Financial Viability Of Incorporating Different Bioenergy Systems To An Existing Sawmill

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Project Submitted in Partial Fulfillment of

The Requirements for the Degree of

Master of Business Administration

The University of Northern British Columbia

April 2009

ABSTRACT

The mountain pine beetle has devastated the forests of northern British Columbia. As this fibre deteriorates, there will come a time when this timber is no longer economical to harvest for dimension lumber. The Government of British Columbia has tried to get new entrants to utilize these damaged stands before the fibre is no longer economical to harvest. The provincial government has also been promoting bioenergy as a source of clean electricity to ensure that British Columbia (B.C.) becomes energy self-sufficient by 2016. The provincial government has also introduced carbon taxes to try and curb the use of fossil fuels. As a result of these government initiatives, the primary objective of this study was to determine if bioenergy systems could be incorporated into an existing sawmill; the second objective was to determine under the conditions under which bioenergy systems could become financially viable. The data used to determine capital cost of bioenergy systems was from existing publications, which investigated the viability of bioenergy systems using mountain pine beetle damaged timber. An analysis of the data concluded that, under all scenarios bioenergy production as a financial endeavour, is, at best, marginal. By contrast, pellet manufacturing can be a viable alternative to these bioenergy projects under certain conditions. In order for bioenergy projects to become financially viable, different economic conditions need to exist. For example, electricity rates paid by BC Hydro would have to be in line with the high-priced jurisdictions of North America; internal interest rates or hurdle rates would have to drop substantially, capital costs and operating costs would need to be reduced and a longer time frame for payback would have to be considered.

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DEDICATION

To my lovely wife Judy and my beautiful daughter Linnea, thank you for your patience.

1 CHAPTER ONE - INTRODUCTION

The Government of British Columbia announced that the province would become energy self-sufficient 2016 (BC Energy Plan 2008). Part of the plan stated that energy would be generated from an initiative called the Small Power Standing Offer, which directs BC Hydro to purchase electricity from small producers (<10 MW) with no set limit on the amount of power to be purchased. To help achieve energy self-sufficiency, the provincial government has promoted the bioenergy sector. At the same time, the Province of B.C. has experienced a mountain pine beetle (MPB) outbreak that has killed over 90,000,000 m^3 of the pine trees in the Prince George Timber Supply Area (Ministry of Forests and Range PG TSR Data Package 2008). To assist the new bioenergy sector the provincial government has been discussing ways to use MPB damaged timber as the feedstock for successful bioenergy proposals. There will come a time in the future when the dead timber is no longer economically viable for dimension lumber however, this date is unknown. Moreover, economics and new technologies in sawing beetle-damaged trees are playing a significant part in extending shelf life of MPB damaged timber. The provincial governments believes that developing the bioenergy sector is one way in which MPB damaged timber can be utilized. To this end, the government enacted legislation to partition the Annual Allowable Cut (AAC) in the province (Bill 31 2008) which allows the bioenergy sector access to MPB-damaged timber (feedstock) to operate their plants.

In 2008, there were 20 applicants in the BC Hydro Phase One Call for Power. These proposals for power generation in northern BC ranged from 10 MW plants in Anahim and Cheslatta to a 30 MW proposal in Mackenzie (BC Hydro 2008). The majority of these projects are stand alone proposals, that is they are independent of an existing sawmills or pulp mills. While Phase One projects are intended to support electricity generation, there are other uses for mill by-products and MPB damaged timber such as pellet manufacturing and heat generation.

With the provincial government's push towards clean energy, there may be opportunities for medium-sized sawmill operators (< 1,000,000 m^3 annual consumption) to incorporate different bioenergy systems as part of their business since most sawmill facilities consume large amounts of electricity to operate the mill and natural gas to kiln dry lumber. The main reasons why sawmills would consider incorporating a bioenergy system are a) after initial capital investments, to reduce the amount of cash outlay that would normally be spent on natural gas and electricity and b) to provide an additional revenue stream to the company from the sale of excess electricity not consumed by the mill.

Carrier Lumber Ltd. (Carrier), like most other mills in the central interior of B.C., receives revenue for all by-products from milling, including hog fuel (predominantly bark). Until recently, hog fuel was considered the lowest value by-product produced and as such no revenue was generated from its production. Yet given the low value of hog fuel, opportunities may exist to convert this product into energy to heat the kilns, which would generate savings by reducing the need to purchase natural gas. Moreover, the National Energy Board and Energy Information Administration indicate that the price of natural gas will increase over time and remain volatile until new supplies are brought online (NEB 2006, EIA 2006). The B.C. government's initiative to fight climate change with carbon taxes will also increase the cost of natural gas to the consumer. Therefore, developing a bioenergy system would allow Carrier to avoid the wild fluctuations in natural gas as experienced from May 2008 to December 2008 and avoid the expected long term increase in natural gas pricing. Additionally a bioenergy system presents Carrier with opportunities to generate a new revenue stream by producing electricity and selling the excess power to BC Hydro. Another option to try and diversify the revenue stream is to construct a pellet plant that can utilize milling by-products. Not only would this allow for a new revenue stream, it would also aid in the diversification of a traditional lumber manufacturer into other industries.

The purpose of this study then is to determine the financial feasibility of constructing a bioenergy system at a medium sized sawmill in Prince George, British Columbia primarily using sawmill by-products as primary feedstock, purchasing feedstock on the open market and/or utilizing MPB killed fibre as a feedstock supplement. By analysing the financial viability of these bioenergy projects given certain assumptions, lumber manufactures can decide whether these systems are worth pursuing.

1.1 CARRIER LUMBER BACKGROUND

Carrier is a medium sized non-integrated dimension lumber producer located in Prince George B.C. Traditionally Carrier consumes 750,000 m^3 to 850,000 m^3 of logs per year (based on operating double shifts five days a week). Carrier's sawmill consists of one high speed small log line capable of curve sawing and one double band saw large log line. The primary break down of logs is a Linden bucking deck with full computer optimization. Carrier has four Salton 120' kilns that are fully computerized and all constructed within the last six years, as well as one older kiln which is used sparingly. The planer mill was completely rebuilt with the latest technology four years ago. Carrier undertook these major upgrades to the facility to improve lumber production and recovery and to reduce labour costs per board foot. Table 1-1 summarizes the average mill outputs based on the annual consumption on a double shift basis.

Table 1-1. *Annual Production from Carrier Lumber*

Product	Amounts Produced/Consumed
Saw logs consumed per year	750,000 m^3 to 850,000 m^3
Dimension Lumber	187,000 mfbm to 212,000 mfbm
Shavings yr	20,600 to 23,000 ODt
Sawdust yr	16,000 to 18,000 ODt
Hog Fuel yr	20,000 ODt
Chips yr	100,500 to 113,000 ODt
Electricity Consumption	4 MW/h to 6 MW/h
Natural Gas Consumption	120,000 GJ/yr to 140,000 GJ/yr

Based on these by-products, Carrier has enough hog fuel to operate a hot oil energy system but if a pellet plant or electrical bioenergy (co-generation) system is being contemplated additional feedstock would be required.

1.2 FOREST INDUSTRY BACKGROUND IN CENTRAL B.C.

The forest industry, as with other commodity industries, is a cyclical industry. The recent collapse in lumber prices has caused temporary and permanent sawmill closures throughout North America. As B.C. dimension sawmills try to become more efficient to survive the economic downturn they face another problem plaguing the industry in B.C. The mountain pine beetle (*Dendroctonus ponderosa* Hopkins) has and continues to attack and kill pine trees throughout the central and southern interior of the province. To date the MPB has damaged over 9.2 million hectares of pine forests which amounts to approximately 582 million cubic metres of timber (MoFR MPB Action Plan 2006/2007). By 2013, 80% of all the pine in B.C. will be infested by the MPB. Over time this damaged wood deteriorates and is no longer economically viable for dimension lumber. While some studies indicate that the damaged timber may be economical between one and three years post attack (Byrne et *al.* 2005) the exact economic timeframe has not been determined with certainty.

To try and recover as much volume as possible from MPB damaged stands in the Prince George Timber Supply Area (PGTSA), the Chief Forester of the Province of British Columbia completed an expedited Timber Supply Review to increase the AAC to 14,944,000 m3, which is an increase 22% (Ministry of Forests TSR 3 2004). While a large portion of the AAC has shifted to harvesting MPB stands, there is too much damaged timber for existing sawmill capacity. Since the AAC uplift in 2004, the amount of timber harvested has not achieved the new AAC target. From 2004 until the end of 2006, the North American lumber market was extremely strong with standard 2x4 random lengths above $300/mfbm for the period. It was not until the beginning of 2007 that lumber prices for 2x4 random lengths fell below $300/mfbm and have remained soft to present day. Figure 1-1 below illustrates the harvest from government owned Crown Land in the Prince George Timber Supply Area to the average composite lumber prices from 2003 to 2008.

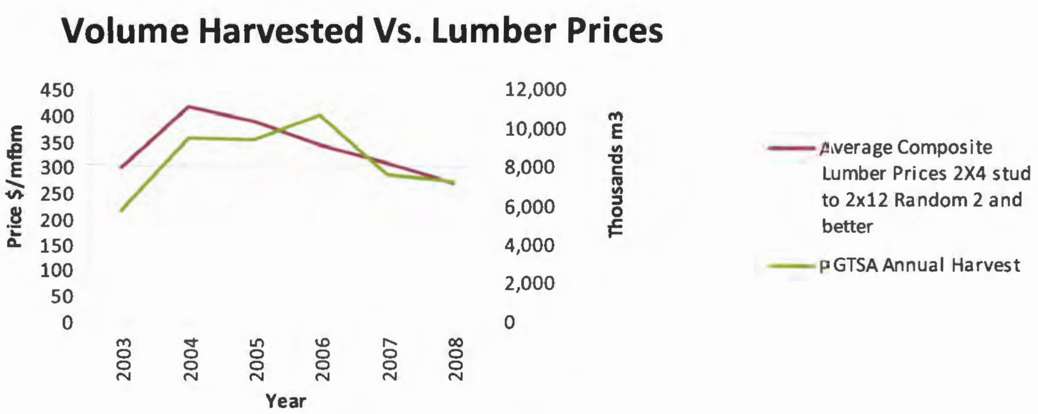

Figure 1-1. Harvested Volume vs. Lumber Prices
Source HBS and Random Lengths

The Ministry of Forests and Range (MoFR) expects there will be 1,300,000 m3 of beetle damaged timber available in the PGTSA for bioenergy however, no bioenergy licenses will be granted in the Prince George Forest District (PGFD) (Ministry of Forests and Range

2008). This bioenergy volume would come from MPB stands that are too deteriorated for traditional dimensional lumber manufactures to utilize or from roadside debris. By not having any bioenergy licenses available in the PGFD, transportation costs to deliver feedstock increases substantially thereby reducing the viability of bioenergy project in Prince George.

