Ontario Ministry of Energy

An Assessment of the Viability of Exploiting Bio-Energy Resources Accessible to the Atikokan Generating Station in Northwestern Ontario

Final Report

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Additional technologies or data may differ materially from those presented in this report as they are subject to a number of known and unknown risks and uncertainties including but not limited to changes and/or delay in international agreements, national and provincial policies, technology availability, public acceptance of new technologies, change in pricing of various feedstocks and/or materials and/or actions by stakeholders, as well as general economic and market conditions.

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Study Steering Committee Members

Dennis Brown	Mayor	Township of Atikokan
Garry McKinnon	Executive Director	Atikokan Economic Development Corporation
Wilf Thorburn	Chief Executive Officer	Atikokan Hydro
Mike Lewis	Citizen	Ad Hoc Energy Committee
Tony Rockingham	Assistant Deputy Minister	Ministry of Energy
Jon Norman	Senior Policy Advisor	Ministry of Energy
George Ross	Assistant Deputy Minister	Ministry of Natural Resources
Jim McClure	Assistant Deputy Minister	Ministry of Northern Development & Mines;

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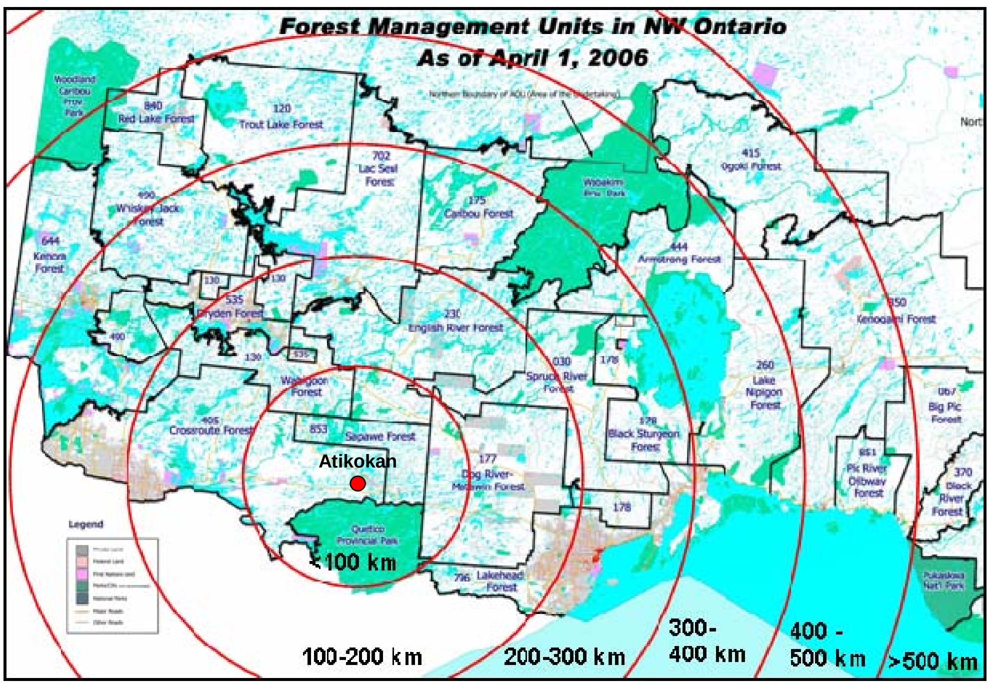
Executive Summary

Forest BioProducts Inc. was retained by the Ontario Ministry of Energy to evaluate alternative feedstock options for replacing coal power generation at the Atikokan GS and provide an estimate of the cost of converting this material using known combustive technologies. The availability and landed cost of biomass feedstocks and fuel-grade peat were assessed to meet a need for over 500,000 bone dry tonnes per annum at the Atikokan GS. Here, biomass is defined as renewable or sustainable materials of forest, agricultural (plant or animal) or marine origins or from municipal and industrial waste. Biomass feedstocks in the form of unutilized wood supply, forest harvest residues, mill wood waste, landfilled wood waste, energy plantations and municipal solid waste were treated in this study. The availability and landed cost of the biomass feedstocks were expressed in terms of 100 km increments from the Atikokan GS and originating from Canada:

Figure I. Distance classes used in this study



The region's fuel-grade peat resource made up the bulk of the available material with roughly 60 million bone dry tonnes (BDT) within 100 km of the Atikokan GS. The remaining biomass feedstocks made up a collective theoretical pool of approximately 3.2 million BDT of biomass per year, far exceeding the estimated demand at the Atikokan GS. Table I shows the theoretical amount of biomass available as well as the practical amount of biomass available which has been modeled based on access and other practical considerations. The third component of Table I lists the landed cost (FOB Atikokan GS) of this biomass as a function of distance from the Atikokan GS, which integrates all cost components for procurement, processing and transport.

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Table I: Theoretical and practical amounts of feedstocks in support of the Atikokan GS

	'Theoretical' Amount of Biomass Available With Distance from the AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Annual Resource - BDT/yr							
Unutilized Wood Supply	190,700	531,400	725,600	368,900	242,100	96,700	2,155,400
Forest Harvest Residues	57,300	147,700	115,800	75,400	55,300	24,100	475,600
Mill Wood Waste	7,400	45,800	14,600	15,200	200	21,700	104,900
Dedicated Energy Crops	n/a	42,300	3,700	n/a	n/a	n/a	46,000
Refuse Derived Fuel	n/a	n/a	n/a	n/a	n/a	379,000	379,000
'Theoretical' BDT/yr	255,400	767,200	859,700	459,500	297,600	521,500	3,160,900
Finite Resource - BDT							
Fuel-Grade Peat	59,921,700	148,396,500	124,617,000	106,580,100	157,587,700	66,976,000	664,079,000
Landfilled Wood Waste	n/a	n/a	n/a	n/a	n/a	n/a	4,022,076

	'Practical' Amount of Biomass Available With Distance from the AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Annual Resource - BDT/yr							
Unutilized Wood Supply	95,400	265,700	362,800	184,500	121,100	48,400	1,077,900
Forest Harvest Residues	28,700	73,900	57,900	37,700	27,700	12,100	238,000
Mill Wood Waste	5,900	36,600	11,700	12,200	200	17,400	84,000
Dedicated Energy Crops	n/a	42,300	3,700	n/a	n/a	n/a	46,000
Refuse Derived Fuel	n/a	n/a	n/a	n/a	n/a	379,000	379,000
'Practical' BDT/yr	130,000	418,500	436,100	234,400	149,000	456,900	1,824,900
Finite Resource - BDT							
Fuel-Grade Peat	29,960,850	74,198,250	62,308,500	53,290,050	78,793,850	33,488,000	332,039,500
Landfilled Wood Waste	n/a	n/a	n/a	n/a	n/a	n/a	2,011,038

	$/BDT of Biomass FOB AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	AVERAGE
Annual Resource							
Unutilized Wood Supply	$54	$79	$104	$129	$154	$180	$107
Forest Harvest Residues	$44	$75	$106	$137	$168	$199	$106
Mill Wood Waste	$21	$51	$82	$113	$145	$175	$88
Fuel-Grade Peat	$65	$96	$127	$158	$189	$220	$143
Dedicated Energy Crops	n/a	$155	$186	n/a	n/a	n/a	$157
Refuse Derived Fuel	n/a	n/a	n/a	n/a	n/a	$82	$82

Steering Committee members have forwarded the following unsolicited project pre-proposals to FBi for consideration in the study:

- Atikokan Power Corporation, a company to be formed for the specific purpose of owning and operating the Atikokan GS and targeting the use of forest biomass based on fluidized bed boiler technologies;
- Triangle Energy Group, a proponent from Minnesota attached to a whole-tree combustion technology;
- Peat Resources Ltd., a publicly traded corporation with the goal to produce and provide fuel-grade peat to replace lignite at the Atikokan GS; and,
- A request to assess refuse derived fuel processed from Toronto's municipal solid wastes.

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These pre-proposals were used as case studies and permitted us to compile a great deal of information prepared by various sources from the private and public sectors. The proponents, feedstock strategies and boiler technologies associated with the various case studies are listed in Table II.

Table II: Profile of case studies presented to Forest BioProducts Inc. by the Steering Committee

Case Study	Involvement	Feedstock Strategy	Boiler Technology
Atikokan Power Corporation	Owner/Operator	100% Forest Biomass	Fluidized bubbling bed combustor
Peat Resources Ltd.	Fuel Supplier	100% Fuel-Grade Peat	Minimal modifications to existing boiler
Triangle Energy Group	Owner/Operator	100% Forest Biomass	Proprietary whole-tree combustion system
Refuse derived fuel	Fuel Source	60% Refuse Derived Fuel 40% Forest Biomass	Extensive modifications to existing boiler

In order to facilitate comparisons among the different case studies we have also applied, independently of the proponents' pre-proposals, standard emission reduction technologies as an added scenario to all options. Furthermore, costs of electricity production were assessed with and without emission control to permit a greater understanding of the impact of imposing emissions controls on these options.

It is noteworthy to mention that although numerous biomass conversion and emission control technologies are commercially available or in development, these technologies are not discussed in this report. Indeed, the primary objective of this investigation was to emphasize the feasibility of biomass feedstock options. Therefore current emission controls should be seen as benchmarks. In fairness to the project proponents of the case studies (Table II), the levelized costs of power production have been expressed with and without additional emission control measures.

Emission control measures (Table III) would represent capital and annual operating costs of $206 million and $2.6 million/yr, respectively, and would add roughly $26/MWh to the cost of producing electricity from biomass feedstocks. It is assumed that this set of emission controls would have similar contaminant removal efficiencies for woody biomass, peat and refuse derived fuel as it would for lignite regardless of the baseline level associated with each of these feedstocks.

Emission factors for lignite were from in-house measurements at the Atikokan GS, which has low NO_x burners and a cold-side electrostatic precipitator to reduce NO_x and particulate matter emissions. Emission factors reported by a previous study (DSS and RWDI, 2005) for a medium-sized (i.e. 300-700 MW) natural gas single-cycle system with low NO_x burners were used.

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All other feedstocks were assumed to be fired in a modified version of the current AGS boiler at a biomass-to-power conversion efficiency of 36%. Uncontrolled emission factors for woody biomass, peat, and refuse derived fuel were taken from the literature and were adjusted based on the addition of the following set of emission control technologies:

Table III: Emission control methods used to estimate contaminant releases in conditioned flue gas at the Atikokan GS

Control	Contaminant Removed	Removal Efficiency
Selective catalytic reduction	NOx	67%
Flue gas desulfurization	SOx	80%
Electrostatic precipitator	PM	94%
Electrostatic precipitator	Hg	75%

DSS & RWDI (2005)

The data in Table III were taken from DSS and RWDI (2005) in which the capital and operational costs of alternatives to coal-fired power generation are reported.

Forest Biomass as a Replacement Feedstock

For the purpose of this study, forest biomass encompasses unutilized wood supply, forest harvest residues and mill wood waste. Fuelling the Atikokan GS with forest biomass would result in a decrease in net capacity from 215 MW to 150 MW owing to physical limitations associated with firing forest biomass in the current infrastructure as forest biomass is a relatively low energy density feedstock as compared to lignite. This conversion would require roughly $306 million in capital costs for boiler retrofits ($100 million) and the addition of stringent emission controls ($206 million) as discussed above. The combustion technologies are well established and, as such, the biggest risk element associated with this option is the long term procurement of feedstock.

Competition with current forest users and potential losses of value-added opportunities are identified as a potential issue of concern in the region with respect to the procurement of forest biomass. The theoretical demand for forest biomass to fully satisfy in-mill energy requirements for the pulp and paper industry was estimated at 3.3 million BDT per year, which is well in excess of the amount forest biomass assessed as practically available in the region. However, lack of data about the pulp and paper industry usage does not permit us to provide a final answer to that question since, at this point time, the in-mill supply mix of energy/power for the region's pulp and paper industry is not available. Therefore, there is potential for competition with the forest industry if forest biomass were to be allocated and/or diverted toward the Atikokan GS. This is further exacerbated by the fact that the pulp and paper industry is under pressure to reduce its energy input cost. In practice, it would be the responsibility of the operator of the Atikokan GS to demonstrate that a feedstock strategy based on forest

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biomass is not deleterious to the forest industry. As well, it will be important to include First Nations interests as part of the project definition and/or partnerships.

Importing pelletized waste sawmilling residues from British Columbia was investigated as an alternative source of biomass but our results showed this feedstock not to be cost-effective as compared to the other options.

Fuel-Grade Peat as a Replacement Feedstock

The use of fuel peat at the Atikokan GS would maintain the current station rating of 215 MW and would require a capital cost of $211 million to modify the existing boiler ($5 million) and add stringent emission controls ($206 million). Our data shows that there is sufficient fuel-grade peat from bogs in the region to meet the entire demand of the Atikokan GS. Peat would be harvested from bogs in the region and delivered in pellet form at 20-25% moisture. The peat would be pulverized before entering the boiler. The biggest risk element of this option is associated with securing environmental permitting for peat harvesting on crown lands. Indeed, permitting would be subjected to Individual Environmental Assessment and the onus is on the proponent to meet environmental regulations. At this point in time, the proponent has undertaken a number of mitigating measures to reduce environmental risks associated and increase benefits to First Nations together with meeting requirements for environmental permitting.

Refuse Derived Fuel as a Replacement Feedstock

Refuse derived fuel is generated from removing recyclables and non-combustibles from municipal solid waste followed by shredding, drying and pelletizing the enriched fraction. The use of refuse derived fuel as part of a blended feedstock strategy with forest biomass would result in a decrease in net capacity from 215 MW to 150 MW at the Atikokan GS. The conversion would incur $406 million in capital costs owing to the fact that refuse derived fuel is corrosive and would require extensive modifications to the combustion chamber ($200 million) and additional flue gas conditioning technologies ($206 million). Under this scenario, 380,000 BDT/yr of refuse derived fuel would be produced in Toronto and shipped by rail freight to the Atikokan GS. At 15 GJ/BDT, this amount accounts for over half of the gross energy input requirement at the Atikokan GS and, as such, this option would require a supplemental feedstock procurement strategy. Processing municipal solid waste into refuse derived fuel in Toronto and shipping it to the Atikokan GS would increase Toronto's diversion rate and thereby improve the garbage situation there.

Greenhouse Gas and Contaminant Emissions

Greenhouse gas (GHG) and atmospheric contaminant emissions from firing lignite, natural gas, woody biomass, peat or refuse derived fuel were modeled based on the basis of a net generation of 900,000 MWh at the Atikokan GS (Table IV). Note that the emission factors and total emissions listed in Table IV are for combustion only and do

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not account for other life-cycle contributions. In our experience, combustion emissions account for over 95% of a given fuel's total life-cycle emissions. Owing to the complexity of numerous scenarios and carbon accounting processes potential carbon credits are not compounded in the following table. Also note that the use of woody biomass feedstocks could generate carbon offsets if the fuel is derived from dedicated energy plantations, dedicated silvicultural activities that increase forest productivity or from wood waste that would otherwise generate methane emissions through anaerobic decomposition in landfills, or carbon dioxide emissions through the prescribed burning of forest harvest residues. Likewise, carbon accumulation by peat was not included under the current scenario as they do not meet agreements under the Kyoto protocol.

Table IV: Greenhouse gas and contaminant emissions at the Atikokan GS—life cycle emissions are not included in this table but discussed in the schedules. NB: carbon emissions are not affected by emission control measures except as carbon credits.

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
Fossil										
Lignite	986,000	1,100 a	2,960	3,290 a	5,400	6,000 a	37	41 a	38	42 a
Natural Gas	489,000	543 b	100	110 b	3.1	3.4 b	49	54 b	0	0 b
Uncontrolled										
Woody Biomass	1,021,000	1,130 c	900	1,000 d	100	110 d	1,340	1,490 d	14	16 d
Peat	1,189,000	1,320 e	200	2,200 f	3,380	3,750 f	n/a	n/d	n/a	n/a
Refuse Derived Fuel	993,000	1,100 g	1,860	2,070 g	1,440	1,610 g	25,790	28,650 g	1,770	1,970 g
Controlled										
Woody Biomass	1,021,000	1,130	300	330	20.0	22.0	80	89	3.6	4.0
Peat	1,189,000	1,320	70	730	680	750	n/a	n/a	n/a	n/a
Refuse Derived Fuel	993,000	1,100	610	680	290	322	1,550	1,720	440	490

n/a = data not available

[a] in-house measurements at the Atikokan GS

[b] DSS and RWDI (2005)

[c] Environment Canada (2005)

[d] EPA (1995a)

[e] Uppenberg et al. (1999)

[f] Government of Ireland (2005)

[g] EPA (1995b)

Comparative Cost of Power Production

The levelized unit energy cost (LUEC) of generating electricity using the various feedstocks was modeled on a case-by-case analysis for the unsolicited project proposals forwarded to FBi by members of the Steering Committee (Table V). LUEC is defined as the net present value of the capital, operating and maintenance and fuel costs divided by the discounted level of generation over the life of the project:

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Table V: Levelized unit energy cost of power generation for each of the case studies

	Atiokan Power Corporation	Peat Resources Ltd.	Triangle Energy Group	Toronto Garbage
Project Capital Costs - $				
Boiler Retrofits	$100,000,000	$5,000,000	$100,000,000	$200,000,000
Emission Controls	$206,000,000	$206,000,000	$206,000,000	$206,000,000
Project Capital - $/MWh				
with emission controls	$34	$23	$34	$45
without emission controls	$11	$1	$11	$22
Operations & Maintenance - $/MWh				
with emission controls	$31	$26	$31	$36
without emission controls	$28	$23	$28	$33
Fuel - $/MWh	$51	$58	$51	$58
LUEC - $/MWh				
with emission controls	$115	$108	$115	$140
without emission controls	$89	$82	$89	$114

Risk Factors and Mitigation Strategies

The following is a summary of the key risk factors and mitigation strategies associated with each of the case studies addressed in this investigation.

Table VI: Key risk factors and mitigation strategies associated with the case studies

Case Study	Risk	Mitigation
Atikokan Power Corporation	Feedstock Risk – allocation of unutilized wood supply; competition with pulp and paper industry for biomass as a fuel	Assess actual needs of forest industry for bioenergy and weigh those needs based on the forest industry's usual simple payback requirement for 1-2 years on such projects
	Environmental Risk – nutrient depletion from harvested sites; reduced biodiversity	Acquire supporting data that is site-specific showing what forest types can tolerate nutrient depletion from long term slash harvesting
	Social risk—First Nations involvement was solicited which raises the possibility for First Nation participation.	Develop a working relationship with local First Nations as to interest in participating at all stages of the project

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Table VI continued…

Case Study	Risk	Mitigation
Peat Resources Ltd.	Environmental Risk – permanent changes to water recharge and quality in harvested sites and adjacent lands; potential impacts on biodiversity and carbon budget of peatlands	Require the project proponent to keep full control and monitoring of effluents following environmental standards
	Technological Risk – final harvesting and drying technologies not identified; burn trials using fuel-grade peat pellet have not been conducted.	For harvesting technologies the proponent is assessing three drying technologies with proven track records in similar applications. For combustion at the Atikokan GS there is a need for a pilot project to assess the performance of peat pellets and to optimize the moisture of the delivered feedstock
	Social Risk – negative impact on ecotourism, First Nations way of life and treaty rights	Proponents reports that discussions are underway with some tourist lodge operators and First Nations to mitigate potential issues as component of Environmental Assessment
Triangle Energy Group	Feedstock Risk – competition with pulp and paper industry for biomass as a fuel	Assess actual needs of forest industry for bioenergy and weigh those needs based on the forest industry's usual simple payback period of 1-2 years on such projects
	Environmental Risk – nutrient depletion from harvested sites; reduced biodiversity	Acquire supporting data that is site-specific showing what forest types can tolerate nutrient depletion from long term slash harvesting
	Technology Risk – proprietary whole-tree combustion technology not proven at the scale of the Atikokan GS	Require performance guaranties from boilermakers
	Social Risk—First Nations involvement was not solicited	Develop a working relationship with local First Nations as to interest in participating at all stages of the project
Toronto Garbage	Feedstock Risk – Refused Derived Fuel is not currently produced in Toronto	Develop a business plan for sorting and processing municipal solid waste in Toronto
	Environmental Risk – contaminant emissions from combustion of Refused Derived Fuel, particularly mercury, dioxins and furans	Require performance guaranties from technology providers; consideration of alternative technologies (i.e. gasification)

Specific Environmental Issues

Ontario Regulation 116/01 details Environmental Assessment requirements for electricity projects. MOE has classified electricity projects based on the type of fuel to be used, the size and, in some cases, the efficiency of the planned facility. The feedstocks proposed here are addressed in Ontario Regulation 116/01.

