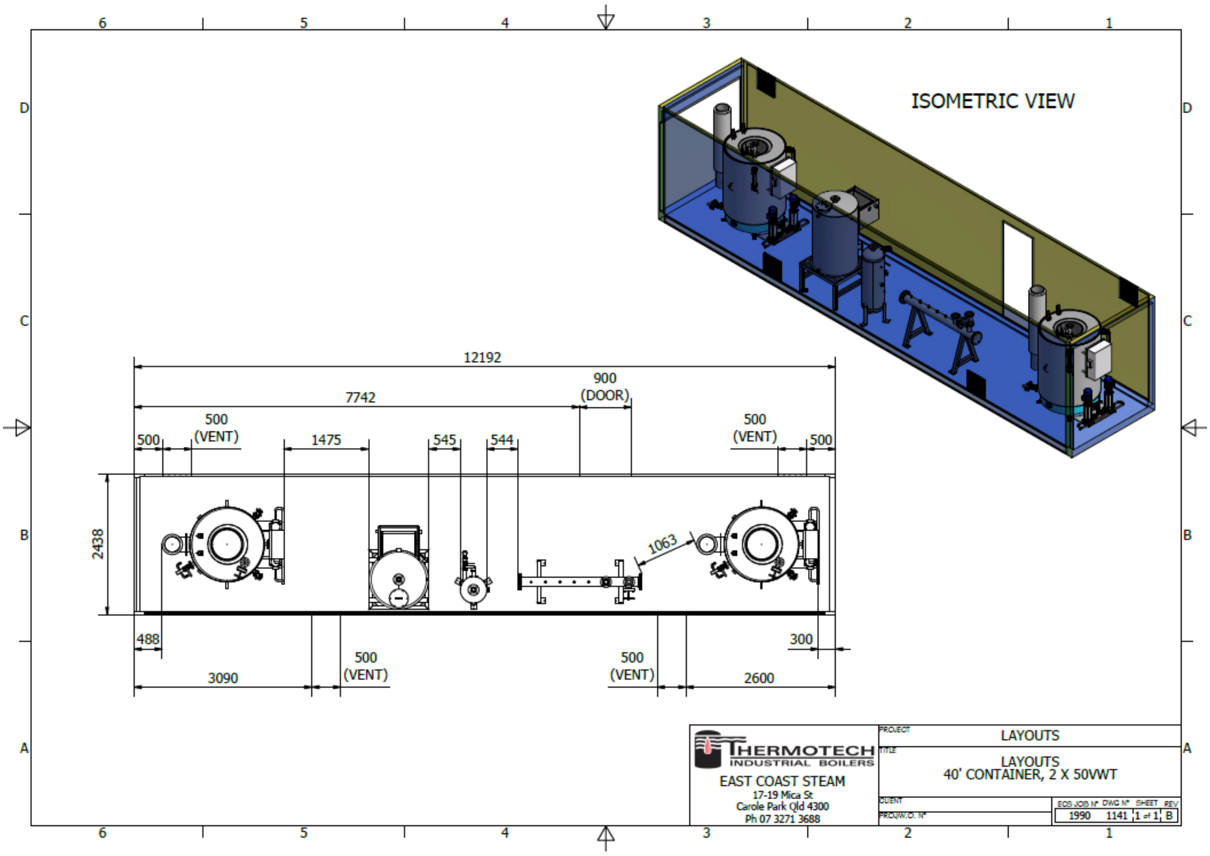

Figure 4- Diagram of 2 x tandem 500 KW boilers in a shipping container

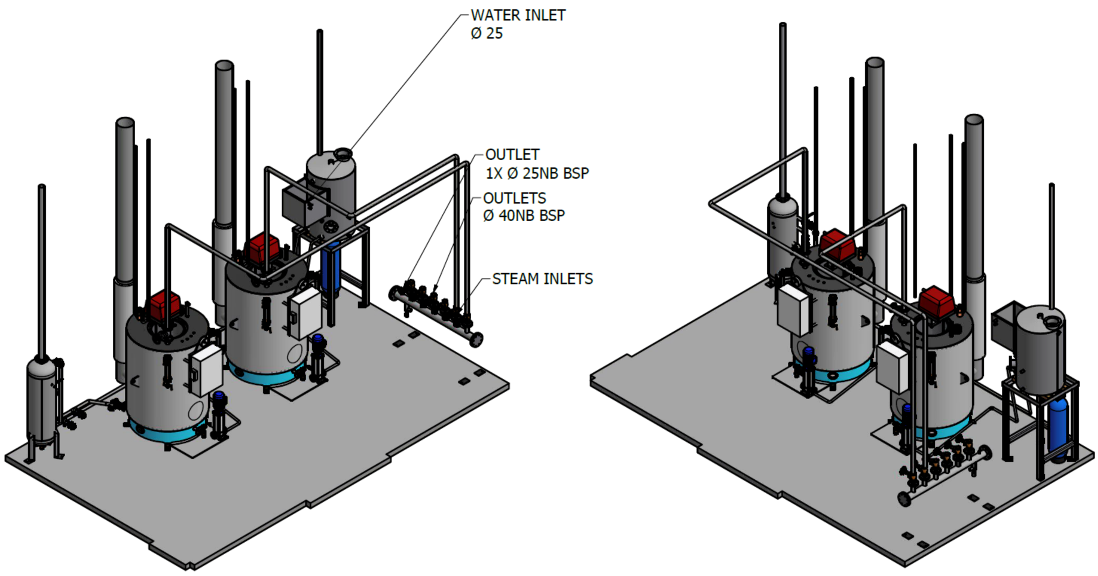

Figure 5- Example layout of tandem boilers and ancillary

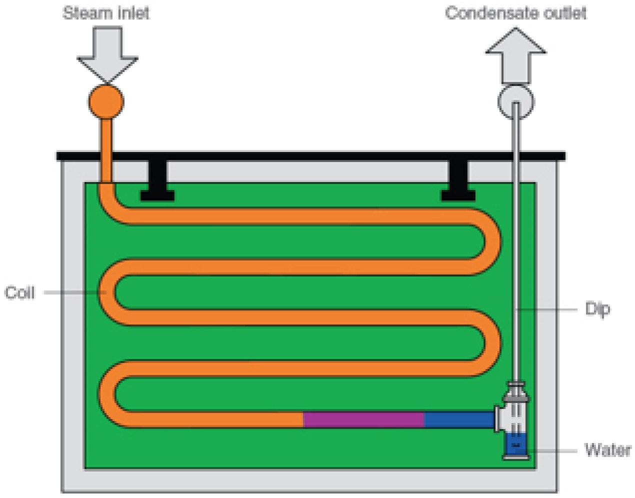

Fig. 2.10.3 Side hung coils

