CASE STUDY

Bioenergy cogeneration plant estimated to contribute $1 million annually to the bottom line

The bioenergy cogeneration plant at Red Stag Timber in Rotorua is turning 21 years old. It's the most recent in a long line of cogeneration plants at the site dating back to 1939, and it's one, that the owner estimates, contributes up to $1 million annually (before interest and depreciation) to the bottom line. This case study tracks the plant through its conception, growth and prospects in today's volatile energy markets.

Overview

In 1986 a 20MW boiler and associated 3.5MW electricity generator were commissioned at the Waipa Sawmill (now owned by Red Stag Timber). In 1992 the boiler capacity was doubled to 40MW. The boilers consume all the sawdust, bark and off-cuts from the Mill making it largely self-sufficient for energy.

During the weekends and other times when the Mill is not running at full capacity it can sell electricity back into the national grid. The economics of doing so depend on the Mill's demand for energy, the prevailing cost of sawmilling waste products that may have to be bought in and the price of electricity on the spot market.

This case study provides some useful considerations for any business interested in installing a cogeneration plant using forestry waste products. It looks at the physical design and operation of the cogeneration plant at Waipa, as well as the issues it faces around a volatile energy market.

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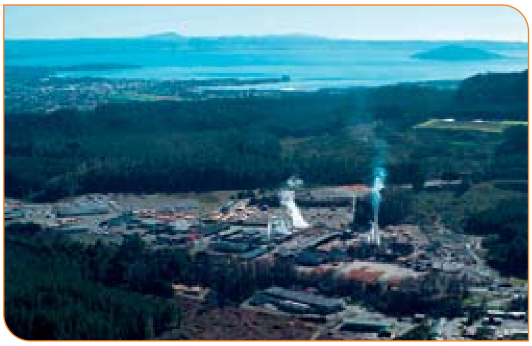
About Red Stag Timber and the Waipa Sawmill

Red Stag Timber is a privately owned timber company based in Rotorua. It operates the Waipa Sawmill and associated timber processing operations. It produces 300,000m^3 of lumber per annum, with an annual turnover of around $110 million, and it employs approximately 240 staff.



Waipa is the largest sawmill in the country.

The Waipa Sawmill was originally established in 1939 as a state-owned experimental sawmill to pioneer the milling of Pinus radiata. The Mill has grown since that time to become both a local and national icon of sawmilling and the largest sawmill in New Zealand. And it is still growing.

The Mill was corporatised in 1988 and later privatised in 1996. In 2003 it was purchased by the new owners and now trades as Red Stag Timber Ltd.

Red Stag has recently taken the Mill to new levels of production. This increase in production is matched by increases in energy demands, and the creation of additional bioenergy fuels in the form of sawdust, bark, block and shavings.

The waste from the sawmilling process has been used at the Mill since 1939 to generate steam for drying timber, mechanical energy to drive equipment and to generate electricity. Several generations of boilers, stationary steam engines and steam turbines have come and gone over its lifetime.

By the mid 1980s the existing boiler was over 30 years old and due for replacement. It triggered the opportunity to install a new, state-of-the-art cogeneration plant that is still at the heart of the Mill's operation today. The plant enables the Mill to be largely self-sufficient in energy and to sell electricity back into the national grid under certain conditions.

The principles of cogeneration

The underlying principle of cogeneration is to use a single energy source to generate both hot water (and often steam) and electricity. When supplied as a turnkey solution it can also be called Combined Heat & Power (CHP) plant.

In New Zealand we have examples of cogeneration solutions at both ends of the size scale. In Christchurch, WhisperGen, owned by Meridian Energy, manufactures and exports domestic cogeneration plants that burn diesel or natural gas to produce up to 12kW of water heating and 1kW of electricity. At the other end of the scale, the Kinleith Pulp and Paper Mill has a biomass-fired 160MW cogeneration plant, of which 40MW is converted to electricity and the balance is used as heat in manufacturing processes.