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Potential impacts to the air, land, water and biosphere as a result of using of the various biomass feedstocks for power generation at the Atikokan GS are listed below:

Table VII: Environmental impacts resulting from the use of the different feedstock options

Unutilized Wood Supply	Forest Harvest Residues
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion ***Land*** – Damages resulting from road construction and harvesting operations. Pollution inputs from forestry equipment and combustion ash disposal ***Water*** – Damages and pollution inputs resulting from road construction and harvesting operations ***Biosphere*** – Loss of wildlife habitat, nutrient removal from forest ecosystem	***Air*** – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion ***Land*** – Damages resulting from road construction and harvesting operations for new fiber. Pollution inputs from forestry equipment and combustion ash disposal. Possible problems associated with soil impoverishment. ***Water*** – Damages and pollution inputs resulting from road construction and harvesting operations ***Biosphere*** – Loss of wildlife habitat, nutrient removal from forest ecosystem
Sawmill Wood Waste	**Dedicated Energy Plantations**
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion ***Land*** –Pollution inputs resulting from combustion ash disposal	***Air*** – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion ***Land*** –Pollution inputs resulting from chemical pesticides and combustion ash disposal ***Water*** – Pollution inputs from chemical pesticides
Fuel-Grade Peat	**Refuse Derived Fuel**
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion ***Land*** – Damages and pollution inputs resulting from extraction, processing operations and combustion ash disposal. Permanent alteration of the landscape ***Water*** – Damages and pollution inputs resulting from extraction and processing operations. Permanent alteration of surface and groundwater chemistry and hydrology. ***Biosphere*** – Loss of wildlife habitat. Nutrient-rich processing effluents can negatively impact on aquatic ecosystems	***Air*** – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion. Emissions of heavy metals and dioxins/furans are of concern ***Land*** – Pollution inputs resulting from combustion ash disposal

Table VIII lists the effect of using biomass feedstocks for power generation at the Atikokan GS on job creation, competing end-users and First Nations communities in the region:

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Table VIII: Impacts of using biomass on job creation, competing end-users and First Nations communities

Atikokan GS Makes Use of Forest Biomass

Job Creation – increase of 200 jobs for harvesting forest biomass in support of the Atikokan GS

Competing Uses – potential for increased competition for forest biomass by pulp and paper industry for in-mill energy needs

First Nations Impact – potential for participation and/or brokering

Atikokan GS Makes Use of Fuel-Grade Peat

Job Creation – increase of 100 jobs for harvesting peat; potential increase of 200 jobs for harvesting forest biomass in support of the pulp and paper industry

Competing Uses – potential conflict with operators of tourist lodges

First Nations Impact – potential to partake as partners; support community infrastructure

Atikokan GS Makes Use of Municipal Solid Waste from Toronto

Job Creation – unquantified creation of jobs in Toronto for processing of municipal solid waste into refuse derived fuel

Competing Uses – none

First Nations Impact – no direct positive impact, potential impact on environment and traditional way of life.

Other – help the City of Toronto resolve its waste management problem

How to Read This Document

This document is organized in three main sections. Section 1 deals with the terms of reference and working hypotheses of the study. Section 2 addresses the analysis of case studies which were advanced to us by the steering committee. The third section comprises 6 schedules which include detailed calculations, supporting documentation and models supporting the conclusions drawn in section 2. We have referenced key points of the different schedules. However, for a thorough understanding of our hypotheses and models we recommend a review of the different schedules.

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Schedule 2 - **Air Emissions from Using Lignite, Fuel Grade Peat, Woody Biomass, or Refuse Derived Fuel at the Atikokan Generating Station**

Schedule 3 – **Economic Modeling of Production Costs Associated with the Various Project Proposals**

Schedule 4 – **Expressions of Interest in Woody Biomass Received by the Ministry of Natural Resources**

Schedule 5 – **Consideration of First Nations Rights for Peat Harvest**

Schedule 6 – **Environmental Assessment of a Peat Harvesting and Processing Operation Near Upsala, Ontario – Terms of Reference**

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List of Abbreviations

AAC	Annual Allowable Cut
AAV	Annual Available Volume
AAH	Annual Allowable Harvest
AF	Availability Factor
AGS	Atikokan Generating Station
APC	Atikokan Power Corporation
BDT	Bone Dry Tonne (i.e. 0% moisture content)
BFB	Bubbling Fluidized Bed
ESP	Electrostatic Precipitator
FBC	Fluidized Bed Combustor
FGD	Flue Gas Desulfurization
FMP	Forest Management Plan
FMU	Forest Management Unit
FOB	Free on Board
GJ	Gigajoule (i.e. 10^9 Joules)
GWP	Global Warming Potential
kW	Kilowatt (i.e. 10^3 Watts)
LUEC	Levelized Unit Energy Cost
MDF	Medium Density Fibreboard
MNR	Ministry of Natural Resources
MSW	Municipal Solid Waste
MW	Megawatt (i.e. 10^6 Watts)
MWh	Megawatt-hour
ODD	Oven Dry Density
OGS	Ontario Geological Survey
OMAFRA	Ontario Ministry of Food and Rural Affairs
OPG	Ontario Power Generation
OSB	Oriented Strand Board
PMH	Productive Machine Hours
PRL	Peat Resources Ltd.
RDF	Refuse Derived Fuel
SCR	Selective Catalytic Reduction
SFL	Sustainable Forest Licence
SMH	Scheduled Machine Hours
SNCR	Selective Non-Catalytic Reduction
SRW	Short Rotation Willow
TEG	Triangle Energy Group
VSF	Volumetric Shrinkage Factor
UWS	Unutilized Wood Supply

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1. Introduction

1.1 Project Scope

As part of its plan for cleaner air, a more sustainable environment, and healthier Ontarians, the government of Ontario is replacing the province's coal-fired electricity generation with cleaner sources of energy and conservation. On June 15th, 2005 the government of Ontario announced the scheduled closures of Ontario's four remaining coal-fired plants.

The Atikokan Generating Station (Atikokan GS) currently uses lignite coal as a feedstock and is scheduled to terminate operations by the end of 2007. This planned closure would impact the local economy by eliminating 90 direct full time positions and 80 indirect positions as well as reduce roughly tax revenues to the Township of Atikokan by one third. Consequently the Township of Atikokan has made a request to the Ontario Government to convert the Atikokan GS from lignite coal to sustainable biomass feedstocks.

The government has responded to the Township of Atikokan's request to consider other options for the plant by proceeding to engage a consultant to examine sustainable and viable feedstock alternatives for the Atikokan GS.

Forest BioProducts Inc. (FBi) submitted a proposal in response to a Request For Proposal from the Ontario Ministry of Energy which was posted on Merx (www.merx.com) on October 17th, 2005.

In December 2005, FBi was retained by the Ontario Ministry of Energy to assess parameters of significance to the conversion of the Atikokan GS from using lignite coal as a feedstock to bio-energy resources accessible to northwestern Ontario for the Atikokan GS.

FBi's mandate was to gather and summarize data on fundamental issues that represent the key hurdles that should be met by potential bio-energy alternatives to be viable and sustainable options:

1) What is the availability of biomass resources accessible to northwestern Ontario that could be used for electricity generation? What are the competing uses for these resources?

2) What are the costs and benefits (including economic spin-offs) of procuring, processing and transporting the biomass fuels to the Atikokan GS and are they reasonable to make the resource a viable option and at what capacity?

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3) What are the environmental impacts of harvesting the resource and converting it to electricity?

Specific study deliverables were:

1) Assessment of the availability of each bio-energy resource accessible to northwestern Ontario identified by the Supplier including, but not necessarily limited to, wood waste and crop residue (straw), that could be used for electricity generation;

2) Assessment of the availability of fuel-grade peat resources accessible to northwestern Ontario, including consideration of the distance from transportation routes, such as roads or rail lines;

3) Quantification of the delivered fuel cost for each resource identified by the Supplier, i.e. the cost to bring the resources to Atikokan/other locations, including harvesting, processing (including capital and operating costs of processing facility) and transporting to the generating station;

4) Estimation of the total electricity production costs (i.e. $/MWh) using each of the resources considered, or a mix of the resources, including capital costs of electricity plant/conversion of the Atikokan GS (one or more units), operating costs, and delivered fuel costs.

5) Identification of the environmental impacts of harvesting, processing and combusting each resource;

6) Quantification of the life-cycle emissions associated with electricity generation using each resource;

7) Identification and quantification of positive economic benefits resulting from each resource, including job creation, industry development and economic spin-offs;

8) Comment on how life-cycle costs and environmental impacts may be reduced.

This project was under the supervision of a steering committee which included:

- Dennis Brown, Mayor, Township of Atikokan
- Garry McKinnon, Executive Director, Atikokan Economic Development Corporation
- Wilf Thorburn, Chief Executive Officer, Atikokan Hydro
- Mike Lewis, Citizen, Ad Hoc Energy Committee
- Tony Rockingham, Assistant Deputy Minister, Ministry of Energy
- Jon Norman, Senior Policy Advisor, Ministry of Energy
- George Ross, Assistant Deputy Minister, Ministry of Natural Resources

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- Jim McClure, Assistant Deputy Minister, Ministry of Northern Development & Mines

1.2 Project Approach & Sources of Information

A great deal of independent research and analyses have been conducted with regard to the economic significance of the Atikokan GS to the region, possible procurement strategies for conversion from lignite coal to biomass feedstocks, environmental impacts of the feedstock options, competition for biomass resources in the region and technological upgrades to meet conversion from lignite to biomass.

For the preparation of this study FBi acquired information from the following sources:

- Peer-reviewed material from scientific and technical journals;
- Study reports from various groups, ministries and agencies;
- Diligence material conducted by arms' length investigators;
- Business plans prepared by project proponents;
- Information posted on the Internet; and,
- Communications from various stakeholders through emails, letters and phone interviews.

The totality of the information gathered constituted our dataset and the various sources are listed in the reference section and throughout this document. Our first impression about the dataset was:

- A subset of the dataset converged;
- A subset of the dataset diverged;
- A subset of the dataset was speculative;
- A subset of the data was substantiated by empirical data; and,
- For some of the data we had no accessible means to verify its veracity.

The first challenge in the conversion of the Atikokan GS to biomass feedstocks is to secure enough biomass to meet input and output requirements and to identify feedstock scenarios that would minimize the landed cost of biomass as compared to lignite. Lignite is priced at $44/BDT or $1.80/GJ FOB Atikokan GS, giving a fuel cost of $18/MWh (Table 1). Here, fuel cost refers to the contribution of fuel to the all-in unit cost of producing electricity at the Atikokan GS. Cost data for lignite was provided by Ontario Power Generation and is for 2008, based on forecasted market activity and rail freight rates (Mr. C. Young, Ontario Power Generation, personal communication).

Table 1. Cost of lignite used to generate electricity at the Atikokan GS

Delivered Fuel Cost	$44	per BDT
Energy Density	24	GJ/BDT
Fuel Unit Energy Cost	$18	per MWh

Source: Ontario Power Generation

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Since 2000, the Atikokan GS has generated approximately 1 million MWh of electricity each year by burning lignite at a conversion efficiency of 36% (Table 2). Assuming an energy density of 19 GJ/BDT, a supply of biomass in the range of 526,000 BDT/yr would be required to maintain this level of production, depending on the moisture content of the biomass at the boiler gate and the conversion efficiency of biomass to steam. At the onset of the study, FBi was instructed by the Steering Committee to assess the feedstock sources listed in Table 3.

Table 2. Lignite consumption and electricity generation at the Atikokan GS

Year	Consumption (tonnes)	Gross Energy Input		Gross Generation (MWh)	Conversion Efficiency (%)	Net Generation (MWh)
		GJ	MWh			
2005	670,000	10,720,000	2,978,000	1,067,000	36%	n/d
2004	715,000	11,440,000	3,178,000	1,126,000	35%	1,018,000
2003	655,000	10,480,000	2,911,300	1,046,000	36%	946,000
2002	572,000	9,152,000	2,542,400	914,000	36%	823,000
2001	557,000	8,912,000	2,475,800	920,000	37%	838,000
2000	669,000	10,704,000	2,973,600	1,091,000	37%	994,000
MEAN	640,000	10,235,000	2,843,000	1,027,000	36%	924,000

Source: Ontario Power Generation

Table 3. Biomass feedstocks treated in this study

Biomass Feedstock	Primary Data Source
Unutilized Wood Supply	Ministry of Natural Resources
Forest Harvest Residues	Ministry of Natural Resources
Mill Wood Waste	Ministry of Natural Resources
Landfilled Wood Waste	Ministry of the Environment
Fuel-Grade Peat	Ministry of Northern Development & Mines
Dedicated Energy Crops	Ministry of Agriculture, Food & Rural Affairs
Municipal Solid Waste	Ministry of the Environment

FBi has assessed the landed cost of feedstocks at the Atikokan GS based on a number of factors which varied by feedstock type:

- For unutilized wood supply, FBi prepared cost estimates for harvesting, processing and transport;
- For forest harvest residues, FBi prepared cost estimates for collection, processing and transport;
- For mill wood waste, FBi assumed a nominal fee for procurement and prepared cost estimates for transport;
- For fuel grade peat, FBi sought cost estimates for harvesting and processing and prepared cost estimates for transport;
- For dedicated energy crops, FBi prepared models based on yield estimates, and prepared cost estimates for transport;

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- For municipal solid waste, FBi prepared cost estimates for processing into refuse derived fuel and sought quotes for rail transport from Toronto.

In order to simplify this report, FBi, in consultation with the Project Steering Committee, has elected to organize the information as several analyses of case studies. Steering Committee members have forwarded unsolicited project pre-proposals to FBi dealing with the following:

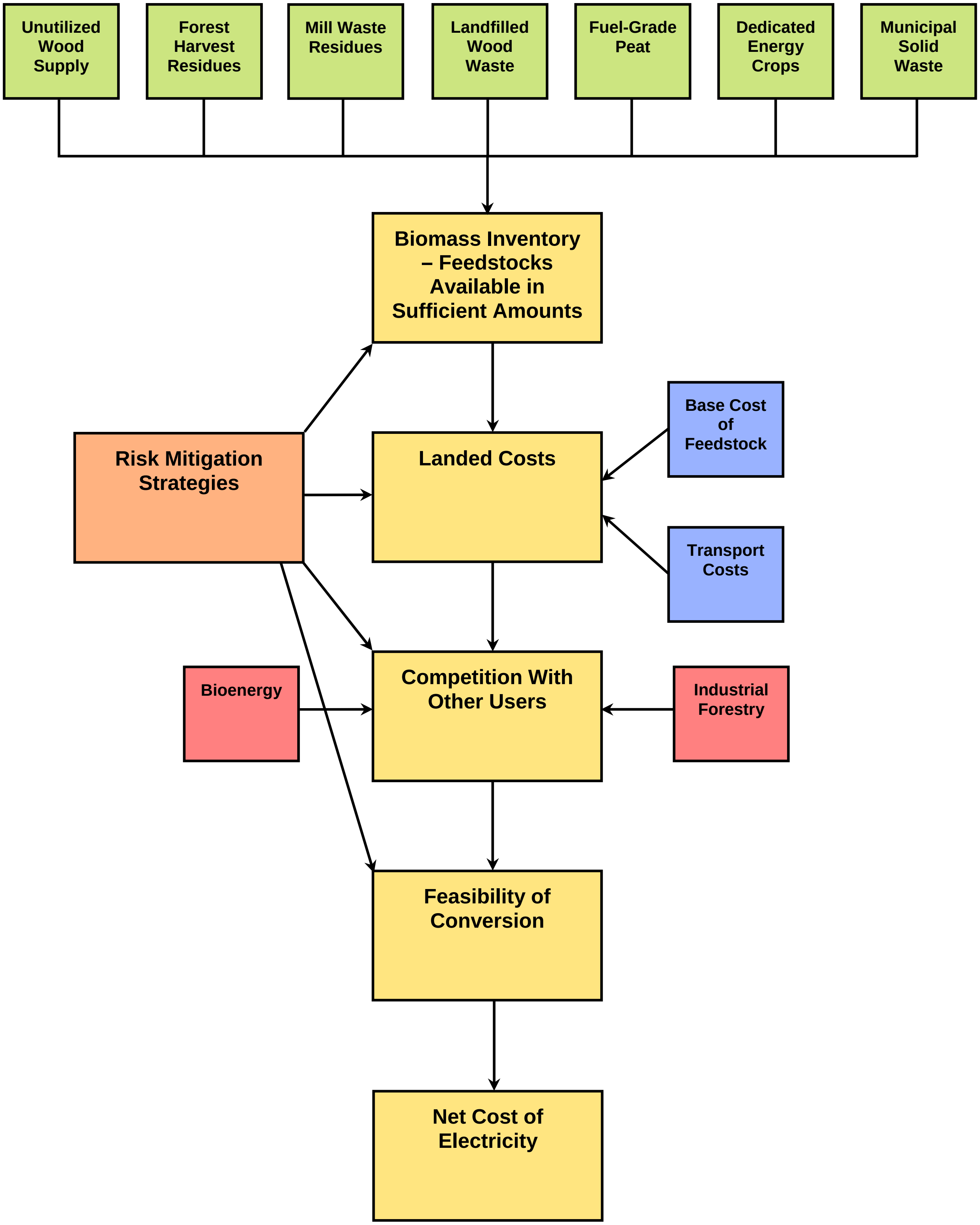
- Atikokan Power Corporation, a company to be formed for the specific purpose of owning and operating the Atikokan GS;
- Triangle Energy Group, a proponent from Minnesota attached to a whole-tree combustion technology;
- Peat Resources Ltd., a publicly traded corporation with the goal to produce and provide fuel-grade peat to replace lignite at the Atikokan GS;
- Refuse derived fuel processed from municipal solid wastes from Toronto, an option that was put forward by the Project Steering Committee in response to a request from the Township of Atikokan; and,
- Synfuel Power, an Ontario corporation with gasification capabilities looking to sell steam to the Atikokan GS in response to a request from Township of Atikokan.

The Synfuel Power proposal involved a technology that produces syngas through the gasification of petroleum coke. However, this feedstock falls outside of the terms of reference set out by the Project Steering Committee, and, as such, it has been omitted from the report.

FBi has addressed these pre-proposals as case studies by assessing their feasibility in view of our estimates of the availability and anticipated pricing of feedstocks, together with perceived technological, environmental and social risks. Further, the case studies were compared from environmental, social, and economic perspectives. Risk mitigation strategies are discussed for each case study.

Our investigations were based on the primary information that was transmitted to us which was followed in many cases with phone interviews or email correspondence in order to seek precisions. These phone interviews and email correspondences are listed as personal communications throughout the document. It is noteworthy that other technologies and proponents may come forward at a later date and that our analysis should be seen as a pre-feasibility of some base case scenarios. As such, our report does not represent a complete technology scan. As well, FBi did not conduct due diligence on the proponents, their track records and financial positions as this fell outside our mandate. FBi's general approach was to integrate all available information from the various sources and to organize comparison matrices by applying a critical path for the selection of a feedstock(s) (Figure 1). It is noteworthy that our analysis was conducted without public consultation. As well, FBi did not conduct experimentation to acquire field or laboratory data to test key study assumptions and other observations.

Figure 1. Graphical representation of the critical path for selecting feedstocks to replace coal at the Atikokan GS



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Results of the biomass inventory are attached as Schedule 1. Life-cycle emissions of lignite and fuel-grade peat and combustion emissions for woody biomass and refuse derived fuel are presented in Schedule 2. Schedule 3 describes the financial model developed to estimate the cost to produce electricity at the Atikokan GS. Expressions of interest in woody biomass in northwestern Ontario as reported to FBi by the MNR are included in Schedule 4 and Schedule 5 contains the consideration of First Nations rights with respect to peat harvesting.

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2. Case Study Analyses

2.1 Atikokan Power Corporation

Background

Atikokan Power Corporation (APC) is a company to be formed by a group of proponents and/or investors with the intention to own and operate the Atikokan GS. The plant would be converted to make use of woody biomass in a blended feedstock strategy that could include forest harvest residues, unutilized wood supply in the form of chips, mill waste residues as bark, sawdust and planer shavings, fuel-grade peat and wood pellets imported from Northern British Columbia. In this scenario the Atikokan GS would be moved from a peak load to a base load production strategy.

Feedstock Strategy

The proponents are contemplating unallocated annual allowable cut (AAC) and residuals from the forest industry both from woodland and sawmilling operations as their primary feedstocks. Landfilled wood waste, sawdust and shavings, dedicated energy plantations, bio-oil and wood pellets have been put forward as alternate feedstock options.

The proponents have completed a literature scan for the purpose of assessing the availability of feedstocks. BIOCAP is cited as an authority. BIOCAP is a credible non-for-profit organization supported by government funding with the mandate to investigate and promote bioenergy and bioproducts across Canada (www.biocap.ca).

There was no evidence provided to FBi supporting that contractual relationships and/or tenure on biomass feedstocks have been secured for any of the proposed feedstock options although several preliminary discussions have taken place with various private and public stakeholders and a First Nation tribal council.

At the completion date of this report, the proponent reported the recent completion of a Memorandum of Understanding for forest biomass procurement with a First Nation entity in the region.

Technology for Conversion

The proponent proposes to modify the Atikokan GS in order to accommodate the new feedstocks. Plans are to introduce bubbling fluidized beds, which would be engineered and installed by Babcock & Wilcox Canada. Bubbling fluidized bed (BFB) technology offers the following advantages:

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- Recognized as a proven process for burning woody biomass with several installations around the world;
- Ability to combust high moisture wood with varying seasonal characteristics;
- Reduced NO_x, SO_x and CO emissions from existing coal-fired operation by conversion to woody biomass burning;
- Established operating and maintenance practices ensure plant availability required for the utility market;
- The existing skills of the plant operating and maintenance personnel can be used to full advantage with additional training for BFB specific equipment;
- Much of the existing assets at the Atikokan GS can be utilized in the conversion.

The specific plant modifications required to convert to firing woody biomass are:

- Installation of new wood fuel reclaimer, screens and sizing hog;
- Installation of new boiler fuel conveyors and metering screw feeders;
- Installation of new sand unloading, storage, conveying and recycling system;
- Installation of new bottom ash system;
- Modification of existing boiler furnace to accept the BFB. This includes extension of the frontwall and addition of sidewall panels to increase plan area;
- Installation of a new BFB sized for 484 MWt fuel input;
- Installation of new high pressure underbed air fan with associated combustion air ducting;
- Installation of new high pressure gas recirculation fan and associated flues;
- Reuse of existing primary air fans for overfire combustion air;
- Installation of new dust collector upstream of existing air heaters;
- Installation of new natural gas fired auxiliary burners for unit start up (58.6 MWt);
- Upgrade of existing Bailey 820 unit controls and 861 burner management systems.

