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NWT Wood Pellet Pre-feasibility Analysis

Prepared for

The Government of the Northwest Territories

By

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November 2009

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Abstract

In 2009, the Government of the Northwest Territories (GNWT) commissioned a study entitled "Assessing the NWT Energy Opportunity for Wood Biomass". While assessing various applications of woody biomass, the study identified that one of the most promising “low hanging” opportunities was the potential for wood pellet manufacturing. This study provides an analysis of the economic feasibility of wood pellet manufacturing in the NWT at various production levels. The study concludes that the economics of a wood pellet business based on today's market potential of 12,000 tpy would be difficult if not impossible to finance. Increasing the NWT wood pellet market to 30,000 tpy and building a wood pellet plant of similar size would provide a reasonable return on invested capital. Government investment in the wood pellet business would further reduce risk and the capital required by private sector investors. Finally the report makes recommendations on ways and means of growing the current NWT market to a minimum of 30,000 tpy.

Acknowledgements

FPInnovations would like to thank to the Government of Northwest Territories, namely to departments of Environment and Natural Resources and Industry for funding this project.

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1 Objectives

The NWT government has expressed interest in developing a wood pellet industry in the NWT. To assess the opportunity a series of studies were conducted as part of a Pre-feasibility Analysis. The studies include:

- An assessment of current and future market for wood pellets in the NWT
- An assessment of the minimum feedstock quality requirements and quality of wood pellets
- An examination of the life cycle greenhouse gas impact of wood pellet production
- An assessment of wood pellet feedstock characterization
- Modeling business cases for wood pellet production at 1, 5, 10 and 30 thousand tonnes/year of production

2 Introduction

The demand for wood pellets in the NWT has grown significantly in recent years. Despite this growth the size of the market was estimated at 12,000 tonnes per year in 2008, approximately 40% of the production of a small pellet manufacturing facility in BC or Alberta. Moreover, feedstock costs for pellet production will be significantly higher than pellet plants currently serving the NWT market that obtain their raw material from nearby sawmill operations. Despite these limitations, the production of wood pellets in the NWT may be feasible given the transportation cost advantage of local production relative to imported wood pellets.

3 Background

In 2009 the Government of the Northwest Territories (GNWT) commissioned a study entitled "Assessing the NWT Energy Opportunity for Wood Biomass". While assessing various applications of woody biomass, the study identified that one of the most promising “low hanging” opportunities was the potential for wood pellet manufacturing. Wood pellets are a growing commodity in the NWT market and potential exists for competitively priced products in the export markets as well. The rough economic analysis conducted in the latest study, based on the 30,000 tonnes of wood pellets per year, suggests the potential of a 20% ROI even when considering higher delivered raw material costs and higher operating costs that would be incurred in an NWT enterprise. To provide a higher level of comfort that this opportunity truly exists, a prefeasibility study for wood pellet manufacturing was deemed necessary. The detailed study will also assist with assessing long term sustainability of such a business and will be critical in attracting potential investors.

4 NWT Market Outlook for Wood Pellets

Currently the NWT pellet market is estimated at 12,000 tonnes per year (tpy). Approximately 10,000 tonnes is currently consumed in Yellowknife.

The NWT market is currently served by imported wood pellets that come primarily from the La Crete pellet mill in northern Alberta. Additional tonnage is imported from Pinnacle Pellet's mills in central BC.

Pellets from La Crete are imported primarily in bulk form by truck to service institutional customers in Yellowknife. The majority of Pinnacle sales are in bag form servicing the home heating market.

Local distributors such as Arctic Green Energy in Yellowknife import pellets from La Crete and resell them to NWT customers. Initially, Arctic Green Energy also installed pellet boilers, selling heat to institutions. This marketing arrangement is now changing as institutions such as NWT Public Works become more comfortable with boiler operation and maintenance. Future sales are likely to be limited to pellet sales rather than heat.

Wood pellet boilers have now been installed as retrofits in several large NWT government facilities in Yellowknife. Public Works officials are pleased with boiler performance but more importantly with the cost savings of pellets vis a vis existing heating oil fired boilers. Greenhouse gases have also been significantly reduced as a result of these retrofits. Public Works officials plan more retrofits as there are still several large buildings in Yellowknife and outlying communities that could be retrofit candidates.

Despite this significant market penetration in NWT government buildings, there is still significant room for growth. The largest commercial buildings in Yellowknife for example are owned by private companies that lease space to private and government clients. Furthermore, there are several buildings owned by the federal government that are candidates for conversion to wood pellets.

Physical space to locate the boilers and feed systems is a limiting factor for retrofits. Setbacks for fire safety are currently being challenged as they appear to be more restrictive than fuel oil boilers. One possible solution to the space issue is to place boilers and feed systems in containers in parking lots adjacent to downtown buildings. Containers could be elevated on stilts if parking is at a premium.

The home heating market is also expected to grow as homeowners become more familiar with wood pellet stoves, furnaces and home boiler systems. Unfortunately, houses are not designed for wood pellet fuel and homeowners are forced to use pellets in bagged form. Bagged pellets currently sell for $320 tonne in Yellowknife compared to bulk pellets sold to institutions for $200/tonne significantly reducing cost savings for homeowners. Homeowners are also faced with the need to dispose of wood ash. With whitewood pellets this is typically less than 1% of total pellet weight. The cost of a home wood pellet boiler is approximately $12,000, more than double a high efficiency gas furnace. However, part of this cost is offset by government grant programs available from the NWT and federal governments. Despite these issues many homeowners are making the switch to pellets.

Given the foregoing market dynamics, a major wood pellet supplier speculated that the NWT market could grow to 50,000 tpy within the next ten years.

4.1 NWT Market Potential

The potential market for wood pellets in the NWT is substantial relative to the current market penetration that is limited primarily to government buildings and residential heating. As noted in a recent Arctic Energy Alliance report, "If every public building within Yellowknife was heated by wood pellets the demand would be 200,000 tpy". While this illustrates the local market potential, it doesn't reflect potential market growth in outlying regions of the NWT as well as potential industrial sales to the mining industry. It also does not reflect the potential use of wood pellets for combined heat and power.