Industrial cogeneration plants are typically installed at sites where there are significant demands for process heat distributed as steam. Fuels such as diesel, coal or biomass are burnt in boilers to produce normal processing steam as well as super-heated, high-pressure, steam for electricity generation (typically 400°C at 40 bar). The pressurised steam drives a turbine which, in turn, drives an electrical generator. After the steam has passed through the turbine its temperature and pressure are much lower because some of the energy has been converted to electricity. Depending on the configuration of the cogeneration plant, the low-pressure steam discharged from the turbine may be used as normal process steam or be condensed and fed back through the boiler.

Generating electricity this way, as a by-product of having to create steam for industrial processes, is very efficient from an energy utilisation perspective. It can bring other advantages such as reduced reliance on outside supply of electricity, and reduced lines charges and peak demand charges. But it also has costs over and above those associated with on-site generation of heat only. Those costs relate to:

- the higher capital cost of the high-pressure boilers, steam turbine, generator and control systems;
- more stringent and costly annual surveys (due to the high pressure system);
- higher qualification and pay requirements for the boiler operators (they must hold a 1st class stationary engine driver's certificate or the EMChem level 4 qualification – which are qualifications also in high demand in the maritime industry); and
- larger condenser units and their associated maintenance costs.

Forestry derived bioenergy

The forestry and timber industries produce residues that can be either used as bioenergy fuel or disposed of as waste.

The amount of residue available for use as bioenergy depends on the rate at which forests are harvested, and the proportion of logs that are exported versus processed locally.

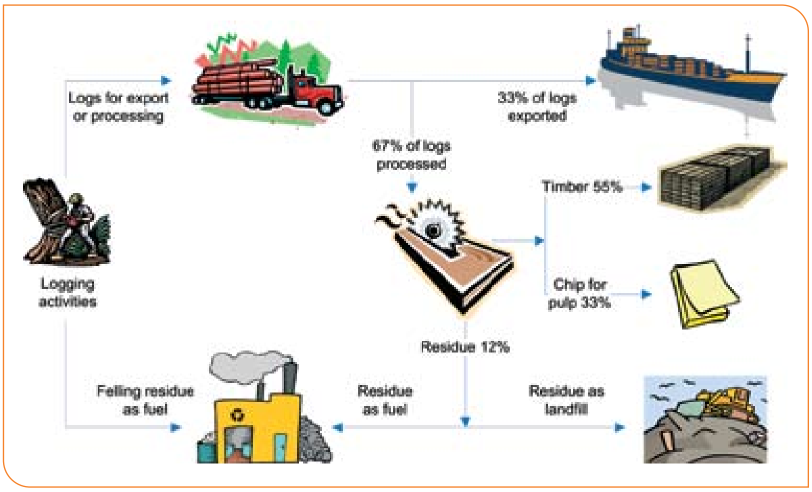
The actual take-up of the available residue as a bioenergy fuel depends on the economics of recovering residues from the forest felling site, the costs of dumping milling residues, transport costs and the cost of alternative fuel sources.

At present, 33% of the harvested volume is exported as whole logs, and 67% is processed in our mills. A small percentage of the residue on the felling sites is recovered, chipped and transported (mostly to Kinleith) as a bioenergy fuel. The remaining bioenergy fuel comes from milling processes, with 12% of the log volume being turned into sawdust, bark, shavings and block.

Sawmills are major consumers of heat energy, mainly for kiln drying. It's estimated that 94% of South Island sawmills and 74% of North Island sawmills derive most of their heat energy from using their own milling residues for fuel.