The bioenergy plan would assist the province in trying to achieve its goal to be energy self-sufficient by 2016 and it would also help convert damaged stands into productive forests. The provincial government has enacted legislation (Bill 31) that allows applicants of BC Hydro's Phase Two (successful Phase One applicants) to be awarded tenure equivalent to the proposal needs. Bioenergy advantageously is considered source of renewable energy, which could help Canada meet its commitment to the Kyoto agreement (BIOCAP 2008, Kumar et *al.* 2005, Cameron 2007), it burns cleaner than fossil fuels and has lower sulphur and nitrous oxide emissions, two chemicals which contribute to the creation of smog (McIlveen-Wright et *al.* 2001).

For an existing sawmill with kilning capacity, the greatest variable cost apart from raw logs is the cost of energy. The cost of electricity has been relatively steady but the cost of natural gas has been volatile. Since 2000, natural gas prices have become volatile due to several factors such as a lack of exploration when natural gas prices are low and an increased demand for natural gas being used in cogeneration facilities (NEB 2006, EIA 2006). An example of extreme volatility in natural gas prices occurred in 1997 and 2001 when natural gas prices fluctuated over 100% within a 12 month period as illustrated in Figure 1-2. In March 2008 natural gas prices climbed to \$13 GJ before falling to a low of \$5.42 GJ in January 2009, a change in price of almost 60%. Volatility in natural gas pricing is expected to remain until new sources are discovered or imports of liquefied natural gas (LNG) come on stream (EIA 2008, Gobert 2008).

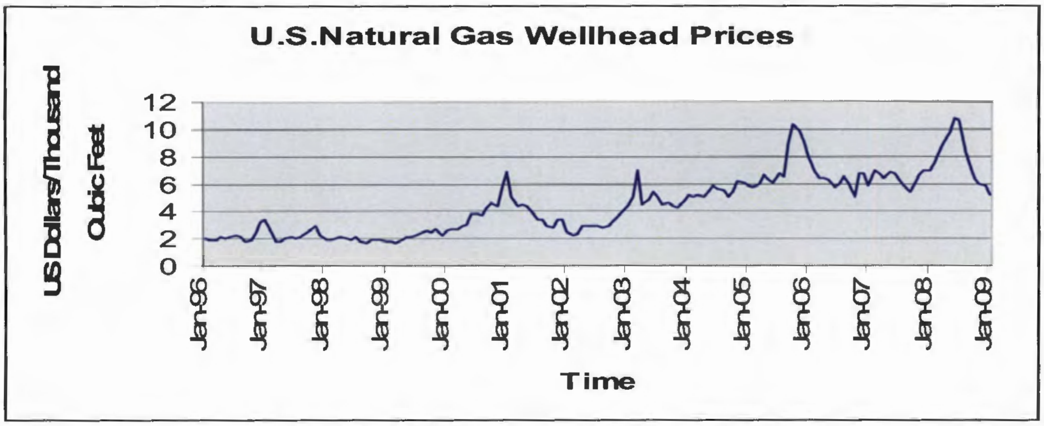

Figure 1-2: U.S. Natural Gas Wellhead Prices
Source: EIA 2009

Since Prices for natural gas are projected to increase until 2030 at which time enough LNG projects will be in production to meet the increased demand, which will then keep natural gas prices level (see Table 1-2 below).

Table 1-2. *Total Energy Supply 2006 to 2030*

Product	2006	2007	2010	2015	2020	2025	2030	Annual Growth Rate 2007-2030 (percent)
Natural Gas price per thousand cubic feet	6.66	6.39	5.92	6.26	6.75	7.31	8.39	1.2
Natural Gas consumption Quadrillion Btu/yr	22.26	23.7	23.09	23.34	24.03	25.31	25.08	0.2
Average Electricity Prices cents/kWh)	8.9	9.1	9.4	10.5	12.1	13.6	15.2	2.2

Source:2007 base US dollars EIA 2009

With the excess MPB fibre that potentially will be available and the projected increase in energy rates there may be financial opportunities for an existing sawmill manufacturer to incorporate a bioenergy system into their facility to eliminate the need to purchase energy.

1.3 OBJECTIVES

The objectives of this study are as follows:

1 To assess the financial viability of a hot oil bioenergy system located at Carrier Lumber Ltd. in Prince George using hog fuel as the primary feedstock.

2 To assess the financial viability of producing electricity and heat by cogeneration system to generate a revenue stream by using mill residues and MPB damaged timber as a feedstock supplement as required.

3 To assess the financial viability of incorporating a pellet plant as another revenue stream utilizing mill residues and MPB damaged timber as a supplement as required.

2 CHAPTER TWO - BACKGROUND OF BIOENERGY IN BC

In Canada most bioenergy systems are associated with existing facilities such as pulp mills where the heat and electricity are consumed (Stennes and McBeath 2006). In B.C. alone, an estimated 1.815 million bone dry tonnes (BDt) of wood such as hog fuel, sawdust shavings and chips are currently being burned in beehive burners (Bradley 2006). This practice of burning sawmilling by-products will continue until such time as the provincial government eliminates the use of Tier 2 burners in 2010. The British Columbian forest industry is currently the largest producer of biomass energy in Canada generating $150 million of electricity and $1.5 billion of heat energy each year (BC Ministry of Environment 2009). The only stand alone cogeneration plant in British Columbia is a 65 megawatt (MW) plant in Williams Lake which obtains the majority of its feedstock from the local sawmills. Various authors (Haygreen and Bowyer 1982, BIOCAP 2008) estimate that each megawatt of electricity requires 8,000 to 10,000 BDt/yr of biomass. These values are also consistent with the cogeneration plant in Williams Lake which consumes approximately 650,000 ODt of material per year.

The current MPB harvest in the Prince George Forest District over the last four years has steadily increased from 50% of the volume harvested to a peak of 70% in 2006. Current levels of MPB harvest in Prince George has now started to decline, which indicates that the local harvest is switching to more mixed stands or the volume harvested is being transferred to other districts such as Vanderhoof and Fort St. James (Pousette 2008). As a result, the amount of biomass available for bioenergy varies and will continue to vary throughout the province. Exacerbating the issue the estimated MPB infestation is projected to leave almost 750 million cubic metres on the landscape that will be uneconomical for use in dimension lumber (Ministry of Forests and Range 2008). While there may be millions of metres of dead pine trees remaining throughout the province after the beetle epidemic, the amount actually available for use is estimated to be substantially less. For example, the Ministry of Forests and Range (MoFR) indicates that 26,299,984 m^3 of MPB attack timber currently exists in the PGTSA. By 2024, the MoFR projects an accumulative 220,889,120 m^3 of MPB killed timber (PGTSA Data Package 2008). With a maximum shelf life of 20 years less than a third of the remaining damaged timber will be available for harvest (BIOCAP 2008, Ralevic 2006). The remaining volume will be left for due to other reasons and objectives such as inoperable ground and biodiversity.

Of all this available MPB-damaged timber, the unanswered question is what is the shelf life of this damaged timber? The data package being used to assist the Chief Forester of B.C. in determining the AAC for the PGTSA uses a 20-year shelf life for MPB-damaged timber (i.e. the timber can be utilized for dimension lumber). Licensees have indicated that shelf life ranges from 3 years to 15 years, while some areas in the Chilcotin trees that have been dead for over 20 years are still suitable for producing lumber. Once trees fall to the ground their deterioration increases rapidly and no longer contribute to timber supply (PG TSA Timber Supply Review 2008). In fact, the beetle epidemic has been ongoing since 1997. In some areas where the infestation first started, the damaged timber is still being harvested for dimension lumber.

The biomass energy sector is more developed in Europe then in North America. Several European countries have promoted the use of bioenergy for electricity by exempting these industries from carbon taxes that are applied to other forms of energy production in particular fossil fuels. Supporting the use of bioenergy in Finland the government provided tax rebates of €0.042/kWh for generating electricity from bioenergy. Generating heat from plants in Finland is not taxed and in Denmark, companies were subsidized up to 26% of the cost of installation for wood pellet heat (IEA 2004). In Sweden, the amount of electricity produced from biomass increased from 1200 MW in 1990 to 1800 MW in 2001 as Sweden used a variety of tax incentives to assist the expansion of the bioenergy sector. Most European countries are signatories to the Kyoto Protocol, an international treaty that sets limits on a country's greenhouse gas emissions, and as such have established hard targets to double the share of bioenergy production from 6% to 12% by 2010 (McIlveen-Wright et *al.* 2001). The world's largest bioenergy plant is a 240 MW plant located in Pietarsaari Finland and it must burn coal when there is a lack of feedstock (Kumar et *al* 2005). Other European countries have also used wood particularly pellets as a co-firing feedstock in their coal plants due to concerns about climate change (IEA 2008). Obtain energy from wood is considered carbon neutral so co-firing reduces the accountable carbon emissions.

2.1 NATURAL GAS SUPPLY IN THE NORTH AMERICAN MARKET

As previously discussed natural gas pricing will remain volatile until new supplies are either discovered or Liquefied Natural Gas (LNG) facilities are constructed. The world's largest natural gas reserves are in the Middle East, Eurasia and Africa and imports to the US from LNG are expected to exceed gross pipeline imports from Canadian supplies by 2015. With the US being the largest consumer of natural gas, in order for supply to meet demand more LNG import facilities will need to be constructed. In 2004, the US had five LNG facilities in operation with another four additional facilities under construction. There are currently plans to construct several LNG terminals in North America to help maintain the declining supply from North American fields. Until such time as these terminals become operational, consumers can expect that prices for natural gas will remain volatile (EIA 2006).

Industrial use of natural gas is expected to rise by 1.9% annually from 2004 to 2030 (see Figure 2-1 for projected natural gas consumptions volumes to 2030). The major use of natural gas in the OECD has been for electricity production. Moreover, with governments shifting their focus to other energy sources to reduce CO_2 emissions, a greater reliance on natural gas other than coal can be expected. Specific to Canada, expansion in the oil sands is expected to account for the increase use of natural gas (to extract bitumen from sand) in Canada.

