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

Kimberly Robertson

FORCE Consulting

July 2003

Greenhouse Gas Balance of a Bioenergy System Utilising Wood Processing Residues in New Zealand

Summary

There is growing concern internationally about the increase in greenhouse gases such as CO_2, CH_4 and N_2O. These are not the only greenhouse gases but they are the main ones. There is increasing evidence that the emission of these gases mainly from the burning of fossil fuels is causing global climate change.

There are several ways in which bioenergy and wood products can be used to mitigate climate change: direct substitution replacing fossil fuels; replacing more fossil fuel intensive materials and by enhancing forest carbon sequestration. This study looks at the potential of a bioenergy 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. The reference system to which the bioenergy system is compared is the use of natural gas to meet the electricity and heat demand and disposal of residues in the forest and to landfill.

Currently the bioenergy system is essentially GHG neutral, with emissions estimated at 165 tCO2e/yr. The only fossil fuels used on site are minimal. If the mill did not utilise bioenergy then their energy requirements would have to be met another way. Under the assumptions used in this study the GHG emissions of the reference system is estimated to be substantially higher at 62000 tCO_2^e/yr and have a balance of 16400 tCO_2^e/yr when the carbon stocks in landfill are taken into account. Giving a greenhouse gas emission reduction potential of 16235 t CO_2^e /yr (see table below). This could be increased further if the bioenergy system is run at full capacity using available wood processing and forest residues.

	Bioenergy system	Reference System
Emissions	165	62541
C stock change		
Landfill	0	-46140[1]
Balance	165	16400
Emission reduction potential	**16235**	

If such a bioenergy project is implemented now it may reduce emissions compared to a 'business as usual' scenario of increasing energy requirements. Under the Kyoto Protocol New Zealand is required to reduce emissions to 1990 levels over the first commitment period (2008-2012). However the bioenergy project will not reduce the actual emissions at all unless the current use (rather than the 'business as usual' future use) of gas decreases directly as a result of the bioenergy project.

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.

[1] A negative number indicates a positive stock change of the landfilled residues.

If the bioenergy system was implemented as a Joint Implementation project potentially all emission reductions units generated could be sold to another Annex 1 party. If the bioenergy project does not lead to an actual emission reduction compared to 1990 levels (only compared to a BAU of increasing emissions) the impact of this is to increase New Zealand's national greenhouse gas reduction target under the Kyoto Protocol.

Introduction

There is growing concern internationally about the increase in greenhouse gases such as CO_2, CH_4 and N_2O. These are not the only greenhouse gases but they are the main ones. There is increasing evidence that the emission of these gases mainly from the burning of fossil fuels is causing global climate change. Annual global temperature over the next 100 years is predicted rise by 1.4 – 5.8 ^oC. (Intergovernmental Panel on Climate Change (IPCC), 2001).

Many countries have signed the United Nations Framework Convention on Climate Change which aims to 'achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 1992). However there are no legally binding emission reduction commitments in the UNFCCC, therefore the Kyoto Protocol was adopted in 1998 which does provide legally binding commitments to reduce fossil fuel use in many developed countries. The Kyoto Protocol does not become legally binding until it has been ratified by 55 parties including developed countries accounting for at least 55 % of the total 1990 carbon dioxide emissions from this industrialized group (UNFCCC 1998). New Zealand ratified the Kyoto Protocol in 2002 and has agreed to reduce greenhouse gas emissions to 1990 levels in the first commitment period (2008-2012). Currently it is estimated that New Zealand will emit 3Mt/year of carbon above 1990 levels over the commitment period.

CO_2 emissions from energy use in New Zealand are estimated at 28 Mt in 2000 (MED 2001a). In 2000 30 PJ out of 453 PJ of New Zealand's primary energy was generated from woody biomass (MED 2001b). The National Efficiency and Conservation strategy aims to increase renewable energy by 25-55 PJ by 2012 (EECA 2001). This includes small scale hydro, wind, and bioenergy.

Biomass can be considered as a form of solar energy stored in plant material. Biomass may be produced from purpose-grown crops or forests, or as a by-product of forestry, sawmilling and agriculture. (Matthews and Robertson 2001). The biomass is then converted to a useful energy carrier such as heat, gas, electricity or liquid fuels. Bioenergy is considered a renewable energy when generated from sustainably produced biomass.

