IEA Bioenergy

Task 38

Greenhouse Gas Balances of Biomass and Bioenergy Systems

Greenhouse Gas Benefits of a Combined Heat and Power Bioenergy System in New Zealand

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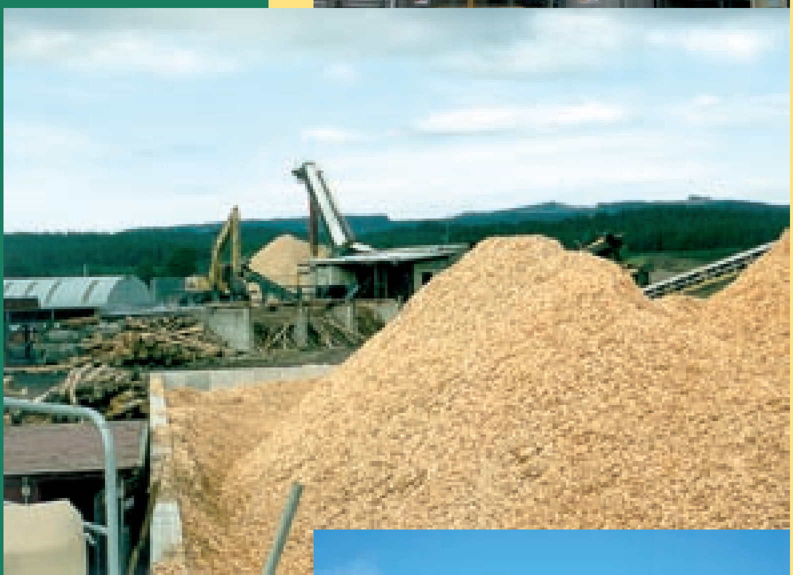
Courtesy of Red Stag Timber Ltd, New Zealand



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Summary

This study looks at the greenhouse gas emissions of a Combined Heat and Power(CHP) bioenergy system utilising wood processing residues and compares net emissions with a 'reference system' using natural gas to provide the same energy service. Opportunities for improving the greenhouse gas (GHG) balance are also explored. Results indicate that the bioenergy system reduces GHG emissions by 16,235 tonnes of CO_2 equivalent (t CO_2e) per year. This equates to a GHG emission reduction of 0.08 t CO_2e/t of dry biomass used or 0.15 t/MWh of energy produced. The results of this analysis are specific to the bioenergy system, reference system and assumptions used. Under the default assumptions used in this study the bioenergy system compares favourably with the reference system, but small changes in uncertain factors can reverse this result.

Bioenergy offers the opportunity to maintain energy supply and reduce gross emissions relative to 1990, if it replaces an energy source that was emitting greenhouse gases in 1990. Bioenergy can also increase energy supply without the associated increases in emissions from fossil fuels sources, and hence reduces emissions relative to a BAU scenario.

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Scope

This study looks at the substitution potential of a CHP system for reducing greenhouse gas emissions based on a bioenergy system in New Zealand that utilises wood processing residues to meet the electricity and heat demands of the associated wood processing plant. Figure 1 provides an overview of the bioenergy system. The residues are derived from a sustainably harvested forest (where regrowth of the forest compensates for harvest) and therefore the CO_2 emissions from the burning of residues do not need to be taken into account.

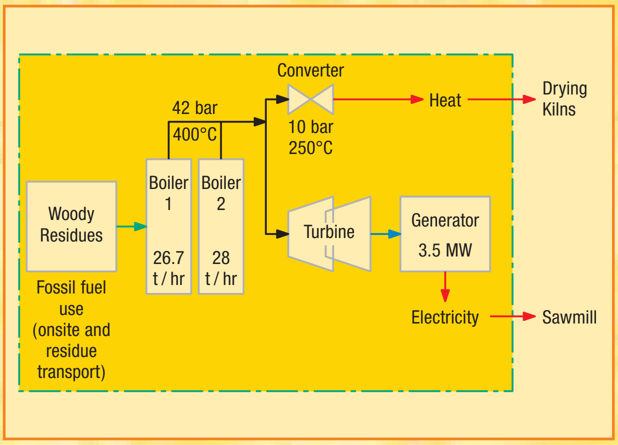

Figure 1. Bioenergy System

In the absence of a bioenergy system it has been assumed that the same electricity and heat services will be provided by natural gas as this is what commonly occurs at other sawmills within New Zealand. Where the residues are not utilised for bioenergy it is common practice to dispose of the residues in the forest or landfill. Figure 2 provides an overview of the reference system.