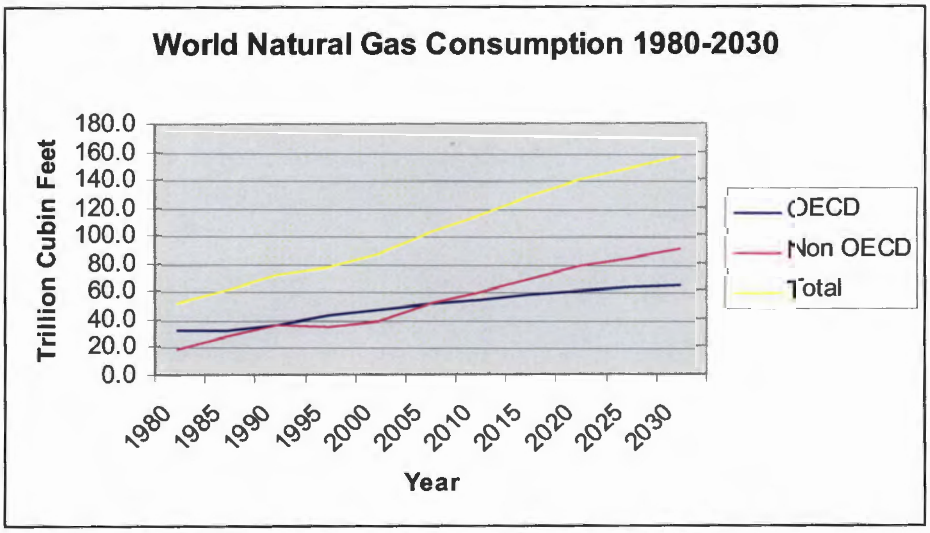

Figure 2-1: Forecasted Natural Gas Consumption to 2030
Source EIA 2009

As the price of natural gas fluctuates, so too does the cost of drying lumber. On a given year, Carrier's consumption of natural gas ranges from 120,000 GJ to 140,000 GJ depending on the amount of lumber being dried. This means that each dollar increase in natural gas increases operating costs by $120,000 to $140,000 per year. To reduce the variability in the affects of natural gas pricing, long term contracts are usually negotiated with natural gas suppliers to try and shift the gas from a variable cost to a fixed cost (Bolinger et *al.,* 2006).

Another reason why industries are considering switching away from natural gas to bioenergy is the recently introduced B.C. government's Carbon Tax which became effective July 1, 2008. For natural gas, as of July 1, 2008 the tax increase is $0.4966 per GJ of energy. This will steadily rise to $1.4898 per GJ by July 1, 2012 (BC Small Business and Revenue 2008). While these taxes are designed to be revenue neutral to the government, this project cost neutrality was not assumed and as such the tax implications were included in the analysis. Another source of taxation on fossil fuels could result from price impacts on fossil fuels due to the implementation of a Canadian greenhouse gas cap and trade system. If the cap and trade system of taxation is implemented, a maximum $15 per tonne of carbon will be added to the price of natural gas (NEB 2006). Depending on the yearly consumption cap and trade would increase operating costs of $88,800 to $103,000 per year or approximately $0.74 per GJ of natural gas. With the increase in taxes on fossil fuels there may be a greater need to shift to becoming energy self sufficient and to save the continual cash outlay.

2.2 BIOENERGY ELECTRICITY COSTS

One of the main deterrents to using biomass energy for electricity in B.C. has been the price that BC Hydro is willing to pay for electricity. The BC Hydro energy price for purchase of electricity in the central interior is $77.53 MW (BC Hydro 2008). Kumar et *al.* (2005) determined that the cost to produce electricity from MPB damaged timber, depending on plant location varied from a low of $68.08 MW to $73.71 MW. These values assumed that the plant size would produce 300 MW of electricity (based on the best case scenario of a plant in Quesnel of $2 million/MW). This same study also indicated that plant sizes from 50 to 100 MW were 50% to 60% less cost effective than larger plants. These authors' capital costs were based on the 240 MW Pietarsaari plant operating in Finland. Stennes and McBeath (2006) determined that the cost to produce electricity, including the cost of feedstock, is $117 MW based on a 100 MW facility. On the higher end, Dowaki and Mori (2005) determined that the break-even point for bioenergy was between $348 and $646 per MW. These studies used a plant that is substantially higher than the 10 MW that is allowed under the open Call for Power. The capital cost of bioenergy has a large impact on the viability of the bioenergy sector. While several papers have estimated the capital costs of a bioenergy plant, most of these estimates are based upon large scale facilities that are conceptual (Stennes and McBeath 2006, Kumar 2008). The state of Michigan appears to be ahead of the bioenergy sector in continental USA with no less then four biomass or biomass combined electricity plants in operation. These plants range in size from 17 MW to 36 MW. For example, the Grayling Energy Station one of these four plants was constructed in 1991 at a cost of $2 million per MW. Adjusting for currency exchange of $1.2 Canadian, to $1 US the cost of this project increased to closer to $2.4 million per MW (1991 dollars).

The most recently constructed bioenergy system was at Canfor's Intercon Pulp Mill in Prince George, B.C. which was completed in 2005 at a cost of $117 million for 48 MW of production or $2.45 million MW/h (Canfor Annual Report 2004). While substantially smaller than the ideal plant sizes determined by Kumar et *al.* (2005) and Stennes and McBeath (2006), this is a larger project than several proposals under the call for power; thereby it has achieved some economies of scale. By contrast, the majority of projects submitted under BC Hydro's Call for Power are under 10 MW and cannot capitalize on the economies of scale. The Canfor cogeneration plant is consistent with other mid-scale plants being constructed in the United States and throughout the world (Lockerbie Scotland 44 MW at $4.09 million/MW US and a 100 MW plant in Sacul Texas at $4 million/MW [Coombs 2008]). Taking the range of these capital costs for construction of a 10MW plant and not discounting the loss due to economies of scale (Cameron et *al.* 2007), a plant can be expected to cost between $2.450 million/MW and $4 million/MW. At the low end a 10 MW plant's capital cost would be $24.5 million and at the high end of $40 million. The bioenergy system at $40 million is higher than several other studies have indicated but this increase can be attributed to the loss in economies of scale for the plant. The National Energy Board (NEB) (2006) estimates that worldwide bioenergy projects are $2 million per MW and the costs for generation of electricity vary between $60 MW and $90 MW. The costs determined by the NEB are based on plant sizes from 20 MW to 50 MW. As such there may be some further increased cost due to the loss of economies of scale.

While there are several physical plants and studies estimating the cost of producing electricity from biomass there are few examples available for establishing the costs to produce heat from biomass. However, in July 2008 Canfor announced that it was purchasing a hot oil system for its Fort St. John sawmill (Canfor New Release 2008). As this system would be similar in size to one which Carrier would require, the same purchase price that Canfor announced for its systems of $13.5 million (turn key) is the same values which this study uses.

2.3 ELECTRICITY DEMAND AND PRICING IN NORTH AMERICA

The demand for electricity in B.C. is expected to grow by 20% to 45% over the next 20 years (BC Hydro 2007). BC Hydro is expected to increase its supply of electricity by purchasing electricity from Independent Power Producers up to 10 MW in size with all of which must be must be zero net emitters of greenhouse gases (BC Bioenergy Plan 2008). The size of these green projects and the fact that they are to be greenhouse gas neutral should give bioenergy a competitive advantage to provide energy to the province of B.C. Bioenergy has to compete with other forms of green energy such as wind, solar, geothermal, tidal and small hydro. Based on the cost for listed in Table 2-2 bioenergy should be a reasonable alternative to some of the other forms of energy available.

Table 2-2. *Estimated Electricity Costs by Method*

Option	Estimated Cost $/MW hour
Large hydro electric	43-62
Natural Gas	48-100
Coal	67-82
Biomass	75-91
Wind	71-74
Solar	700-1700

Source BC Hydro 2008

Current prices for electricity in the North American market are extremely variable. British Columbia has some of the lowest rates for electricity for industrial users in North America (see Table 2-3 for comparison). Compared to the European Union, the North American market for electricity is extremely favourable as North American markets are not subject to carbon taxes.

Table 2-3. *Average Prices of Large Electricity Users for Selected North American Cities and European Countries (cents/kWh)*

Power Demand Consumption Voltage Load factor	10,000 kW 5,760,000 kWh 120 kV 80%
Selected Canadian Cities	
Montreal Que.	4.57
Charlottetown PEI	8.88
Toronto ON	8.58
Edmonton AB	10.15
Vancouver BC	3.89
Selected US Cities	
Boston MA	14.93
New York NY	15.39
Seattle WA	4.59
Selected European Countries	
Denmark	45.39
UK	25.09
Finland	19.18

Source Hydro Quebec 2008, Energy EU converted to$ Can at 1.64

2.4 TYPES OF BIOENERGY SYSTEMS

There are several different types of bioenergy systems available but operationally there are only subtle differences. A fluidized bed combustion system uses a fluidized bed of sand to dry and break up the material for combustion. A grate system uses metallic grates to accomplish the same purpose as a fluidized bed. Both systems consume the biomass at high temperatures greater than 900°C and the higher the temperature the more efficient the facility (Mathieu and Dubuisson 2002). The cost of the grate systems is slightly higher than the cost of fluidized bed (Richardson et *al.* 2002) but there does not appear to be any appreciable difference in efficiency between systems. To produce only electricity from biomass, plant efficiency ranges from 20 to 30%. When heat is captured from the process (cogeneration) the systems efficiency increases to 80% or more. While the optimum efficiency can vary depending upon the end result, there is the question of plant optimal size. Recall that several researchers have indicated that the optimal size for biomass energy is greater than 250 MW while others indicate that the efficient size of the plant is above 100 MW (Dornburg and Faaij 2001). There are three main problems with trying to construct a large bioenergy plant a) the uncertainty, longevity and availability of the feedstock b), the high capital cost requirements to construct a large facility and c) the low electricity rates in B.C.