There are several ways in which bioenergy and wood products can be used to mitigate climate change:

- Energy from wood products can be used to replace fossil fuels or as a 'direct substitute'.
- Wood products can be used to replace more fossil fuel intensive materials such as steel or concrete, this is known as material substitution.
- Planting of new forests for wood products enhances the forest sink and may create a wood products sink.

Direct substitution and greenhouse gas emission reductions occur only if bioenergy actually replaces fossil fuels rather than increasing overall energy use. Using bioenergy to meet increases in energy demand will prevent greenhouse gas emissions from increasing but will not reduce them.

In New Zealand the biomass sources with the most potential for bioenergy include wood processing residues, forest residues, purpose grown energy crops, and agricultural wastes. Currently wood processing residues are often utilised for energy by wood processing companies to meet their electricity and heat requirements. If the residues are not used for this purpose they are disposed of in the forest or in landfills. If residues are landfilled this is often at considerable cost to the company.

This study is 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. This paper:

- annual energy production (heat, electricity) of the bioenergy system
- investigates the annual fossil fuel use
- calculates the greenhouse gas balance of the bioenergy system.
- calculates the emission reduction potential of the bioenergy system compared to a 'reference' energy system.
- identifies opportunities for improving the greenhouse gas balance and emission reduction potential.

The conversion technology used in the example bioenergy system is direct combustion for electricity and heat production, where wood is burned in a furnace heating a boiler, creating steam for heat. Some of the steam also passes through a steam turbine that rotates an electric power generator.

Methods

Bioenergy System

The bioenergy system being analysed is based at a sawmill that utilises wood processing residues (mainly generated onsite) to produce energy to meet the electricity and heat demands of the sawmill. This report looks at the greenhouse gas balance of the bioenergy system in comparison to a reference system where no bioenergy is available. Figure 1 provides an overview of the bioenergy system. The residues are sourced from a sustainably harvested forest therefore the stock change in the forest due to the use of the residues is assumed to be zero or neutral and no CO2 emissions are attributed to the bioenergy system as emissions are assumed to be balanced by subsequent growth of the forest. The emissions attributed to the bioenergy system include those from fossil fuel used to transport residues to and around the bioenergy plant. Emissions due to construction of the bioenergy facility have not been included as it has been assumed that these emissions are similar for both the bioenergy facility and fossil fuel facility.

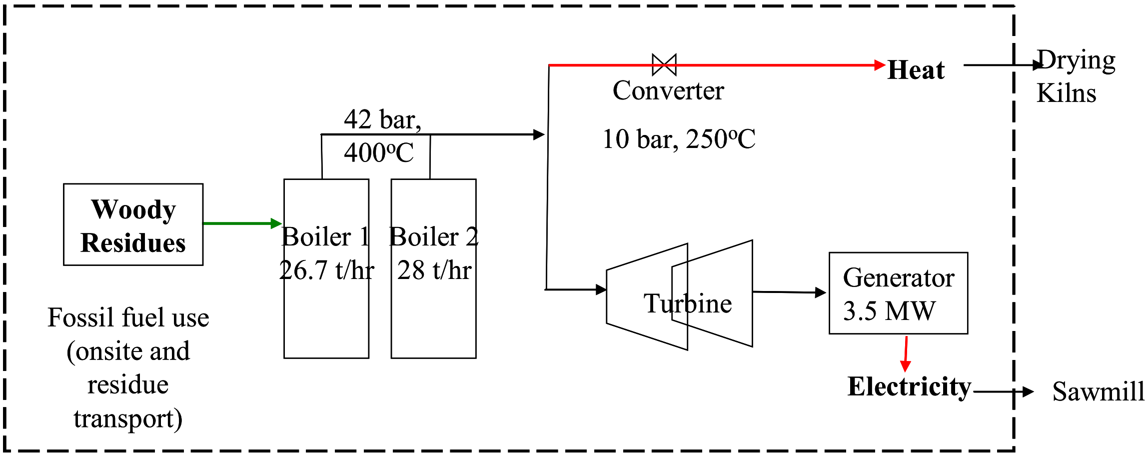

Figure 1. Bioenergy System

Woody Residue Production

Processing residues generated on site were calculated using Equation 1.