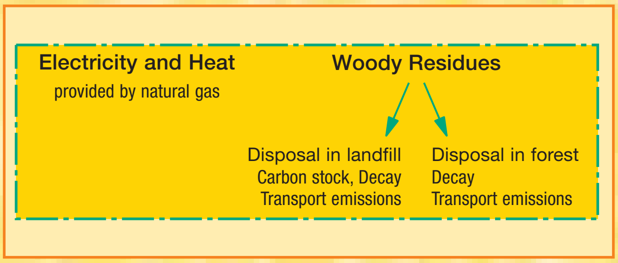

Figure 2. Reference system

Methods

Bioenergy System

Residues used by the CHP plant were estimated based on the assumptions that the system produces 33 t/hr of steam and 1 t of residues provides 2.5 t steam. Electricity is generated on site using a 3.5 MW turbine and electricity generator. The turbine requires 19 t/hr or 149 400 t/yr steam to run at full capacity. It has been assumed that the turbine is run 90 % 24 hours a day, 7 days a week allowing some time for maintenance and breakdowns giving a load factor of 7 862 hrs/yr. A steam to electricity conversion efficiency of 70 % is assumed. The remainder of the steam (14 t/hr) is used to produce heat for timber drying.

It is estimated that approximately 19 GWh (69 000 GJ/yr) of electricity are generated annually. Heat generated on site is estimated at 90 GWh (324 000 GJ/yr). Diesel is used by on site machinery to move residues around the site, emissions are allocated to the residues and sawn lumber based on mass where 31 % of wood was assumed to become residues. A small amount of residues are also imported from other wood processing sites in the region and fossil fuel use is estimated based on a travel distance of 100 km return.

Reference System

In this study it is assumed that 50 % of the residues go to landfill and 50 % is disposed of in the forest. The carbon stock change of the landfilled residues are estimated. Emissions of CH_4 from landfilled residues are estimated assuming that 3 % of the carbon is released as landfill gas and 10 % of this is released as CH_4. The remainder becomes a permanent carbon stock in the landfill (Micales and Skog 1997). The residues spread in the forest are all assumed to decay and the emissions are assumed to be 10 % CH_4. (Mann and Spath 2001). It is assumed that all emissions are released in the year of disposal. Fossil fuel emissions due to the transport of residues to landfill are based on a return transport distance of 10 kms, and to forest a return transport distance of 5 kms is assumed.

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The following GHG emission factors were used for natural gas (MED 2001a): CO_2 52.1 Kg/GJ; CH_4 0.0027 Kg/GJ; N_20 0.00009 Kg/GJ. All GHG emissions are presented in tonnes of t CO_2 equivalents (t CO_2e). When compared to CO_2 over a 100 year period, CH_4 has a Global Warming Potential (GWP) of 21 and N_20 has a GWP of 310 (IPCC 1995). For more detailed information on the methods used to calculate GHG emission reductions please see the full report (Robertson, 2003. www.joanneum.at/iea-bioenergy-task38/projects/task38casestudies/nz_fullreport.pdf)

Results

CHP Bioenergy system

The only GHG emissions from the bioenergy system are due to the transport of residues and are estimated at 165 t CO_2e/year (Table 1).

Table 1. GHG balance of the bioenergy system (t CO_2e/yr)

	Diesel Use (l)	CO_2	CH_4	N_20	Total
On site transport	30 787	80	0.34	1	81.34
Residue import	31 450	82	0.35	1	83.35
Total	**62 237**	**162**	**0.69**	**2**	**165**

Reference system

As indicated in Table 2 the overall GHG emissions of the reference system are 16 400 (t CO_2e/yr). The major source of emissions for the reference system is methane emitted from decay of residues in the forest. The disposal of residues into landfill would increase the carbon stock in the landfill by 12 584 t C/yr (46 140 t CO_2e/yr). While residue disposal to the landfill leads to an increase of the carbon stock in the landfill it also leads to significant methane emissions.