Apart from the minor differences in system efficiencies feedstock availability has been identified as a barrier to expanding biomass energy in the southern US (Mayfield et *al.* 2007). In B.C., high capital costs and long payback periods and low energy rates has remained a barrier to bioenergy expansion (Evans and Zaradic 1996). The benefit of using MPB damaged timber is the longer the wood remains standing the moisture content of the wood becomes at equilibrium with the surrounding environment. This drier wood becomes, the more efficient it is to transport as less water is retained in the fibres. This is important because transportation is normally the greatest cost to supply feedstock to a bioenergy plant (McIlveen-Wright et *al.* 2001, Haygreen and Bowyer 1982). The efficiency in burning drier wood is that less energy is used to evaporate the water which is normally retained in the fibres of fresh feedstock.

While there are benefits to trying to save money by eliminating the need to purchase energy, there may be opportunities for developing a new revenue stream and pellet manufacturing can utilize the same feedstock as a hot oil system or co-generation system. Demand for wood pellets used for heat and power in Europe has grown by 27.5% from 1995 to 2004 with 95% of the wood pellets being consumed in seven countries namely Sweden, Netherlands, Denmark, Belgium, Italy, Germany and Austria (AEBIOM 2007). The manufacturing of wood pellets involves a multi-stage process. The first stage is drying which involves reducing the moisture content of the material to 12%. Generally most pellet manufactures use natural gas kilns for drying feedstock. The second phase is grinding. The optimal feedstock size in pellet manufacturing is less than 6mm. Whether the feedstock is used in the hot oil system or the cogeneration system, the size of the material must be less than 25mm so in all cases a hammer mill is required to grind the material to size. The next step is to condition the fibre by super heating the wood. This aids in softening the lignin which assists in bonding the fibre together (Peksa 2007). Pelletizing occurs next which is forming the material into the desired length and diameter followed by cooling and storage. Sinclair (2008) uses an estimated conversion cost of $35.57 tonne, which is the value used in this study.

2.5 GOVERNMENT POLICIES

As the MPB infested timber deteriorates over time, other alternative uses to dimension lumber are actively being explored. Bioenergy has been on the forefront of the provincial government's mandate as an alternative to traditional uses for timber. The Mountain Pine Beetle Action Plan 2007 has as a core objective to "Recover the greatest value from dead timber before it burns or decays, while respecting forest values". Some of these objectives include bioenergy, composite panels, pulp and various engineered products. Enacting legislation (Bill 31) to partition the AAC and created new forms of tenure will assist in the development of the bioenergy sector. Trying to maintain economic sustainability when the AAC eventually falls has been priority for government. Projects such as bioenergy have been key to the government's goal of trying to diversify the economy in areas heavily impacted by the MPB.

3 CHAPTER THREE - METHODOLOGY

This study uses data from a medium sized sawmill located in Prince George, B.C. to determine a) the financial viability of a hot oil energy system to replace natural gas for heat, b) to determine the viability of a cogeneration system to replace natural gas and electricity and determine if the revenue obtained from sales of excess electricity would be enough to entice a lumber manufacturer to pursue either of these options. The final option is to determine if constructing a pellet plant would be a better option than either a hot oil system or cogeneration system. While a pellet plant does not save the company money in terms of energy consumption, there may be an opportunity to utilize mill residues and MPB to generate a new revenue stream. The majority of the values for the pellet plant are derived from Sinclair's (2008) project 'Financial Viability of Standalone Wood Pellet Production Using Pine Beetle Fibre'. The inputs for feedstock for all systems come from a combination of by-product of the sawmilling processes, which includes hog fuel, planer shavings, sawdust and chips. If there is not enough feedstock to operate the facility, then costs to supply and deliver supplemental feedstock were derived by analysing three separate sources of data; a) the Interior Appraisal Manual, b) purchase of hog fuel on the open market from area mills and trucked to the facility, and c) delivered prices of market pulp logs. The data obtained for the amount of by-products produced can vary from mill to mill but the differences are assumed not to be significant.

3.1 FRAMEWORK OF FINANCIAL VIABILITY CALCULATIONS

The financial viability for this project was determined by using the capital costs of each system in year one for each system, estimating operating costs based on available data, calculating the cash savings for generating heat and electricity and then by calculating these projected savings over five years, ten years and fifteen years. Due to the high capital cost for all projects, this timeframe to determine financial viability was substantially longer than traditional projects that a lumber manufacturer would normally consider. The project capital costs and cash savings-flow were then entered into Internal Rate of Return (IRR) and Net Present Value (NPV) formulas to determine if these projects would be considered viable for a medium sized lumber manufacturer. Different scenarios were then calculated to determine under what conditions these projects would become financially viable. The worst case scenario determined the financial viability under conditions where the majority of the feedstock had to be supplied from whole log harvesting. The scenario were based on the following criteria and following assumptions:

1. Scenario One: Hot Oil Base Case - This scenario used the current values of natural gas. Feedstock was supplied internally from sawmilling by-products. The lost revenue for selling the hog fuel was included in the calculations for NPV and IRR. Additionally this Scenario also examined the impact that the carbon taxes would have on the future viability of a hot oil system.

2. Scenario Two: Cogeneration Base Case - This scenario used the current prices that BC Hydro planned on paying for electricity under their Clean Energy Program. Feedstock would be supplied from hog fuel produced internally and excess hog fuel would be purchased from surrounding sawmills and transported to Prince George. Natural gas prices and carbon taxes are included in the discussion of the results discussions.

3. Scenario Three: Cogeneration Pessimistic Case - In this scenario, the electricity and natural gas values were considered identical to Scenario Two. The only difference with this

scenario was that all extra feedstock was assumed to come from MPB damaged timber purchased on the open market.

4. Scenario Four: Cogeneration Optimistic Case - This scenario analyzed what gas and electricity prices needed to exist in order for this project to become financially viable.

5. Scenario Five: Pellet Plant Base Case - This scenario considered using all the mill by-products as feedstock for pellet production.

6. Scenario Six: Pellet Plant Pessimistic Case - This scenario would consider the same selling and manufacturing scheme as Scenario Five. This scenario considered a sawmill that could not produce enough feedstock to make pellets and that the extra feedstock required for the pellet plant and the feedstock would come from MPB damaged timber.

Once the costs and savings were established, an internal rate of return and net present value calculation using Carrier's historic minimum rate of return was conducted. If both internal rate of return and net present value were positive it indicated that the projects are financially viable. Negative results indicated that the projects were not financially viable. The values used in the scenarios for both systems are described in Table 3-1. They represent current market values for these products.

Table 3-1. *Average Feedstock Revenues and Interest Rates*

Interest Rate	10%
Feedstock Costs	
Hog Fuel	$2 ODt
Sawdust	$5 ODt
Shavings	$30 ODt
Chips	$79 ODt
Purchased Hog	$ 2 ODt
Purchased Logs	$40 t

The interest rates used in this project are higher than that used by Sinclair (2008); however as described in Evans and Zaradic (1996) forest companies normally do not undertake investments that last over seven years. Generally, for most sawmill upgrades, a payback period would need to occur within three years, otherwise, the project would not be considered. To have a project pay for itself in three years the internal interest rate would have to be 26%, which demonstrates the difficulty in using traditional analysis for bioenergy projects.

4 CHAPTER FOUR – METHODOLOGY FOR DETERMINING FINANCIAL VIABILITY BIOENERGY SYSTEMS

For each bioenergy system, the methodology used to determine the financial viability of a hot oil system, cogeneration system or pellet plant, had four basic components. These four components are described below. Additionally, manpower and operating costs are described for each system, based on available data.

4.1 COST BENEFIT ANALYSIS OF A HOT OIL SYSTEM

In determining the cost benefit analysis of a hot oil system, three main variables were considered to determine a system's financial viability:

1) Capital Cost Estimation - This is the estimated cost to have a system built on site to a turnkey operation.
2) Natural gas consumption savings - This is the savings obtained by using the hot oil system to dry lumber in the kilns instead of natural gas.
3) Operating costs - These are the costs associated with staffing, maintenance and completing minor repairs to the system.

4.2 CAPITAL COST AND OPERATIONAL ESTIMATES

Naturally the capital costs for a hot oil system vary from supplier to supplier. The capital costs used in this analysis as previously mentioned, were based on Deltech's hot oil system that was purchased by Canfor in July 2008 for $13.5 million. Based on the square metre heating capacity of the grate, a fourth class steam engineer would be required to operate the plant. The hourly rate for this position would be covered under the collective agreement with the local union. Weekend coverage could be completed by training the weekend cleanup crew to ensure that feedstock was available for continuous operation of the plant. No new positions would be needed for weekend operations of the facility. As there are no expensive boilers or turbines to operate, annual maintenance costs were expected to be significantly lower than the cogeneration system (discussed in detail in the following section). A conservative 1% of the purchase price or $135,000 per year was used to estimate maintenance costs. The cost of the extra employee including benefits is $85,000 per year for a combined cost of $220,000 per year.

4.3 COST BENEFIT ANALYSIS OF A COGENERATION SYSTEM

As discussed earlier, the capital costs for an electrical bioenergy system varies depending upon plant size. Recall that smaller plants have higher capital and operating costs per MW. Based on Canfor's 45 MW system and values obtained from other suppliers such as Wellons and Deltech, this project considers $4 million per MW to be realistic capital cost due to the small size of the bioenergy plant as is being considered for the Carrier sawmill. To determine the cost benefit analysis of constructing a 10 MW system at Carrier's sawmill, the following variables were used in determining the financial viability of the cogeneration system project:

1) Capital Cost of the plant to operations. These include all costs related to making the plant operational such as site preparation, building construction and connecting the cogeneration system to BC Hydro's electricity grid.
2) Natural gas consumption savings. These would be identical to the savings achieved from using a hot oil system.

3) Operational Costs. These costs include the labour and maintenance required to operate the plant on a continual 24 hour 7 day a week basis for 50 weeks per year. For two weeks per year, the plant would be closed for annual maintenance.
4) Feedstock Costs. Unlike the hot oil system which could run at a lower capacity when required, the nature of cogeneration systems must operate at capacity therefore, large amounts of feedstock would be required.