$$R = \frac{s}{g} \times LF$$ **Equation 1**

Where

R = residues generated on site

s = steam production (t/hr) from on site residues = 30 t/hr

g = amount of steam generated per 1 tonne of residues used = 2.5 t

LF = load factor (hours/annum) = 7862 = (24*365)*0.9

Residues imported from off site are estimated based on the total steam production on site minus amount steam generated/year from residues on site (Equation 2)

$$IR = \frac{Ts - s}{g} \times LF$$ **Equation 2**

Where

IR= imported residues

Ts = total steam production = 33 t/hr

s = steam production (t/hr) from on site residues = 30 t/hr

g = amount of steam generated per 1 tonne of residues used = 2.5 t

LF = load factor (hours/annum) = 7862 = (24*365)*0.9

Total residues = R + IR **Equation 3**

Steam Production

The sawmill has two boilers that produce steam and are fed by residues mostly produced on site. Each boiler produce steam at 42 bar pressure and 400 degrees (Table 1). The steam is then used to generate electricity and heat. Both boilers are connected to a Siemens 3.5 MW turbine with 2 stage alternator and a pressure reduction valve. Currently the boilers are running at 60 % of capacity, producing on average 33 t/hr or 259460 t/yr of steam at 42 bar steam pressure and 400^{o}C. 58 % of this steam is then used to run the turbine generating 27 GWh/yr of electricity and the remaining provides 98 GWh/yr heat for drying of sawn lumber. It is assumed that the residues used in the CHP plant are produced on site from the processing of logs and the carbon stock changes that occur in the forest due to harvesting are not accounted for here. The residues are therefore available at very low greenhouse gas (GHG) cost due to production or transport of the biomass (see the section on diesel usage below).

Table 1: Specifications for the two bioenergy boilers.

	Boiler 1	Boiler 2	Total
Type of boiler	Babcock and Willcox - pinhole grate, conventional 2 drum boiler (mud and steam)	Eckrokessel design boiler - fed onto v large sloping mechanical grate (Kablitz) to facilitate drying	
Steam pressure capacity (bar)	42	42	
Potential Steam Production (t/hr)	26.7	28	54.7
Potential Steam Production (t/annum)	209926	220147	430073
Actual Steam Production (t/annum)			259459
Steam used to generate electricity (t/yr)			149400 (19 t/hr)
Steam used to generate heat (t/yr)			110073 (14t/hr)

Electricity Production
Electricity is used on site for the sawmilling process as well as for general office equipment, lighting and heating offices and is estimated using equation 4.

Electricity production (GJ) = (GC*LF)*E *3.6 **Equation 4**

Where GC = Generator capacity (MW) =3.5
LF = Load factor (plant operating hours/annum) = 7862
E = conversion efficiency (%) = 70%
3.6 = conversion factor, MWh to GJ

Electricity is generated on site using a 3.5 MW turbine and electricity generator. The turbine requires 19 t/hr or 149400 t/yr steam to run at full capacity. It has been assumed that the turbine is run at 90% of 24 hours a day, 7 days a week allowing some time for maintenance and breakdowns giving a load factor of 7862 hrs/yr. A conversion efficiency of 70% is assumed.

It is assumed that no fossil fuels are consumed due to electricity generation and therefore there are no GHG emissions associated with this process.

Heat Production
Heat is produced based on demand and used on site in the kiln drying of the sawn timber. The steam goes through a pressure reduction valve, which reduces the steam from 400 ^{o}C, 42 bar to 250 ^{o}C,10 bar. Heat is lost in this process. Heat production is estimated using equation 5.

Heat production (GJ, 250 ^{o}C, 10 bar) = ((TS - ES)* Ent/1000) – PRL **Equation 5**

Where TS = Total steam production (t/yr 400 ^{o}C, 42 bar pressure)
ES = Steam production used for electricity (t/yr 400 ^{o}C, 42 bar pressure)
Ent = Enthalpy value (400 ^{o}C, 42 bar pressure, kJ/kg)
PRL = Pressure reduction loss (heat value at 400 ^{o}C, 42 bar pressure - heat value at 250 ^{o}C, 10 bar).