Table 2. GHG Balance of the Reference System (t CO_2e/yr)

Emissions	CO_2	CH_4	N_20	Total
Electricity (nat gas)	3 613	4	2	3 619
Heat (nat gas)	16 883	18	9	16 911
Transport (diesel)	67	0	1	69
Decay of residues		41 773	170	41 943
Total				**62 541**
C stock change				
Landfill	–46 140 [1)]			
Balance				**16 400**

Comparison of the CHP Bioenergy System with the Reference System

The CHP bioenergy system reduces greenhouse gas emissions by 16 235 t CO_2e/yr (Table 3) when compared to the reference system. This equates to a GHG emission reduction of 0.08 t/t dry biomass used or 0.15 t/MWh of energy produced.

Table 3. Emission reduction (t CO_2e/yr)

Emissions	Bioenergy system	Reference System
Electricity	0	3 619
Heat	0	16 911
Fossil fuel	165	69
Residue disposal	0	41 943
Total	**165**	**62 541**
C stock change		
Landfill	0	-46 140
Balance	165	16 400
Emission reduction	**16 235**	

Uncertainty of Results

Selected assumptions, chosen to cover those aspects of greatest uncertainty, were varied to determine the impacts on the estimation of comparative GHG balance. Factors that have a large impact on emission reduction are mostly associated with the reference system and residue disposal (Figure 3), changing the emissions to which the CHP system is being compared rather than the CHP system itself. The percentage decomposition of residues disposed of in the forest had the greatest impact. The reference system assumes that 100 %

1) A negative number indicates a positive stock change (or carbon sequestration) of residues disposed of in the forest decay; the sensitivity analysis also looked at the impact of 90 % and 80 % decay. The emission reduction is reduced from 16 235 to 7 846 t CO_2e / yr if 90 % of residues decay and further reduced to –543 t CO_2e / yr (that is, a net increase in emissions for the bioenergy compared with the reference system) if only 80 % of the residues decay and the remaining 20 % increase the carbon stock in the forest.

Table 4. Sensitivity analysis variables

Variable	Default	Min	Max
% waste to landfill	50 %	45 %	55 %
% c released in landfill	3 %	1 %	5 %
% landfill gas released as CH_4	50 %	40 %	60 %
% CH_4 released from residues disposed of in forest	10 %	5 %	15 %
Residue to landfill transport distance (kms)	10	5	15
Truck payload (tonnes)	15	10	20
Conversion efficiency (steam to electricity)	70 %	63 %	77 %
Load Factor	7 862	7 076	8 647

The impact of all other variables tested (Table 4) on the emission reduction of the CHP project can be seen in Figure 3. The percentage of methane emitted by residues disposed of in the forest has a large impact on the overall emission reduction as all these residues are assumed to decay and methane has a high GWP compared to carbon dioxide.

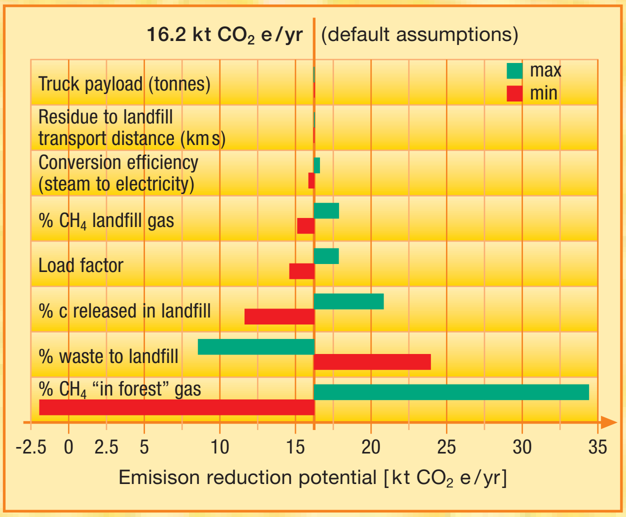

Figure 3. Sensitivity analysis

Courtesy of Forest Research, New Zealand

Improvements

Currently the CHP system is working at 60 % of full capacity. There is potential to increase the steam production from 33 to 54 t / hr, this could then be used to produce more heat. There is a local heat demand by a variety of other users within a short distance of the bioenergy system. There is also a supply of biomass available at little or no cost.