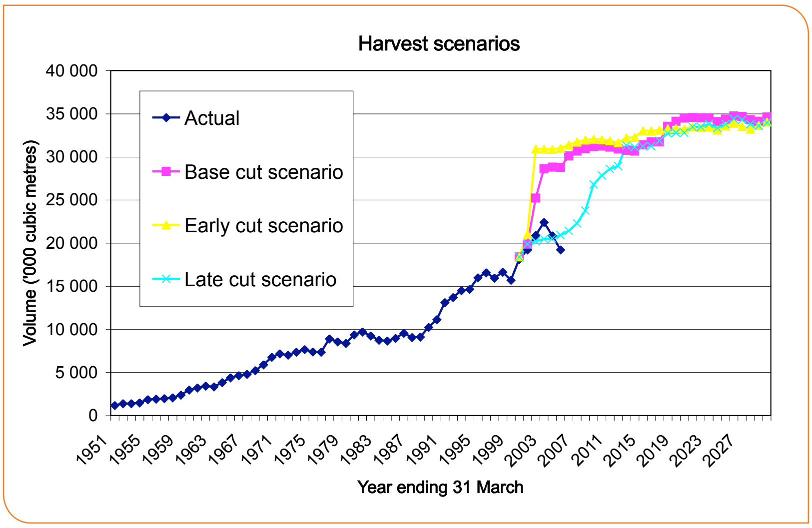
Most mills currently produce more residues than they can use. The surplus is either being dumped, or transported to a range of users including a few mills with higher energy demands than the average mill (due to the range of processes on-site), to heat-pellet making facilities or, for particular grades of residue, to fibre-board factories.

Traditionally the 'market' in residues as a fuel source has been very fragmented and localised due to the high transport cost of residues relative to their energy value. There have been cases of residues being delivered by one mill to another at no charge, simply to avoid dumping costs. Generally the buyer at least pays for the freight.



More recently there have been signs of a market forming, with some mills entering into forward contracts to supply residue that will be used as a bioenergy fuel.

The forecast is for a significantly increased supply of forest and milling residues as a direct consequence of an increased harvest of our exotic forests.



What is much harder to forecast is whether the demand for the residues will increase correspondingly. There are many factors that may influence the demand.

If demand grows faster than supply, then the cost of forestry derived bioenergy fuel for process heating, and cogeneration, will increase. However, its economic appeal will depend on its long-run cost relative to that of other renewable and non-renewable types of fuel.

The 21-year-old bioenergy cogeneration plant at Red Stag's Waipa Mill

By the mid 1980s the 30-year-old boiler and two 55-year-old steam turbine generators at the Waipa Mill were at the end of their economic life. The plant was incurring soaring maintenance costs and a labour intensive work programme to keep it operating. Also, the Mill was continuing to expand and would soon need more heat and electrical energy than could be provided by the old plant and limited electrical supply from the local power board.

The new design was for a 20MW boiler that could burn wet sawdust, shavings, and hogged[1] material. High-pressure, superheated steam from the boiler would power the by-pass condensing turbine to drive the 3.5MW alternator. Then, 33% of the by-pass steam would be extracted and used as process heat, and the rest condensed and re-used in the boiler.

The boiler was constructed by Babcock (NZ) in Dannevirke and then transported to Waipa in kitset form. The steam turbine and generator for the electricity plant was manufactured by Siemens and installed by McConnell Dowell. It was fully operational by early 1986, and completely replaced previous heat and electrical generation on the site. The total cost of the project was $7.2 million.

The Mill was owned at that time by the Government, and the economics of the investment may well have been fully justified, either on a purely commercial basis, or with the additional benefit of it being a demonstration project with the potential of being replicated elsewhere. Unfortunately, due to the passage of time, the business case could not be located for this article.

From left to right: Condenser unit, chimney, No. 2 boiler, No. 1 boiler, control room / turbine generator building.

The steam turbine spins at 11,800 RPM and makes a noise similar to a jet airliner.

By 1992, heat demand at the site was increasing significantly and a second 20MW boiler was added to the plant. Unlike No. 1 boiler, this boiler was specifically designed to be able to burn bark and consequently has a moving grate to handle the higher ash content. Up until then bark residue from the milling process actually represented a cost, for dumping, rather than having value as a fuel source.