The enthalpy or heat value contained in the steam is based on standard super heated steam tables (Mayhew and Rogers, 1973). The values are given in Table 2

Table 2: Enthalpy value of steam

Steam	Enthalpy (kJ/kg)
400^oC, 42 bar	3214
$250\ ^oC$, 10 bar	2944

It is assumed that no fossil fuels are consumed due to heat generation and therefore there are no GHG emissions associated with this process.

Fossil Fuel Use

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. Estimates of total diesel used (litres) on site were made based on company records.

A small amount of residues are also imported from other wood processing sites in the region. The amount of diesel used to transport residues to the site is estimated based on the following equation 6.

DCT = IR/T * D* DC **Equation 6**

Where
DCT = Total diesel consumption (l)
IR = Imported residues (tonnes biomass)
T = Truck payload (tonnes biomass) = 15
D = Average distance travelled return (km) = 100
DC = Diesel consumption for heavy trucks (l/km) = 0.5

GHG emissions are then estimated using the emission factors below which were derived from information in MED 2001a , Energy Greenhouse Gas Emissions.

Table 3. Diesel emission factors

	g/l	kg/GJ
CO_2	2597.86	68.7
CH_4	0.53	0.014
N_20	0.12	0.0031

Reference System

Electricity and Heat

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. Emission factors were obtained from MED 2001a (Table 4). Emissions due to construction of the fossil fuel facility have not been included as it has been assumed that these emissions are similar for both the bioenergy facility and fossil fuel facility.

Table 4. Gas GHG Emissions Factors (kg/GJ)

CO_2	52.1
CH_4	0.0027
N_20	0.00009

Residue Disposal

If residues are not used for bioenergy then they may be used for an alternative product or be disposed of in another manner. In New Zealand some high quality residues are now being used to manufacture wood products such as medium density fibreboard (MDF). The processing residues utilised by this bioenergy plant currently have no alternative market as they are not deemed suitable for the production of MDF or other wood products.

If the residues are not utilised for bioenergy it is common practice to dispose of the residues in the forest or landfill. In this study it is assumed that 50% of the residues go to landfill and 50 % is disposed of in the forest. Carbon stocks of the landfilled residues are estimated. Emissions of CO_2 and CH_4 from landfilled residues are estimated assuming that 3% of the carbon is released as landfill gas (Micales and Skog 1997, IPCCC 2000,) and this is split 50/50 between CO_2 and CH_4 (Equations 7, 8 and 9). However only CH_4 emissions (which are additional to the bioenergy system) are included in the overall budget.

Emissions from the residues disposed of in the forest are all assumed to decay and the emissions are split 90/10 between CO_2 and CH_4. (Mann and Spath 2001). It is assumed that all potential CO_2 and CH_4 is released in the year the waste is disposed of. Again only CH_4 emissions are included in the overall budget (see Equations 10 and 11).

Emissions due to the transport of residues to:

- landfill are based on a return transport distance of 10 kms,
- forest are based on a return transport distance of 5 kms

all other assumptions are the same as used for fossil fuel use in the bioenergy system.

Landfill Emissions and carbon stock calculation

CO_2 emissions (t CO_2/yr) = RT *MC*C*F*0.5*44/12 **Equation 7**

CH_4 Emissions (t CO_2 /yr) = RT *MC*C*F*0.5 *16/12 *GWP **Equation 8**

Landfill C stock change (t CO_2/yr) = RT*MC*C - (CO_2 +CH_4) *44/12 **Equation 9**

Assumptions:
RT = total residues sent to landfill (tonnes/yr)
MC = moisture content = 50%
C = carbon content of wood = 50%
F= fraction released as gas =3%
Proportion landfill gas that is CH_4 = 50%
Proportion landfill gas that is CO_2 = 50%
44/12 = conversion of Carbon to CO_2
16/12 = conversion of Carbon to CH_4
GWP CH_4 =21

In forest emissions

CO_2 emissions (t CO_2/yr) = RT *MC*C*F*0.9*44/12 **Equation 10**

CH_4 Emissions (t CO_2 /yr) = MSWT *MC*C*F*0.1 *16/12 *GWP **Equation 11**

Assumptions
RT = total residues sent to forest (tonnes/yr)
MC = moisture content = 50%
C = carbon content of wood = 50%
F= fraction released as gas =100%
Proportion gas that is CH_4 = 10%
Proportion gas that is CO_2 = 90%