The cost to modify the existing boiler is estimated at $80 million to which we have included a variance of $20 million, and has been confirmed by Babcock & Wilcox (Mr. B. Roberts, Babcock & Wilcox, personal communication). Capital and annual operating costs associated with the addition of flue gas desulfurization, selective catalytic reduction, and enhanced electrostatic precipitators are estimated at $206 million and $2.6 million/yr, respectively (DSS & RWDI, 2005)

Risk & Feasibility Analysis

Feedstock Risks

Securing a long-term supply of feedstocks is the greatest risk to the project based on the availability of biomass in the region and its landed cost at the Atikokan GS. Currently, over 10 million GJ/yr of input energy from lignite supports 1 million MWh/yr of gross generation at the Atikokan GS. Roughly 1,052,000 green tonnes of woody

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biomass (i.e. 526,000 BDT) would be required to maintain this level of output. However, it would be physically impossible to burn this amount of material based on the boiler configuration put forward by the proponent. As a result, net capacity would be expected to decrease to 150 MW.

The proponent is exploring the following feedstock options:

Unutilized Wood Supply

We have assessed the theoretical amount of unutilized wood supply at 2.2 million BDT/yr in northwestern FMU's (Table 4; Schedule 1, Table 23A) based on recent levels of wood allocation. Our average landed cost of $107/BDT (Table 4; Schedule 1, Table 23C) is similar to the proponent's estimate of $100/BDT. Two-thirds of this biomass occurs within 300 km of the Atikokan GS at an average landed cost of $88/BDT or $4.70/GJ.

Table 4. Amounts and landed costs of unutilized wood supply biomass with distance from the Atikokan GS

	Distance Class						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Amount (BDT/yr)							
Theoretical	191,000	532,000	726,000	369,000	243,000	97,000	2,158,000
Actual	95,500	266,000	363,000	184,500	121,500	48,500	1,079,000
Delivered Cost							AVERAGE
$/BDT	$54	$79	$104	$129	$154	$179	$107
$/GJ	$2.80	$4.20	$5.50	$6.80	$8.10	$9.40	$5.60

On January 26 2006, Bowater Inc. announced that one of its two Kraft pulp mills in Thunder Bay will permanently close in the second quarter of 2006. According to the proponent this is expected to release upwards of 1,000,000 m^3 or 350,000 BDT per year of wood in the region that could be used to generate electricity at the Atikokan GS. This can create competition issues which are discussed below. Specifically, we have created a model to evaluate the total potential in-mill energy requirements of the pulp and paper industry in the region.

However, stakeholders in the region are currently laying claims on forest biomass to support sawmilling and pulp and paper operations. According to the Ministry of Natural Resources (MNR), most conventional forest biomass may be subject to competition although this statement requires further clarification. Due to recent mill closures and the way the forest fiber is allocated FBi was not in measure to asses how unallocated resources might be spoken for, especially because expressions of interest are recorded by the MNR (see Schedule 4).

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Recent announcements of mill closures in the northwest region might lead to the hypothesis that a decrease in regional wood demand is creating a favorable climate for the disposition of roundwood supplies toward power generation. This was emphasized to FBi as a procurement strategy for two of the case studies. Consequently, we have sought advice from the Ontario Ministry of Natural Resources to understand the critical path involved in the wood procurement process as per their legislated requirement under the Crown Forest Sustainability Act.
These requirements specify that the Minister of Natural Resources will consider commitments to existing license holders and their right to harvest all tree species from that license area and to supply wood to their processing facilities. If there is an available supply of unused tree fiber, the Minister may elect to dispose of the tree fiber by initiating a competitive process or by applying a process set out by regulation (Order-in-council 993/95), that among other things, provides economic opportunities for aboriginal people and considers supply shortfalls to the existing commitment holders.

For the Atikokan GS to procure logging residues and/or timber for power generation, its application to MNR will be treated as a greenfield proposal and the Minister may consider a competitive process; application of the regulated process; or, a proposal on the strength of providing a satisfactory supply of forest resources from business arrangements with existing SFL holders. To be successful a proposal would need to address a number of criteria to secure the rights to the fiber/biomass:

1) *A successful project proposal would be required to indicate how they have sought aboriginal involvement. Involvement such as indirect participation in the project or some form of profit sharing strategy are some of the potential approaches that MNR would consider when evaluating a project of this nature*

Condition #34 of Ontario's Class Environmental Assessment Approval for Forest Management on Crown Lands calls for increased benefits from forest management and greater involvement in related negotiations between the province and First Nations. At this point in time, there has been no reported First Nation involvement in this case study which may limit its acceptability. This is an issue that may cause concerns to project proponents and, given that securing the participation of First Nation communities can be lengthy owing to the need to create meaningful relationships, this process may be a risk factor to proponents. The existence of a Memorandum of Understanding is a positive step forward.

2) *A successful project must not compete with current forestry operations in the region. The entire region is covered by Sustainable Forest Resource Licences that are currently supplying existing mills. Most of these mills are currently using or evaluating the use of tree fibre as an alternative to offset the use of electricity or fossil fuels. This is a key issue that goes well beyond the framework and data available for this study*

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Paper making is an energy intensive process which requires roughly 25 GJ per tonne of product (consolidated in-mill use of energy). Since January 2000, the cost of crude oil has more than doubled, climbing from US$31 to US$66 per barrel, which is roughly a hundred percent increase in the cost of energy. Therefore, energy contribution to the cost of paper making has climbed by $173/tonne of paper based only to commodity pricing of crude oil (C$0.80 = US$1.00; 6.1 GJ per barrel of oil). Note that many companies have long term energy contracts which may provide cushioning against fluctuations in the commodity pricing of energy and may create a hedge against high energy costs.

In addition, the appreciation of the Canadian currency is causing hardships on the forest industry. Consequently, most forest industries in the region have shown the need to acquire new energy sources to offset the cost of energy associated with the cost of production. It is not possible to account for the current energy need of each of the pulp and paper mills in the region. For this purpose, FBi has prepared an overall energy budget of current in-mill energy requirements for pulp and paper mills within the 500 km catchment area surrounding the Atikokan GS which we have broken down as follows:

Table 5. Estimated annual in-mill energy demand by northwestern Ontario pulp and paper mills

Company	Location	Production (tonnes/yr)	In-Mill Energy (million GJ)
Pulp			
Bowater	Thunder Bay	514,000	13.4
Neenah Paper	Terrace Bay	450,000	11.7
Abitibi-Consolidated	Fort Frances	87,000	2.3
Paper			
Abitibi-Consolidated	Fort Frances	286,000	7.4
Abitibi-Consolidated	Fort William	149,000	3.9
Abitibi-Consolidated	Kenora	242,000	6.3
Weyerhaeuser	Dryden	332,000	8.6
Bowater	Thunder Bay	385,000	10.0
	Total	2,445,000	63.6

Therefore the overall in-mill energy demand for all pulp and paper mills in the region is roughly 64,000,000 GJ/year – the energy equivalent of 3,368,000 BDT/year of woody biomass. FBi does not have access to the current in-mill energy mix, including contribution by biomass but we can assume that there are variations among the different mills based on levels of modernization and access to biomass.

Table 6 shows different levels of biomass requirements based on the targeted percent of biomass power conversion. In practice it means that if the pulp and paper

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industry is looking to supply 50% of its in-mill energy needs it might consume all of the 2,000,000 BDT of annual biomass feedstocks identified in this investigation (Table 20). It is possible that this biomass and/or fiber is the only viable solution to the survival the pulp and paper industry in the region and therefore it is critical to ascertain that the allocation of fiber as well as logging residues to the Atikokan GS does not put the current pulp and paper industry in jeopardy. Note that Table 6 assumes an energy conversion efficiency of 100%. In reality conversion efficiency varies from 35% (power generation) to 95% (steam generation). Therefore the biomass requirements are greater than represented below.

Table 6. Amount of biomass required by the pulp and paper industry based on the percent conversion to biomass power

% Conversion to Biomass Power	Biomass (BDT/yr)	% Conversion to Biomass Power	Biomass (BDT/yr)
10%	335,000	60%	2,008,000
20%	670,000	70%	2,343,000
30%	1,004,000	80%	2,677,000
40%	1,339,000	90%	3,012,000
50%	1,673,000	100%	3,346,000

Furthermore, there is need for a cautionary note on the harvest of forest residues for bioenergy. This type of harvest is a marginal operation which can only take place in parallel with harvesting for logs. Therefore any scenario based on the harvest of forest residues can only take place if the forest industry is financially sound.

3) *An evaluation of any proposal for use of tree fiber would consider the best end use of the resource to show that the value added potential is used to optimize benefit to Ontarians.*

This is an important concept which has been the object of very little modeling but has significant policy implications. There is no legislated requirement to provide value added in a proposal. The means for this is set out in the evaluation criteria for a competitive process. The ancillary question is whether or not it is more advantageous for Ontarians to generate revenues from roundwood fibre to energy projects than from fiber to paper projects.

We must acknowledge that policy requirements may restrict the allocation of fibre toward power production.

Forest Harvest Residues & Mill Wood Waste

The proponent considers forest harvest residues as tree tops and branches as one of their primary feedstocks.

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Our models estimate that 480,000 BDT/yr of tops and limbs are produced each year in northwestern Ontario (Table 7; Schedule 1, Table 23A). Assuming this is typical of past harvest years and that logging slash loses its usefulness as a fuel after 3 years in the field, a theoretical pool of 1.4 million BDT exists in the region. The full amount could sustain production at the Atikokan GS for over 2.5 years. Note that slash pile burning, reduced site accessibility and the economics of salvaging this material would limit the actual amount available for use at the Atikokan GS.

The proponent has modeled the landed cost of forest harvest residues at $54/green tonne which is consistent with our findings within 100 km of the Atikokan GS (Table 7; Schedule 1, Table 23C). At $17.50/green tonne, trucking accounts for almost 33% of their landed cost. This is consistent with our estimates for hauling green biomass to the Atikokan GS from within a distance of 300 km.

Table 7. Amounts and landed costs of forest harvest residues with distance from the Atikokan GS

	Distance Class						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Amount (BDT/yr)							
Theoretical	58,000	148,000	116,000	76,000	56,000	25,000	479,000
Actual	29,000	74,000	58,000	38,000	28,000	12,500	239,500
Delivered Cost							AVERAGE
$/BDT	$43	$75	$106	$136	$166	$192	$105
$/GJ	$2.30	$3.90	$5.60	$7.10	$8.70	$10.10	$5.50

Sawmills generate waste in the form of bark, sawdust and planer shavings. Sawdust and planer shavings are commodity items highly sought after by secondary wood product manufacturers and are arguable as feedstocks to the Atikokan GS.

Our data suggests that over 105,000 BDT/yr of bark would be available from sawmills in northwestern Ontario (Table 8; Schedule 1, Table 23A). This material would have an average landed cost of $88/BDT at the Atikokan GS (Table 8; Schedule 1, Table 23C), assuming a nominal fee of $5/BDT.

Table 8. Amounts and landed costs of waste bark from sawmills with distance from the Atikokan GS

	Distance Class						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Amount (BDT/yr)							
Theoretical	7,400	45,800	14,600	15,200	200	21,700	104,900
Actual	5,900	36,600	11,700	12,200	200	17,400	84,000
Delivered Cost							AVERAGE
$/BDT	$21	$51	$82	$113	$145	$175	$88
$/GJ	$1.10	$2.70	$4.30	$6.00	$7.60	$9.20	$4.60

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Growing interest in cogeneration and the production of cellulosic ethanol from wood will likely increase competition for waste bark in the short-term. Moreover, according to MNR most sawmills currently sell the bulk of this material to the pulp and paper industry as a feedstock for power boilers.

In the event that residues from logging or sawmilling became available, the proponent will need to secure 20 year tenure and/or a supply contract to support operations at the Atikokan GS. Demonstrating a long-term supply of biomass will be critical for project financing, but may be difficult to do because of the economic instability of the sawmilling industry.

Landfilled Wood Waste

The proponent has emphasized that landfilled wood waste is available throughout the region.

> Our models suggest that almost 105,000 BDT/yr of waste bark is disposed of in on- or off-site dumps tied to sawmilling operations in northwestern Ontario. We estimate that the 30 active wood waste sites in the Thunder Bay region together contain some 2 million BDT of biomass that could be mined, processed and burned to generate electricity at the Atikokan GS (Schedule 1, Table 23B). The landed cost of this material has not been assessed.

Although we recognize this as a valid feedstock option from a qualitative point of view, hard data on the amount and quality of this biomass is unavailable and introduces a new element of risk. Decay, contamination and recovery issues would limit the usefulness of landfilled wood waste as a fuel and greatly increase its landed cost. As such, the proponent cannot capitalize on this material and the lack of quantitative data would limit the possibility of securing project financing. If this option is to be investigated, there is a need to conduct on-the-ground sampling to assess the energy density, quality, contamination and actual quantity of material.

Dedicated Energy Plantations

Biomass from energy plantations has been proposed as a possible feedstock by the proponent. This is not a viable option in the short-term as there are no energy plantations in the region, which, in practice, are harvested after 4 growing seasons.

> If 10% of available lands in the region were converted to fast-growing tree species producing 7 BDT/ha/yr on a harvest cycle of 4 years, 46,000 BDT would be available to the Atikokan GS every 4 years (Table 9; Schedule 1, Table 23B). The delivered cost of this biomass would range from \$155 to \$186/BDT or \$8.10 to \$9.80/GJ assuming an energy density of 19GJ/BDT (Table 9; Schedule 1, Table 23C, D).

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Table 9. Amounts and landed costs of waste bark from sawmills with distance from the Atikokan GS.

	Distance Class						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Amount (BDT/yr)							
Theoretical	n/d	42,300	3,700	n/d	n/d	n/d	46,000
Actual	n/d	42,300	3,700	n/d	n/d	n/d	46,000
Delivered Cost							AVERAGE
$/BDT	n/d	$155	$186	n/d	n/d	n/d	$157
$/GJ	n/d	$8.10	$9.80	n/d	n/d	n/d	$8.20

Wood Pellets from British Columbia

A substantial amount of biomass is presumably available as pelletized sawmill waste in British Columbia through members of the BC Wood Pellet Manufacturers Association (BCWPMA). FBi contacted the BCWPMA to seek information on the wood pellet industry in that province.

Around 650,000 tonnes/yr of wood pellets are produced per annum in BC, with output expected to increase to 1.3 million tonnes/yr within 18-24 months and 3 million tonnes/yr in 4-5 years. Today, these pellets are valued at $6/GJ or $115/BDT FOB Vancouver (Mr. J. Swaan, BC Wood Pellet Manufacturers Association, personal communication).

Almost 80% or 500,000 tonnes/yr is currently shipped via Vancouver to customers in Sweden, Belgium, Holland, Denmark and the United Kingdom where it is burned alone or commingled with coal or other forms of biomass in older pulverized coal boilers, much like the boiler at the Atikokan GS. These customers hold 3-4 year supply contracts with the pellet manufacturers. Roughly 150,000 tonnes/yr is shipped by rail to markets in Quebec and eastern United States at $5,000-$6,000 per railcar, giving a rail freight rate of $55-$65/BDT and a landed cost of $170-$180/BDT.

The proponent has represented that it has access to such material, which would be shipped by rail to the Atikokan GS. The cost of this material to the proponent is not known and there was no evidence of a contractual relationship presented to us.

We have modeled the cost to produce electricity using wood pellets from BC and present the results below.

The mountain pine beetle (MPB) has caused extensive damage to trees in British Columbia. The infestation is expected to affect about 500 million m^3 of merchantable roundwood over three years. At least 40% or 200 million m^3 of MPB killed trees is forecast to remain unharvested. Kumar et al. (2005) suggest that this large-scale, concentrated source of woody biomass could be burned to generate green power.

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Technology Risks

The proponent would modify the current boiler by installing a fluidized bubbling bed (FBB). FBB technology is well known and reliable and the capital costs of retooling the Atikokan GS are credible at this level of pre-feasibility at $100,000,000. Risks associated with this technology seem minimal.

It is important to note that under the proposal suggested by the proponent, the Atikokan GS would be down-rated from 225 MW to 150 MW owing to physical limitations associated with passing from lignite - a high energy density feedstock (i.e. 24 GJ/BDT) to woody biomass - a relatively low energy density feedstock (i.e. 19 GJ/BDT).

Environmental Risks

There are two potential long-term environmental risks associated with the use of unutilized wood supply and forest harvest residues, namely nutrient depletion from harvested sites and reduced biodiversity.

The long-term effect of full-tree harvesting on nutrient losses in harvested sites are not clearly understood and could be questioned. Harvesting results in reduced plant uptake and can increase nutrient losses due to leaching. Alternatively, harvesting tends stimulate carbon turnover and nitrogen mineralization, thereby improving the fertility of forest soils. To date, the net effect of these processes on the productivity of harvested sites may offer a long term environmental risk. Indeed, undertakings to harvest logging residues are questioned in New Brunswick. FBi's knowledge on this issue is articulated as follows:

- Current full tree practices already remove nutrients from the forest floor and concentrate them on landings where the slash piles reduce the available land for growing trees by as much as 5%. Therefore the practice of slash collection may have a net positive impact on fiber growth;
- Nutrient-rich sites have a different level of tolerance to nutrient removal as compared to nutrient-poor sites. As such, it might be useful in targeting residue removal from nutrient-rich sites alone.

Forest harvest residues have ecological value in that they provide habitat for plant and animal wildlife, are a food source for decomposer organisms, represent a capital pool of nutrients to the soil, regulate water flow and play a role in long-term carbon storage. Removing slash from the harvest site can therefore impact negatively on biodiversity and alter biogeochemical cycles in forest ecosystems. On the other hand, removing logging slash can improve conditions for soil preparation and replanting and therefore enhance regeneration rates. In Finland about a third of harvest residues are left evenly distributed over the site to reduce nutrient losses and provide cover for wildlife.

Burning woody biomass emits CO_2 to the atmosphere. However, growing forests remove CO_2 from the atmosphere through photosynthesis. As such, forests actively

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participate in the short-term global carbon cycle and there is no net emission of carbon to the atmosphere when this material is burned. Alternatively, natural gas is a non-renewable fossil resource that does not participate in the global carbon cycle. Instead, natural gas can be regarded as a long-term carbon reservoir that, when burned, releases carbon that has been sequestered for millennia. In this way, burning natural gas generates anthropogenic CO_2 emissions that add to the atmospheric CO_2 burden.

Our research indicates that for a given level of power generation, CO_2 emissions from wood-fired boilers are roughly 2% greater than that from lignite-fired boilers and over three times that from natural gas-fired boilers (Table 19). Unlike woody biomass, CO_2 emissions from burning coal and natural gas are of fossil origin and, because these are non-renewable fuels, contribute to the atmospheric burden of CO_2.

Table 10 lists the greenhouse gas and contaminant emissions from the combustion of woody biomass as per APC's proposal. The following assumptions have been made:

- Gross generation of 1 million MWh and a biomass-to-power conversion efficiency of 36% were used to give a gross energy input of 10 million GJ/yr;
- Fuel is 100% woody biomass (i.e. unutilized wood supply, forest harvest residues, mill wood waste) with a moisture content of 50% and an energy density of 19 GJ/BDT;
- Fuel input of 526,000 BDT/yr or 1,052,000 green tonnes/yr;
- Greenhouse gas emission factors for green woody biomass of 950 g CO_2/kg (of woody biomass burned), 0.09 g CH_4/kg and 0.06 g N_2O/kg were used (Environment Canada, 2005) along with a net generation of 900,000 MWh/yr to compute emission factors in terms of mass per unit of net generation;
- Global warming potentials of 1, 23 and 310 were used for CO_2, CH_4 and N_2O, respectively;
- Uncontrolled contaminant emission factors for green woody biomass of 0.11 g SO_x/kg, 0.96 g NO_x/kg, 1.42 g PM/kg and 0.02 mg Hg/kg were used (EPA, 1995a) along with the reduction efficiencies listed in Table III of the executive summary and a net generation of 900,000 MWh/yr to compute emission factors for conditioned flue gas in terms of mass per unit of net generation.

Table 10. Greenhouse gas and contaminant emissions from burning woody biomass feedstocks at the Atikokan GS with stringent emission controls

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
100% Woody Biomass	1,021,000	1,130	300	330	20.0	22.0	80	89	3.6	4.0

Transportation Risks

The cost of transporting biomass is a significant variable which cannot be safely controlled. Indeed, freight rates will continue to increase with the rising cost of crude oil.

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Although CN Rail is identified as a project partner in the pre-proposal and will presumably offer favorable freight rates, the idea of using rail to move logging slash is not a realistic one. This material is scattered throughout the region, in areas without rail access and where distance to transfer points would make such a system cost prohibitive. Simply put, forest harvest residues are subject to the same types of logistical limitations as the transport of roundwood and do not lend themselves well to economic rail transport at the regional level. Therefore, the proponent needs to create a convincing model to support the assertion that a favorable freight rate would minimize project costs.

Project Risk Mitigation Strategies

FBi has undertaken discussions with APC to determine what risk mitigation measures can be taken.

With regard to feedstock procurement, the onus is on the proponent to demonstrate that the project does not create competition with traditional fiber users in the region. As part of the feedstock procurement strategy, the proponent will have to demonstrate tenure on several proven feedstock streams which would show resilience to shifting market conditions. This will be critical to address two needs:

- To gain wholesale support from various regional stakeholders;
- To secure flexible financing.

One simple task is to determine the actual need for additional biomass by the pulp and paper industry. This will enable the proponent to rule out competition issues.

With regard to retooling of the Atikokan GS, the proponent can secure performance warranties from the engineering firm that would be contracted to perform the work.