Each Christmas the plant is shut down for three weeks to allow for the annual survey of the boilers, general maintenance and for upgrades that have been planned during the year.

The entire plant is now largely automated, and is managed from a central control room adjacent to the two 20-metre-high boilers. A SCADA system provides the operators with real-time operating data and finger-tip control of the main systems.

The plant controllers work in pairs, two shifts a day. They monitor systems and alarms, adjust settings to optimise performance, carry out preventative maintenance and operate the loader that supplies and mixes the fuel.

The steam turbine and generator are housed a few metres from the control room. Soundproofing is essential as the turbine spins at 11,800 RPM creating a very high-frequency, high-decibel, noise similar to a jet engine.

Sensors monitor the phase of the external electricity supply coming into the site, and then signal control systems to synchronise the phasing of the generator.

[1] Ground up off-cuts (also referred to as a block).

Experiences with sourcing & mixing bioenergy fuels

The Waipa Mill currently produces enough bioenergy fuel from its milling operations to get the heat it needs for its timber processing activities. However, there are times when additional fuel must be bought in when the electrical demands of the site require the steam turbine to run at full capacity or, when the milling operation is shut down (weekends) and thus not producing milling residues that can be used as fuel, and the plant is still being run to export power back into the national grid.

An understanding of the optimum mix of fuel for the boilers provides, in turn, an understanding of the fuel buy-in requirements of the Mill.

- Boiler No. 1 burns a mix of sawdust, shavings and hogged material in roughly equal quantities. It has a forced air, fixed grate system, and ash must be manually raked out.
- Boiler No. 2 burns a mix of sawdust, bark and hogged material in roughly equal quantities. It has a forced air, moving grate system, and automatic ash removal.

Sawdust and shavings from on-site milling operations.

Wet sawdust and bark ready for mixing with dry materials.

Sourcing wet sawdust:

The sawdust generated at the Waipa Mill tends to be drier than that of many other mills because of the way they tightly control the supply of water to the saw blades. This, combined with their on-site production of dry shavings from their planing operation, provides Waipa with a large source of relatively dry fuel.

With the Mill's large on-site source of dry fuel, when it does need to buy in fuel, it can buy the cheaper wet sawdust from other mills, and mix it with the dry material, to still achieve the target moisture content of 50% to 55%.

Sourcing bark:

The ability of Boiler No. 2 to burn bark also has a significant impact on the Mill's fuel buy-in decisions. The bark residue from the Mill's own operations is not sufficient to run Boiler No. 2 with a 33% bark mix.

Of all the forestry residues, bark has the least number of economic uses, and many boilers are unable to burn it efficiently. It has therefore been a relatively cheap fuel source in the past, however the cost has steadily risen as bark becomes more and more sought after as a landscaping product. It now costs much the same per tonne as sawdust.

"Now and then the Mill must buy in additional fuels – an understanding of the optimal mix of fuel for the boilers is a necessity."

Handling and mixing the fuel:

Handling and mixing the fuels effectively requires substantial capital and operational costs, although they are all costs that are common to running bioenergy fuelled boilers, and are not specific to the cogeneration features of the plant.

The handling issues are in getting the mill residues to the boiler site. The Waipa Mill is spread over many hectares of land, and residues are transported by truck, conveyor belts and front-end loader.

Block is hogged down to easily combustible lumps. Their size is important to ensure the final fuel mix with sawdust has the right texture to allow air flow to maximise combustion and to avoid smothering the grates in the boilers. This is as important as getting the moisture level of the mix to no more than 50% to 55% of its dry weight.

The mixing process is initially done by front-end loader. It is literally a bucket of each type of fuel dumped together, turned over a couple of times and pushed into the hoppers that feed the conveyors that take the fuel to the boilers.