44/12 = conversion of Carbon to CO_2
16/12 = conversion of Carbon to CH_4
GWP CH_4 =21

Up to 1.2% of nitrogen is emitted as N_20 during decay (Prototype Carbon Fund 2002). The nitrogen content of *Pinus radiata* which is the predominant plantation species in New Zealand is estimated at 0.39% N in bark and 0.06% N in stemwood (Orman and Will 1960, Beets and Madgwick 1988). The breakdown between bark and stemwood was based on the values given in the results section on woody residues. N_20 emissions were estimated according to Equation 12.

N_20 Emissions (t CO_2 /yr = RT * MC*N*E *GWP **Equation 12**

Where:
RT = Total waste landfilled or sent to forest
MC = moisture content
N = Nitrogen content
E = % emission
N_20 GWP = 310

Results

Woody Residue
It is estimated that 94349 tonnes of onsite residues were utilized in the bioenergy plant in 2000. This is very similar to the Wall 2000 estimate of 92947 t in 1999. Imported residues are estimated at 9435 t in 2000. Total residues used as a boiler feedstock are estimated at 103 784 t/year. Figure 2 provides a breakdown of the make up of the residues.

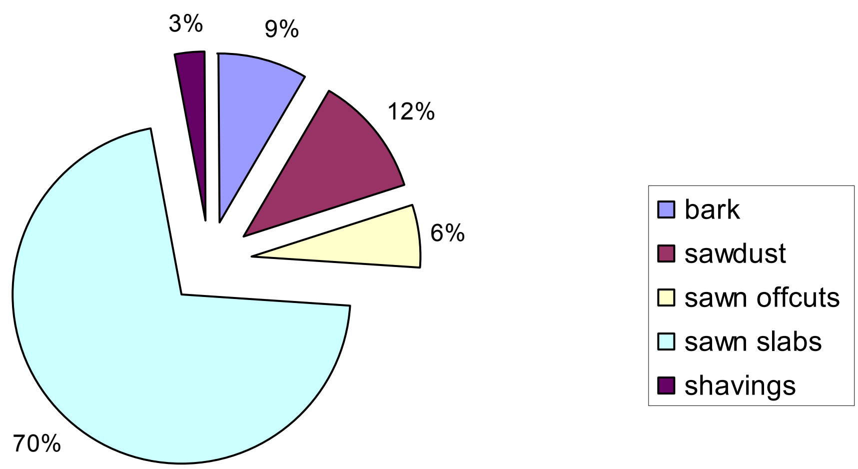

Figure 2: Type of woody residues utilised on site

Bioenergy System

Steam Production
The total amount of steam generated is calculated to be 259 459 tonnes/annum at 42 bar steam pressure and 400°C. 58 % of this steam is then used to run the turbine generating electricity and the remaining provides heat for drying of sawn lumber. If the bioenergy system is working at full capacity it can potentially produce up to 54.7 t/hr or 430 073 t/year steam. Currently the bioenergy system is working at 60% of its capacity.

Electricity Production
It is estimated that approximately 19 GWh (69000 GJ/yr) of electricity are generated annually.

Heat Production
Heat generated on site is estimated at 90 GWh (324000 GJ/yr). Table 5 shows the estimates of heat value at both temperatures and pressures and the heat loss in the pressure reduction process. Heat at 250°C, 10 bar represents the heat available for drying of the sawn lumber.

Table 5: Heat generation at the sawmill

	Heat (GJ/year)	**Heat (GWh/yr)**
400°C, 42 bar	353 777	98
250°C, 10 bar	324 057	90

Fossil Fuel Use
As mentioned previously the only greenhouse gas emissions from this system are associated with the use of diesel by machinery in moving the residues around the site and the transport of a small amount of residues to the site from other wood processing plants. Total GHG emissions are estimated at 165 t CO_2e/year (Table 6).

Table 6. GHG balance of the bioenergy system.