4.4 OPERATIONAL COSTS OF A COGENERATION SYSTEM

It is estimated that the size of the boiler would have to be approximately 3000 m^2 to have the capacity to produce 10 MW of electricity. As per the *Safety Standards Act 2008*, operating a plant of this size would require one first class power engineer, who would act as the chief engineer, five second class power engineers, four third class power engineers and a minimum of one yard employee to feed the plant. The first class engineer would work a regular shift (i.e. Monday to Friday). The second and third class engineers would be required to monitor plant operations 24 hours a day. It would be expected that the first and second class engineers would be paid salary while the third class engineers and the yard employee would work hourly under the union's collective agreement. The yard equipment used to feed the facility is not being included in the calculations as these costs are expected to be charged against the sawmill operation. Maintenance costs are based on estimates from Kumar et *al.* (2005) and Stennes and McBeath (2006) at 2% of the capital costs even though Evans and Zaradic (1996) estimated maintenance costs to be slightly higher at 2.5% and Dornburg and Faaij (2001) used estimates of 3% to 6%. Maintenance costs for this study will be $800,000 per year and extra employee wages would be $1.2 million per year for a combine owning and operating cost of $2 million annually.

4.5 CAPITAL COSTS OF A PELLET PLANT

The capital cost of constructing a pellet plant is expected to be approximately $100 per tonne (Sinclair 2008). The majority of the pellet plants in the central interior of B.C. produce in the range of 150,000 tonnes of pellets per annum per plant (Karidio 2007). Therefore, this is the size of the pellet plant used in this project which will be analysed. The capital costs would then be $15 million while operating costs are included in the conversion cost of pellet manufacturing .

4.6 NATURAL GAS SAVINGS

Currently, at Carrier, the amount of natural gas used is approximately 130,000 GJ/yr. The average charge or time it takes to dry lumber to 19% moisture content is 18 hours to 32 hours depending on the product and species being dried. In order to receive Kiln Dried Heat Treated (KDHT) certification, the lumber must be dried for a minimum of 30 minutes at 56 °C and a moisture content of less than 20% (CFIA 2009). All lumber being exported to the United States market must be stamped KDHT. The hot oil system and the cogeneration systems would displace all the natural gas used at the mill. The yearly savings would depend on the commodity price for natural gas during that particular year, but, based on historical natural gas prices, the savings could range from $1.1 million to $1.6 million annually. During the period when the kilns are not operational, the excess heat would have to be wasted. Wasting the heat would be required because the hot oil systems similar to cogeneration systems are designed to operate continuously around the clock in order to maintain their efficiency. Naturally, the pellet plant would have no impact on the natural gas consumed for drying lumber. The anticipated increase in natural gas consumption for pellet manufacturing is included in the conversion cost calculations.

To see the summary the major inputs such as capital cost, operating costs, interest rates, labour costs and natural gas consumption used to compare each system see Table 4-1.

Table 4-1. *Comparison of Capital Costs of the Three Bioenergy Systems*

	Hot Oil System	Cogeneration	Pellet Plant
Capital Cost	$13,500,000	$40,000,000	$15,000,000
Operational Costs	1%	2%	N/A
Interest Rate	10%	10%	10%
Labour Costs $/yr	82,000	1,200,000	2,900,000
Natural Gas Savings GJ/yr	130,000	130,000	N/A

4.7 FEEDSTOCK COSTS

The feedstock costs are broken into three types of analyses. The first analysis uses the lowest value by-products of sawmilling which is hog fuel. If further supplements the required feedstock from surrounding sawmills, as previously mentioned. In the case of pellet manufacturing the scenarios contemplate using internally generated by-products including hog, sawdust, chips and planer shavings. Since the sale these products currently generate revenue, the lost revenue stream by using these products to manufacture pellets is accounted for in the calculations. Moreover, Carrier does not produce enough feedstock to operate a 10 MW cogeneration plant. As such, the additional hog fuel would have to be purchased on the open market for a nominal fee. Trucking rates for hauling are based on the BC Blue Book 2008/2009. The greatest cost of supplying the feedstock would be for hauling the material to the power plant.

The second analysis considers harvesting whole logs and grinding them at the plant. To determine the costs of delivering whole logs the following variables were determined:

1) Tree to Truck Costs - These costs include planning, road construction, falling, skidding, processing and loading onto a truck
2) Hauling Costs - These costs includes the truck transportation from the field to the plant
3) Stumpage - These costs are the royalties demanded by the Crown to harvest timber on Crown Land.
4) Grinding - These costs are associated with breaking down the material from log form to a size usable for the plants
5) Purchase of logs through private sources - rather than log timber for feedstock there may be opportunity to purchase low grade timber on the open market cheaper than harvesting on a forest license.

4.8 TREE TO TRUCK ESTIMATES

Several studies have evaluated the cost of MPB damaged timber as a feedstock for bioenergy. Some of these studies have determined that the delivered costs for harvesting to be between \$25.80 m^3 in the best case scenario (Kumar et *al.* 2005) up to \$51.33 m^3 in some forest districts (MoFR 2008). Using the formulas in the Interior Appraisal Manual (IAM) to determine the total logging costs, prices range from \$30.62 m^3 for the best case to \$40.55 m^3 for the likely case (see Appendix 1 for complete calculations using the IAM).

The closest timber and the best quality fibre would be harvested first by licensees. Anything left for bioenergy would be the lowest quality fibre and located furthest from the mill. Taking this likely scenario approach in determining the cost of delivered fibre results in dramatic changes to the delivered log cost as indicated in Table 4-2.

Table 4-2. *Estimated Delivered Feedstock Costs*

Phase	Best Case Scenario $/m^3	Likely Scenario $/m^3
Tree to Truck	13.49	26.08
Hauling	5.54	8.2
Overhead	2.15	2.15
Roads	1	1
Road Maintenance	1.78	1.78
Silviculture	4	4
Combined Price $/m^3	30.62	40.55

Source IAM March 2008

Other studies have established varying rates for the delivery of feedstock to the producing plant from Stennes and McBeath (2006) where costs were estimated to be $100.61 BDT for logs hauled to a facility while chipping on site was $83.35 BDT. The Ministry of Forests and Range estimate that whole tree harvesting in Prince George Forest District to be $33.37 m^3 while the cost of removing roadside debris is substantially less at $11.91 m^3 (MoFR 2008). The roadside debris does not account for the sunk costs incurred by the primary licensee (falling, skidding processing overhead etc.) which may have to be charged to the secondary licensee. Table 4-3 summarizes all the different methods for harvesting, or purchasing off grade logs on the open market.

Table 4-3. *Average Delivered Feedstock Costs*

Author	Best Case Delivered Costs $/m^3	High Value Delivered Cost $/m^3
Kumar *et. al.* 2005	25.52	32.25
My Analysis	30.62	40.55
Ministry of Forests	33.37	51.33
Purchase on open market	23.75	30.00

The above calculation assumes that the wood will be delivered to the facility in whole log form and chipped there. The extra costs of chipping then needs to be added into the cost of bioenergy. Most forest roads are not suitable for a chip truck (turning radius and steep haul roads etc.). While wood is considered carbon neutral, it is not as efficient to generate electricity compared to fossil fuels. As an example, the amount of energy needed to generate the equivalent amount of energy from one tonne of coal, three tonnes of wood would be required. If the timber was living, the ratio of wood to coal equivalent would be higher since living wood contains more water. This water would have to be evaporated prior to combustion taking place. As the wood becomes drier the issue is how to transport enough wood economically. The ideal situation is having the feedstock as close as possible to the plant to reduce the transportation costs. When hauling costs increase, the marginal efficiency of the plant decreases (Faundez 2008). As the minimum amount of material required to continually operate is greater than the material produced at Carrier, the feedstock must be brought in from other sources. Other sources include either purchasing material from other sawmills or bringing the material in from the forest. The issue in Prince George is that the local pulp mills already consume all the available hog fuel from local sawmills for their energy needs. As such, if Carrier wishes to create a cogeneration system, it would be forced to either; harvest and transport feedstock, or purchase hog fuel from sources where Tier 2 burners still exist (e.g. Vanderhoof and Fort St. James).

The other option is to purchase logs that do not meet saw log quality specifications on the open market and would otherwise be left on the harvesting site to be burned. For a harvesting contractor or licensee, this type of product sort would be appealing as it provides another source of revenue for a product that would otherwise be left at the harvesting site. The average purchase price for off grade logs (Grade 4) would range from \$38 tonne to \$42 tonne (\$23.75 m^3 to \$30 m^3). An assumed value of \$40 tonne or \$25.00 m^3 is used in this analysis. As the volume of Grade 4 logs slowly increases with each passing year from MPB attack, by purchasing the off-grade timber, licensees could harvest more area and convert damaged stands into young forests. This occurs because, currently, Grade 4 logs delivered to non-lumber manufactures are not counted toward licensees Annual Allowable Cut. Figure 4-1 illustrates that the amount of off-grade fibre is substantially higher than the amount of sawlog fibre that has been harvested since 2005.

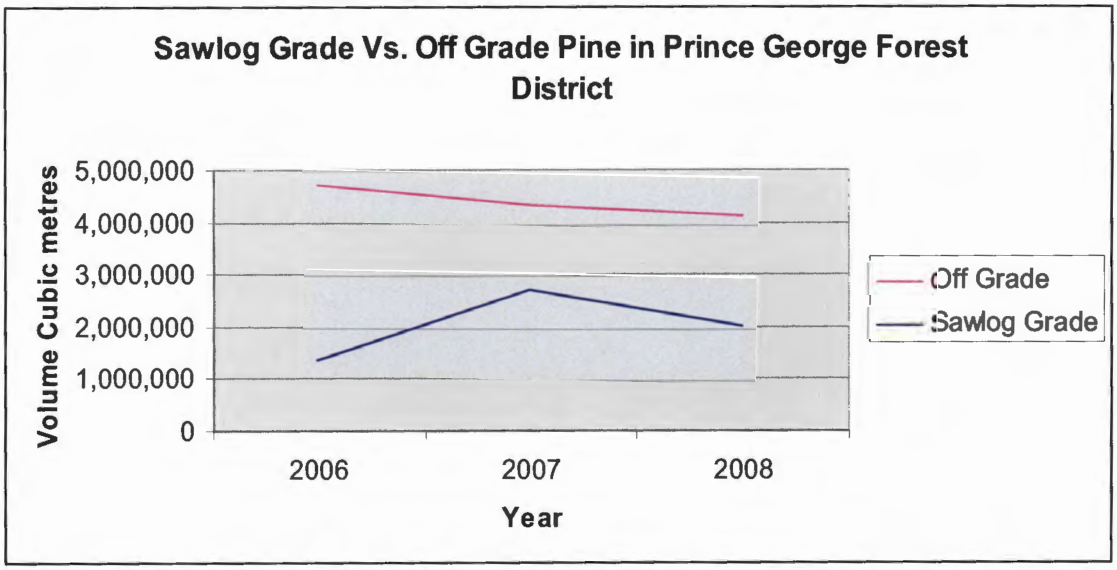

Figure 4-1: Sawlog Grade Vs. Off Grade Pine
Source HBS

There are two issues with low cost fibre options. The first issue is that there is no legislative framework in which roadside debris can be utilized by a third party. Second, there is also the operational issue of having chip trucks on logging roads since their configuration is not suitable to steep winding terrain which occurs in most areas in the interior of B.C.