4.2 Heating Market Potential

As previously indicated, wood pellet market growth is currently focussed on the displacement of heating oil in government buildings. The GNWT owns more than 350 buildings that use an estimated 17.7 million litres of heating fuel per year (2007 GNWT Energy Plan). Installed pellet boilers currently displace about 2.1 million litres of heating oil per year (~12% of GNWT heating fuel). Not all of these buildings are candidates for displacement due to remoteness of location and the higher cost of transportation associated with wood pellets relative to heating oil[1]. Government officials indicated that a further 1.5 million litres of heating oil could be displaced in government buildings managed by the GNWT throughout the NWT. Public Works officials further indicated that any new government buildings would also be candidates for pellet boilers.

Given the success of wood pellet boilers in reducing fuel cost and greenhouse gas emissions, the Department of Public Works has hired a specialist whose mandate is to develop further projects. Public Works has subsequently developed a poster of existing, new and planned projects over the next few years.

Table 1: NWT Pellet Heating Projects 2008 -2010

Location	Project	Completion Date	Fuel Displacement litres	Equivalent Tpy Pellets
Behchoko	Jimmy Bruneau School	2009	155,000	282
Hay River	Highways Maintenance Garage	2010	100,000	182
Hay River	Central Heating for Schools	2010	318,000	579
Yellowknife	Kalemi School	2008	30,000	55
Yellowknife	North Slave Correctional Facility	2008	587,000	1,068
Yellowknife	Legislative Assembly Building	2010	83,000	151
Yellowknife	St. Joes School	2009	102,000	186
Yellowknife	Sir John Franklin School	2008	142,900	260
Ft. Smith	PWK School & Recreation Complex	2010	200,000	364
Ft. Smith	Thebacha College	2010	200,000	364
Ft. Smith	Health Centre	2010	200,000	364
Total			**2,117,900**	**3,855**

[1] Wood pellets have slightly more than half the energy value of heating oil on a weight basis.

Excluding projects already completed, there will be an immediate growth in the NWT market of 2,500 tpy simply as a result of these planned projects.

The use of wood pellet heating in remote communities also needs to be further examined. Despite the relative advantage of heating oil energy density compared to wood pellets, pellets have a distinct cost advantage. Even at a relatively low price of $0.85/litre, the price of fuel oil equates to $23.35/GJ compared to wood pellets at $11.11/GJ - less than half the price of fuel oil in Yellowknife. Some of this cost advantage will be eroded in higher transportation costs for wood pellets compared to fuel oil but there is likely still a good business case in most remote communities.

Potential wood pellet sales for heating have likely only scratched the surface. As indicated, the potential market in Yellowknife alone is 200,000 tpy. Besides the further penetration of government buildings, there are several large buildings housing government offices that are owned or managed by private property managers.

4.3 Combined Heat and Power

The current focus in the NWT has been to substitute wood pellets for heating oil. While this program has been successful and is ongoing, there is also a significant opportunity in some communities for the installation of combined heat and power units. Diesel fuel is currently the primary fuel used to supply power in remote communities. In the NTPC General Rate Application filing of November 24, 2006, the Power Corporation indicated that more than 12 million litres of diesel fuel was consumed for power production by the NTPC. The majority of this consumption is in remote communities where power is generated by diesel fuelled gensets. Further diesel is also consumed by diesel gensets operated by Northland Utilities including those in Trout Lake, Kakisa, Fort Providence, and Wekweti. In communities on hydro power, including Yellowknife and Behchoko, Ft. Smith, Hay River and Ft. Resolution, there is still significant diesel consumption in standby diesel gensets that are utilized during hydro-line outages. Natural gas fuelled turbines supply commercial and residential customers in Norman Wells and Inuvik.

***Table 2:* NWT Electricity Generation Consumption by Fuel Type and Sector 2004/05**

2004/05 NWT Annual Electricity Consumption (MWH)[2]	Utility	Industrial	Total
Hydro	292,087		292,087
Diesel	76,377	181,899	258,276
Gas Turbine	22,748	107,353	130,101
Total	391,212	289,252	680,464

The cost of electricity generation varies widely dependent on energy source and the remoteness and size of the communities. Diesel fuel costs alone averaged $0.386/kWh or $386/MWh in communities serviced by the NTPC according to the General Rate Application November 24, 2006. Operating, maintenance and capital costs are over and above the cost of fuel.

Even in communities served by Hydro power, electricity costs are high by Canadian standards. In Hay River, for example, the electricity market is serviced by Northland Utility, an Atco subsidiary. Current

[2] Data from: NWT Statistics Quarterly

electricity rates range from $134/MWh for large commercial users to $287/MWh for residential users including fixed demand charges.

At these relatively high electricity costs there may well be a strong business case for a combined heat and power project utilizing wood fuel either in pellet or raw ground fibre form (hog fuel). Wood fuelled combined heat and power would stabilize the supply of power in Hay River. Typically, wood fired power plants have an availability factor exceeding 92% rivalling diesel gensets. Existing diesel gensets could be utilized during scheduled maintenance periods or unscheduled outages. Waste heat from wood fired power units could be utilized for buildings in a central core as well as any residential units nearby the power generation unit.

Combined heat and power utilizing wood fuel has a strong track record having been utilized for decades in the Canadian pulp and paper industry. However, the economics of steam turbine wood power generation are poor at sizes less than 20 MW due to high labour costs associated with the need to employ certified steam engineers. In recent years new technology has been developed negating the steam cycle and the need to employ steam engineers. Effectively this means that electric power can now be produced cost effectively even in units as small as 250 KW. Assuming a wood fuel cost of $200 per tonne (oven dry), electricity could be produced for approximately $250/MWh in the one MW range dependent on the community load factor. The cost of electricity production could be significantly less than this estimate if larger gensets are employed and if there is no need to pelletize wood fuel as is the case in the Ft. Simpson region where the wood supply is nearby the community.

The economics of wood residue power production would be further improved if there was a use for the waste heat produced by the power plant. In remote communities waste heat utilization will likely be limited to nearby large public and private buildings.