		Greenhouse Gas Emissions (t Co2e)			
	Diesel Use (l)	**CO_2**	**CH_4**	**N_2O**	**Total**
On site transport	30787	79.95	0.34	1.12	81.41
Residue import	31450	81.67	0.35	1.14	83.16
Total	**62237**	**161.62**	**0.69**	**2.26**	**164.57**

Reference System

It is assumed that the reference system is required to produce the same amount of energy in the same form as the bioenergy system or

- 19 GWh (69000 GJ/yr) of electricity and
- 90 GWh (324000 GJ/yr) of heat.

As indicated in

Table 7 the overall GHG emissions of the reference system is 16400 (tCO_2^e/yr). The disposal of residues into landfill would increase the carbon stock in the landfill by 12584 t C/yr (46140 t CO_2 e/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 which constitute the major source of emissions for the reference system.

Table 7. GHG Balance of the Reference System (tCO_2^e/yr)

	CO_2	CH_4	N_2O	Total
Emissions				
Electricity (nat gas)	3613	4	2	3619
Heat (nat gas)	16883	18	9	16911
Fossil Fuel	67	0	1	69
Decay		41773	170	41943
Total				62541
C stock change				
Landfill	-46140			
Balance				**16400**

Comparison of the Bioenergy System with the Reference System

Currently the bioenergy system is essentially GHG neutral, with emissions estimated at 165 tCO2e/yr. The only fossil fuels used on site are minimal. If the mill did not utilise bioenergy then their energy requirements would have to be met another way. Under the assumptions used in this study the GHG emissions of the reference system are estimated to be substantially higher at 62500 tCO_2^e/yr and have a balance of 16400 tCO_2^e/yr when the carbon stocks in landfill are taken into account. Giving a greenhouse gas emission reduction potential of 16235 tCO_2^e /yr (Table 8).

Table 8. Emission reduction potential (t CO_2^e /yr)

Emissions	**Bioenergy system**	**Reference System**
Electricity	0	3619
Heat	0	16911
Fossil fuel	165	69
Residue disposal	0	41943
Total	165	62541
C stock change		
Landfill	0	-46140
Balance	165	16400
Emission reduction potential	**16235**	

Sensitivity analysis

A range of assumptions that contribute to the calculation of the overall emission reduction potential of the bioenergy system were varied (Table 9) and the impact of this change on the overall emission reduction potential was analysed. Most of the assumptions looked at in the sensitivity analysis relate to the estimation of emissions from landfill and in forest disposal as this constitutes the largest source of emissions in the reference system and is also likely to be the greatest source of potential error as some of the assumptions made in calculations are not specific to the local conditions but are default assumptions taken from the literature (IPCC 2000, Micales and Skog 1997).

Table 9. Sensitivity analysis variables

Variable	Default	neg	pos
% waste to landfill	50%	45%	55%
% c released in landfill	3%	1%	5%
% landfill gas CH4	50%	40%	60%
% 'in forest' emissions released as CH4	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 (hours)	7862.4	7076.16	8648.64

The impact of the percentage decomposition of residues disposed of in the forest was also analysed and this had the greatest impact on the emission reduction potential. The reference system assumes that 100% of residues disposed of in the forest decay, the sensitivity analysis also looked at the impact of 90% and 80% decay. If 90% of residues decay then the emission reduction potential is reduced from 16236 to 7846 t CO2e/yr and if only 80% of the residues decay then disposal of in forest residues increases the carbon stock and the emission reduction potential is estimated at -543 tCO2e/yr (or a carbon stock increase of 543 tCO2e/yr). This assumes that the 20% of residues that do not decay increase the carbon stock in the forest.

The impact of all other variables tested on the emission reduction potential of the bioenergy 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 potential as methane has a high GWP compared to carbon dioxide.