5 CHAPTER FIVE - DISCUSSION OF RESULTS

Now that all the major parameters for capital costs of the facility, feedstock cost, and operating costs have been established, the results are discussed for each scenario in the following sections listed below.

5.1 SCENARIO ONE HOT OIL ENERGY SYSTEM

Scenario One analysed the financial viability of a heat oil bioenergy system. As expected, after 5 years IRR and NPV were both negative (see Table 5-1 for results and Appendix 2 for complete calculations). This was a result of the high capital cost experienced in year one and the low volumes of natural gas being consumed. As the price of natural gas increased above $13 per GJ the hot oil system started to look attractive but due to the long period of time to for this project to have a positive return it is unlikely that it would proceed.

Table 5-1. *Parameters of Hot Oil System (NPV in thousands of dollars)*

Natural Gas $/GJ	7	9	11	13	15	16
IRR @ 15 years	-2%	-1%	4%	7%	10%	11%
NPV 10% 5 yrs	-$10,191	-$8,848	-$7,952	-$7,056	-$6,160	-$5,712
NPV 10% 10 yrs	-$8,899	-$6,721	-$5,269	-$3,817	-$2,364	-$1,638
NPV 10% 15 yrs	-$8,097	-$5,401	-$3,603	-$1,805	-$7.57	$891,322

To determine the full impact of the carbon taxes, add an approximated $2 per GJ to the cost of natural gas. This estimated carbon tax of $2 per GJ would not only include the full impact of a direct provincial carbon tax it would include the indirect tax created by implementation of a cap and trade regulatory system on greenhouse gases. If carbon taxes were significantly higher, than the estimate used in this project, this could potentially sway decisions on moving forward on this type of project as IRR and NPV become positive sooner. However, with the capital costs of a hot oil system being so high and the amount of natural gas being consumed so low, the likely outcome it that this project would still not move forward.

If different parameters were used for the interest rates such as 5% versus 10% then this project would look more attractive. Without changing any other parameters other than using a lower interest rate, this project would become viable in 15 years with gas prices at $12 GJ. The issue for Carrier is that there is an existing market hog fuel. This means that Carrier is not impacted by the implementation of the *Clean Air Act* with respect to decommissioning beehive burners or subject to tipping fees for disposal of hog fuel into a landfill. If Carrier were subjected to these externalities then different parameters would be required to determine the viability of this system.

5.2 SCENARIO TWO COGENERATION SYSTEM BASE CASE

There are no scenarios in which both IRR and NPV of a cogeneration system are positive for a 10MW facility using the same parameters as a hot oil system. These smaller cogeneration systems truly suffer from not obtaining economies of scale. Under the best case scenario where feedstock is purchased for a nominal fee and hauled to Prince George, the IRR remains marginally positive and NPV is always negative. The best outcome for the base case NPV at 15 years with a 10% interest rate, is negative $13 million assuming natural gas are $16 per GJ, (see Table 5-2 below for results and Appendix 3 for the complete calculations).

Table 5-2. *Scenario Two Bioenergy Parameters and Results (dollars in thousands)*

Electricity Saved	$1,000				
Net Sales	5 MW/h				
Value of Sales	$0.08 kWh				
Natural Gas $/GJ	9	11	13	15	16
IRR @ 15 years	-1%	0%	1%	3%	3%
NPV 10% 5 yrs	-$27,891	-$26,995	-$26,099	-$25,203	-$24,755
NPV 10% 10 yrs	-$22,631	-$21,178	-$19,726	-$18,274	-$17,547
NPV 10% 15 yrs	-$19,364	-$17,566	-$15,769	-$13,971	-$13,072

This scenario assumes that the electricity produced is consumed to operate the sawmill and planer and the excess power is sold back to BC Hydro using their Tier 2 pricing of $80 MW. The impact of carbon taxes has a negligible effect on the overall outcome of the project. The high capital cost of the plant and high operating costs, high required return on investment and low electricity rates are all major factors as to why this type of project are not economically viable.

If the capital costs could be reduced, each one million dollar value in capital represents a savings in NPV of almost $910,000 and each $1 per GJ increase in natural gas saves $130,000 year. If the capital costs could be reduced to be more comparable with larger cogeneration facilities, and natural gas prices and electricity rates increased substantially then this project could become marginally viable. However the project would be too risky to undertake given these constraints.

As discussed earlier, the price of natural gas is expected to increase over the next 30 years, but as more LNG facilities are constructed, the price of natural gas is expected to remain steady at $9 per GJ to $10 per GJ. Electricity rates are expected to increase over time. For example in the US, electricity rates are expected to rise until 2030 to an average of $0.152 kWh, but this still would only marginally improve financial viability of this system. Overall, even under the best scenario for cogeneration system the project would not be financially viable.

5.3 SCENARIO THREE COGENERATION PESSIMISTIC CASE

In this worst case scenario, hog fuel would not be available for purchase from outside sources and therefore, harvested logs would supply the feedstock for the electricity plant.

Advantageously, this scenario would follow the government's strategy of not letting the MPB damaged timber go to waste. Yet under this scenario the full costs associated with traditional harvesting on Crown Land is included in the delivered log costs such as harvesting, silviculture, stumpage, and log hauling and road construction. The major assumption with this scenario is that the Grade 4 logs would be purchased from other licensees operating on Crown Land or from private land. Purchasing private timber would then allow the silviculture obligations to remain with the primary licensee. Extra costs would have to be included for chipping the whole logs at the mill site, but it is assumed that there will not be any extra manpower required to operate the yard equipment. The value of logs purchased on the open market would be $40/tonne. Table 5-3 shows the results under this scenario (see Appendix 4 for complete calculations).

Table 5-3. *Scenario Three: Pessimistic Cogeneration Results (dollars in thousands)*

Electricity Saved	$1,000				
Net Sales	5 MW/h				
Value of Sales	$0.08 kW/h				
Natural Gas $GJ	9	11	13	15	16
IRR @ 15 yrs	N/A	N/A	N/A	N/A	N/A
NPV @ 15 yrs	-$40,562	-$38,764	-$36,966	-$35,168	-$34,269

There are no conditions under which this scenario becomes remotely financially viable. The combination of high feedstock costs, high capital costs, extra costs to chip the material and low electricity rates would always make this scenario unattractive. Interestingly, the majority of the proposals submitted under BC Hydro's call for power were stand alone projects and would fall under this criterion with respect to financial viability.

5.4 SCENARIO FOUR COGENERATION OPTIMISTIC SCENARIO

Using the similar assumptions as Scenario Two for all inputs except electricity pricing, interest rates and feedstock costs, what price would electricity and natural gas need to be in order for this type of system to be financially viable? If the feedstock were free, that is, if beehive burners were no longer allowed such that mill operators would be willing to give the hog fuel away for free, natural gas would have to cost $10 per GJ while electricity would have to be $110 MW. Table 5-4 shows the results for the variables that need to exist to ensure a cogeneration system is financially viable (see Appendix 5 for complete calculations).

Table 5-4. *Optimistic Scenario: Conditions under which Cogeneration is Viable (dollars in thousands)*

Electricity Saved	$1,000				
Net Sales	5 MW/h				
Value of Sales	$0.11 kW/h				
Interest Rate	5%				
Natural Gas $/GJ	9	10	13	15	16
IRR @ 15 yrs	5%	5%	7%	8%	8%
NPV @ 10 yrs	-$10,500	-$9,544	-$6,676	-$4,764	-$3,808
NPV @ 15 yrs	-$1001	$284	$4,139	$6,709	$7,994

Under these conditions, that is if natural gas were $16 per GJ, IRR at 15 years would be 8% and NPV would be $7.9 million. While this is better than Scenario Two in that NPV and IRR are finally positive, it is unrealistic to expect a forest company to be enticed by this venture. It is unrealistic due to the low interest rate and the fact that natural gas, even in consideration of the carbon taxes, would have to be at historical highs. As mentioned when applying a realistic interest rate of 10% to the projects NPV become negative under all conditions. It is unlikely that BC Hydro would purchase electricity at these optimistic rates as they would be close to the highest rates of electricity in North America. The final cost in this scenario considers feedstock cost. These would be expected to increase because the closest damaged fibre is harvested first leaving the fibre for bioenergy furthest from the facility. This resulting in high cost delivered fibre putting downward pressure on the project financial viability.

5.5 SCENARIO FIVE FINANCIAL VIABILITY OF A PELLET PLANT

The final scenario that may work for a sawmill manufacturer is to construct its own pellet plant and thereby diversify its revenue stream. As discussed previously, the amount of planer shavings and sawdust account for almost 40,000 oven dry tonnes of material per year. Including the production of hog fuel this amount is approximately 60,000 ODt per year. The calculations for the both scenarios were drawn on by the values generated in the Realistic Scenario and Pessimistic Scenario for a similar project completed by Sinclair (2008). The change in harvesting cost was reduced by the amount of feedstock generated from the sawmilling process, other than these minor changes all other calculation remained constant. Sinclair (2008), who generated scenarios from baseline to optimistic, analysed the impact of feedstock cost, inflation and exchange rates in determining the financial viability of a stand alone pellet plant.

Providing the mill runs continual double shifts so that it can supply 40% of the fibre requirements and that the remaining feedstock come from the chips produced, the NPV becomes positive in 10 years (see Table 5-5 for results and Appendix 6 and 7 for complete calculations).

Table 5-5. *Scenario Five Optimist and Six Pessimistic Pellet Plant Results (dollars in thousands)*

	5 yrs	10 yrs	15 yrs
Optimistic NPV	-$3,532	$2,742	$6,637
Pessimistic NPV	-$17,330	-$19,623	-$21,047

In the optimistic scenario all fibre is supplied internally. This scenario occurs when the price of pulp drops and subsequently the value of chips declines. Naturally the reverse is true so if this option were being considered, there is the risk of forgoing greater revenues if chip values increased.