Economic Modeling

FBi has developed an economic model to assess the levelized unit energy cost associated with APC's proposed feedstock strategy and technology retrofits. The model was run on two scenarios:

1) Using woody biomass feedstocks (i.e. 287,000 BDT/yr of unutilized wood supply and 240,000 BDT/yr of forest harvest residues) and extensive boiler modifications (i.e. $100 million, including a $20 million variance on cost estimates of $80 million provided by the proponent). Delivered costs for the woody biomass feedstocks estimated by FBI's biomass inventory model were used (i.e. Schedule 1, Table 23). This fuel mix was assumed based on the following:

    - Waste bark from sawmills would be spoken for by the region's pulp and paper industry and therefore not available to the Atikokan GS;

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- 100% of the practical pool of forest harvest residues is dedicated to the Atikokan GS (i.e. 240,000 BDT/yr);
- Unutilized wood supply makes up the balance of the energy input at the Atikokan GS (i.e. 287,000 BDT/yr).

2) Using pelletized sawmill residues (i.e. 526,000 BDT/yr) from BC without modifications to the boiler. Here we assume a nominal conversion cost of $5 million. The landed cost of BC wood pellets in eastern Canada as provided by the BCWPMA was used (i.e. $180/BDT).

Further to the basic assumptions embedded in the model itself (see Schedule 3), the following assumptions were made:

- An annual gross generation of 1 million MWh was assumed to which a combined parasitic load and equivalent forced outage factor of 10% was applied to give a net generation of 900,000 MWh;
- Zero purchase/lease price for the Atikokan GS;
- Capital and annual operating costs for the various emission controls (flue gas desulfurization - SO_x, selective catalytic reduction - NO_x, electrostatic precipitator - PM/Hg) are $206 million and $2.6 million /yr, respectively.

Based on our findings, the levelized unit energy cost of electricity under APC's proposal using woody biomass feedstocks procured from northwestern Ontario would range from $89/MWh for uncontrolled emissions to $115/MWh for stringently controlled emissions (Table 11). Using wood pellets imported from BC is not a viable option for power generation at the Atikokan GS (Table 12). Depending on the extent of emission control, associated production costs are estimated between $129/MWh and $155/MWh.

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Table 11. Levelized unit energy cost for Atikokan Power Corporation's proposed operation using regional woody biomass feedstocks. Biomass is a presumed to be available and competition from the pulp and paper industry is not factored in

Net Generation (MWh)	**900,000**
Levelized Unit Energy Cost	
LUEC with EC ($/MWh net)	**$115**
LUEC without EC ($/MWh net)	**$89**
Electricity Production	
Electricity Available For Sale (MWh/yr)	900,000
Plant Assumptions	
Project Capital Cost with EC ($)	$306,000,000
Project Capital Cost without EC ($)	$100,000,000
Feedstock Requirement (BDT/yr)	527,000
Plant Economic Life (years)	20
Cost Assumptions	
Feedstock Cost ($/BDT, FOB Atikokan)	$87
Financing Assumptions	
Debt Financed Portion (%)	100%
Debt Finance Rate (%/yr)	5.0%
Income Tax Rate (%)	30%
Inflation Rate (%/yr)	2.2%

Cost Component	$/MWh	%
Project Capital		
with emission controls	$34	30%
without emission controls	$11	12%
Operations & Maintenance		
with emission controls	$31	27%
without emission controls	$28	31%
Fuel	$51	44%
LUEC		
with emission controls	$115	100%
without emission controls	$89	100%

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Table 12. Levelized unit energy cost for Atikokan Power Corporation's proposed operation using wood pellets from BC

Net Generation (MWh)	**900,000**
Levelized Unit Energy Cost	
LUEC with EC ($/MWh net)	**$155**
LUEC without EC ($/MWh net)	**$129**
Electricity Production	
Electricity Available For Sale (MWh/yr)	900,000
Plant Assumptions	
Project Capital Cost with EC ($)	$211,000,000
Project Capital Cost without EC ($)	$5,000,000
Feedstock Requirement (BDT/yr)	526,000
Plant Economic Life (years)	20
Cost Assumptions	
Feedstock Cost ($/BDT, FOB Atikokan)	$180
Financing Assumptions	
Debt Financed Portion (%)	100%
Debt Finance Rate (%/yr)	5.0%
Income Tax Rate (%)	30%
Inflation Rate (%/yr)	2.2%

Cost Component	$/MWh	%
Project Capital		
with emission controls	$23	15%
without emission controls	$1	0%
Operations & Maintenance		
with emission controls	$26	17%
without emission controls	$23	18%
Fuel	$105	68%
LUEC		
with emission controls	$155	100%
without emission controls	$129	100%

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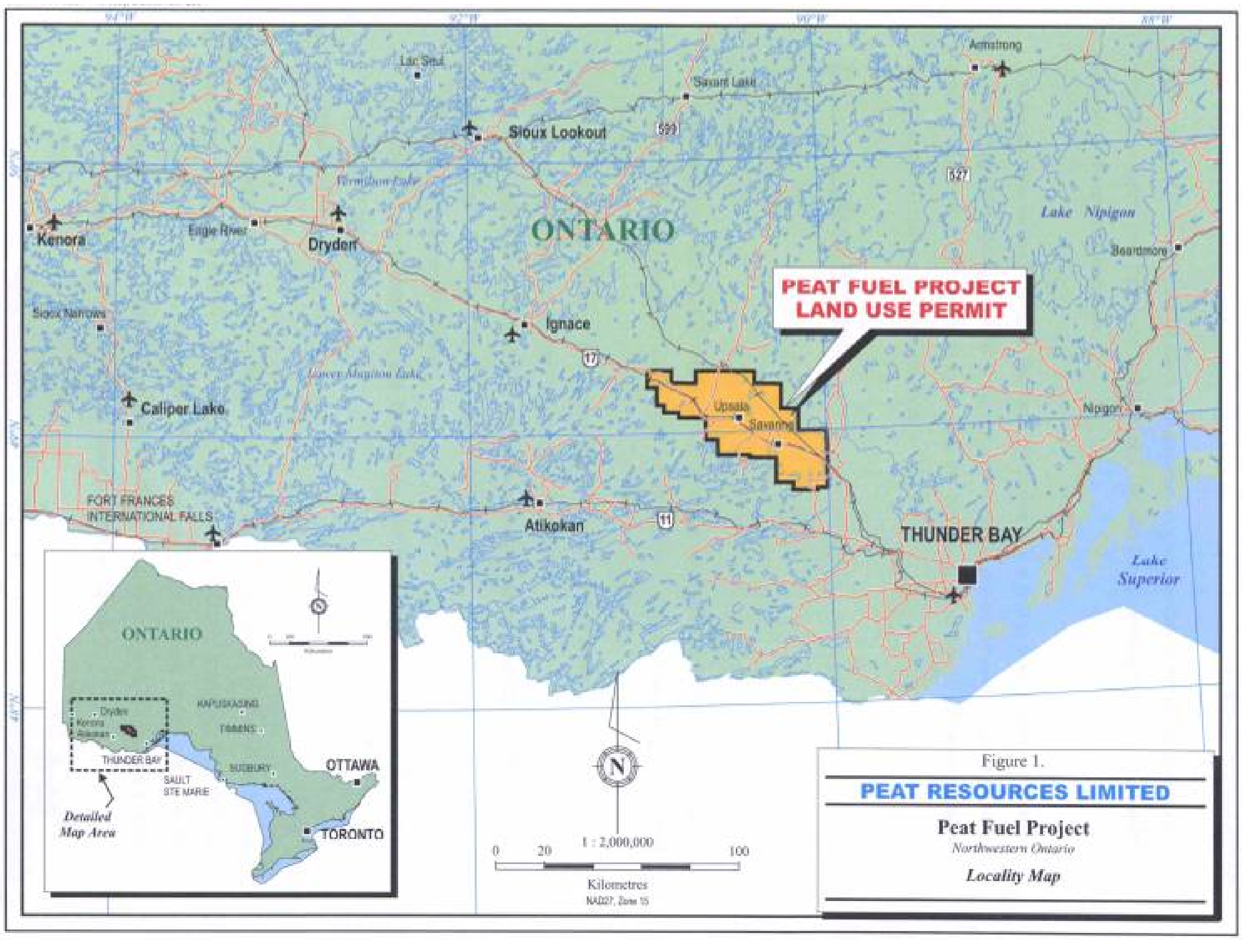
2.2 Peat Resources Ltd.

Background

Peat Resources Ltd. (PRL) is a publicly traded corporation formed in 1980 to explore, develop, produce and market peat as a fuel to substitute for coal at coal-fired generating stations. PRL plans on harvesting and processing fuel grade peat for sale to the Atikokan GS based on a purchase agreement between the two entities. The company currently holds exploration rights on 186,000 ha of property under land use permits issued by the MNR. The permit area is centered on the town of Upsala, about 130 km northwest of Thunder Bay (Figure 2).

Figure 2. Location of the Peat Resources Ltd. project area. Source: SENES (2006)



To date PRL has contracted consultants and engineering firms to conduct an exploration program and resource assessment (DST, 2005), a greenhouse gas monitoring program (SENES, 2006), a survey of rare plant and animal species (Foster and Harris, 2005) and to seek advice on acceptable peat harvesting and processing systems. The company has also consulted with two First Nation band councils and local community and business leaders to gauge regional support for and interest in the fuel peat project.

PRL has identified an indicated and measured resource of roughly 22 million tonnes (at 10% moisture content) and has proposed a harvesting operation that will extract 1 million tonnes of peat per annum over a period lasting at least 20 years.

In August 2005, the Thunder Bay District of the Ministry of Natural Resources received an Application to Develop from PRL to harvest peat on Crown lands near Upsala. The undertaking was to involve:

- Harvesting peat from two potential development areas southeast of Upsala (16,500 and 9,100 ha) with additional sites having been identified for future consideration. Initial screening by the MNR suggests that the peatlands under consideration would score as provincially significant;
- Harvesting and transfer of wet peat (90-95% moisture content) to on-site processing plants for drying and densification into fuel-grade peat pellets (10-30% moisture content);
- Transportation of the fuel-grade peat to market; and
- Rehabilitation of the harvested bogs.

Feedstock Strategy

The proponent plans to clear the peatland of trees (gradually, a small section of the bog will be open at a time) and use a wet-harvesting technique with on-site processing to produce 1,000,000 tonnes per year of dry fuel-grade peat pellets which exceeds the requirement for Atikokan GS. The operation would run continuously during the frost free season (200 days/year) and will consume roughly 500 ha of peatland per year.

In the proposed operations, an average depth of peat of 3 m would be extracted using excavators and pumped via pipelines to a series of on-site processing stations where the material would be mechanically dewatered, dried and compressed into a fuel-grade pellet. It is assumed that a biomass-powered generator (<10 MW) would be required if local power is insufficient.

PRL's processing methods are still under evaluation with third party commercial entities with proven technologies. Waste water removed during processing would be returned to the original excavation site, the impacts of which are not understood and warrant further investigation. However, the proponent indicates that waste water removed during processing would be returned back to the environment under controlled conditions. Fines will be removed from the waste water using settlement ponds or by filtering through the shallow parts of the undisturbed bog; pH levels will be adjusted according to the local environmental regulations. Other by-products of processing depend on the technology used, which has not yet been specified by PRL. LIDAR

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studies are underway to assess the elevation of the post-harvest landscape and preliminary evidence supported by ground-truthing by legal surveyors suggests an elevation differential within sites which opens the possibility for mitigation strategies for potential surface water contamination.

The fuel-grade peat pellets would be transported to the Atikokan GS via trucks or from rail loading facilities near Upsala. The implications in terms of existing infrastructure remain undefined.

Bog rehabilitation is anticipated through the stimulation of sphagnum growth on excavated areas. To date, most of the scientific research into bog restoration has been directed toward gravity-drained, dry-harvested peatlands used for horticultural peat production. This is a significant point of difference with the current proposal and at this point in time it is not known how well restoration techniques applied to dry-harvested bogs can be or needs to be transferred to wet-harvested sites. However, this may offer an advantage over dry harvesting rehabilitation. Indeed, the biggest challenge of the dry-harvested peatlands restoration is to raise the water table back to rewet the growing surface. Unlike the dry-harvesting system, PRL plans to keep the water table as high as possible, therefore restoration will require a lot less effort.

Moreover, it was pointed out to FBi that there may be losses of economic potential associated with ecotourism, harvest of medicinal plants, nutraceuticals and food from the forests. At this point in time, none of these issues have been quantified and it is not possible to ascribe a financial impact to them. However, our experience in this type of forest ecosystem for non timber forest products (excluding peat from this definition) is such that non timber forest products may represent upward of $10 per ha per annum (untested in the region) which is comparatively small to the anticipated revenues from peat.

PRL has modeled the effect of their operations on flooding in harvested bogs based on surface plots generated using LIDAR technology (Figure 3). The PRL bogs are sloped and preliminary results suggest that water will pond in topographic lows to ultimately cover between 0-30% of the area of individual bogs. These new open water areas may be rehabilitated by planting wild rice or creating fish habitat. Although originally wet-harvested, the relatively higher ground, that is, where the water table is below the post-harvest surface, would be analogous to a dry-harvested peatland ecosystem and could possibly support restoration attempts.

PRL's proposed fuel-grade peat pellet is targeted at 10-30% moisture with an energy density ranging from 18-22 GJ/BDT. The proponent reports that the final moisture content will be adjusted to meet the specific need and performance criteria at Atikokan GS.

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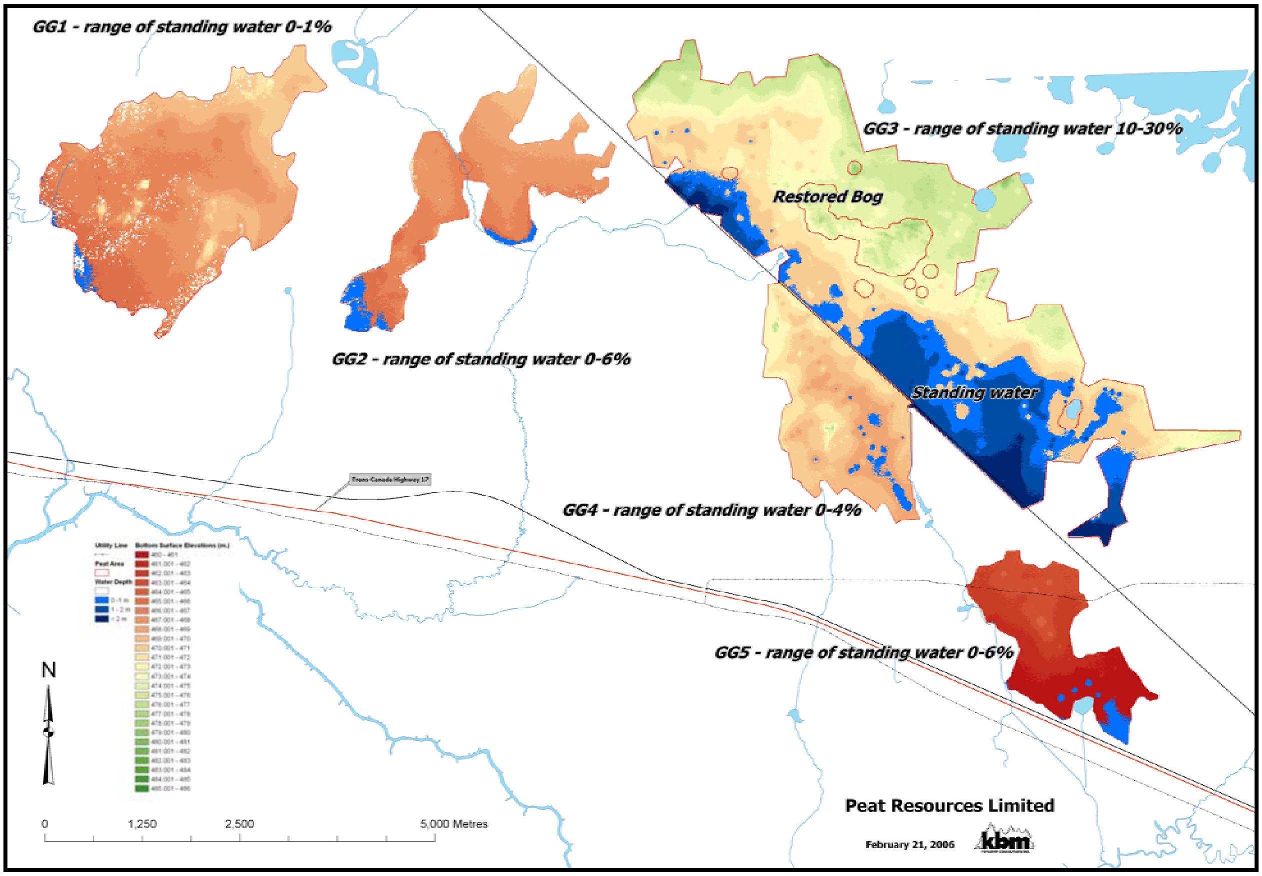
Figure 3. An estimate of the range of standing water in bogs following peat extraction by PRL



Based on an energy density of 18 GJ/BDT, roughly 570,000 BDT/yr of fuel-grade peat would be required to maintain production at the Atikokan GS. This is well within PRL's annual production target. PRL estimates the higher-end cost to harvest and process peat at $11/BDT and $39/BDT, respectively. The PRL peatlands fall within a haul distance of 180 km of the Atikokan GS and at $0.129/BDT-km, trucking costs (two-way) are assessed at $45/BDT. As such, the landed cost of fuel-grade peat supplied by PRL would be roughly $95/BDT or $5.30/GJ (Table 20C, D).

Three additional factors may affect the landed price of peat:

1) Capital cost for the plant that would harvest and dry the peat. At this point in time the final technology has not been firmed up, which may affect capital requirements;
2) Operating expenses, especially with regard to the final moisture content of the fuel-grade peat pellets. Indeed, the final delivery moisture content will impact the operating cost;
3) Stumpage fees aren't included in our model but we should expect MNR to contemplate some form of harvest tax. This amount is undetermined.

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The data provided to us from PRL is presumed to include variance associated with capital cost requirements, operating expenses and stumpage fees. We believe that the current pricing offers some room to recover unforeseen costs by the proponent. For example, as a crude comparable, the landed cost of peat at Finnish power plants averages $51/BDT or $3/GJ (Mr. J. Poikola, Pohjolan Voima, personal communication) which is just over half the cost to the Atikokan GS based on PRL's estimates.

Table 13. Landed costs of peat in Finland and at the Atikokan GS

Cost Component	$/GJ	
	Finland	Atikokan
Land	$0.40	$0
Production	$1.50	$2.90
Transportation	$1.20	$2.70
TOTAL	$3.10	$5.60

We point out that in Finland peat is normally sourced from within 80 km and burned at a moisture content of 45-50%. The cost of drying peat to 10-30% moisture and longer trucking distances would account for the added expense of PRL's peat. Also, the Finnish fuel peat industry is well-developed and costs are moderated by competition between suppliers. However, we emphasize that this is acrude comparable which suggests that the PRL operations should be economically viable.

Risk and Feasibility Analysis

There are three elements of risk associated with this project:

- Risk of not securing final environmental permitting to operate;
- Technological risks of failing to secure proper drying procedure;
- Social risks.

Risk of Not Securing Final Environmental Permitting to Operate

The development of peatlands for fuel or horticultural peat production involves several environmental issues that include:

- Provision of wildlife habitat and the protection of rare or unusual species;
- Release of stored carbon in relation to global climate change;
- Water quality aspects such as suspended solid discharge and changes in water chemistry;
- Water quantity factors such as runoff rates and flow attenuation;
- Air quality issues (i.e. dust control); and
- Reclamation/restoration issues.

Peat harvesting can lead to drastic and oftentimes irreversible changes in peatland ecosystems. Dry-harvested bogs are drained, cleared of vegetation and a thick layer of material is removed. Left alone, dry-harvested harvested sites rarely return to functional peatland ecosystems after abandonment because there is no seedbank and the harvested surface does not support the natural regeneration of bog vegetation. Indeed, drainage and peat extraction alters the physical and hydrological conditions necessary for Sphagnum moss re-establishment by lowering the water table and exposing relatively decomposed peat (van Seters and Price, 2001). However, it should be noted that PRL is not proposing a dry harvesting system. The wet harvesting system proposed by PRL offers a range of other mitigation and rehabilitation possibilities. In addition, the ability to re-wet the subsurface may offer a unique rehabilitation possibility which surpasses dry harvesting operations and their ensuing rehabilitation.

Loss of wildlife habitat, particularly waterfowl nesting areas, is an issue of national and international concern. The diverse range of vegetation and occurrence of open water make swamps and marshes favored habitat for waterfowl and other wildlife species. Viable fuel-grade peat deposits tend to occur in bogs which, in contrast, usually have a minimum of open water, low diversity of vegetation and limited cover for waterfowl or other bird nesting purposes. The number of waterfowl and wildlife species and the total wildlife populations in bogs are generally lower in comparison to other wetland classes or to mineral soil ecosystems (Daigle and Gautreau-Daigle, 2001).

PRL must receive approval from the MNR for the rights to harvest peat. MNR has followed the process and screening criteria outlined in the *Class Environmental Assessment for MNR Resource Stewardship and Facility Development Projects* (RSFD Class EA). Whereas PRL has sought a ministerial letter of approval to proceed with individual environmental assessment, it is possible that environmental permitting may be delayed due to the uniqueness of the proposed operations.

Peat harvesting raises multi-jurisdictional issues. Notably, the project has the potential to impact air and water quality within the peatlands and on adjacent lands and waters as a result of harvesting and processing operations. The nature and extent of impacts, within and beyond the excavated areas, are unknown at this point in time, in part because supporting scientific literature for wet-harvesting methods is lacking and in part because PRL has yet to define how the peat will be processed. The drying process will involve some combination of mechanical compression and heat derived from biomass combustion and/or electricity and will generate waste water, airborne emissions and noise.

Likewise, the ratio of energy input to output for the production system is unknown. However, based on a comparable pricing structure from Finland, the input cost of energy for production is embedded within the sales cost to the end-user.