Figure 6- example steam heating manifold for water vat walls

Figure 7-example 'gasifier' or biomass burner

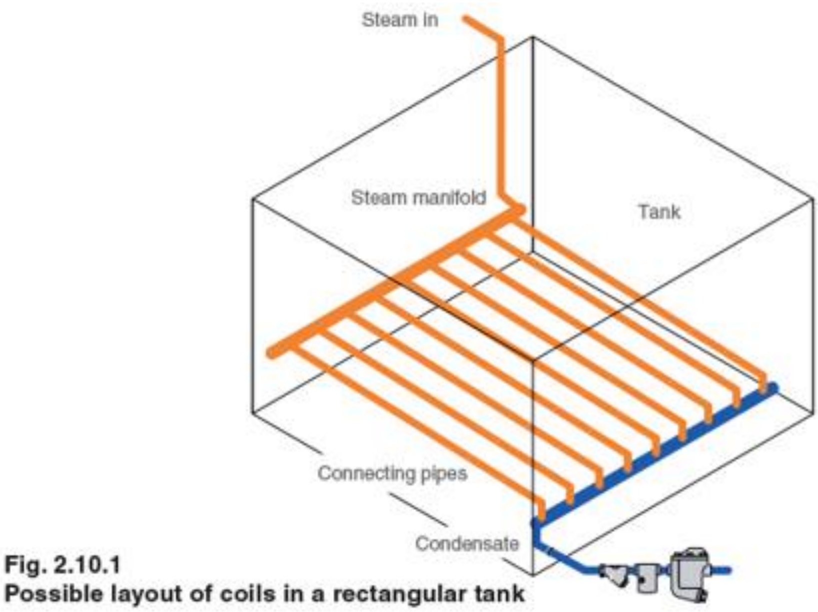

Figure 8- example of steam heating manifold for water vat 'floor' and return condensate

Figure 9- example of 'gasifier'