To prove the economics of wood fuelled combined heat and power, a study should be undertaken to determine the potential business case for this application. Should the study confirm the business case, a project should be undertaken to demonstrate the advantages of such an approach.

4.4 Mining Applications

More than 70% of industrial diesel consumption for power development (est. 90 million litres per year) in the NWT is at the three diamond mines north-east of Yellowknife that consume more diesel than the combined communities in the NWT. This represents a theoretical potential market of 182,000 tpy of wood pellets which would reduce GHG by approximately 240,000 tCO2e[3] per year at full substitution. The mines provide a unique opportunity for biomass power production. The mines have a power load of more than 40 MW and a capacity factor[4] of approximately 90% unlike communities that often have capacity factors of less than 40% in an off grid situation such as exists throughout much of the NWT.

A significant barrier to the utilization of wood pellets at the diamond mines is the lower energy density of wood pellets compared to diesel fuel. In essence it would take 2.5 times the number of trucks to deliver the same amount of energy to the mine sites using wood pellets. Given the difficulties in delivering

[3] Tonne of CO_2 equivalent
[4] Capacity factor is defined ratio of the actual output of a power plant over a period of time and its output if it had operated at full capacity the entire time.

sufficient diesel fuel to the mines in recent years this may be an insurmountable barrier despite the cost savings and GHG reduction opportunities.

Other renewable energy options such as wind power or connection of the mines to the hydro grid are currently under consideration by NWT government agencies. Both of these options also have significant issues. The construction of a hydro line would require significant up front capital spending. Wind power production avoids the need for significant transmission spending but the power availability factor for wind power generation is typically <25% meaning diesel gensets will have to operate most of the time. Moreover, wind power is somewhat unpredictable leading to scheduling issues. These options should be considered together with the wood pellet option.

New mining activity may also provide a market opportunity for combined heat and power production. Fortune Minerals are in the final stages of developing their NICO gold-cobalt-bismuth-copper deposit project 160 kilometres northwest of the City of Yellowknife. It is likely that this project will be serviced by hydroelectric power from the Snare hydro complex 22 kilometres away. However, hydroelectric power does not provide a waste heat source unlike a wood pellet combined heat and power facility. The need to keep tailing ponds from freezing can be accommodated from a wood pellet combined heat and power unit.

Avalon Ventures Rare Earth Minerals is still in the exploration stage of mining activity at Thor Lake south east of Yellowknife on the shores of Great Slave Lake. Once the mine is developed, Avalon is considering a barge delivery system across the lake to Hay River, a distance of 215 kilometres. Should the mine be developed and the barge system instituted, the delivery of wood pellets to the mine site would be expedited. The delivered cost of wood pellets to the mine should be less than $200 per tonne. Depending on the electricity load and capacity factor, power could likely be produced for less than $200/MWh with waste heat available for de-icing tailing ponds.

4.5 Incentive Programs

Government incentive programs to switch fuel sources have an impact on pellet consumption especially at the residential level. The government of the NWT has in place a number of programs that provide incentives for energy efficiency as well as the use of wood pellets. In 2008 the Energy Efficiency Incentive Program was revised increasing the wood pellet furnaces and boiler rebates as follows:

- Pellet stove - $500 (approximate cost of new stove $2,500)
- Pellet residential furnace - $700 (approximate cost of new furnace $7,000)
- Pellet residential boiler - $1,000 (approximate cost of a new boiler $11,500)

In addition to the NWT rebate program, the federal government has a matching program that subsidizes the replacement of wood stoves with EPA certified wood stoves including pellet stoves.

The federal ecoENERGY Fund provides funding for Renewable Energy Projects. Replacement of wood stoves with EPA certified stoves are eligible for a $375 grant. Also, up to $250,000 is available through INAC to help for Aboriginal and Northern Communities Program to reduce or displace coal and diesel generation of electricity thereby reducing greenhouse gas emissions, along with criteria air contaminants resulting in cleaner air.

The NWT government also offers a Business Incentive Program that effectively subsidizes the sale of goods produced in the NWT to government agencies. While this program does not currently affect the price of wood pellets, it may have some effect on lowering pellet prices if a pellet manufacturing facility is built in the NWT. However, it is unclear how much of this subsidy might actually be passed along to customers.

5 Wood Pellet Feedstock Characterization

Wood has been used as a fuel for heating dating back to the cave man era. Together with coal, wood was the primary source of heating in North America until the widespread use of natural gas, propane and heating oil after the Second World War. Some wood fuel use has continued, especially in rural areas where wood fuel is plentiful and much cheaper than fossil fuel alternatives. However, it was not until the 1990s that wood pellets became common as a fuel source for home and industrial purposes. The growth of wood pellets as a fuel has been driven by several factors:

- In Europe wood pellets are being utilized as a renewable fuel alternative to heating oil and coal in response to the need to reduce greenhouse gases (GHG).

- In North America wood pellets are viewed as a convenient alternative to cordwood for home heating.

Consequently, in North America wood pellet sales are primarily for home heating whereas in Europe, sales are primarily to large industrial customers such as coal fired power utilities as well as home heating.

5.1 Wood Pellet Process

Wood pellets are typically manufactured from sawmill wood residues. Sawmill planer shavings are the preferred feedstock as this source does not require any additional drying prior to pellet manufacture. Sawmill sawdust is the next most preferable source but it does require drying down to at least 15% moisture content. As both sawdust and planer shavings are already partially processed, the cost of processing in a hammer mill prior to pelletizing is minimized.

In Canada, the increasing shortage of sawmill residue has caused pellet manufactures to begin sourcing fibre directly from the forest. The shortage of sawmill residues for wood pellet manufacturing has been exacerbated by the downturn in US housing starts and the prolonged closure of many sawmills servicing the US lumber market. As a result most pellet manufacturers are currently sourcing up to 25% of their feedstock from forest harvesting residues.