A transportation network will be required to support the construction of facilities, harvesting, peat processing and to support highway or rail transport of processed peat fuel to markets.

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The proposed harvest areas are in bogs and fens which have been preliminarily assessed as provincially significant wetlands. There are unidentified, long term impacts to the values and functions of these features. The Provincial Policy Statement under the *Planning Act* states that development and site alteration shall not be permitted in significant wetlands in the Canadian Shield north of Ecoregions 5E, 6E and 7E unless it has been demonstrated that there will be no negative impacts on the natural features or their ecological functions.

Ultimately, the proponent must demonstrate whether the creation of open water sites within provincially significant wetlands constitutes a potential improvement in terms of their biodiversity and is at least neutral in terms of their ecological function in the broader landscape.

MNR has recognized the following as potential environmental impacts resulting from peat harvesting operations in the region:

- Changes to water recharge and/or water quality in nearby streams and lakes;
- The impacts of hydrological changes on provincially significant wetlands, within and adjacent to the project area;
- Loss of bog and fen wetland types and associated impacts to avian species and other wildlife that depend on these specific wetland habitats;
- Sedimentation and changes to surface water quality and quantity impacting walleye habitat and the recreational fishery of Lac des Milles Lacs. One of the proposed harvest sites is directly adjacent to Lac des Milles Lacs, a regionally significant sport fishery which supports resident day-use and non-resident resource-based tourism;
- The feasibility of successful bog restoration under wet-harvesting methods. Although dry-harvested bogs have been cost-effectively restored in other jurisdictions, wet-harvesting may introduce unforeseen ecological variance and reduce the efficacy of restoration initiatives.

MNR's *Resource Stewardship and Facility Development Class EA* was designed to address repetitive resource management undertakings for which environmental impacts can be predicted and mitigated.

While there are standard mitigation techniques that can be applied to components of the project (i.e. road or site-specific facility construction), this proposal has a number of potentially significant, landscape-scale impacts. Contingent on the success of this project, more peat extraction proposals are likely within the immediate area. The cumulative hydrological impacts of additional operations need to be considered.

MNR's policy for peat land exploration and development provides direction related to exploration activities but has not been fully developed to deal with large scale peat harvesting on the scale identified in this application. In addition, unlike other non-

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renewable resources (i.e. minerals, aggregates), there is no resource-specific legislation governing peat exploration and extraction. The *Public Lands Act* provides limited support around administrative, but not environmental, considerations.

In the assessment of this undertaking, factors such as magnitude, values of features, duration and frequency of the project, the likelihood of effects and irreversibility were all taken into consideration by the MNR. As a result, it has been determined that the project goes well beyond the intent and scope of a Class EA. This is, in terms of provincial and federal experience, a 'one-off' type of project which will likely precipitate considerable interest among environmental stakeholders and the general public. As such, it is recommended for categorization as a Class D – individual environmental assessment.

The proponent has initiated a voluntary agreement to undertake an Environmental Assessment with the Ministry of Environment and is awaiting ministerial signature before proceeding with the submission of Terms of Reference (see Schedule 6). Once this voluntary agreement has been signed the permitting process is expected to last between 6 to 12 months.

This area has had relatively little life science inventory outside of protected areas, and the status of vascular plants, birds, and odonates (dragonflies and damselflies) is poorly known. Wetlands, and the species that depend upon them, are a significant component of the area's biodiversity, and warrant consideration in land use management. A field study conducted by an arm's length contracting firm on behalf of PRL showed that the proposed harvest areas within Ecodistrict 3W-2 contribute less than 3% of the Ecodistrict total, which suggests that this is not a significant portion of the Ecodistrict (Northern Bioscience, 2006).

In general, undisturbed northern peatlands are net C sinks because they absorb more C as carbon dioxide (CO_2) than they emit as methane (CH_4). In other words, these ecosystems slowly accumulate C because the rate of C fixation through photosynthesis by bog vegetation exceeds the rate of anaerobic decomposition at depth in the deposit. Indeed, peatlands are a substantial reservoir of C in northern latitudes, making up at least one fifth of the world's total soil C pool - an amount equivalent to roughly half the amount of CO_2 in the atmosphere.

Dry-harvesting peat for fuel alters the C balance of peatland ecosystems and their net emission of greenhouse gases to the atmosphere by two mechanisms:

- Draining the site enhances oxygen diffusion into the surface layer, thereby increasing the rate of aerobic decomposition. This tends to increase CO_2 emissions and decrease CH_4 emissions;
- By removing the living biomass from the peatland surface, CO_2 uptake falls to zero until such time as restoration has been conducted. Opening a small section at a time should minimize this effect.

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The current proposal may differ from the normally accepted dry harvesting impact on C evolution. When virgin peatlands are dry-harvested, they switch from being C sinks to C sources and, if not actively rehabilitated, will remain as such for hundreds to thousands of years. Dry-harvested bogs that have been successfully restored by re-introducing sphagnum can revert to being C sinks in the short-term. Using wet harvesting, with the potential to re-wet the surface which should help revegetation and return ecosystems to C sinks within 5 years.

To our knowledge, the wet-harvesting technique put forward by PRL is not commonly used and, as such, information on the C balance from wet-harvested peatlands could not be found. PRL's harvesting and processing operation is expected to create areas of standing water (Figure 3) that could become CH_4 hot-spots due to the onset of anaerobic conditions and the surplus availability of dissolved organic C in the return effluent. Filtration of waste water, as proposed by PRL may resolve this issue. Moreover, PRL plans to discuss the merits of creating standing water (flooded areas) with interested parties, such as MNR, Lakehead University, related experts, environmentalists, and Duck's Unlimited. The amount of standing water can be pre-designed from a very low range to higher ranges, based on the drainage controls that currently exist in the area and that have been surveyed by legal surveyors

LIDAR studies conducted by a third party on behalf of PRL may suggest a mitigation strategy as the imagery shows that the resulting flooded would range in the order of 0-30% of the harvested area with a median in the order of roughly 5-8%. This suggests that a carbon mitigation strategy is possible for the harvested areas.

The situation of flooding can be taken as an analogue to a beaver pond. Many studies have shown beaver ponds and their associated wetlands as large sources of CH_4 (Yavitt et al., 1992; Bubier et al., 1993). Roulet et al. (1997) measured CO_2 and CH_4 fluxes on a beaver pond for 120 days. Their results indicate that the beaver pond was a large source of CO_2 and CH_4 for the entire study period, having released more than 190 g C m^{-2}. A readily available source of C is required to sustain such a large gaseous efflux. If unfiltered, the process water returned to sites excavated by PRL will contain very high levels of dissolved organic C, as will the flooded peat substrate which will be saturated and therefore devoid of oxygen. These conditions are ideal for methane production and the areas of standing water created as a result of PRL's operations could play a disproportionately large role in the carbon exchange of the harvested peatlands.

Table 14 lists the greenhouse gas and contaminant emissions from the combustion of fuel-grade peat supplied to the Atikokan GS by PRL. The following assumptions have been made:

- Gross generation of 1 million MWh and a biomass-to-power conversion efficiency of 36% were used to give a gross energy input of 10 million GJ/yr;
- Fuel is 100% fuel-grade peat with a moisture content of 20% and an energy density of 18 GJ/BDT;

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- Fuel input of 556,000 BDT/yr or 695,000 green tonnes/yr;
- Greenhouse gas emission factors for peat combustion of 1,690 g CO_2/kg, 0.09 g CH_4/kg and 0.06 g N_2O/kg were used (Uppenberg et al., 1999) along with a net generation of 900,000 MWh/yr to compute emission factors in terms of mass per unit of net generation;
- Global warming potentials of 1, 23 and 310 were used for CO_2, CH_4 and N_2O, respectively;
- Uncontrolled contaminant emission factors for green woody biomass of 4.86 g SO_x/kg and 2.88 g NO_x/kg were used (Government of Ireland, 2005) along with the reduction efficiencies listed in Table III of the executive summary and a net generation of 900,000 MWh/yr to compute emission factors for conditioned flue gas in terms of mass per unit of net generation. Reliable emission factors for PM and Hg could not be found for peat-fired boilers.

Table 14. Greenhouse gas and contaminant emissions for the Atikokan GS burning fuel-grade peat

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
100% Fuel-Grade Peat	1,189,000	1,320	70	730	680	750	n/a	n/a	n/a	n/a

n/a = not available

Technological Risks

At this point the final harvesting and processing technologies are not disclosed owing to ongoing negotiations with technology providers. Wet-harvesting of peat for commercial processing into fuel has not been attempted in Ontario and there are no precedents elsewhere in Canada.

Discussions with Babcock & Wilcox Canada Ltd. suggest that if peat is used at 50% moisture, capital expenditures in the order of $100 million would be required to convert from lignite coal to peat pellets. Firing peat at 50% moisture is equivalent to converting from lignite to forest biomass. However, as proposed by PRL, peat in the moisture range of 10-30% to emulate lignite requires minimum capital cost at the Atikokan GS. For the purpose of the model represented below we are using $5 million as the cost to retrofit the boiler and $206 million as the cost of emission controls.

In burn trials conducted by Ontario Hydro (Vasquez et al., 1990), the combustion of dried peat was found to be problematic as the low density of the feedstock led to a decrease in flame stability. However, the use of pelletized peat, which would have to be pulverized before entering the boiler, can resolve this issue and emulate lignite.

Social Risks

The Lac des Milles Lacs First Nation's Reserve 22A1 is immediately adjacent to one of the proposed development areas. Informal discussions have taken place with the local

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community. There are unknown impacts upon native hunting, fishing and trapping rights. Conversely, there are potential social and economic benefits which have yet to be quantified. With its proximity to these federal lands and potential impacts on migratory bird habitat, this proposal clearly has *Canadian Environmental Assessment Act* considerations. In addition, FBi has consulted with the Band Administrator and confirmed that the band welcomes this project under the assumption that it meets the requirements of Elders for environmental protection (see Schedule 5).

As currently conceived, this project has a minimum twenty-year life span and would result in new road and facility development. The economic and social impact is expected to be significant. PRL is projecting that approximately 200 direct jobs would be associated with the main project with further job potential in wild rice harvesting, chipping slash piles from tree harvesting operations, and other spin-off opportunities.

Although the proponent has been active in garnering support from the municipalities of Atikokan and Thunder Bay, there is a risk that local landowners and other stakeholders in the area, especially tourist lodge operators, will dispute peat harvesting. The center of operations is in an unorganized area where there are no municipal structures to oversee and plan for development. PRL plans to spread its operations over several districts to minimize the impact on any one watershed area, as well as spread the job opportunities over the communities of Thunder Bay, Upsala, Ignace, and Atikokan.

Project Risks Mitigation Strategies

FBi has consulted with PRL to determine project risk mitigation measures that can be taken.

With regard to environmental permitting, while waiting for a ministerial letter of approval to proceed with Individual EA, the company has prepared terms of references (see Schedule 6) and has begun discussions with stakeholders including two First Nations (mentioned above) and lodge operators on Lac de Mille Lacs. According to PRL, the stakeholders consulted thus far are supportive of the project.

Furthermore, the extent of flooding as a result of PRL's peat harvesting and processing operations is being assessed based on LIDAR imagery, existing topography and control elevations at existing culverts. Figure 3 shows the peat bogs after excavation has taken place and is a preliminary look at the post-harvest range of standing water. This modeling approach enables PRL to predict the fate of residual water from their operations and to develop a post-harvest design for the bogs. PRL believes that Figure 3 shows that it will be possible to extract peat and leave behind a very acceptable restored bog that will continue to control and filter the overland flows, and in the lower areas, offer standing water areas that can be designed for waterfowl, wild rice, and other wetland uses.

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Carbon emissions from the post-harvest landscape can be reduced by removing dissolved organic compounds from processing effluents and/or by re-vegetating the harvested bogs which should lead to increased C absorption especially if fast growing species are introduced in the ecosystem.

With regard to technology, PRL is reporting progress in its investigation of secondary drying technologies and is confident that a small-scale pilot project for harvesting, drying and pelletization could be in place within six months. Given that there are three possible drying technologies involved from three different providers, the project risks of not securing a cost effective technology are minimized.

With regard to the technical feasibility of burning peat at the Atikokan GS there will be a need to conduct burn trials with pelletized peat. The proponent reports that this can be achieved with 500 BDT of material and may require a week of testing. This should confirm that there is no technological risk associated with conversion of the Atikokan GS.

Economic Modeling

An economic model was developed by FBi to assess the levelized unit energy cost at the Atikokan GS using fuel-grade peat as the sole feedstock. Further to the fundamental assumptions embedded in the model itself (see Schedule 3), the following assumptions were made:

- An annual gross generation of 1 million MWh was assumed to which a combined parasitic load and equivalent forced outage factor of 10% was applied to give a net generation of 900,000 MWh;
- Annual feedstock requirement of 556,000 BDT is met entirely by fuel-grade peat pellets;
- Landed cost of peat estimated by FBi's biomass inventory model was used (i.e. Table 23);
- Zero purchase/lease price for the Atikokan GS;
- Peat is direct-fired in the existing boiler at the Atikokan GS;
- Costs of converting the boiler are set at $5 million which includes $1 million in contingency based on the assumption that no substantial conversion costs are to be incurred as per discussions with Babcock &Wilcox (Mr. B. Roberts, Babcock & Wilcox, personal communication). Costs to equip the Atikokan GS with stringent emission controls are set at $206 million with an annual operating cost of $2.6 million/yr based on data presented by DSS & RWDI (2005).

Based on the preliminary harvesting and processing costs put forward by PRL, our model estimates a levelized unit energy cost range of $82/MWh to $108/MWh depending on the extent of emission controls used (Table 15).

Table 15. Levelized unit energy cost for the use of fuel-grade peat at the Atikokan GS

Net Generation (MWh) **900,000**

Levelized Unit Energy Cost	
LUEC with EC ($/MWh net)	**$108**
LUEC without EC ($/MWh net)	**$82**

Electricity Production	
Electricity Available For Sale (MWh/yr)	900,000

Plant Assumptions	
Project Capital Cost with EC ($)	$211,000,000
Project Capital Cost without EC ($)	$5,000,000
Feedstock Requirement (BDT/yr)	607,000
Plant Economic Life (years)	20

Cost Assumptions	
Feedstock Cost ($/BDT, FOB Atikokan)	$95

Financing Assumptions	
Debt Financed Portion (%)	100%
Debt Finance Rate (%/yr)	5.0%
Income Tax Rate (%)	30%
Inflation Rate (%/yr)	2.2%

Cost Component	$/MWh	%
Project Capital		
with emission controls	$23	22%
without emission controls	$1	1%
Operations & Maintenance		
with emission controls	$26	24%
without emission controls	$23	28%
Fuel	$58	54%
LUEC		
with emission controls	$108	100%
without emission controls	$82	100%

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2.3 Triangle Energy Group

Background

Triangle Energy Group (TEG) is a group of investors from Minnesota with considerable experience in power generation. They promote a whole-tree combustion technology that is unproven at the level required at the Atikokan GS. TEG is proposing to own and operate the Atikokan GS and is considering unutilized wood supply from Crown Lands, forest harvest residues and biomass from energy plantations as primary feedstocks.

The following edited excerpt is from the Electric Power Research Institute Journal (January/February 1994) and gives a summary of test results of TEG's technology:

> The first test site was at St. Johns University in Collegeville, Minnesota, utilizing their 1.6 MW boiler. Feeding the unit 4 ft (1.3 m) tree sections, the test was able to attain a high enough temperature and heat release rate to allow an efficient superheat cycle typical of the largest coal plants in the country. The test demonstrated the capability to go beyond the 1590°C required in typical utility boilers. The test limitation was not the fuel but the boiler itself.
>
> The next test was conducted at Northern States Power, in a formerly coal-fired 10 MW unit that was converted to accept wood fuel. The challenge for this experiment was to reach an output equivalent to 30% of the full capacity (i.e. 3 MW) which would indicate that the technology could succeed on a utility scale. The results exceeded the test objectives by 300% by achieving a peak output equivalent to 90% of the full capacity (i.e. 9 MW) while maintaining an average output of 200% of the test objectives by maintaining 6-7 MW during sampling periods throughout the 100-hour test.
>
> Just as significant were the favorable data on emissions. At the time, the Environmental Protection Agency said the NO_x levels were the lowest ever measured for solid fuel in the United States. This did not come as a complete surprise, since clean wood contains only about one-fourth the nitrogen of an average coal, and conventional wood-fired plants generally emit 45% less NO_x that coal-fired units. SO_2 emissions from the test were almost unmeasurable, being far below the levels set by air quality regulations. Because clean wood has such a low sulfur content (at least five times lower than that of a low-sulfur coal), a very low SO_2 level can be achieved without the aid of the costly SO_2 removal systems used at many coal plants.
>
> Particulate emissions in the test were also low, even without the aid of a particulate collection device. This is due primarily to the low ash content of wood, which is typically between one-twentieth and one-tenth of the ash content of coal. Although boiler and/or plant efficiencies were not measured directly, a Whole Tree Energy™

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system is expected to have significantly better cycle efficiency than a comparable coal fired plant. This improved efficiency is derived primarily from two characteristics. First, the systems have lower total air requirements (i.e. they operate closer to theoretical air requirements) resulting in higher boiler efficiency. Second, the whole tree systems use significantly less “station use” electric energy (i.e. fewer parasitic loads) resulting in more MWh to sell for equivalent fuel input.

Discussions with the proponent have revealed that their whole tree technology has not been deployed since the publication of the article in 1994. However, the proponent has secured a letter of support from a reputable boiler maker suggesting that the technology risks should be mitigated by providing performance guaranties.

Feedstock Strategy

TEG’s feedstock procurement strategy is purely qualitative and based on the assumption that forest harvest residues, energy plantations, and whole trees from Crown Lands are available in the region. It is similar in all points to the strategy proposed by Atikokan Power Corporation.

Unutilized Wood Supply

TEG’s technology is proven for whole trees and they are proposing to use unutilized wood supply as the primary feedstock to the project. They have identified rail transport as a means to extend the collection area and thereby expanding the number of timber stands available to meet biomass requirements at the Atikokan GS.

Forest Harvest Residues

The proponents have stated that logging slash has little if any associated procurement cost (i.e. stumpage fee) and that it can be recovered, baled and transported from a much wider draw area than distances considered in an economic analysis where stumpage fees were assumed. Furthermore, TEG claims that there are potential rail-transport options that would significantly extend the catchment area for forest harvest residues.

Energy Plantations

The proponents have suggested making use of biomass from energy plantations. In TEG’s opinion, hybrid species timber farming has the added benefit of significantly increased timber growth rates when compared with natural stands. This is not a short-term feedstock option since there are no energy plantations in the immediate region.

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Technology for Conversion

The proponent proposes to retool the Atikokan GS in order to accommodate the new feedstocks. The following additions and modifications would be required:

- Replace existing boiler bottom with a new ash pit and char burnout zone;
- Install water-wall headers at the cut;
- Add whole tree injection pit and combustion box with individual feed rams using a floor supported structural design;
- Modify original combustion air system to provide three-stage combustion;
- Provide a combination mechanical-water seal between the new whole tree combustion system components and the modified original boiler water-walls;
- Revise boiler water steaming loops to encompass modifications to original water-walls and the new steaming circuits added as part of the new timber combustion pit;
- Install additional boiler flue gas to air heater system in the ducts including fans and ductwork to supply drying air to the timber drying dome;
- Install timber drying dome and associated conveyor and material handling systems needed to dry, store and feed whole trees and other baled wood fibre to the boiler.

According to TEG, fuel-grade peat could be used as fuel in their whole tree combustion system so long the results of a complete fuel and ash analysis met certain minimum criteria. The ash chemistry must be understood since certain alkali compounds in large percentages can cause severe fouling on the boiler water-walls and in the super heat section, thus requiring frequent boiler maintenance outages.

Capital costs for the boiler retrofits are estimated by the proponent at less than $85 million.

Project Risks Mitigation Strategies

FBi has undertaken discussions with TEG to determine what risk mitigation measures can be taken.

With regard to feedstock procurement, the onus is on the proponent to demonstrate that the project does not create competition with traditional fibers users in the region. As part of the feedstock procurement strategy it will have to demonstrate tenure on several proven feedstock streams which would show resilience to shifting market conditions. This will be critical to address two needs:

- To gain wholesale support from various regional stakeholders;
- To secure flexible financing.

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With regard to retooling of the Atikokan GS, the proponent can secure performance warranties from the engineering firm that would be contracted to retool the Atikokan GS.

Economic Modeling

TEG's proposal is very similar to that of Atikokan Power Corporation's (APC) both in terms of feedstock strategy and conversion costs.

As such, the levelized unit energy cost at the Atikokan GS for TEG's proposal is taken to equal APC's at $89/MWh to $115/MWh depending on the extent of emission control.

The following assumptions were made:

- An annual gross generation of 1 million MWh was assumed to which a combined parasitic load and equivalent forced outage factor of 10% was applied to give a net generation of 900,000 MWh;
- Annual feedstock requirement of 526,000 BDT is met using 287,000 BDT of unutilized wood supply and 239,000 BDT of forest harvest residues. This is the fuel mix used in APC's LUEC model and is based on the same rationale;
- Landed cost of unutilized wood supply and forest harvest residues estimated by FBi's biomass inventory model was used (i.e. Schedule 1, Table 23);
- Zero purchase/lease price for the Atikokan GS;
- Woody biomass is direct-fired in TEG's whole-tree combustion system;
- Boiler retrofit costs are set at $100 million which includes $20 million in contingency based on estimates provided by the proponent. The capital and annual operating costs associated with adding stringent emission controls are set at $206 million and $2.6 million/yr, respectively (DSS & RWDI, 2005).