Under the pessimistic scenario, if the economic conditions were to continue and the sawmill operated single shifts instead of double shifts, and the pellet plant continued to operate at full capacity, extra feedstock would be required. This scenario uses would utilize fibre from harvesting MPB damaged timber to supplement the plants requirements. This scenario produces no positive NPV's. In fact, the high cost actually causes the NPV to worsen over time; therefore, so this option in not financially viable.

In deciding to construct a pellet plant, the fact that there are four pellet plants operating within a 120 km radius of Prince George should weigh heavily on the decision to proceed. If the average pellet plant is 150,000 tonnes/yr then each pellet plant can utilize all the feedstock of three sawmills that consume approximately 750,000 m^3/yr. The four existing pellet plants therefore are consuming almost all the feedstock that the sawmills in the Central Interior of B.C. can produce. It is unlikely that constructing a new plant to compete with established players would be a sound business decision. Downtime at several interior sawmills has dramatically reduced supply to the pellet manufacturers and subsequently they have had to resort to grinding logging debris for feedstock in order to remain operational. Adding a fifth plant would only exacerbate this problem.

6 CHAPTER SIX - CONCLUSIONS

British Columbia is blessed with an abundance of natural resources. While these resources have been beneficial in expanding the prosperity of the province, it has also impacted the provinces ability to diversify. Since B.C. experiences some of the lowest electricity prices in North America any new renewable forms of energy due to the cost will not be able to compete with hydro electric power. Trying to utilize MPB damaged timber to generate electricity is not viable under the Tier 2 pricing system from BC Hydro. This study also demonstrated that the expected cost of producing electricity from biomass with small facilities is substantially higher than the estimates published by BC Hydro.

As the MPB stands further deteriorate and lose their value for saw log material, the provincial government will push other sectors to utilize this damaged timber. Unfortunately, small energy plants are not financially viable even with the addition of carbon taxes added onto the price of fossil fuels. Under any cap and trade system, BC Hydro claims the credit as they are subsidizing the higher cost to generate electricity, so these direct benefits are also lost to the proponent of bioenergy. Achieving economies of scale to reduce capital cost may help make these plants more attractive. Also, the low amounts of natural gas being consumed for kiln drying do not even make a heat oil system financially viable.

Sinclair's (2008) analysis of a standalone pellet plant using MPB damaged timber was not financially viable. My analysis demonstrates that, incorporating a pellet plant within an existing plant, is a viable project but only if the feedstock is available and inexpensive to deliver. Given the current lack of feedstock supply and the number of existing pellet plants already in production around Prince George, constructing another pellet plant would only put further pressure on feedstock supply and potentially drive feedstock prices higher.

All these scenarios were calculated using mill by-products based on double shift basis. If the economic conditions deteriorate and the mill is forced to reduce shifts then the financial viability of these projects become even less attractive.

Feedstock costs are a significant factor in the viability of these energy systems. In Prince George, with three operational pulp mills utilizing all the hog fuel from mills located within the city, transportation plays a significant cost in the procurement of feedstock. Harvesting whole logs for feedstock is not a viable option. Grinding roadside debris has limited appeal as it is costly to grind in the field and transport the material by truck to Prince George. With more sawmills announcing downtime and closures, in order to buy hog from surrounding sawmills, one could be in a position to have to bid against the existing pulp mills. The pulp mills could also, as part of their chip contracts have hog fuel included as feedstock for their operations.

6.1 POLICY IMPLICATIONS

There are several policies that, if addressed would allow a bioenergy industry to flourish. Staffing requirements for a 10 MW system are the same as other larger systems such as a 300 MW system. If the legislation changed to allow for remote monitoring of these plants, the same amount of staff could monitor four or five operations from one control room, thereby reducing operating costs. For example, if remote monitoring could incorporate the supervision of five facilities, staffing costs could be reduced to $240,000/year from $1.2 million/year, a savings of 80%. Changing the requirements so that the BC Hydro would accept larger proposal other than smaller than 10 MW would allow larger plants to be constructed and achieve economies of scale. The capital costs per MW for small plants are almost double that of any system that is greater than 100 MW. This fact alone eliminates the financial viability of the energy plant from the start. The forest tenures that are required for a bioenergy industry to succeed cannot be the same as a traditional forest license. Having the bioenergy sector responsible for silviculture and stumpage, as an example, add significant costs to the program. Changes in tenure type would require substantial legislative amendments to the Forest Act and could be politically difficult to sell to the public especially if changes to silviculture obligations are contemplated. However, the citizens of B.C., as owners of the resource, must begin to realise that the economic value of the fibre is deteriorating each year post beetle attack and the same obligations attached to a healthy forest should not be attached to a dead forest. The government, in trying to develop this industry, should take over the silviculture obligations for the bioenergy sector. Government will also have to reduce their stumpage and rents to zero. This is required because the value in the standing timber is not the same as a normal forest. If a stand is considered for bioenergy and not saw log different valuations of timber are required. Other operational issues that would be required are no cruising or scaling. While not expensive processes, if the timber is not high quality then spending money to measure it for quality is surely a waste. These are simple regulatory changes which can assist the development of the sector. However, given the requirements for these projects to become economically viable the government may have to look to other alternatives if they decide to address these infested stands.

6.2 GOVERNMENT INCENTIVES

Both the provincial and federal governments would be required to provide assistance in terms of tax incentives. Currently, the federal government incentive is $0.01 kWh for renewable energy projects which expires in 2010. This amount is too low to entice a lumber manufacturer into the business of electricity generation. This incentive amount could be increased and maintained for a longer period of time at little cost to taxpayer and be promoted as Canada trying to meet its Kyoto commitments. The capital cost allowance would also be required to be changed to amortize the total cost of the project as soon as practicable but less than five years after start up as a minimum. Another subsidy that could promote the development of this industry is to provide start up grants. In construction of Canfor's energy system BC Hydro provided almost $40 million dollars in grants. While this amount seems excessive, it allowed BC Hydro the ability to sell that freed power into the US market at higher rates then if Canfor were to consume the electricity. Continuing with this type of grant would assist in the development of a bioenergy sector. BC Hydro could continue with that program to assist in laying the foundation for a new sector. Expanding existing facilities at existing pulp mills would be a better approach as the infrastructure is already in place. They may also have the ability to complete further research into the value chain by extracting other compounds from the fibre rather than just burning for electricity. It would also assist the government in achieving its goal of energy self sufficiency by 2016. If governments truly wish for these projects to succeed, a different approach is required. That is, smaller facilities are not cost effective due to the high capital cost. Larger plants while obtaining economies of scale with respect to operating costs have other risks such as; higher financing costs, obtaining large amounts of capital for construction, default risk and risks from the public review process as plants larger then 10 MW are subject to a full environmental assessment. This study did not consider the requirements for financing as the purpose was to determine if these projects would meet a minimum threshold for investment and as discussed they do not meet the hurdle rate.

6.3 STUDY LIMITATIONS

The study was limited in scope and primarily focused on small energy systems that use mill by- products and MPB damaged timber for feedstock. Also it did not investigate what business decisions are causing other forest companies to switch to heat oil systems or what their current natural gas or electricity consumption is. The only values used were that of Carrier Lumber. The financial valuations used were estimated from publications that dealt with larger scale projects as there a few small scale projects in operation. More specific capital cost estimates and actual negotiated electricity rates could change results and conclusions.

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APPENDIX 1 – Harvesting Calculations Using IAM

- To determine the delivered cost using the Interior Appraisal Manual (IAM) 2008 for an average conventional pine leading stand the best tree to truck rate is as follows:

$/m^3= CONSTANT + (6.13 * SLOPE%/100) - (3.06 * VOLHA/1000) + (1.65 * BD%/100) + (9.78 * DEFECT%/100) + (1.64 * DPCUT) + (7.45 * SMALLTREED) - (21.52 * SMALLTREEVOL) + (2.05 * NEWDIST200/100)

Where CONSTANT = 14.25

- The Truck Haul Cost Estimate from the IAM is:

$/m^3 = CONSTANT + (2.05 * CT) - (1.3 * CE%/100) + (2.18 * DE%/100) + (1.18* FI%/100) + (2.29 * HE%/100) + (1.85 * WH%100)

Where CONSTANT = 0.41, CT = Cycle Time, CE = cedar, DE = deciduous, FI = Fir, HE = Hemlock WH = White Pine.

- The Road Construction Cost Estimate from the IAM is:

$/km = 5939+ (80 * SLOPE%) + (1220 * SMR) + (3168 * LT) - (920*T)

Where SMR is soil moisture regime, LT is long term road and T is temporary.

- Combining formulas to determine a delivered log cost the lowest delivered $/m^3 log cost with the following assumptions:

Best case scenario would be: A stand of Pine with no slope, 1.5 hour one way trip, clear cut, not a small tree piece size, 200 m^3/ha. The likely scenario small volume pine 15% slope, clear cut, small piece size, 2.5 hour one way 200 m^3/ha, blow down 10%, defect 20%.