The pelletizing process begins with a drying phase that reduces the moisture content to <15%. Drying is followed by processing through a hammer mill where the wood particles are reduced to <3mm. Dryers can be fuelled by natural gas or propane but most manufacturers utilize fines from the production process or bark if they are utilizing forest harvesting residues.

The processed and dried wood residue is then fed into the pelletizing machine where wood is forced at high pressure and temperature through steel dies that effectively plasticizes the lignin in the wood which then re-forms and acts as a natural binding agent to hold the pellet together. After the pelletizing process, the pellets come out of the pelletizer between 200 and 250 degrees Fahrenheit. A cooling tower is used to bring the temperature down and harden the pellets. After cooling, they are usually stored in a large silo to await bagging or bulk distribution. The heat created by the pelletizing process reduces the final moisture content of a pellet to <10% by weight.

5.2 Wood Heating Value

Wood is a made up of a combination of basic elements only two of which have energy value - carbon and hydrogen. However, these basic elements are embedded in complex molecules that fall into four categories - cellulose, hemi-cellulose, lignin and extractives. Cellulose fibres give wood its strength and are extracted in the kraft pulping process to make pulp and paper products. Lignin is the glue that binds cellulose and hemi-cellulose fibres together. Some of the extractives in wood are volatile organic hydro carbons that are often lost in wood manufacturing processes. Table 3 gives the relative energy value of wood components.

Table 3: Energy Value of Wood Components

Calorific Value of Wood Components	
Wood Component	**Calorific Content GJ/Bone Dry Metric tonne**
Cellulose	17 - 18
Hemi-cellulose	16 – 17
Lignin	25 – 26
Extractives	33 - 38

There is little variation in the percentage of cellulose, hemi-cellulose, lignin and extractives within softwood tree species such as spruce, pine, balsam fir and larch common to the NWT. Pine does have a slightly higher percentage of extractives than most softwood species. Hardwood species in general have a lower percentage of lignin than softwood tree species which is offset by a higher percentage of hemi-cellulose compared to softwood tree species. Table 4 shows the relative percentages of tree components common to the NWT.

Table 4*: *Composition of Trees Species Common to the NWT

Typical Composition of a Tree (% of bone dry material)				
Species	**Cellulose**	**Hemi-cellulose**	**Lignin**	**Extractives**
Aspen	40	30	19	2
Birch	41	32	22	3
Spruce	42	28	27	2
Pine	40	28	28	4

There is significant variation in the distribution of wood components between the tree trunk, bark, branches and needles.

- The tree trunk of softwood tree species has a much higher percentage of cellulose than the bark, needles or branches; explaining its appeal to pulp producers.
- Most of the extractives in softwoods are embedded in needles and therefore never recovered by industrial harvesting processes.

- The non-combustible ash portion of a tree is much higher in the bark and needles than the trunk or whitewood portion.

Table 5: Typical Composition of Wood Components (% of bone dry material)

Typical Composition of Wood Components (% of bone dry material)					
Species	**Cellulose**	**Hemi-cellulose**	**Lignin**	**Extractives**	**Ash**
Lodgepole Pine (70 years old)					
Trunk	41	27	28	3	1
Bark, inner	36	26	29	5	4
Bark, outer	25	20	48	3	4
Branches	32	32	31	4	1
Needles	29	25	28	13	5
White Spruce (110 years old)					
Trunk	43	27	28	1	1
Bark	36	20	36	4	4
Branches	29	30	37	2	2
Needles	28	25	35	7	5

Wood moisture content is by far the most important variable affecting wood energy content. The moisture content of live trees varies somewhat by species. However, the biggest factor affecting moisture content is the site location of the tree. Trees growing in well drained sandy soils have lower moisture content than trees growing in bog like conditions or riverside riparian areas common in the NWT. Aspen growing in a riparian area can have moisture content as high as 60% by green weight. However, most tree species have an average moisture content of approximately 50% by weight. The effect of moisture content on calorific value is illustrated by Table 6.

Table 6: Affect of Moisture Content on Wood Residue Calorific Value and Boiler Efficiency

Fuel	As fired Gross calorific value (GJ/t)	Typical burner efficiency (%)	Useable Net heating value (GJ/t)
Wood at 0% moisture content (m.c.)	19.8	80	15.8
10% m.c	17.8	78	13.9
20% m.c.	15.9	76	12.1
30% m.c.	14.5	74	10.7
40% m.c.	12	72	8.6
50% m.c.	10	67	6.7

Fresh or green wood at 50% moisture content has a calorific value of approximately 10 GJ per metric tonne. Dry wood pellets have an energy value of approximately 19 GJ per tonne at 5% moisture content - almost double that of green wood.

The percentage moisture content of wood fuel can also affect boiler efficiency. When wood fuel moisture content exceeds 60%, furnace and boiler efficiency drops dramatically as most of the energy in wood is being used to boil off water.

5.3 Chemical Analysis of SPF Bark and Sawdust

The majority of wood pellets sold in North America are produced from softwood tree species. Sawmills throughout North America do not commonly distinguish their softwood lumber production by species. Most construction lumber sold in NA is marketed as SPF (spruce, pine and balsam fir species) with the percentages varying widely dependent on the source of the lumber[5]. Consequently, most wood pellets are produced from a combination of the whitewood residues produced by mills producing SPF lumber.

Laboratory analyses[6] of white spruce, lodgepole pine and alpine fir bark and sawdust samples from a central BC Interior sawmill indicates a number of differences between bark and sawdust feedstock used for pellet manufacture.