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Table 16. Levelized unit energy cost for Triangle Energy Group's proposed operation using regional woody biomass feedstocks. Biomass is a presumed to be available and competition from the pulp and paper industry is not factored in

Net Generation (MWh)	**900,000**
Levelized Unit Energy Cost	
LUEC with EC ($/MWh net)	**$115**
LUEC without EC ($/MWh net)	**$89**
Electricity Production	
Electricity Available For Sale (MWh/yr)	900,000
Plant Assumptions	
Project Capital Cost with EC ($)	$306,000,000
Project Capital Cost without EC ($)	$100,000,000
Feedstock Requirement (BDT/yr)	527,000
Plant Economic Life (years)	20
Cost Assumptions	
Feedstock Cost ($/BDT, FOB Atikokan)	$87
Financing Assumptions	
Debt Financed Portion (%)	100%
Debt Finance Rate (%/yr)	5.0%
Income Tax Rate (%)	30%
Inflation Rate (%/yr)	2.2%

Cost Component	$/MWh	%
Project Capital		
with emission controls	$34	30%
without emission controls	$11	12%
Operations & Maintenance		
with emission controls	$31	27%
without emission controls	$28	31%
Fuel	$51	44%
LUEC		
with emission controls	$115	100%
without emission controls	$89	100%

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2.4 Municipal Solid Waste from Toronto

Background

Removing recyclable and non-combustible materials from municipal solid waste (MSW) produces an upgraded fuel known as refuse-derived fuel (RDF). RDF can be direct-fired or gasified alone or blended with other fuels to produce steam to generate electricity.

Processing MSW into RDF in Toronto and shipping it to the Atikokan GS as a biomass feedstock represents a possible solution to at least half of Toronto's current garbage situation and to keeping the Atikokan GS on-line. Our findings indicate that the City of Toronto ships roughly 80% or 1.2 million tonnes of its solid waste to Michigan for disposal at a cost of $51 to $54/tonne.

This amount of garbage could be processed into 380,000 BDT/yr of RDF at a landed cost of $79/BDT or $4.40/GJ at the Atikokan GS depending on revenues generated through tipping fees at the RDF plant and the sale of recyclables recovered in the process (Table 23C, D, E).

It is noteworthy that roughly 550,000 tonnes of non-combustible material (i.e. metals, glass, appliances and hazardous waste) separated out of the RDF feed would still have to be disposed of through a combination of recycling and landfilling. Processing MSW into RDF could significantly increase Toronto's diversion rate and add to revenues generated from the sale of recyclable materials.

RDF is used to generate electricity in several countries, including the United States, Japan, Finland, Sweden and Germany. Most RDF-fired power plants use spreader stoker boilers and fire fluff RDF in a semi-suspension. Emissions of particulate matter, acid gases and mercury are of prime concern in waste-to-energy facilities. However, technologies capable of cleaning the flue gases of particulate matter, sulfur dioxides, halides (i.e. chlorine, fluorine), nitrogen oxides and mercury and other trace elements have been demonstrated. There are several RDF combustion plants operating in the United States that report emissions well below all federal, state and local air emission requirements. By-products such as fly ash, aggregate and bottom ash residues can be recycled for use in cement manufacturing, mine reclamation and road construction.

Capital costs for an RDF processing facility tied to a waste-to-energy power plant range from $85 to $145 per kW of capacity. As such, capital costs for an RDF processing facility capable of supplying the amount of RDF required by the Atikokan GS would range from $19 to $33 million. The possibility of retooling any of Toronto's transfer stations with RDF processing lines and associated capital and operational costs were not explored in this study.

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Environmental Risks

Contaminant emissions are the greatest environmental risk associated with burning RDF which, compared to other boiler fuels, contains high levels of nitrogen, halides and metals. However, combustion chamber controls and flue gas conditioning technologies can be used to greatly reduce these emissions.

The Atikokan GS is equipped with low NO_x burners to control NO_x emissions and cold-side electrostatic precipitators to remove particulate matter from the flue gas. Emission control devices for acid gases or mercury are not used. Our findings indicate that the Atikokan GS currently emits more SO_2 from burning lignite (i.e. 5,500 tonnes SO_2/yr) than it would burning a typical RDF feed (i.e. 1,400 tonnes SO_2/yr) in a boiler without an SO_2 control device (Table 19).

Table 17 lists the greenhouse gas and contaminant emissions from the combustion of refuse derived fuel and woody biomass at the Atikokan GS. The following assumptions have been made:

- Gross generation of 1 million MWh and a biomass-to-power conversion efficiency of 36% were used to give a gross energy input of 10 million GJ/yr;
- Fuel mix is 60% refuse derived fuel and 40% woody biomass (i.e. unutilized wood supply, forest harvest residues, mill wood waste)
- Refuse derived fuel input of 380,000 BDT/yr or 422,000 green tonnes/yr with a moisture content of 10% and an energy density of 15 GJ/BDT;
- Woody biomass fuel input of 227,000 BDT/yr or 454,000 green tonnes/yr with a moisture content of 50% and an energy density of 19 GJ/BDT;
- Greenhouse gas emission factors for green woody biomass of 950 g CO_2/kg (of woody biomass burned), 0.09 g CH_4/kg and 0.06 g N_2O/kg were used (Environment Canada, 2005) along with a net generation of 900,000 MWh/yr to compute emission factors in terms of mass per unit of net generation—note that carbon offsets are not included in the CO_2 balance owing to the fact that carbon offsets must be incremental to current levels of silviculture and afforestation programs;
- Greenhouse gas emission factors for refuse derived fuel of 1,340 g CO_2/kg (of refuse derived fuel burned) and 0.03 g N_2O/kg were used (EPA, 1995b) along with a net generation of 900,000 MWh/yr to compute emission factors in terms of mass per unit of net generation. An emission factor for CH_4 for refuse-derived fuel could not be found;
- Global warming potentials of 1, 23 and 310 were used for CO_2, CH_4 and N_2O, respectively;
- Uncontrolled contaminant emission factors for green woody biomass of 0.11 g SO_x/kg, 0.96 g NO_x/kg, 34.8 g PM/kg and 0.02 mg Hg/kg were used (EPA, 1995a) along with the reduction efficiencies listed in Table III of the executive summary and a net generation of 900,000 MWh/yr to compute emission factors for conditioned flue gas in terms of mass per unit of net generation;

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- Uncontrolled contaminant emission factors for refuse derived fuel of 1.45 g SO_x/kg, 2.51 g NO_x/kg, 34.8 g PM/kg and 3 mg Hg/kg were used (EPA, 1995b) along with the reduction efficiencies listed in Table III of the executive summary and a net generation of 900,000 MWh/yr to compute emission factors for conditioned flue gas in terms of mass per unit of net generation.

Table 17. Greenhouse gas and contaminant emissions for the Atikokan GS burning refuse derived fuel and woody biomass feedstocks

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
60% Refuse Derived Fuel	565,000	1,100	350	680	160	322	880	1,720	300	490
40% Woody Biomass	349,000	1,130	127	330	14.4	22.0	26.5	89	1.5	4.0
TOTAL	914,000		477		174		907		302	

Economic Modeling

At 15 GJ/BDT, the 380,000 BDT/yr of RDF imported from Toronto would satisfy almost 60% of the gross energy input to the Atikokan GS. We have modeled the levelized unit energy cost at the Atikokan GS using RDF as the primary feedstock based on the following assumptions:

- An annual gross generation of 1 million MWh was assumed to which a combined parasitic load and equivalent forced outage factor of 10% was applied to give a net generation of 900,000 MWh;
- The fuel mix is composed of the entire supply of refuse derived fuel from Toronto (i.e. 380,000 BDT/yr) with forest harvest residues making up the balance of the energy input (i.e. 226,000 BDT/yr). Unutilized wood supply and mill wood waste were not used here because of presumed competition with the region's sawmilling and pulp and paper industries;
- Landed cost of refuse derived fuel and unutilized wood supply estimated by FBi's biomass inventory model was used (i.e. Schedule 1, Table 23);
- Zero purchase/lease price for the Atikokan GS;
- Boiler retrofit costs are set at $200 million which includes $20 million in variance, as per discussions with Babcock & Wilcox (Mr. B. Roberts, Babcock & Wilcox, personal communication);
- Capital and annual operating costs associated with adding stringent emission controls are set at $206 million and $2.6 million/yr, respectively (DSS & RWDI, 2005).

Our model estimates the LUEC of power generation using RDF as a primary feedstock at $114/MWh for uncontrolled emissions and $140/MWh for controlled emissions (Table 18).

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Table 18 Levelized unit energy cost at the Atikokan GS using refuse derived fuel as the primary feedstock

Net Generation (MWh)	**900,000**
Levelized Unit Energy Cost	
LUEC with EC ($/MWh net)	**$140**
LUEC without EC ($/MWh net)	**$114**
Electricity Production	
Electricity Available For Sale (MWh/yr)	900,000
Plant Assumptions	
Project Capital Cost with EC ($)	$406,000,000
Project Capital Cost without EC ($)	$200,000
Feedstock Requirement (BDT/yr)	606,000
Plant Economic Life (years)	20
Cost Assumptions	
Feedstock Cost ($/BDT, FOB Atikokan)	$87
Financing Assumptions	
Debt Financed Portion (%)	100%
Debt Finance Rate (%/yr)	5.0%
Income Tax Rate (%)	30%
Inflation Rate (%/yr)	2.2%

Cost Component	$/MWh	%
Project Capital		
with emission controls	$45	32%
without emission controls	$22	19%
Operations & Maintenance		
with emission controls	$36	26%
without emission controls	$33	29%
Fuel	$58	42%
LUEC		
with emission controls	$140	100%
without emission controls	$114	100%

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3. Conclusions

From a supply perspective and within the confines of the data provided to us, sufficient amounts of forest biomass sourced from the region or from Toronto as refuse derived fuel exist to support power generation at the Atikokan GS. Adequate amounts of woody biomass as unutilized wood supply, forest harvest residues, fuel peat reserves and mill waste residues are available at a landed cost of $21 to $220/BDT (i.e. $1.10 to $12.20/GJ) (Schedule 1, Table 23C, D). Our models have assessed the total amount of woody biomass within 500 km of the Atikokan GS in excess of 1.4 million BDT/yr. Further, 380,000 BDT/yr of refuse derived fuel produced from Toronto's solid waste could be available at $79/BDT or $4.40/GJ (Schedule 1, Table 23C, D).

The case studies presented to us covered a broad spectrum of possibilities which ranged from using whole trees to processed municipal solid waste in a combustion system. Our discussions with technology providers showed that there are technologically and environmentally sound ways to combust biomass to energy. This is further substantiated by the fact that biomass is used elsewhere in the world in facilities that are similar in size to the Atikokan GS.

From the perspective of a reduction in carbon emissions, the use of biomass can create a sustainable carbon cycle owing to the fixation of atmospheric carbon by growing trees or by sphagnum moss. However, the use of this biomass will not create recognized carbon offsets credits unless silvicultural activities and energy plantations are created in addition to the current baseline carbon fixation by forests as per the Kyoto protocol and subsequently attached international agreements.

Plant emissions in terms of particulate matter, nitrogen oxides, sulfur and heavy metals are dependant on technologies and can be controlled in the combustion chamber or through flue gas conditioning for all the potential feedstock sources (Table 19). Therefore this is not an area of great concern, so long as the proper technologies are used.

Tenure on biomass resources is a common risk area associated with all biomass/technology options that were studied here. Indeed, proponents represented access to various biomass streams. Procurement strategies for forest biomass will need to be coupled with a socioeconomic impact strategy that will need to be demonstrated to convince the authorities that all possible attempts are made to resolve potential conflicts among forest users. In making this statement, we are not laying blame on the proponents as the material that was provided to us was on a voluntary basis and, we presume, was acquired in the most cost-effective manner.

However, procurement strategies are an area of concern which was emphasized to us by many representatives of the Ministry of the Environment, the Ministry of Natural Resources, as well as some entrepreneurs who hold tenure on regional biomass resources. Indeed, many forest stakeholders are laying claims on biomass that is

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perceived as available by proponents interested in the refitting of the Atikokan GS (see Schedule 4). In consequence, for the biomass conversion of the Atikokan GS to proceed, a procurement strategy must be clearly spelled out and supported with binding contracts from biomass brokers/owners for long-term supply and pricing.

Table 19. Greenhouse gas and contaminant emissions at the Atikokan GS firing the amount of fuel needed to maintain a net generation of 900,000 MWh at the Atikokan GS

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
Fossil										
Lignite	986,000	1,100 a	2,960	3,290 a	5,400	6,000 a	37	41 a	38	42 a
Natural Gas	489,000	543 b	100	110 b	3.1	3.4 b	49	54 b	0	0 b
Uncontrolled										
Woody Biomass	1,021,000	1,130 c	900	1,000 d	100	110 d	1,340	1,490 d	14	16 d
Peat	1,189,000	1,320 e	200	2,200 f	3,380	3,750 f	n/a	n/d	n/a	n/a
Refuse Derived Fuel	993,000	1,100 g	1,860	2,070 g	1,440	1,610 g	25,790	28,650 g	1,770	1,970 g
Controlled										
Woody Biomass	1,021,000	1,130	300	330	20.0	22.0	80	89	3.6	4.0
Peat	1,189,000	1,320	70	730	680	750	n/a	n/a	n/a	n/a
Refuse Derived Fuel	993,000	1,100	610	680	290	322	1,550	1,720	440	490

n/a = data not available

[a] in-house measurements at the Atikokan GS

[b] DSS and RWDI (2005)

[c] Environment Canada (2005)

[d] EPA (1995a)

[e] Uppenberg et al. (1999)

[f] Government of Ireland (2005)

[g] EPA (1995b)

Proponents speculated that energy plantations would represent a significant amount of biomass supply to the Atikokan GS. Our data puts this assertion in question as there is little land available for such undertakings in the region. Further, if the land was available, high production costs associated with establishing, managing, harvesting and processing this biomass would disqualify it as a viable feedstock.

Proponents speculated that strategic alliances with rail companies would decrease the cost of biomass transport, and logging slash was used as an example. This is not realistic because forest slash and biomass are scattered across the landscape. Preferred rates, however, can be of significance if material is to be procured from the western provinces.

Fuel peat is a possible feedstock but the proponent needs to secure environmental permitting as well as select a harvesting and processing technology. And then this project can contribute significantly to the economy of the region. However, if peat is selected as the final feedstock it would be prudent to envision a blended or phase-in strategy to mitigate the risk of delays in the production of peat.

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FBi was not mandated to make recommendations to the Steering Committee whether or not to proceed with the conversion of the Atikokan GS to using biomass. Below are key legal documents that would be needed by proponents to prepare a credible business plan for operating the Atikokan GS using biomass:

- Plant lease;
- Power Purchase Agreement;
- Collective Bargaining Agreement;
- Long term supply contracts;
- Proof of financial capabilities and economic viability;
- Environmental permits;
- Construction permits.

The following tables summarize the levelized unit energy cost associated with each of the proposals examined here as well as the effect of using the various biomass feedstocks on the environment, job creation, competing end-users and First Nations communities in the region.

Table 20. Levelized unit energy cost of power generation for each of the case studies

	Atiokan Power Corporation	Peat Resources Ltd.	Triangle Energy Group	Toronto Garbage
Project Capital Costs - $				
Boiler Retrofits	$100,000,000	$5,000,000	$100,000,000	$200,000,000
Emission Controls	$206,000,000	$206,000,000	$206,000,000	$206,000,000
Project Capital - $/MWh				
with emission controls	$34	$23	$34	$45
without emission controls	$11	$1	$11	$22
Operations & Maintenance - $/MWh				
with emission controls	$31	$26	$31	$36
without emission controls	$28	$23	$28	$33
Fuel - $/MWh	$51	$58	$51	$58
LUEC - $/MWh				
with emission controls	$115	$108	$115	$140
without emission controls	$89	$82	$89	$114

Ontario Regulation 116/01 details Environmental Assessment requirements for electricity projects. MOE has classified electricity projects based on the type of fuel to be used, the size and, in some cases, the efficiency of the planned facility. The feedstocks proposed here are addressed in Ontario Regulation 116/01.

In the Environmental Screening Process, the definition of “environment” is the same as that in the *Environmental Assessment Act*. "Environment" is broadly defined to include air, land and water as well as natural, cultural, social and economic components. The screening criteria which must be applied to all projects that are subject to the Environmental Screening Process reflect this broad definition of “environment”.

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The Environmental Screening Process is a proponent driven, self-assessment process. The proponent is responsible for determining if the process applies to its project and for determining when to formally commence the process. Depending on the scale and nature of the project, proponents may wish to undertake preliminary consultation and issue scoping prior to formally commencing the screening process. The proponent also determines the time required to adequately conduct the screening process with sufficient agency and public consultation and when it is in a position to issue a Screening or Environmental Review Report for public and agency review.

It is recommended that a proponent commence the screening process before project planning, site layout and facility design have progressed too far and before irreversible decisions or commitments are made. A proponent is not prohibited from making other public announcements or statements about the project, undertaking economic feasibility studies, initiating private discussions or negotiations, public/agency consultations, environmental studies or commencing work to obtain other approvals prior to commencing the Environmental Screening Process.

Table 21. Environmental impacts associated with each of the biomass feedstocks

Unutilized Wood Supply
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion
Land – Damages resulting from road construction and harvesting operations. Pollution inputs from forestry equipment and combustion ash disposal
Water – Damages and pollution inputs resulting from road construction and harvesting operations
Biosphere – Loss of wildlife habitat, nutrient removal from forest ecosystem

Forest Harvest Residues
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion
Land – Damages resulting from road construction and harvesting operations. Pollution inputs from forestry equipment and combustion ash disposal
Water – Damages and pollution inputs resulting from road construction and harvesting operations
Biosphere – Loss of wildlife habitat, nutrient removal from forest ecosystem

Mill Wood Wastes
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion
Land –Pollution inputs resulting from combustion ash disposal

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Dedicated Energy Crops
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion
Land –Pollution inputs resulting from chemical pesticides and combustion ash disposal
Water – Pollution inputs from chemical pesticides

Fuel-Grade Peat
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion
Land – Damages and pollution inputs resulting from extraction, processing operations and combustion ash disposal. Permanent alteration of the landscape
Water – Damages and pollution inputs resulting from extraction and processing operations. Permanent alteration of surface and groundwater chemistry and hydrology.
Biosphere – Loss of wildlife habitat. Nutrient-rich processing effluents can negatively impact on aquatic ecosystems

Refuse Derived Fuel
Air – Greenhouse gas and contaminant emissions associated with harvesting, processing, transport and combustion. Emissions of heavy metals and dioxins/furans are of concern
Land – Pollution inputs resulting from combustion ash disposal

Table 22. The effect of using biomass feedstocks to generate power at the Atikokan GS on job creation, competing end-users and First Nation communities in the region

Atikokan GS Makes Use of Forest Biomass
Job Creation – 90 direct jobs retained at the Atikokan GS; increase of 200 jobs for harvesting forest biomass in support of the Atikokan GS;
Competing Uses – potential for increased demand for forest biomass by pulp and paper industry for in-mill energy
First Nations Impact – potential for participation and/or brokering

Atikokan GS Makes Use of Fuel-Grade Peat
Job Creation – 90 direct jobs retained at the Atikokan GS; increase of 100 jobs for harvesting peat; potential increase of 200 jobs for harvesting forest biomass in support of the pulp and paper industry
Competing Uses – none
First Nations Impact – potential to partake as partners; support community infrastructure

Atikokan GS Makes Use of Municipal Solid Waste from Toronto
Job Creation – 90 direct jobs retained at the Atikokan GS; unquantified job creation in Toronto for processing of municipal solid waste into refuse derived fuel
Competing Uses – none
First Nations Impact – neutral
Other – help resolve the City of Toronto's waste management issue

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Schedule 1

Amounts and Delivered Costs of Biomass Feedstocks Available to the Atikokan Generating Station

1. Introduction

The amounts (BDT/yr) and delivered costs ($/BDT; $/GJ) of the possible feedstocks available to the Atikokan GS were assessed in this study. FBi estimated ‘theoretical pools’ of the different feedstocks from which ‘practical pools’ were derived based on restrictions.

The theoretical pool represented the maximum amount of a given biomass feedstock and was pared down to a ‘practical pool’ by applying discount factors that would account for realities in the region such as reduced access to and recoverability of biomass and decreased heat values due to decay and contamination. These ‘availability factors’ are purely qualitative and range from 0.5 to 1.0 depending on the feedstock type. Their purpose is to provide a conservative estimate of the biomass pool – an opposite goalpost to the theoretical amount. Assessing the true availability of a biomass feedstock would require field auditing and other operational trials which to date have not been conducted in the region. It is also noteworthy that an availability factor is not static and, at least for the woody biomass feedstocks, would tend to increase as biomass procurement and timber harvesting operations became more integrated.

The delivered cost ($/BDT) of a particular biomass feedstock was found by dividing the cost to procure, process and transport the material to the Atikokan GS by the size of the practical pool. The delivered cost was then expressed in terms of its cost per unit energy ($/GJ) based on its energy density (GJ/BDT) irrespective of capital and operating costs at the Atikokan GS. Unless otherwise noted, all currency figures in this report are expressed in Canadian dollars and are in base year 2005.

It is possible that a market for the sale of carbon credits might emerge in Canada, the value of which remains unknown. Also, the federal government announced in the 2005 budget its intention to apply a support payment of $0.01/kWh to biomass power. We do not know if this subsidy would be available to a project of the size and scope of the Atikokan GS. As such, the landed costs of biomass at the Atikokan GS do not include the value of any carbon credits generated by the project or any potential federal or provincial subsidies for green power.