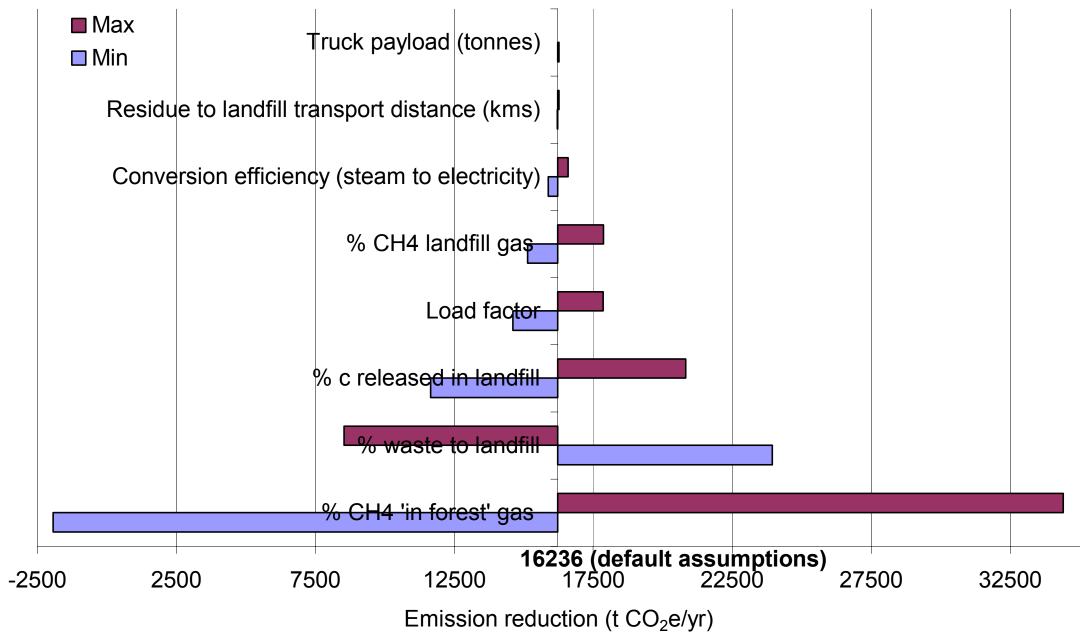

Figure 3. Sensitivity analysis

Improvements

Currently the bioenergy 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 (about 98 GWh of heat energy at 250 °C and pressure of 10 bar after pressure reduction and pipeline losses). 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. Within the district 30 000 t of wood processing waste were landfilled in 1999 (Wall, 2000). Forest residues within a radius of 20 kilometres of the bioenergy plant are estimated at 35 000 t/yr, although these are available at some economic and greenhouse gas cost due to transport. Environmental regulations are becoming more stringent, making maintenance and finding of new landfill sites more difficult and cost prohibitive. Bioenergy could provide an environmentally friendly, cost effective alternative option for the disposal of wood processing residues.

The estimated demand for low grade energy in the local city is shown in Table 10 (based on Nielson and Gifford 2001). The most economic opportunity to use bioenergy to meet this demand will probably be establishing a heat distribution network to the hotels as many of them are within 5-10 kms of the bioenergy system. Potentially if the bioenergy system was utilised to its full capacity the extra heat generated could be used to meet a high proportion (88%) of the low grade energy demand.

Table 10: Local low grade energy demand

		How currently met	
	Low grade energy demand GWh/yr	Electricity	Nat Gas
Hotels	54	6	48
Service sector	40	24	16
Industry	21.6	4.8	16.8
Forest Industry	5.3	3	2.3
Total	120.9	37.8	83.1

If all the processing residues currently being landfilled are utilised in the bioenergy system then a further 75 000 t of steam/year could be generated. If forest residues within 20 km are utilised another 87 500 t/year could be generated, Giving a potential 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 would have go through a pressure reduction valve 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. If the heat requires further pressure and temperature reduction to be in a usable form, heat losses will increase further decreasing the energy available to end users.

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 potential could be increased to 25000 t/yr of CO2e, an increase of about 9500.

Table 11. Emission reduction potential of improved system (t CO_2^e /yr)

Emissions	**Bioenergy system**	**Reference System**		
		Current	Extra capacity	Total
Electricity	0	3619	0	3619

Heat	0	16911	8386	25296
Fossil fuel	491	69	20	88
Residue disposal	0	41943	43296	85239
Total	491	62541	51702	114242
C stock change				
Landfill	0	-46140	-42235	-88376
Balance	491	16400	9466	25866
Emission reduction potential	**25376**			

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.