There is a high degree of judgement required by the operators to get the moisture level right. The separate stores of sawdust, bark and hogged material provide the ingredients for the mix.

Options for separate processes to dry the fuel before going to the boiler have been considered. To date, the prevailing wisdom has been that overly moist fuel reaching the boilers will be dried anyway as it gets fed onto the grate, and that loss of energy due to the high moisture content would have been lost in any pre-drying process anyway.

Mixed fuel for Boiler No. 2 is conveyed 10 metres up to the main feeder hopper.

Generating and selling electricity

When the Waipa Mill is operating at its current full capacity, its electrical demand averages at 4.0MW, and can peak to 4.5MW.

Two-way flow of electricity:

The 11kV power lines from Rotorua have a sustainable capacity of 2.5MW, and so the cogeneration plant must produce a minimum of 2.0MW of electricity when the Mill is running at full capacity. In fact, the cogeneration plant produces 3.0 to 3.5MW most of the time, reducing peak demands for external electricity supply down to just 1.0 to 1.5MW.

In the weekends, when the Mill is not operating, the cogeneration plant could be used to pump 2.5MW straight back into the national grid.

The effect of this two-way flow of electricity is monthly power bills of, typically, $40,000 for energy purchased, and a credit of $20,000 for energy sold back into the grid. There have, however, been instances of $60,000 credits during periods of high spot market electricity prices, and low electricity demands at the Mill.

"The effect of the two-way flow of electricity typically has a dramatic effect on the Mill's power bills".

Metering and reconciliation:

The Waipa Mill buys and sells its electricity through TrustPower. The prices (for both buying and selling) are directly based on the spot market. In fact, the operators in the plant control room are monitoring the spot market rates real-time and could increase or decrease their level of generation based on the economics of every half-hour block.

The connection points to the power company lines for the Mill's consumption of external power are separate to the point where the Mill feeds power back into the grid. Each of those points is separately metered by TrustPower. In addition, the Mill has its own meter on the exit point to the grid so it can reconcile the monthly statement from TrustPower. Generally, there are very few variances and the trading relationship between the Mill and TrustPower works smoothly.

The economics of generating to sell into the spot market:

During the summer of 2006/07 the Mill chose not to run the cogeneration plant at full capacity to maximise its electricity sales into the spot market. Two key influences on this decision were:

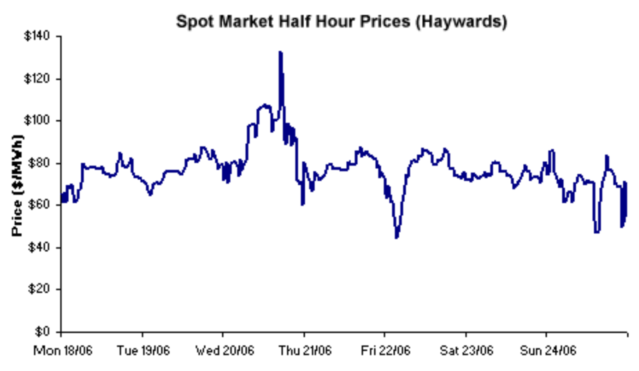
- Spot market electricity prices were particularly low (around 2.5 cents/kWH) due to high lake levels and cheap hydro generation.
- The 'buy-in' costs of extra bioenergy fuels had crept up (possibly due to forward contract purchasing of sawdust by pellet-fuel manufacturers).

While the exact calculation used by the Mill in deciding when to, or not to, sell power into the spot market is commercially sensitive, their general rule of thumb is that:

If the spot market price is over 6.5 cents/kWh,

And the cost of bought-in fuel is under $10 / tonne delivered to site,

Then it is worth ramping up the generation to sell into the spot market.



Plant maintenance

The main points of difference in maintaining a cogeneration plant as opposed to an ordinary boiler relate to the higher pressures and temperatures in the cogeneration steam circuit.