The following general assumptions were used in our models:

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Woody Biomass

- Woody biomass encompasses unutilized wood supply, forest harvest residues, mill wood waste, landfilled wood waste and dedicated energy crops;
- 1 green m^3 of woody biomass is equal to 0.32 BDT of woody biomass;
- As boiler fuel, woody biomass has a moisture content of 50% and an energy density of 19 GJ/BDT;
- Unutilized wood supply and forest harvest residues are evenly distributed throughout the Forest Management Unit from which they are procured;

Fuel-Grade Peat

- As boiler fuel, fuel-grade peat has a moisture content of 20% and an energy density of 18 GJ/BDT;

Refuse Derived Fuel

- As boiler fuel, refuse derived fuel has a moisture content of 10% and an energy density of 15 GJ/BDT.

The cost of transportation is a significant variable in the delivered cost of biomass because of the relatively low energy density of green biomass as compared to fossil fuels. Each type of biomass had a common base rate and the delivered cost was therefore a function of distance from the Atikokan GS. For this reason FBi has assessed biomass costs based on catchment area as follows (Figure 4):

- Less than 100 km from the Atikokan GS;
- 100 km to 200 km from the Atikokan GS;
- 200 km to 300 km from the Atikokan GS;
- 300 km to 400 km from the Atikokan GS;
- 400 km to 500 km from the Atikokan GS;
- More than 500 km from the Atikokan GS.

The results of our biomass determination models are presented in Table 23. The 'theoretical' and 'practical' amounts and delivered costs of the biomass feedstocks are tabulated with respect to distance from the Atikokan GS and expressed as $/BDT and $/GJ. Table 23 was then used to generate Table 24 which shows landed costs for hypothetical fuel mixes at the Atikokan GS. Here, fuel unit energy cost refers to the contribution of fuel to the levelized unit energy cost of power generation. As such, it does not include capital or annual operating costs.

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Figure 4. Distance classes used in this study

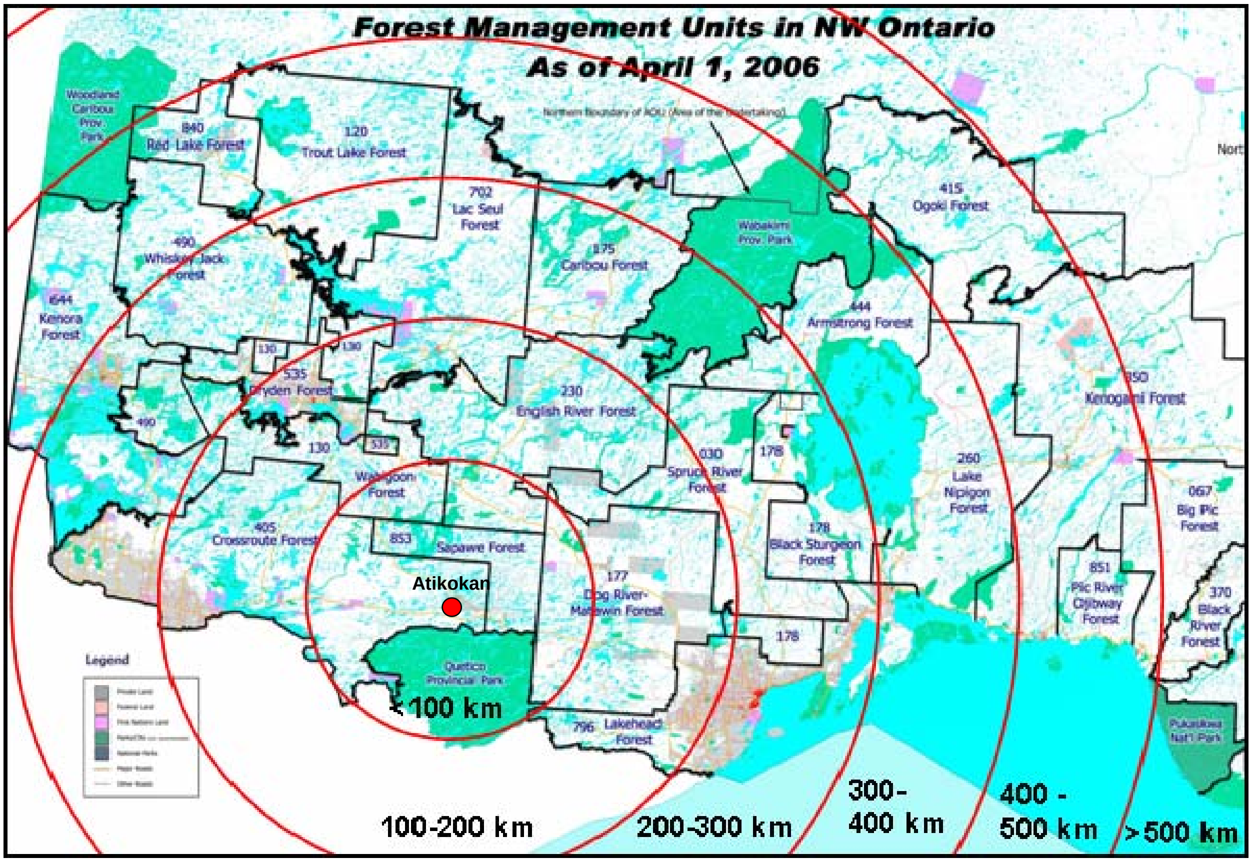

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Table 23. 'Theoretical' (A) and 'practical' (B) feedstock pools and delivered costs (C, D) with distance from the Atikokan GS. Averages presented here are BDT-weighted averages

A	'Theoretical' Amount of Biomass Available With Distance from the AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Annual Resource - BDT/yr							
Unutilized Wood Supply	190,700	531,400	725,600	368,900	242,100	96,700	2,155,400
Forest Harvest Residues	57,300	147,700	115,800	75,400	55,300	24,100	475,600
Mill Wood Waste	7,400	45,800	14,600	15,200	200	21,700	104,900
Dedicated Energy Crops	n/d	42,300	3,700	n/d	n/d	n/d	46,000
Refuse Derived Fuel	n/d	n/d	n/d	n/d	n/d	379,000	379,000
'Theoretical' BDT/yr	255,400	767,200	859,700	459,500	297,600	521,500	3,160,900
Finite Resource - BDT							
Fuel-Grade Peat	59,921,700	148,396,500	124,617,000	106,580,100	157,587,700	66,976,000	664,079,000
Landfilled Wood Waste	n/d	n/d	n/d	n/d	n/d	n/d	4,022,076

B	'Actual' Amount of Biomass Available With Distance from the AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	TOTAL
Annual Resource - BDT/yr							
Unutilized Wood Supply	95,400	265,700	362,800	184,500	121,100	48,400	1,077,900
Forest Harvest Residues	28,700	73,900	57,900	37,700	27,700	12,100	238,000
Mill Wood Waste	5,900	36,600	11,700	12,200	200	17,400	84,000
Dedicated Energy Crops	n/d	42,300	3,700	n/d	n/d	n/d	46,000
Refuse Derived Fuel	n/d	n/d	n/d	n/d	n/d	379,000	379,000
'Actual' BDT/yr	130,000	418,500	436,100	234,400	149,000	456,900	1,824,900
Finite Resource - BDT							
Fuel-Grade Peat	29,960,850	74,198,250	62,308,500	53,290,050	78,793,850	33,488,000	332,039,500
Landfilled Wood Waste	n/d	n/d	n/d	n/d	n/d	n/d	2,011,038

C	$/BDT of Biomass FOB AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	AVERAGE
Annual Resource							
Unutilized Wood Supply	$54	$79	$104	$129	$154	$180	$107
Forest Harvest Residues	$44	$75	$106	$137	$168	$199	$106
Mill Wood Waste	$21	$51	$82	$113	$145	$175	$88
Fuel-Grade Peat	$65	$96	$127	$158	$189	$220	$143
Dedicated Energy Crops	n/d	$155	$186	n/d	n/d	n/d	$157
Refuse Derived Fuel	n/d	n/d	n/d	n/d	n/d	$82	$82

D	$/GJ of Biomass FOB AGS						
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km	AVERAGE
Annual Resource							
Unutilized Wood Supply	$2.90	$4.20	$5.50	$6.80	$8.10	$9.50	$5.60
Forest Harvest Residues	$2.30	$3.90	$5.60	$7.20	$8.80	$10.50	$5.50
Mill Wood Waste	$1.10	$2.70	$4.30	$6.00	$7.60	$9.20	$4.60
Fuel-Grade Peat	$3.60	$5.30	$7.00	$8.80	$10.50	$12.20	$8.00
Dedicated Energy Crops	n/d	$8.10	$9.80	n/d	n/d	n/d	$8.20
Refuse Derived Fuel	n/d	n/d	n/d	n/d	n/d	$4.60	$4.60

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Table 24. Requirements (BDT/yr), delivered cost ($/BDT, $/GJ), and fuel unit energy cost ($/MWh of gross generation - not including capital and operational costs) for various feedstock scenarios at the Atikokan GS

Blended Feedstock	BDT/yr	$/BDT	$/GJ	$/MWh
100% Lignite	417,000	$43	$1.80	$18
100% Fuel-Grade Peat	556,000	$95	$5.30	$58
100% Unitilized Wood Supply	526,000	$83	$4.40	$49
100% Refuse Derived Fuel	667,000	$45	$3.00	$33
50% Fuel-Grade Peat	278,000	$83	$4.50	$50
50% Unutilized Wood Supply	263,000			
50% Fuel-Grade Peat	278,000			
25% Unutilized Wood Supply	132,000	$82	$4.40	$49
25% Forest Harvest Residues	132,000			
50% Fuel-Grade Peat	278,000	$92	$5.60	$62
50% Refuse Derived Fuel	333,000			
50% Fuel-Grade Peat	278,000			
25% Unutilized Wood Supply	132,000	$112	$6.40	$71
25% Refuse Derived Fuel	167,000			
50% Fuel-Grade Peat	278,000			
25% Forest Harvest Residues	139,000	$115	$6.60	$73
25% Refuse Derived Fuel	167,000			
50% Refuse Derived Fuel	333,000			
25% Unutilized Wood Supply	132,000	$80	$4.80	$53
25% Forest Harvest Residues	132,000			

Costs associated with transferring biomass from its point of origin to the Atikokan GS were unique for each feedstock type and models developed to estimate these costs are presented below.

The following relationship was used to estimate the upstream costs associated with the woody biomass feedstocks (i.e. unutilized wood supply, forest harvest residues, mill waste residues). Such costs can include felling, skidding, loading and chipping and are summarized in Table 25.

Cost ($/BDT) = Machine Rate ($/PMH) ÷ Machine Productivity (BDT/PMH)

As private interest in and competition for woody biomass increases, the Province will likely impose a harvest tax on logging residues. In anticipation of this, a harvest tax of $1/m^3$ (i.e. $3.10/BDT) was also included as an upstream cost for forest harvest residues available to the Atikokan GS. The full minimum stumpage rate of $3.72/m^3$ (i.e. $11.60/BDT) was applied to the harvest of unutilized wood supply.

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Table 25. Modelling the machine rate ($/PMH), productivity (BDT/PMH), and upstream cost ($/BDT) of equipment used to harvest, process and transport the woody biomass feedstocks

	feller-buncher	grapple skidder	strokeboom delimber	mobile grinder	90 m^3 chip van - truck
base utilization	85%	85%	85%	85%	90%
SMH/yr	2000	2000	2000	2000	2400
PMH/yr	1700	1700	1700	1700	2160
# of machines	1	2	1	1	1
purchase price ($)	$400,000	$350,000	$350,000	$400,000	$150,000
machine life (yr)	5	5	5	5	8
interest rate	7%	7%	7%	7%	7%
salvage (% of new)	20%	20%	20%	20%	20%
P&I ($/yr)	$95,046	$166,330	$83,165	$95,046	$24,541
insurance ($/yr) - 5% of new	$20,000	$17,500	$17,500	$20,000	$7,500
depreciation ($/yr)	$64,000	$112,000	$56,000	$64,000	$15,000
mileage (km/yr)	n/a	n/a	n/a	n/a	200,000
fuel consumption (L/PMH)	32	26	24	60	0.394
fuel cost ($/L)	$1.00	$1.00	$1.00	$1.00	$1.00
fuel cost ($/yr)	$54,400	$88,400	$40,800	$102,000	$78,800
oil consumption (% of fuel)	35%	35%	35%	35%	10%
oil cost ($/L)	$1.00	$1.00	$1.00	$1.00	$1.00
oil cost ($/yr)	$19,040	$30,940	$14,280	$35,700	$7,880
repair & maintenance (% of dep)	75%	75%	75%	75%	60%
repair & maintenance ($/yr)	$48,000	$84,000	$42,000	$48,000	$9,000
P&I - salvage ($/PMH)	$55.91	$48.92	$48.92	$55.91	$11.36
insurance ($/PMH)	$11.76	$5.15	$10.29	$11.76	$3.47
fuel cost ($/PMH)	$32.00	$26.00	$24.00	$60.00	$36.48
oil cost ($/PMH)	$11.20	$9.10	$8.40	$21.00	$3.65
repair & maintenance ($/PMH)	$28.24	$24.71	$24.71	$28.24	$4.17
labour rate ($/PMH)	$29.41	$58.82	$29.41	$29.41	$27.78
profit and overhead ($/PMH)	$16.85	$17.27	$14.57	$20.63	$8.69
machine rate ($/PMH)	$185	$190	$160	$227	$96
solid green m^3/PMH/unit	35	25	45	50	n/a
solid green m^3/PMH	35	49	45	50	n/a
BDT/PMH	11	16	14	16	n/a
$/solid green m^3	$5.30	$3.86	$3.56	$4.54	n/a
$/BDT	$16.55	$12.07	$11.13	$14.18	n/a

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The average cost of hauling biomass feedstocks by tractor-trailer with a payload of 20 BDT to the Atikokan GS was assessed at $0.129/BDT-km based on a machine rate of $96/PMH (Table 25) and the trip distances listed in Table 26. The model assumes that each trip consists of 50 km of travel on unimproved forest roads at an average speed of 20 km/hr. The balance of the trip occurs by Provincial highway at 80 km/hr.

Table 26. Modelling the cost of hauling biomass feedstocks by tractor-trailer with a payload of 20 BDT

Trip Distance (km)	PMH	$	$/BDT	$/BDT-km
100	3.13	$301.08	$20.07	$0.201
150	3.75	$361.30	$24.09	$0.161
200	4.38	$421.51	$28.10	$0.141
250	5.00	$481.73	$32.12	$0.128
300	5.63	$541.95	$36.13	$0.120
350	6.25	$602.16	$40.14	$0.115
400	6.88	$662.38	$44.16	$0.110
450	7.50	$722.60	$48.17	$0.107
500	8.13	$782.81	$52.19	$0.104
550	8.75	$843.03	$56.20	$0.102
			MEAN	$0.129

As mentioned above, FBi used a radius approach to separate the amount of available biomass into 100 km distance classes from the Atikokan GS. Distances between the Atikokan GS and wood processing facilities and municipal landfill sites were known and trucking costs within each distance class for mill residues and municipal solid waste were calculated using:

Trucking Cost ($) = $0.129/BDT-km × Payload (BDT) × Haul Distance (km)

For the remaining biomass feedstocks, exact points of origin were not known and trucking costs were found by:

Trucking Cost ($) = $0.129/BDT-km × Payload (BDT) × Distance Class Midpoint (km) x 1.2

A factor of 1.2 was applied to account for account for winding roads and hills.

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2. Unutilized Wood Supply

2.1 Introduction

Unutilized wood supply refers to the variance between the average annual available volume of roundwood (m^3) and the average annual actual harvest of roundwood (m^3). Province-wide the annual allowable cut is roughly 32 million m^3 while 22 million m^3 is actually harvested. The 10 million m^3 gap represents the volume of roundwood not harvested within forest management units (FMU) and trees left standing within cutovers. Unutilized wood supply reported for FMU's in the Northwest region of Ontario is on the order of 4.5 million m^3, corresponding to a total amount of over 2 million BDT/yr of biomass (Table 23A).

2.2 Approach

The theoretical pool of unutilized wood supply biomass in each FMU in the Northwest region was calculated using data obtained from the MNR (Mr. J. Maure, Ministry of Natural Resources, personal communication). The tree tops and branches and bark associated with this unutilized roundwood are also included. It is important to note that an additional 5-10% of unutilized wood supply biomass exists in the region as bypassed or culled roundwood and associated tops, limbs and bark. This fraction is not included in calculating the average annual available volume used in forest management planning and is not represented in the biomass inventory compiled here. FMU's treated in this study are listed in Table 27.

Table 27. Forest management units considered in this study

FMU #	FMU Name	FMU #	FMU Name	FMU #	FMU Name
444	Armstrong Forest	350	Kenogami Forest	840	Red Lake Forest
178	Black Sturgeon Forest	644	Kenora Forest	853	Sapawe Forest
175	Caribou Forest	702	Lac Seul Forest	030	Spruce River Forest
405	Crossroute Forest	260	Lake Nipigon Forest	120	Trout Lake Forest
177	Dog River-Mattawin Forest	796	Lakehead Forest	130	Wabigoon Forest
535	Dryden Forest	415	Ogoki Forest	490	Whiskey Jack Forest
230	English River Forest	851	Pic River Ojibway Forest	067	Big Pic Forest

The theoretical pool of unutilized wood supply biomass was found using the expression:

$$UWS = (AAV - AAH) \times (1 + TLF) \times (1 + BF) \times CF$$

where *UWS* is the unutilized wood supply biomass (BDT/yr);
AAV is the average annual available volume (m^3/yr);
AAH is the average annual actual harvest (m^3/yr);
TLF is the tops/limbs factor by tree species;

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BF is the bark factor = 0.05 (i.e. 5%); and
CF is a conversion factor based on tree species (BDT/m^3).

Table 28 lists the tops/limbs factors and the green volume to bone-dry mass conversion factors for the various tree species while Table 29 gives an example of the unutilized wood supply biomass calculation for the Sapawe FMU.

Table 28. Conversion factors used in estimating the amount of unutilized wood supply biomass

Tree Species	tops & limbs factor	green m^3 to BDT
White Birch	0.26	0.57
Other Conifer	0.08	0.39
Poplar	0.26	0.37
White Pine/Red Pine	0.12	0.38
Spruce/Balsam/Jack Pine	0.10	0.32
Tolerant Hardwood	0.20	0.67

Source: Forintek (1997)

Table 29. Calculating the theoretical pool of unutilized wood supply biomass available to the Atikokan GS in the Sapawe FMU

Tree Species	AAV-AAH (m^3/yr)	TLF	BF	CF (BDT/m^3)	UWS (BDT/yr)
White Birch	30,000	0.26	0.05	0.57	22,700
Other Conifer	1,000	0.08	0.05	0.39	500
Poplar	37,000	0.26	0.05	0.37	18,200
White Pine/Red Pine	0	0.12	0.05	0.38	0
Spruce/Balsam/Jack Pine	31,000	0.10	0.05	0.32	11,500
Tolerant Hardwood	0	0.20	0.05	0.67	0
TOTAL	99,000				52,900

The practical pool of unutilized wood supply biomass was then estimated by multiplying the theoretical pool by an availability factor of 0.5. The following full-tree harvesting scenario was assumed when modelling the delivered cost of unutilized wood supply biomass to the Atikokan GS (Table 25):

- Trees are harvested by a single feller-buncher at $17/BDT;
- Trees with tops and limbs attached are delivered to the roadside landing by 2 grapple skidders at $12/BDT;
- Trees are chipped at the roadside by a mobile horizontal grinder into 90 m^3 chip vans at $14/BDT;
- Chips are hauled to the Atikokan GS at $0.129/BDT-km.

The distance class matrix given in Table 30 was used to calculate trucking costs.

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Table 30. Distance class matrix used in calculating the delivered cost of unutilized wood supply biomass to the Atikokan GS

Management Unit	% of Forest Management Unit in Distance Class					
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km
Armstrong Forest	0%	0%	25%	75%	0%	0%
Black Sturgeon Forest	0%	0%	100%	0%	0%	0%
Caribou Forest	0%	0%	75%	25%	0%	0%
Crossroute Forest	40%	45%	15%	0%	0%	0%
Dog River-Mattawin Forest	25%	75%	0%	0%	0%	0%
Dryden Forest	0%	65%	35%	0%	0%	0%
English River Forest	20%	70%	10%	0%	0%	0%
Kenogami Forest	0%	0%	0%	5%	50%	45%
Kenora Forest	0%	5%	50%	45%	0%	0%
Lac Seul Forest	0%	25%	60%	15%	0%	0%
Lake Nipigon Forest	0%	0%	0%	65%	35%	0%
Lakehead Forest	0%	70%	30%	0%	0%	0%
Ogoki Forest	0%	0%	0%	0%	90%	10%
Pic River Ojibway Forest	0%	0%	0%	0%	100%	0%
Red Lake Forest	0%	0%	0%	100%	0%	0%
Sapawe Forest	100%	0%	0%	0%	0%	0%
Spruce River Forest	0%	25%	75%	0%	0%	0%
Trout Lake Forest	0%	0%	30%	70%	0%	0%
Wabigoon Forest	15%	70%	15%	0%	0%	0%
Whiskey Jack Forest	0%	0%	65%	35%	0%	0%
Big Pic Forest	0%	0%	0%	0%	20%	80%

2.3 Findings

Our analysis indicates that over 1 million BDT of unutilized wood supply biomass could be supplied each year to the Atikokan GS from northwestern Ontario FMU's based on current levels of wood allocation and an availability factor of 0.5 and (Table 28).

Figure 5A illustrates how the practical pool of unutilized wood supply biomass is distributed with distance from the Atikokan GS. Roughly 67% (i.e. 724,500 BDT) of if occurs within 300 km of the Atikokan GS at a landed price of $54 to $104/BDT or $2.80 to $5.50/GJ (Table 23B, C, D). As can be expected, the delivered cost of biomass increases markedly with distance owing to the high cost of transport. For example, trucking comprises 70% of the delivered cost of unutilized wood supply biomass in the 400-500 km range compared to 21% for 0-100 km.