Table 7: Summary of the Energy and Chemical Characteristics of SPF Bark versus Whitewood

Parameter	Pine sawdust	Pine bark	Spruce sawdust	Spruce bark	Balsam sawdust	Balsam bark
Gross Calorific value (db)	20.472	20.887	20.263	20.338	20.803	22.083
Gross Calorific value (db, ash free)	20.518	21.426	20.334	21.594	20.920	22.736
Net calorific value constant pressure (db)	19.08	19.56	18.89	19.48	19.42	20.70
Total moisture % of raw material	15.39	49.25	10.59	41.21	14.98	45.01
Total ash % w (db)	0.23	2.52	0.37	4.01	0.57	2.87
Chlorine % w (db)	0.010	0.013	0.011	0.012	0.010	0.012
Sulphur % w (db)	0.11	0.04	0.13	0.03	0.09	0.08
Hydrogen % w (db)	6.47	6.17	6.38	5.98	6.40	6.47
Nitrogen % w (db)	0.30	0.23	0.23	0.25	0.22	0.32
Oxygen % w (db)	41.93	39.31	42.87	37.92	41.95	36.87
Carbon % w (db)	50.96	51.73	50.02	51.81	50.77	53.39
Ash Fusion temp. °C (ID)	1,482	1,382	1,468	1,482	1,420	1,449

Some of the more notable differences between SPF bark and whitewood are as follows:

- There is very little variation in the calorific value of spruce, pine and balsam fir whitewood.
- The calorific value of SPF bark is higher than SPF whitewood with balsam fir having a 10% higher calorific value than pine or spruce. The carbon content of bark samples was higher than whitewood samples (51.92% versus 50.75%) partially explaining the higher calorific value of bark relative to the whitewood samples. Balsam bark had the highest calorific value as well as the highest carbon content at 53.99%.
- However, the SPF bark ash content is approximately ten times higher than whitewood ash content. The weighted average ash content of the spruce, pine, fir whitewood samples[7] was 0.29 % versus bark samples where the weighted average ash content was 2.85%.

[5] In BC for example, the spruce component of SPF lumber was historically more than 50% of the lumber mix. The mountain pine beetle epidemic has shifted this mix in favour of lodgepole pine with many mills now producing more than 75% of their lumber mix from pine.
[6] Lab analysis conducted by SGS Canada Laboratories, Delta BC.
[7] The weighted average is based on 10% balsam fir, 20% white spruce and 70% lodgepole pine.

- After compensating for the higher ash content of bark, the weighted net calorific value of SPF bark samples was 19.66 GJ/BDt (constant pressure basis) versus 19.08 GJ/BDt for whitewood. Weighted average nitrogen levels were slightly lower in bark than sawdust samples (0.24 vs. 0.27) resulting in lower NOx emissions for users.
- Sulphur levels were noticeably lower in bark compared to sawdust (0.04 vs. 0.11) leading to lower SOx emissions.
- Chlorine levels were generally low and slightly higher in bark samples than sawdust samples (0.0127 vs. 0.0102), potentially a concern from a boiler corrosion perspective.

Samples taken from aspen and mixed conifer (spruce, pine and balsam fir) from a northern Alberta sawmill show similar energy values as well as percentage elemental distribution compared to the central BC sawmill residues. The one exception is the higher ash content of the Alberta samples where the percentage ash by weight was three to four times higher than the whitewood samples in BC (see Table 7). As a typical sawmill residue distribution is approximately 40% bark and 60% whitewood, a blend of bark/whitewood mill residue would result in ash content close to that indicated by the Alberta samples suggesting that the sample is a mixture of bark and whitewood.

Table 8: Summary of the Energy and Chemical Characteristics from a Northern Alberta Sawmill

	Aspen Hog		Mixed Conifer Sawmill Residue	
	As Received	Dry	As Received	Dry
GJ/t	13.52	20.12	10.49	20.03
MC %	32.79		43.87	
C (% by Wt.)		54.85	30.14	55.59
H (% by Wt.)		6.34		6.15
N (% by Wt.)		0.28		0.22
S (% by Wt.)		0.02		0.02
Ash (% by Wt.)		1.91		1.79

5.4 European Wood Pellet Standards

Like most commodities, Europe has developed extensive quality standards for wood pellets. Most of the producing nations have developed their own standards. There are very few differences between national standards other than the scope of elements to be tested and testing methods.

Table 9: Summary of European Wood Pellet Standards

	Austria		Sweden	Germany	EU Standard (draft)
Parameter	Whitewood	Bark			CEN/TS 14961
MC %	<12	<18	<10 -12	<12	<10
Calorific Value GJ/t	>18	>18	>16.9	>17.5	>16.9
Ash Content % by Wt.	>0.5	<6.0	<1.5	<1.5	<0.7
Sulphur	>0.04	<0.08	<0.08	<0.08	<0.05
Nitrogen	>0.3	>0.6	NA	>0.3	<0.5
Chlorine	>0.02	>0.04	>0.03	>0.03	>0.07

For other producing countries, such as Great Britain and Finland, they typically follow standards developed by the importing country. In recent years, work has begun on a common EU standard enforced by the European Union. Table 9 summarizes the key wood pellet standards in Europe. Only Austria has a different standard for bark and whitewood pellets. Notably, the allowable limit for bark pellet ash content in the Austrian standard is more than twelve times higher than whitewood reflecting the higher silica content of wood bark compared to whitewood.

5.5 North American Standards

North American wood pellet standards are not as well developed as the European standards. The US-based Pellet Fuels Institute has published ash standards for Premium (<1%) as well as Standard wood pellets (<3%).

5.6 Analysis of Wood Pellets

The Arctic Energy Alliance has recently conducted a blind test of bagged wood pellets from five different suppliers. The analysis indicates only slight variation in the calorific, ash content and moisture value of pellets. All of the pellets were within the draft EU standard for moisture content and the calorific value.

Table 10**:**Analysis of Bagged Wood Pellets Distributed in Yellowknife - AEA[8]

Supplier	Calorific Value	Ash Content	Moisture Content
	GJ/t	%	%
Fireside Ultra	19.548	0.38	5.00
La Crete	19.087	0.45	5.94
Lignetics	18.494	0.92	5.39
Pinnacle Pellet	19.301	0.17	4.86
Dragon Mountain	19.180	0.41	5.52

The wood pellets from Lignetics had a higher ash content then would be allowed by the draft of the EU Wood pellet standard and the Pellet Fuels Institute Premium standard, as well as a somewhat lower calorific value than the other suppliers.