Conclusions and Discussion

Implementation of a bioenergy system based on the use of wood processing residues has the potential to reduce emissions when compared to a reference case of the use of gas and disposal of residues. The emission reduction potential 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 carbon stock increase due to disposal of residues in landfill has been included in this analysis and has a large impact on the overall results – decreasing the avoided emissions significantly. As yet there are no clear guidelines internationally on whether or not these should be included. Including landfill carbon stocks in the reference case decreases the GHG emissions attributable to the reference system and therefore reduces the emissions reduction due to bioenergy.

The National Energy Efficiency and Conservation Strategy aims to increase renewable energy supply to provide a further 25-55PJ 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 bioenergy system electricity turbine when it needs upgrading to allow the maximum production of electricity with the excess being exported to the grid.

Impact on National GHG emissions and Kyoto Protocol Commitments.

If such a bioenergy project is implemented now it may reduce emissions compared to a 'business as usual' baseline scenario of increasing energy requirements. Under the Kyoto Protocol New Zealand is required to reduce emissions to 1990 levels over the first commitment period (2008-2012). However the bioenergy project will not reduce the actual emissions at all unless the current use (rather than the 'business as usual' future use) of gas decreases directly as a result of the bioenergy project.

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.

There may be issues around the ownership of any emissions reduction units generated and this will depend on the national system for implementing such projects. Potentially there could be several separate entities involved for example the forest owner, bioenergy plant operator and the landfill operator. Project designers need to be aware of this and the potential it creates for double accounting for example the landfill operator may claim emission reductions due to less residues being landfilled (and therefore less CH4 emissions), and to avoid double accounting the bioenergy operator can not claim this benefit.

References

Beet, P.N. and Madgwick H.A.I. 1988. Above-ground dry matter and nutrient content of *Pinus radiata* as affected by lupin, fertiliser, thinning and stand age. *New Zealand Journal of Forestry Science* 18(1): 43-64.

Energy Efficiency and Conservation Authority (EECA). 2001. National Energy Efficiency and Conservation Strategy: Towards a sustainable energy future. Available at www.eeca.govt.nz/Strategy/Documents/The%20Strategy.pdf

Intergovernmental Panel on Climate Change (IPCC). 1995. Second assessment report of the IPCC. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Available at www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm

Intergovernmental Panel on Climate Change (IPCC). 2001. Third assessment report "Climate Change 2001: Synthesis Report". Summary for Policy Makers. Available at http://www.ipcc.ch/

Mann M and Spath P.L. 2001. A life cycle assessment of biomass cofiring in a coal-fired power plant. *Clean Prod Processes 3* (2001) 81-91

Matthews R and Robertson, K.A. 2001. Answers to ten frequently asked questions about bioenergy, carbon sinks and their role in global climate change. Available at www.joanneum.ac.at/iea-bioenergy-task38/publications/faq/

Mayhew and Rogers. 1973. Thermodynamic and transport properties of fluids. Published by Oxford, Basil and Blackwell.

Michales J.A. and Skog K.E. 1997. The decomposition of forest products in landfills. *International biodeterioration and biodegradation* 39, No 2-3, (1997) 145-158.

Ministry of Economic Development (MED). 2000. Energy Outlook to 2020.

Ministry of Economic Development (MED), 2001a. Energy Greenhouse Gas emissions, 1990-2000.

Ministry of Economic Development (MED). 2001b. Energy Data File.

Nielson, P.S., and Gifford, J. 2001. Transforming the forest waste streams into biofuels for energy. Presented at 13th Annual Conference and Trade Exhibition. Wasteminz, 31 Oct – 2 Nov, Christchurch, New Zealand.

Orman H.R. and Will G.M. 1960. The nutrient content of Pinus radiata trees. New Zealand Journal of Forestry Science 3, 510-522.

Prototype Carbon Fund.2002. Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles. Final Report. PCF plus Report No 12, 2002.

UNFCCC. 1992 United Nations Framework Convention on Climate Change. Available at www.unfccc.de/resource/conv

UNFCCC. 1998. The Kyoto Protocol to the Convention on Climate Change. Available at www.unfccc.de/resource/protintr.html

Wall, K.L. 2000: Opportunities for Bioenergy Utilisation of Biomass Residues: *A Rotorua Case Study.* Thesis submitted for Master of Science (Technology), University of Waikato, February 2000.