APPENDIX 2 – Scenario One: Hot Oil Parameters

Table A2 – 1. Scenario One Hot Oil Inputs

Staffing Heat only		$	82,000
Capital Cost		$	13,500,000
Maintenance @ 1% of purchase	1%	$	135,000
Interest Rates			10%
Natural Gas Consumption GJ			130,000
Feedstock Costs (lost revenue) cost $/Odt			
20600 tonnes	2	$	41,200

Table A2 – 2. Financial Results for Hot Oil System

Natural Gas Rates $/GJ	7	8	9	11	13	15	16
Natural Gas Costs	910,000	1,040,000	1,170,000	1,430,000	1,690,000	1,950,000	2,080,000
Year	- 13,500,000	- 13,500,000	- 13,500,000	- 13,500,000	- 13,500,000	- 13,500,000	- 13,500,000
1	733,800	863,800	993,800	1,253,800	1,513,800	1,773,800	1,903,800
5	733,800	863,800	993,800	1,253,800	1,513,800	1,773,800	1,903,800
10	733,800	863,800	993,800	1,253,800	1,513,800	1,773,800	1,903,800
15	733,800	863,800	993,800	1,253,800	1,513,800	1,773,800	1,903,800
IRR	-2%	-1%	1%	4%	7%	10%	11%
NPV year 5	-$9,743,928	-$9,295,926	-$8,847,924	-$7,951,920	-$7,055,915	-$6,159,911	-$5,711,909
NPV year 10	-$8,173,742	-$7,447,566	-$6,721,390	-$5,269,038	-$3,816,686	-$2,364,334	-$1,638,157
NPV year 15	-$7,198,781	-$6,299,880	-$5,400,980	-$3,603,180	-$1,805,379	-$7,578	$891,322

APPENDIX 3 - Scenario Two: Cogeneration Plant Base Case

Table A3 – 1. Base Case Inputs for Cogeneration Plant

10 MW Electrical System Parameters				
Staffing Electricity/Heat			$	1,200,000
Capital Cost			$	40,000,000
Maintenance		2%	$	800,000
NG Pricing $/GJ				130,000
Electricity Saved $/year			$	1,000,000.00
Plant Operations (hours/year)				7,560
hours/day* weeks/yr*efficiency	24*50*.9			
Mega Watts Produced per Year				75,600
Net Sales 5 MW/hr	5			37,800
Electricity Produced $/MW gross	80		$	6,048,000
Value of sales $/MW	80		$	3,024,000
Interest Rate				10%
Feedstock Costs		revenue		
Hog tonnes	20600	2	$	41,200
Purchase Hog	80000	2	$	160,000
Transportation (2.5 hr cycle 48 tonne payload 128 $/hr)	2.67	6.68	$	534,400
		Total	$	735,600

Table A3 – 2. Financial Results for Base Case Cogeneration System

NG Rates $/GJ	7	8	9	11	13	15	16
NG Cost $/yr	910,000	1,040,000	1,170,000	1,430,000	1,690,000	1,950,000	2,080,000
year	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000
1	2,198,400	2,328,400	2,458,400	2,718,400	2,978,400	3,238,400	3,368,400
5	2,198,400	2,328,400	2,458,400	2,718,400	2,978,400	3,238,400	3,368,400
10	2,198,400	2,328,400	2,458,400	2,718,400	2,978,400	3,238,400	3,368,400
15	2,198,400	2,328,400	2,458,400	2,718,400	2,978,400	3,238,400	3,368,400
IRR	-2%	-2%	-1%	0%	1%	3%	3%
npv at 5 years	-$28,787,577	-$28,339,575	-$27,891,573	-$26,995,568	-$26,099,564	-$25,203,560	-$24,755,558
NPV at 10 Yrs	-$24,083,440	-$23,357,264	-$22,631,087	-$21,178,735	-$19,726,383	-$18,274,031	-$17,547,855
NPV at 15 years	-$21,162,541	-$20,263,640	-$19,364,740	-$17,566,940	-$15,769,139	-$13,971,338	-$13,072,438

APPENDIX 4 – Scenario Three: Cogeneration Plant Pessimistic Scenario

Table A4 – 1. Pessimistic Scenario Inputs for Cogeneration Plant

10 MW Electrical System Parameters				
Staffing Electricity/Heat			$	1,200,000
Capital Cost			$	40,000,000
Maintenance		2%	$	800,000
Natural Gas Consumption GJ			$	130,000
Electricity Saved $/year			$	1,000,000
Plant Operations (hours/year)				7,560
hours/day* weeks/yr*efficiency	24*50*.9			
Mega Watts Produced per Year				75,600
Net Sales 5 MW/hr	5			37,800
Electricity Produced $/MW gross	80		$	6,048,000
Value of sales $/MW			$	3,024,000
Interest Rate				10%
Feedstock Costs		revenue		
Hog tonnes	20600	2	$	41,200
Logs @ 28.57/m3 @1.4 conversion	80000	40	$	3,200,000
Chipping @ $5 m3 or $7/t	80000	7	$	560,000
		Total	$	3,801,200

Table A4 – 2. Financial Viability Cogeneration Plant Pessimistic Scenario

NG Rates $/GJ	7	8	9	11	13	15	16
NG Cost $/yr	910,000	1,040,000	1,170,000	1,430,000	1,690,000	1,950,000	2,080,000
	-40,000,000	-40,000,000	-40,000,000	-40,000,000	-40,000,000	-40,000,000	-40,000,000
1	-867,200	-737,200	-607,200	-347,200	-87,200	172,800	302,800
5	-867,200	-737,200	-607,200	-347,200	-87,200	172,800	302,800
10	-867,200	-737,200	-607,200	-347,200	-87,200	172,800	302,800
15	-867,200	-737,200	-607,200	-347,200	-87,200	172,800	302,800
IRR	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npv at 5 years	-$39,352,155	-$38,904,153	-$38,456,151	-$37,560,147	-$36,664,142	-$35,768,138	-$35,320,136
NPV at 10 Yrs	-$41,207,790	-$40,481,614	-$39,755,437	-$38,303,085	-$36,850,733	-$35,398,381	-$34,672,205
NPV at 15 years	-$42,359,993	-$41,461,093	-$40,562,192	-$38,764,392	-$36,966,591	-$35,168,790	-$34,269,890

APPENDIX 5 – Scenario Four: Cogeneration Plant Optimistic Case

Table A5 – 1. Optimistic Case for Cogeneration Plant

10 MW Electrical System Parameters				
Staffing Electricity/Heat			$	1,200,000
Capital Cost			$	40,000,000
Maintenance		2%	$	800,000
Natural Gas Consumption GJ/yr				130,000
Electricity Saved $/year			$	1,000,000
Plant Operations (hours/year)				7,560
hours/day* weeks/yr*efficiency	24*50*.9			
Mega Watts Produced per Year				75,600
Net Sales 5 MW/hr	5			37,800
Electricity Produced $/MW gross	110		$	8,316,000
Value of sales $/MW	110		$	4,158,000
Interest Rate				5%
Feedstock Costs		Lost revenue		
Hog tonnes	20600	2	$	41,200
Purchase Hog	80000	0	$	-
Transportation (2.5 hr cycle 48 tonne payload 128 $/hr)	2.67	6.68	$	534,400
		Total	$	575,600

Table A5 – 2. Financial Viability Cogeneration Plant Optimistic Case

NG Rates $/GJ	7	8	9	10	11	13	15	16
NG Cost $/yr	910,000	1,040,000	1,170,000	1,300,000	1,430,000	1,690,000	1,950,000	2,080,000
	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000	- 40,000,000
1	3,492,400	3,622,400	3,752,400	3,882,400	4,012,400	4,272,400	4,532,400	4,662,400
5	3,492,400	3,622,400	3,752,400	3,882,400	4,012,400	4,272,400	4,532,400	4,662,400
10	3,492,400	3,622,400	3,752,400	3,882,400	4,012,400	4,272,400	4,532,400	4,662,400
15	3,492,400	3,622,400	3,752,400	3,882,400	4,012,400	4,272,400	4,532,400	4,662,400
IRR	4%	4%	5%	5%	6%	7%	8%	8%
npv at 5 years	-$23,694,986	-$23,158,956	-$22,622,925	-$22,086,895	-$21,550,865	-$20,478,804	-$19,406,743	-$18,870,712
NPV at 10 Yrs	-$12,412,012	-$11,455,988	-$10,499,964	-$9,543,939	-$8,587,915	-$6,675,866	-$4,763,818	-$3,807,793
NPV at 15 years	-$3,571,507	-$2,286,406	-$1,001,306	$283,795	$1,568,895	$4,139,096	$6,709,297	$7,994,398

APPENDIX 6 – Scenario Five: Pellet Plant Base Case

Table A6 – 1. Base Case Pellet Plant Inputs

			Odt	$/Odt
Annual Production tonnes	150,000	Hog Fuel	20,000	2
Sales Price $/tonne	191.94	Sawdust	18,000	5
Less Transportation Costs	-67.85	Shavings	20,600	30
Net Sales Cost	124.09	Chips	91,400	70
Required Rate of Return	10%	Conversion		37.57
Capital Cost (thousands of dollars)	15,000			

Table A6 – 2. Financial Viability Pellet Plant Base Case

Year	1	2	3	4	5	10	15
Annual Revenue	18,614	18,614	18,614	18,614	18,614	18,614	18,614
Lost Revenue Chips	6,398	6,398	6,398	6,398	6,398	6,398	6,398
Lost Revenue of Shavings	618	618	618	618	618	618	618
Lost Revenue of Sawdust	90	90	90	90	90	90	90
Lost Revenue Hog	40	40	40	40	40	40	40
Raw Fibre Cost	7,146	7,146	7,146	7,146	7,146	7,146	7,146
Conversion Cost	5,636	5,636	5,636	5,636	5,636	5,636	5,636
Gross Profit	5,832	5,832	5,832	5,832	5,832	5,832	5,832
General and Admin Expenses	2900	2900	2900	2900	2900	2900	2900
Net Profit	2932	2932	2932	2932	2932	2932	2932
NPV					-$3,532	$2,742	$6,637

APPENDIX 7 – Scenario Six: Pellet Plant Worst Case

Table A7 – 1. Worse Case Pellet Plant Inputs

			Odt	$/Odt
Annual Production tonnes	150,000	Hog Fuel Odt	10,000	2
Sales Price $/tonne	191.94	Sawdust Odt	9,000	5
Less Transportation Costs	-67.85	Shavings Odt	10,300	30
Net Sales Cost	124.09	Logs tonnes	168,980	56.77
Required Rate of Return	10%	Conversion		37.57
Capital Cost (thousands of dollars)	15,000	Chipping tonnes	168,980	7

Table A7 – 2. Financial Viability Pellet Plant Worse Case

Year	1	2	3	4	5	10	15
Annual Revenue	18,614	18,614	18,614	18,614	18,614	18,614	18,614
Purchase of Logs	9,593	9,593	9,593	9,593	9,593	9,593	9,593
Chipping Costs	1,183						
Lost Revenue of Shavings	309	309	309	309	309	309	309
Lost Revenue of Sawdust	45	45	45	45	45	45	45
Lost Revenue Hog	20	20	20	20	20	20	20
Raw Fibre Cost	11,150	11,150	11,150	11,150	11,150	11,150	11,150
Conversion Cost	5,636	5,636	5,636	5,636	5,636	5,636	5,636
Gross Profit	1,828	1,828	1,828	1,828	1,828	1,828	1,828
General and Admin Expenses	2900	2900	2900	2900	2900	2900	2900