6 Wood Pellet Life Cycle Analysis

Wood pellets are considered a renewable fuel if the wood used to manufacture the wood pellets originates from sustainably managed forest land. In Canada, wood pellets are produced primarily from sawmill wood residues - sawdust and planer shavings. Increasingly, harvesting residues are also being utilized due to the shortage of lower cost sawmill residues. As the wood supply for Canadian sawmills originates from Crown owned forests, managed under long term forest management agreements, there is only a minute chance that wood pellets do not originate from sustainably managed forests. To satisfy concerns of their European customers, wood pellet manufacturers are routinely audited by independent verifiers to certify that pellets originate from sustainably managed forests.

Throughout the world, wood pellets have become a key tool in the reduction of greenhouse gases by the substitution of renewable wood fuel for fossil fuels. The consideration of wood fuel as a renewable energy source is founded on Articles 3.3 and 3.4 of the Kyoto Protocol agreement on climate change that

[8] Arctic Energy Alliance analysis conducted by SGS Canada Laboratories.

recognizes the role of forests to sequester CO_2 and thereby reduce the concentration of CO_2 in the earth's atmosphere.

As a result of the Kyoto agreement, the International Panel on Climate Change committee on Land Use, Land-Use Change and Forestry has ruled that wood fuel is considered CO_2 neutral relative to fossil fuels when the wood fuel originates from managed forest as described in Article 3.4. The effective result is that greenhouse gas emissions from wood fuel are miniscule when compared to fossil fuels.

The notion of renewability of wood fuel and its CO_2 neutrality has led to a significant worldwide growth of woody biomass fuel particularly in Europe. Coal fired utilities are utilizing wood pellets as a substitute for coal in order to meet renewable energy content standards driven by the need to reduce greenhouse gas (GHG) emissions. In 2008, Canada shipped more than 700,000 tonnes of wood pellets to European customers.

While there is little debate about the CO_2 neutrality of wood fuel, environmental groups have expressed concerns about life cycle GHG emissions resulting from the shipment of wood pellets from Canada to Europe. This has forced the wood pellet industry to focus on the issue to satisfy environmental groups but also customer enquiries. In addition to the independent audits for sourcing wood pellet furnish, pellet producers are also subject to independent analysis of their GHG emissions from production through transportation to the market place.

The principle of environmental life cycle analysis is a "cradle to grave approach" to the measurement of environmental impacts. The purpose of this section is to quantify the GHG emissions associated with wood pellet production as well as the offset of GHG emissions associated with the substitution of wood pellets for fossil fuels.

6.1 Wood Pellet Manufacturing and Transportation GHG Emissions

Most wood pellets are manufactured from sawmill residues (bark, sawdust and planer shavings) created in the manufacture of wood products such as lumber and plywood. Historically, there was no market for most mill residues and they were simply burned as waste in bee-hive shaped incinerators. Today wood pellets, MDF fibreboard, sawdust pulp and wood power production provide a ready market for most mill residues. As wood residues are considered a by-product of the solid wood manufacturing process, all of the GHG emissions associated with delivering wood to the mill are attributable to the manufacturing of solid wood products. From a life cycle perspective, the only GHG emissions associated with the manufacture of wood pellets from sawmill residues are the GHG emissions associated with the manufacturing process and delivery to the marketplace.

For wood pellets manufactured from harvesting residues, GHG emissions include not only manufacturing and product delivery GHG emissions, but also GHG emissions associated with roadside processing and delivery of processed wood residue to the pellet plant. Table 1 provides estimates of the energy consumption and potential pollutants associated with wood pellet manufacturing[9].

[9] Bi T. 2006. A Streamlined Life Cycle Analysis of Canadian Wood Pellets. Biomass and Bioenergy Research Group Department of Chemical & Biological Engineering University of British Columbia Vancouver, BC, Canada

***Table 11**: Summary of Emission Factors and Energy Consumption for each Process in g/tonne Wood Pellets*

	Harvest	Truck	Production		Train	Ocean Vessel
			Sawdust Fuel	Natural Gas Fuel		
Energy Consumption	2.09	0.07	3.78	2.97	0.26	2.6
CO_2	4,628	4,675	27,800	193,000	12,785	206,440
CO	135	26.5	222	239	33.6	420
CH_4	76.7	0.39	5.3	924	n.a.	23
N_2O	8.5	0.062	0.177	3.01	n.a.	5
NOx	2.78	54.7	482	514	246	5,280
VOC	1,347	3.9	4.84	220	14.05	140
PM	452	2.61	14.2	22.6	8.59	430
SO_X	858	4.34	127	209	10.9	2,780
ALDEHYDE	n.a.	1.73	n.a.	n.a.	n.a.	n.a.
NH3	n.a.	n.a.	0	3.81	n.a.	6

The Bi analysis is based on the manufacture and shipping of wood pellets from BC to European markets including 137 km of trucking, 750 km of rail transport and 15,500 km of ocean transportation.

However, only CO2, CH4 and N2O are considered GHGs. Moreover, the CO2 emissions associated with the incineration of wood fuel in the drying process are considered CO2 neutral and not counted in GHG emission calculations as are GHG emissions associated with wood harvesting. Estimates of GHG equivalent emissions based on energy consumption from the Bi analysis are included in Table 12.

***Table 12**: Analysis of GHG Emissions for the Production and Ocean Transport of Wood Pellets per tonne of Wood Pellets*

	Harvest	Truck	Pellet Drying Process		Train	Ocean Vessel	Total GHG Emissions tCO2e NG	Total GHG Emissions tCO2e Wood
			Sawdust Fuel	Natural Gas Fuel				
CO_2		4,675	0	144,007	12,785	206,440	0.368	0.224
CH_4	77	0	5	3		23	0.002	0.002
N_2O	9	0	0	3		5	0.005	0.005
tonne CO_2e/t							**0.375**	**0.231**

The results of this analysis indicate that there is 0.231 tonnes of carbon dioxide equivalent (CO2e) emissions associated with the production and transportation of one tonne of wood pellets from BC to European markets assuming the drying of wood pellets is associated with wood residue. If natural gas is associated with pellet production then GHG emissions increase to 0.375 tCO2e.