The demand for low grade heat in the local city is estimated at 120 GWH / yr. One option is to use bioenergy to meet this demand by establishing a heat distribution network to local hotels as many of them are within 5 – 10 kms of the bioenergy system. The heat generated could be used to meet a high proportion (88 %) of the low grade energy demand.

A further 75 000 t of steam / year could be generated if all the processing residues currently being landfilled are utilised in the bioenergy system. Another 87 500 t / year could be generated if forest residues within 20 km are utilised. This gives an increase of 162 500 t / year of steam at 250 °C and pressure of 10 bar. This equates to 133 GWh of heat, but the steam needs to go through another pressure reduction before final use, potentially losing 12 GWh. It is estimated that a further 20 % or 27 GWh would be lost along the pipeline, therefore there could be 97 GWh available to consumers.

Based on the heat from the bioenergy system replacing the use of natural gas and residues not being disposed of in landfill or forest, the GHG emission reduction could be increased to 25 000 t / yr of CO_2 e, an increase of about 9 500.

There is also potential to increase the efficiency of the system through pre-drying of residues before they enter the boilers. Currently residues are moved from the sawmill by conveyer belts and are stock piled near the boilers. They are used very soon after they are brought to this area giving them little time to dry, usually a matter of days. Therefore the moisture content of the fuel is likely to be very high.

Discussion

The CHP system based on the use of wood processing residues reduces emissions when compared to a reference case of the use of natural gas and disposal of residues. The emission reduction can be increased further by the full utilisation of the bioenergy system to provide electricity and heat for the sawmill and also provide input to the local heat demand. The major emission in the reference system is due to methane emissions from residue decay in the landfill and forest, however many of the assumptions used to calculate methane emissions need to be validated. The choice of natural gas as the reference energy carrier also has an impact on the reference emissions. It is possible that in the future coal may be used instead of natural gas to provide electricity services which would increase the reference system emissions considerably and hence the emission reduction of the CHP bioenergy system.

The National Energy Efficiency and Conservation Strategy aims to increase renewable energy supply to provide a further 25–55 PJ of consumer energy by 2012. In the future energy or electricity retailers may be obliged to obtain a certain amount from renewable sources. This could represent an opportunity for the bioenergy operator to utilise their current system to its full potential, increasing heat production, contributing an estimated extra 0.4 PJ/yr consumer energy. However this is only possible if residues are available at reasonable cost and there is a market for the heat. Another alternative is to increase the size of the turbine, when it needs upgrading, to allow the maximum production of electricity with the excess being exported to the grid.

Bioenergy offers the opportunity to maintain energy supply and reduce gross emissions relative to 1990, if it replaces an energy source that was emitting greenhouse gases in 1990. Bioenergy can also increase energy supply without the associated increases in emissions from fossil fuels sources, and hence reduces emissions relative to a BAU scenario. Both will contribute to Kyoto commitments, the first by reducing the absolute 1990 emissions, and the second by reducing the rate of increase in emissions.

Under the Kyoto Protocol all emissions due to the bioenergy system are accounted for as they are due to fossil fuel combustion. In the reference system all emissions are accounted for including the fossil fuel and methane emissions (in landfill, due to decay) but there remains some discussion about accounting for harvested wood products and therefore the carbon stock change (increase) due the disposal of residues in landfill.

Courtesy of Red Stag Timber Ltd, New Zealand

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IEA Bioenergy

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IEA Bioenergy (www.ieabioenergy.com) is an international collaborative agreement, set up in 1978 by the International Energy Agency (IEA) to improve international cooperation and information exchange between national bioenergy research, development and demonstration (RD & D) programs. IEA Bioenergy aims to realize the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, thereby providing a substantial contribution to meeting future energy demands.

IEA Bioenergy Task 38 brings together the work of national programs in 13 participating countries on Greenhouse Gas (GHG) Balances for a wide range of biomass systems, bioenergy technologies and terrestrial carbon sequestration. As one example of work, case studies have been conducted by applying the standard methodology developed by the Task 38. In the case studies GHG balances of different bioenergy and carbon sequestration projects in the participating countries have been assessed and compared, of which that of New Zealand is one example.

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