The Waipa Mill employs nine qualified operators to cover a 24/7 operation. This may be double the number of operators required for a normal boiler, and being so specialised and qualified these operators command higher rates of pay.

The annual survey costs are also higher than for a standard boiler. Because of the higher pressures in the cogeneration circuit, the level of scrutiny is higher and the time taken is longer. In the past, one boiler could be shut down for the three weeks required for the annual survey and maintenance, while the other boiler kept operating to allow the Mill's business activities to continue. In more recent times, because of the growth of the Mill and its increased need for heat to run efficiently, both boilers and the whole Mill are closed down at the same time.

The steam turbine and generator have been very reliable over the 21 years with very few problems encountered. The only major issue in recent time was in February 2006 when back-up power to the oil pump feeding the turbine bearings failed during an outage.

Fortunately, replacement bearings were available within New Zealand and the strip-down, repair and re-alignment of the turbine was made within three weeks. The repair bill was $150,000 and the additional cost of electricity purchases was of a similar order. During that period the local lines company, Unison, ran the 11kV feeder line at 3.5MW (150% of sustainable capacity) to help keep the Mill operational, albeit at reduced production levels.

There is always the potential for a major failure of the turbine. If something does go wrong, parts may have to be shipped from Germany with substantial lead times. To mitigate this risk the Mill carries a comprehensive set of spare parts.

Summing up the last 21 years and planning for the future

Red Stag's Chief Financial Officer, Paul Laing, is very clear about where the cogeneration plant sits in business priorities. He says:

"Our core business is milling and marketing timber products, first and foremost. The supply of processing heat is essential to that, and the generation of on-site electricity is a bonus. Cogeneration has been very beneficial to us over the years as we've had a surplus of cheap bioenergy fuel and surplus heat capacity. It could be worth about $1 million a year to us. But, our heat demands are growing. If we have to sacrifice electricity generation to get more heat, then we will. We can always import more electricity, but we can't import heat."

Paul's conscious that the company has insufficient built-in system redundancy if the turbine goes down. Plans are already in place with local lines company, Unison, to upgrade the line capacity from 2.5MW to 6.0MW before the end of the year. This will give the Mill the option of sending the full 3.5MW capacity of the cogeneration plant out into the spot market at times when the Mill isn't operating. The economics of doing so will depend on the spot market price for electricity and the prevailing cost of bought-in forest residues.

The upgraded lines also provide the opportunity to redirect the energy used by the cogeneration plant to, instead, go directly to meet the heat demands of the milling processes and to import all the Mill's electricity requirements.

Looking out beyond 2010, Paul forecasts that the electricity demands for the site may exceed 6.0MW. He's already talking to Unison about a further upgrade to their lines, to 33KV, to meet that potential demand. And, while the continued operation of the cogeneration plant can help defer such a further upgrade for many more years, the potential for a catastrophic failure of the turbine or a spike in the cost of bioenergy fuels means that the extra lines capacity, sooner rather than later, is a good back-up to ensure continuity of Red Stag's core business.

When asked for advice to other businesses contemplating cogeneration, Paul says:

"For Red Stag and this plant it's not a hobby. It's a big capital investment, and a big operational investment in specialised staff and materials handling. There are real issues of scale that need considering. The supply and price of fuel are also critical."

EECA – supporting the use of woody biomass

This resource is one of a number of demonstration projects being publicised under a new forest bioenergy initiative co-ordinated by the Energy Efficiency and Conservation Authority (EECA).

Representing the woody biomass stream of the Government's Forest Industry Development Agenda (FIDA), the initiative is designed to increase renewable energy use, and industry participants' incomes, through the use of wood waste from tree harvesting as well as waste produced from wood processing sites.

Sharing the results of these demonstration projects will help other businesses understand their bioenergy options and increase the utilisation of woody biomass.

This case study is part of a set available to industry. To source the others in the series, or for more information, visit **www.bioenergy-gateway.org.nz**

FOR MORE INFORMATION

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