These results are consistent with an analysis conducted by a University of Toronto study[10] where GHG emissions were estimated at 0.133 t CO2e for the production and delivery of wood pellets from within Ontario to the Ontario Power Generation coal fired power generation station at Atikokan Ontario. This study assumed that pellets were produced from standing timber and included all of the GHG emissions attributable to forest harvesting.

Table 13: GHG Emissions Associated With the Production and Delivery of One tonne of Wood Pellets to the OPG Atikokan Power Facility

Element	tCO_2e/t
Transportation to Pellet Plant	0.019
Pelletization	0.040
Transportation to Power Plant	0.031
Forest Renewal	0.001
Forest Road Construction and Maintenance	0.002
Forest Harvesting	0.039
Total GHG Emissions per tonne Pellet Production	**0.133**

Bulk wood pellets currently consumed in the NWT come from La Crete, Alberta. Bagged wood pellets come from a variety of sources in Alberta, BC and the US Pacific Northwest. For pellets originating from La Crete and delivered into Yellowknife, the expected GHG emissions for one tonne of wood pellets are as follows:

Table 14: Estimated GHG Emissions tCO2e per tonne of Delivered Wood Pellets La Crete to Yellowknife

Total Litres Diesel	EMISSIONS				
	CO_2	**CH_4**	**N_2O**	**CO_2 equiv**	**tCO_2e/t**
				tonnes	
1,000	2.73	0.00	0.00	3.074	0.0715

The La Crete wood pellets are made from sawmill sawdust and shavings that would otherwise be incinerated as waste if they were not converted into wood pellets. For this reason, there are no GHG emissions associated with the delivery of logs to the sawmill as is the case in Table 3. GHG emissions are therefore significantly less than pellets delivered to Europe or pellets produced from standing timber as is the case in Ontario (see Table 13 & 14).

6.2 Upstream Fossil Fuel Emissions

Most discussions of fossil fuel GHG emissions are limited to fuel tip emissions. In the case of gasoline and diesel used in transportation, GHG emissions are most often simply end-of-pipe readings. Similarly, coal and natural gas GHG emissions used for heat and power production are generally burner tip estimates. Missing from these estimates are the significant GHG emissions associated with the well head

10 http://www.opg.com/power/fossil/MacLean%20Life%20Cycle%20Assessment%20of%20Wood%20Pellet%20Use.pdf

in the case of oil and natural gas, or mine mouth emissions in the case of coal. There are also often significant GHG emissions associated with the transport of fossil fuels to the market place. In the case of the University of Toronto study, upstream GHG emissions were relatively low for coal and approximately 10% of total emissions for natural gas fired turbines and boilers. In absolute terms, upstream GHG emissions for wood pellets were somewhat higher than fossil fuel sources. However, if the pellets originated from sawmill residues as is now the case for most wood pellet production, upstream wood pellet GHG emissions would be less than the fossil fuel sources.

Table 15: Upstream and Burner Tip GHG Emission Estimates (g CO2e/kilo watt hour of electricity production)

Source Fuel	Upstream	Burner Tip	Total
Wood Pellet	74	16	90
Combined Cycle Natural gas	43	343	390
Simple Cycle Gas	64	501	570
Coal	40	1,154	1,190

In the NWT, wood pellets are typically displacing heating oil. Heating oil life cycle GHG emissions are estimated at 3.5 kg CO2e/litre[11]. For a residential furnace, burner tip GHG emissions are estimated at 2.84 kg CO_2e/litre of fuel. Upstream fuel oil GHG emissions are therefore approximately 20% of total GHG emissions. However, oil product upstream GHG emissions can vary widely dependent on the source of crude oil. For example, for steam injected heavy oil development it takes the equivalent of one barrel of oil to create steam to bring two barrels of oil to the surface. This compares to conventional oil development where natural oil bearing structures sometimes have enough pressure to bring oil to the surface by natural means.

When compared on a life cycle basis and adjusted for energy equivalency, the total GHG emissions from the La Crete wood pellets is 0.0037 t CO2e/GJ. This compares to heating oil at 0.075 t CO2e/GJ. Therefore, heating oil has approximately 20 times the GHG emissions of wood pellets on an energy equivalent basis when used for home heating.

7 Generic Business Case Analysis for Manufacture of Wood Pellets

The utilization of wood pellet fuel has expanded significantly in recent years in the NWT. Many homeowners have switched from heating oil to wood pellet furnaces or boilers to reduce the cost of home heating. Similarly, several government institutional buildings have been converted with more in the planning stages for conversion.

All of the pellets currently consumed in the NWT are imported either in bag or bulk form. Bagged pellets come from at least five sources located in BC, Alberta or the US Pacific Northwest. Bulk pellets are imported from the La Crete, Alberta pellet mill. All of the pellet mills that supply pellets to the NWT have a minimum capacity of 30,000 tonnes pellets per year. Large pellet mills today have a capacity of approximately 200,000 tonnes per year.

[11] D. O'Connor S&T[2] personal communication.

The NWT government and local wood fuel suppliers have expressed interest in the development of a wood pellet industry in the NWT. Despite the growth of wood pellet consumption in the NWT, consumption was only 12,000 tonnes in 2008; approximately 40% of the production of even a small commercial pellet facility in BC or Alberta. Given the relatively small size of the current market and long transportation distances in the NWT, there is a desire to see if smaller pellet mills or reduced production from larger pellet mills might be economically feasible. The following analysis looks at a variety of pellet mill sizes and production levels.

7.1 Methodology

To determine the feasibility of developing an NWT based pellet facility, pellet mills of a variety of sizes were modeled and financial projections were run on a 15 year basis for the following scenarios:

- a 2 tph pellet plant producing 1,000 tpy and 5,000 tpy
- a 4 tph pellet plant producing 10,000 and 30,000 tpy

To conduct the analysis, several pellet mill vendors were contacted to supply turnkey quotes for pelletizing equipment. Additional capital costs estimates were added for onsite development and ancillary equipment such as grinders necessary to convert whole logs into wood residue suitable for pellet manufacture[12]. Further estimates were made on annual operating cost including wood supply, labour, electricity and insurance etc.

Revenues were estimated based on the current landed bulk price of pellets in Hay River ($150/t) and $200/t in Yellowknife. Bagged pellet revenue was estimated at $320 in Yellowknife. Sales revenue was increased by 15% to reflect the Business Incentive Program[13] (BIP) that provides a 15% sales price increase for sales to government agencies in the NWT.

7.2 Results

Table 16 provides a summary of the operating metrics and rate of return (IRR) on capital for various size pellet plants and production levels.

Only the 4 tph pellet plant operating year round on a 3 shift basis provided a reasonable return on invested capital. However, the annual production (30,000 tpy) is approximately 2.5 times the current size of the NWT market. While excess pellets could theoretically be exported, the remote location of the NWT relative to competing pellet mills in BC and Alberta would make this an uneconomic proposition. Another possibility is to speed up expansion of the NWT market to the projected 50,000 tpy (see future market report). Expansion of the NWT wood pellet market would be expedited by the adoption of wood biomass combined heat and power applications in remote communities currently serviced by diesel gensets.

Reducing production of the 4 tph pellet mill to size the current NWT market (10,000 tpy) reduced the IRR to only 9% making financing of such a facility problematic.

[12] Unlike pellet mills in southern provinces that have access to cheap and partially processed mill residues; in the NWT sawmill residues are unavailable and whole logs must be processed prior to pelletizing.
[13] The BIP provides a further 5 % sales price increase is provided for local sales nearby pellet plants that might be located in the NWT.

Table 16: Summary of Relative Costs and Returns of Bulk Pellet Mills at Different Production Rates and Sizes

Annual Production (tpy)		**30,000**	**10,000**	**5,000**	**1,000**
Hourly Production (tph)		4	4	2	0.5
Operating hpy		7482	5000	2500	1000
Annual Revenue		$ 5,306,560	$ 1,768,853	$ 1,300,628	$176,885
Capital Costs		$ 3,007,500	$3,007,500	$2,495,000	980,000
Annual Operating Costs					
	Labour & misc.	$852,513	$ 328,650	$ 218,500	$ 146,000
	Wood Costs	$ 2,247,484	$ 749,161	$ 374,581	$74,916
	Electricity	$ 877,500	$ 292,500	$146,250	$ 29,250
Internal Rate of Return		40%	9%	-4%	Negative

A smaller pellet mill (2 tph) that could be suitable for meeting local demand in communities outside Yellowknife was modelled at the 5,000 tpy level. While there was significant capital cost savings in moving from a large (4 tph) to a smaller (2 tph) pelletizer, this cost saving was more than offset by much lower pellet production negatively affecting revenue as well as leading to higher unit labour costs. Unit labour costs ranged from $29/t in the large 4tph pellet facility to $141 in the small 0.5 tph pellet facility.

The smallest pellet mill (0.5 tph) had the smallest capital cost but the relatively small production resulted in a cash loss position even before repayment of capital.

In an attempt to demonstrate the impact of size of a pellet facility, a 10,000 tpy pellet plant was modelled at 4 and 2 tph levels. The operating hours of the 4 tph plant were artificially adjusted to a level of 10,000 tpy. The results are outlined in Table 17:

Table 17: Relative Returns of a 4 tph Pellet Facility Versus a 2 tph Pellet Facility Producing 10,000 tpy

Annual Production (tpy)		**10,000**	**10,000**
Hourly Production (tph)		4	2
Operating hpy		2640	5000
Annual Revenue		$ 1,768,853	$1,768,853
Capital Costs		$ 3,007,500	$2,572,500
Annual Operating Costs			
	Labour & misc.	$ 328,650	$482,450
	Wood Costs	$ 749,161	$749,161
	Electricity	$ 292,500	$292,500
Internal Rate of Return		9%	3%

While there was a significant saving in capital for the 2 tph pellet mill compared to the 4 tph facility, the larger pellet facility provided a better internal rate of return on capital that the smaller facility (9% versus

3%) due to ongoing labour cost savings. In addition to the better return on capital there are a number of other advantages in operating a larger facility on a seasonal basis:

- Larger facilities can grow with increasing markets over time.
- A seasonally operated facility can operate during spring and summer seasons reducing heating costs.
- For integrated facilities, most of the wood deliveries will take place during the winter months enabling virtually full time employment shared between logging and pellet mill operations.

The NWT also provides a market opportunity for bagged pellet sales to commercial and residential customers. Bagged pellets provide a higher sales price ($320/t versus $220/t fob Yellowknife) that is partially offset by higher labour costs and supplies.

There are several factors negatively impacting the immediate development of a wood pellet industry in the NWT:

- The relatively small market means that a pellet mill that is sized to the current NWT market is much smaller than the smallest commercial facility elsewhere in Canada.
- As wood in the NWT must be sourced in log form rather than low cost mill residues from nearby sawmills, wood costs were more than double what competing large scale pellet mills incur in BC and Alberta.
- Electricity costs in the NWT are significantly higher than the southern provinces. Even in regions of the NWT serviced by hydro power, unit electricity costs were more than four times higher than BC or Alberta.

8 Conclusions and Recommendations

Given the limited market size of the NWT wood pellet market (est. 12,000 tpy) the construction and financing of a wood pellet operation would be financially challenging as a 10,000 tpy wood pellet facility will only generate a 9% return on invested capital. To improve the business case, it will be necessary to increase the market growth beyond current business as usual to a minimum of 30,000 tpy. This can be accomplished by a number of measures:

- Speed up the conversion of government buildings from heating oil to wood pellets.
- Increasing the use of wood pellets as the primary heating source in private office buildings. In this context the NWT government should consider an incentive program similar to the program for residential home heating conversion.
- Consider the use of wood pellets to co-generate both heat and power particularly in remote communities currently powered by diesel gensets. To determine the feasibility of cogeneration, a pilot feasibility study should be conducted in cooperation with the NWT Power Corporation.
- Encourage new mine developers to consider wood pellets as their primary heat and power source.
- The NWT government consider an investment in wood pellet manufacturing infrastructure to reduce the capital and risk exposure of private investors.