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Table 31. Unutilized wood supply biomass available to the Atikokan GS by Forest Management Unit in northwestern Ontario

Tree Species	Armstrong	Black Sturgeon	Caribou	Crossroute	Dog River - Mattawin	Dryden	English River
White Birch	25,000	106,600	14,400	22,700	124,800	3,800	31,800
Other Conifer	0	6,700	3,500	4,000	7,100	0	1,800
Poplar	17,700	76,700	19,700	18,200	39,800	10,800	52,100
White Pine/Red Pine	0	0	0	0	0	0	0
Spruce/Balsam/Jack Pine	0	71,400	53,000	11,400	77,300	0	73,600
Tolerant Hardwood	0	0	0	0	0	0	0
Theoretical BDT/yr	42,700	261,400	90,600	56,300	249,000	14,600	159,300
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	21,400	130,700	45,300	28,200	124,500	7,300	79,700

Tree Species	Kenogami	Kenora	Lac Seul	Lake Nipigon	Lakehead	Ogoki	Pic River Ojibway
White Birch	12,100	15,100	3,800	37,800	49,900	9,100	17,400
Other Conifer	6,200	4,000	0	4,900	4,400	1,300	0
Poplar	40,300	48,700	8,800	2,500	5,900	34,400	9,800
White Pine/Red Pine	0	1,300	0	0	700	0	0
Spruce/Balsam/Jack Pine	136,900	42,300	129,500	49,700	0	42,700	5,200
Tolerant Hardwood	0	4,200	0	0	0	0	0
Theoretical BDT/yr	195,500	115,600	142,100	94,900	60,900	87,500	32,400
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	97,800	57,800	71,100	47,500	30,500	43,800	16,200

Tree Species	Red Lake	Sapawe	Spruce River	Trout Lake	Wabigoon	Whiskey Jack	TOTAL
White Birch	800	22,700	31,800	21,900	21,200	18,900	591,600
Other Conifer	400	400	900	6,200	1,300	1,300	54,400
Poplar	4,900	18,200	0	33,900	78,600	91,900	612,900
White Pine/Red Pine	0	0	0	2,200	0	900	5,100
Spruce/Balsam/Jack Pine	0	11,400	25,400	109,300	41,600	6,600	887,300
Tolerant Hardwood	0	0	0	0	0	0	4,200
Theoretical BDT/yr	6,100	52,700	58,100	173,500	142,700	119,600	2,156,000
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	3,100	26,400	29,100	86,800	71,400	59,800	**1,078,000**

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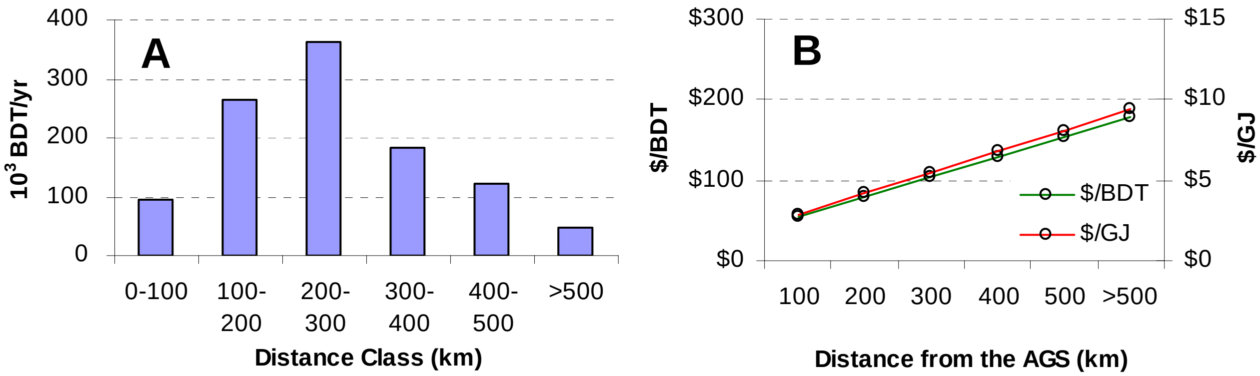
Figure 5. The amount (A) and delivered cost (B) of unutilized wood supply biomass available to the Atikokan GS



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3. Forest Harvest Residues

3.1 Introduction

Timber harvesting operations leave behind residual biomass in the form of tree tops and branches. In practice this material is piled at the roadside and is either burned or left to rot in place. Alternatively, slash can be collected and fed into an industrial grinder with the resulting chips used as fuel in biomass boilers.

The amount of non-stem biomass produced each year in Ontario has been estimated at 17.5 million BDT (Wood and Layzell, 2003). Results presented here indicate that roughly 480,000 BDT of forest harvest residues accumulate per annum in the FMU's treated in this study (Table 23A).

3.2 Approach

In this study, forest harvest residues refer to tree tops and limbs that accumulate at the roadside landing as a result of delimbing and slashing during full-tree harvesting operations. The amount and delivered cost of current forest harvest residues was modelled in a manner similar to that used for unutilized wood supply biomass. Note that roadside slash piles from past harvest and silviculture operations were not considered in this study.

The theoretical pool of tops and limbs in each FMU in the Northwest region was calculated using data obtained from the MNR (Mr. J. Maure, Ministry of Natural Resources, personal communication). FMU's treated in this study are listed in Table 27.

The theoretical pool of tops and limbs was found using:

$$TL = AAH \times TLF \times CF$$

where *TL* is the amount of biomass as tops and limbs (BDT/yr);
AAH is the average annual actual harvest (m^3/yr);
TLF is the tops and limbs factor for a given species;
CF is a conversion factor based on tree species (BDT/m^3).

The tops and limbs factor accounts for the volume of a harvested tree removed and left behind as a result of roadside delimbing and slashing (Table 28). The practical pool of biomass as tops and limbs in each management unit was calculated by multiplying the theoretical pool by an availability factor of 0.5.

The following assumptions were made when modelling the delivered cost of biomass as chipped tops and limbs to the Atikokan GS:

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- The collection, processing and transport of tops and limbs occur at the roadside during full-tree harvesting operations to maximize cost-effectiveness;
- Tops and limbs are loaded into a mobile tub grinder by a strokeboom-delimber at \$11/BDT and chipped into 90 m^3 chip vans at \$14/BDT;
- Chips are hauled to the Atikokan GS at \$0.129/BDT-km.

3.3 Findings

We have identified a practical pool of 238,000 BDT of tops and limbs that could be supplied each year from northwestern Ontario FMU's based on an availability factor of 0.5 (Table 32).

Table 32. Forest harvest residues as tops and limbs available to the Atikokan GS by Forest Management Unit in northwestern Ontario

Tree Species	Armstrong	Black Sturgeon	Caribou	Crossroute	Dog River - Mattawin	Dryden	English River
White Birch	200	1,600	390	2,000	2,600	40	970
Other Conifer	10	10	30	120	150	0	80
Poplar	8,100	10,500	2,000	33,900	27,300	3,700	12,000
White Pine/Red Pine	0	10	0	2,100	20	10	60
Spruce/Balsam/Jack Pine	14,800	7,700	12,900	18,000	26,700	5,300	23,500
Tolerant Hardwood	0	0	0	10	0	0	0
Theoretical BDT/yr	23,100	19,800	15,300	56,100	56,800	9,100	36,600
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	11,600	9,900	7,700	28,100	28,400	4,600	18,300

Tree Species	Kenogami	Kenora	Lac Seul	Lake Nipigon	Lakehead	Ogoki	Pic River Ojibway
White Birch	130	30	270	680	740	130	600
Other Conifer	110	10	20	30	30	80	0
Poplar	18,600	2,600	1,700	12,400	17,700	4,400	2,300
White Pine/Red Pine	0	350	20	20	140	0	0
Spruce/Balsam/Jack Pine	30,800	1,800	14,600	12,100	4,300	13,100	2,800
Tolerant Hardwood	0	0	0	0	10	0	0
Theoretical BDT/yr	49,600	4,800	16,600	25,200	22,900	17,700	5,700
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	24,800	2,400	8,300	12,600	11,500	8,900	2,900

Tree Species	Red Lake	Sapawe	Spruce River	Trout Lake	Wabigoon	Whiskey Jack	TOTAL
White Birch	70	30	1,100	20	100	20	11,700
Other Conifer	0	10	50	30	30	10	800
Poplar	210	4,300	11,300	7,900	11,100	5,400	197,400
White Pine/Red Pine	0	330	0	0	50	10	3,100
Spruce/Balsam/Jack Pine	5,200	4,200	15,000	19,600	18,600	11,500	262,500
Tolerant Hardwood	0	0	0	0	0	0	0
Theoretical BDT/yr	5,500	8,900	27,500	27,600	29,900	16,900	475,500
Availability Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actual BDT/yr	2,800	4,500	13,800	13,800	15,000	8,500	**237,800**

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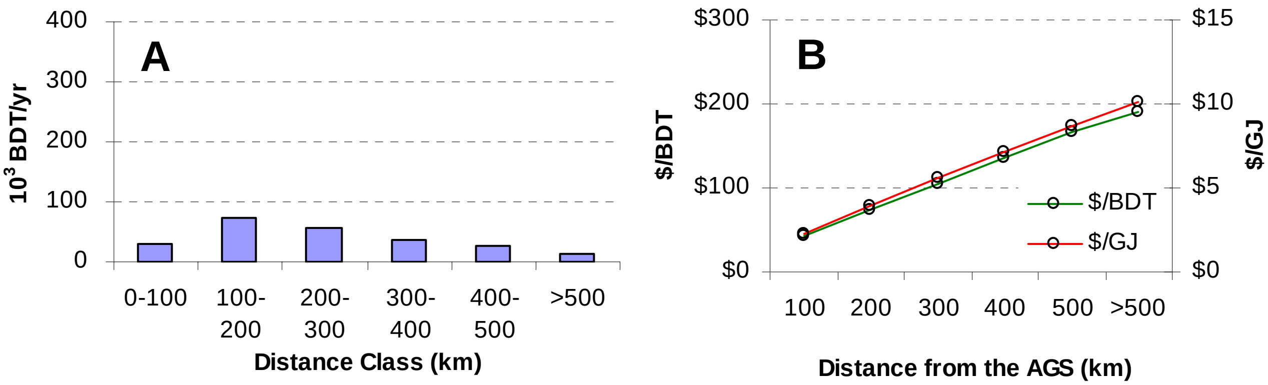
Roughly 67% (i.e. 161,000 BDT/yr) of the practical pool of biomass as tops and limbs occurs within 300 km of the Atikokan GS at a landed price of $43 to $106/BDT or $2.30 to $5.60/GJ (Figure 6, Table 23B, C, D).

Figure 6. The amount (A) and delivered cost (B) of forest harvest residues as tops and limbs available to the Atikokan GS



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4. Mill Wood Waste

4.1 Introduction

Based on the merchantable volume of roundwood harvested in Canada, approximately 78% of a typical sawlog is commoditized – 40% is sawn into dimensional lumber and 38% is chipped for pulp and paper production. The remaining 22% is the residue fraction and consists of bark, sawdust and shavings (Wood and Layzell, 2003).

It is estimated that Ontario sawmills produce 1.53 million tonnes of wood residues, of which 1.08 million tonnes are burned as hog fuel, taken as feedstocks by the secondary wood products industry or used for animal bedding by the livestock and poultry industries. Roughly 0.45 million tonnes remain unused (Hatton, 1999). There is strong competition for sawdust and planer shavings and surplus wood residues normally consist of bark with or without whitewood.

In 2004, approximately 430,000 m^3 of wood waste as bark was reported to the Ministry of Natural Resources by mill facilities in the northwestern region of Ontario (Mr. J. Maure, Ministry of Natural Resources, personal communication).

4.2 Approach

The amount and delivered cost of wood waste as bark available to the Atikokan GS from sawmills and panel board mills in northwestern Ontario was estimated in this study based on forest industry mill statistics compiled by the Ontario Ministry of Natural Resources (MNR, 2005). Wood waste from pulp and paper mills were not considered since pulp and paper mills tend to consume their waste residues in-house as a fuel source for steam.

A model capable of estimating the volume of wood waste generated by sawmills based on the volume of roundwood consumed was developed by performing a regression analysis of data reported to the MNR by sawmills in northwestern and northeastern Ontario (Figure 7). The following equation was used to calculate the theoretical pool of wood waste produced by sawmills in northwestern and northeastern Ontario:

$$WW = \frac{\left(0.8861 \times RC^{0.8097}\right) \times \left(1 - VSF\right) \times ODD}{10^3}$$

where *WW* is the amount of wood waste produced by the sawmill (BDT/yr);
RC is the volume of roundwood consumed by the sawmill (m^3/yr);
VSF is the volumetric shrinkage factor; and
ODD is the oven dry density (kg/m^3)

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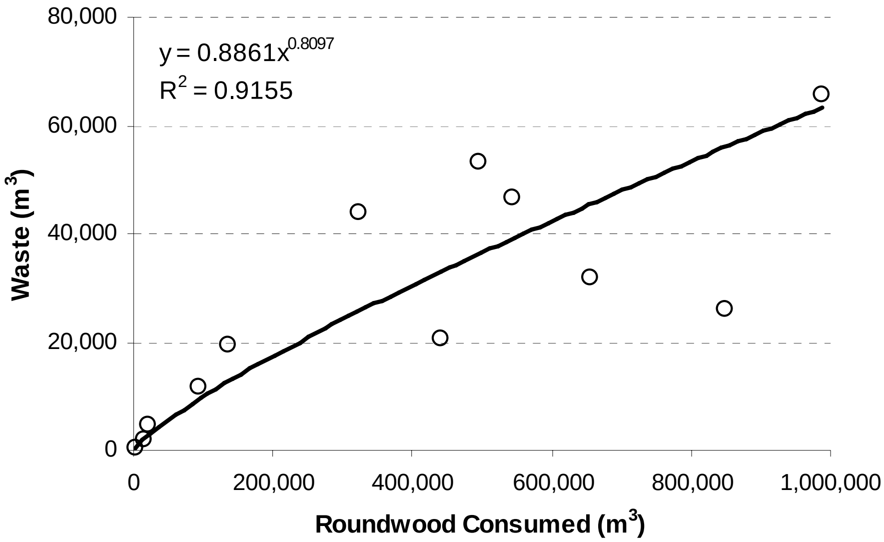
Figure 7. Model used to calculate the amount of wood waste as a function of roundwood consumed by sawmills in northwestern and northeastern Ontario



Panel board mills produce minimal amounts of waste. The theoretical pool of wood waste generated by panel board mills (i.e. plywood, OSB, MDF) was estimated as the BDT-equivalent of 2% of the volume of roundwood consumed by the mill.

The practical amount of waste bark available to the Atikokan GS was calculated by applying an availability factor of 0.8 to the theoretical pool. We have focused on the bark component of the wood waste stream and this amount is estimated as 72% of the total wood waste stream (Table 33). Planer shavings and sawdust are normally commoditized and we have taken the conservative stance that this material would be unavailable to the Atikokan GS as a cost-effective biomass feedstock. Wood waste data for Ontario sawmills was obtained from the MNR (Mr. J. Maure, Ministry of Natural Resources, personal communication).

Table 33. Breakdown of wood waste by fibre type for Ontario mills

Fibre Type	2003	
	m^3	%
Bark	673,000	72%
Other Fibres	182,000	20%
Sawdust	0	0%
Sawdust/Shavings	73,000	8%
Shavings	3,000	0%
Sawmill Chips	1,000	0%
TOTAL	932,000	100%

Source: Ontario Ministry of Natural Resources

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Bark and hog fuel biomass was assumed to be obtained at a rate of $5/BDT in northwestern Ontario with trucking levied at $0.129/BDT-km.

4.3 Findings

The amounts and delivered costs of mill waste residues as bark and hog fuel from sawmills and panel board mills in northwestern and northeastern Ontario are given in Tables 34 and 35.

The practical pool of waste bark potentially available from these mills is estimated at 84,000 BDT/yr (Table 23B). A further 120,000 BDT/yr is produced by mills in northeastern Ontario, however, as seen in Table 35, the high cost of trucking this material to the Atikokan GS disqualifies them as potential sources of biomass. The landed cost of the waste bark from mills in northeastern Ontario ranges from $154 to $258/BDT or $8.10 to $13.60/GJ.

Roughly 65% (i.e. 54,000 BDT/yr) of the practical pool of waste mill residues occurs within 300 km of the Atikokan GS at a landed price of $21 to $82/BDT or $1.10 to $4.30/GJ (Figure 8, Table 23B, C, D).

Table 34. The amount and delivered cost of waste bark from sawmills and panel board mills in the Northwest region of Ontario

Company	input (m^3)	waste (m^3)	bark (m^3)	Theoretical (BDT)	AF	Actual (BDT)	$/BDT	$/GJ
Nipigon District								
Long Lake Forest Products Inc.	614,074	43,073	31,013	9,900	0.8	7,920	$147	$7.70
Nakina Forest Products Ltd.	544,363	39,069	28,130	9,000	0.8	7,200	$147	$7.70
Longlac Wood Industries Inc.	281,204	5,624	5,624	1,800	0.8	1,440	$147	$7.70
Longlac Wood Industries Inc.	154,848	3,097	3,097	1,000	0.8	800	$147	$7.70
Levesque Plywood Ltd.	76,289	1,526	1,526	500	0.8	400	$81	$4.30
Thunder Bay District								
Great West Timber Ltd.	495,301	36,192	26,059	8,300	0.8	6,640	$52	$2.70
Northern Sawmills Inc.	848,962	55,989	40,312	12,900	0.8	10,320	$52	$2.70
Port Arthur Lumber & Planing Mill Ltd.	6,400	1,070	770	200	0.8	160	$52	$2.70
Buchanan Northern Hardwoods Inc.	655,525	45,412	32,697	10,500	0.8	8,400	$52	$2.70
Bowater Canadian Forest Products Inc.	506,528	36,855	26,536	8,500	0.8	6,800	$52	$2.70
Sioux Lookout District								
McKenzie Forest Products Inc.	986,710	63,238	45,531	14,600	0.8	11,680	$70	$3.70
Fort Frances District								
Atikokan Forest Products Ltd.	428,042	32,159	23,154	7,400	0.8	5,920	$5	$0.30
Nickel Lake Lumber	21,069	2,808	2,021	600	0.8	480	$41	$2.20
Manitou Forest Products Ltd.	16,869	2,345	1,688	500	0.8	400	$53	$2.80
Ainsworth Engineered Corp.	677,045	13,541	13,541	4,300	0.8	3,440	$53	$2.80
Kenora District								
Kenora Forest Products Ltd.	233,559	19,691	14,178	4,500	0.8	3,600	$93	$4.90
Devlin Timber Company Ltd.	23,060	3,021	2,175	700	0.8	560	$93	$4.90
Dave Burt General Contractors Ltd.	4,148	753	542	200	0.8	160	$90	$4.70
Red Lake District								
Weyerhaeuser Company Ltd.	564,304	40,224	28,961	9,300	0.8	7,440	$94	$4.90
L.K.G.H. Contracting Ltd.	5,985	1,013	730	200	0.8	160	$114	$6.00

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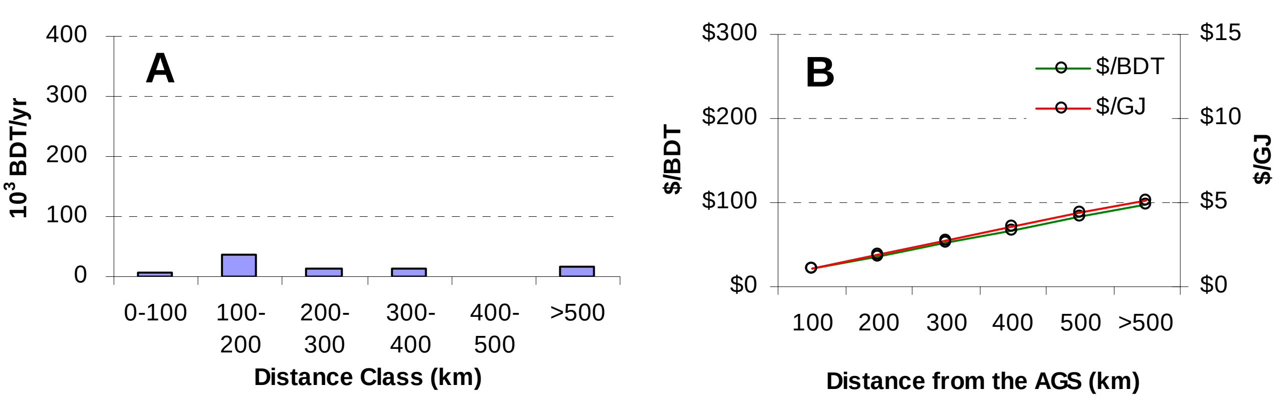
Table 35. The amount and delivered cost of waste bark from sawmills and panel board mills in the northeast region of Ontario

Mill	Input (m^3)	Waste (m^3)	Bark (m^3)	Theoretical (BDT)	AF	Actual (BDT)	$/BDT	$/GJ
Wawa District								
Dubreuil Forest Products Ltd.	642,294	44,669	32,162	11,321	0.8	9,100	$165	$8.70
Domtar Inc.	135,942	12,705	9,147	3,220	0.8	2,600	$154	$8.10
Weyerhaeuser Company Ltd.	590,114	11,802	11,802	2,991	0.8	2,400	$178	$9.40
Hearst District								
Tembec Industries Inc.	560,292	39,992	28,794	10,136	0.8	8,100	$199	$10.50
Lecours Lumber Company Ltd.	471,489	34,777	25,039	8,814	0.8	7,100	$168	$8.80
Excel Forest Products	376,439	28,982	20,867	7,345	0.8	5,900	$204	$10.80
Spruce Falls Inc.	410,423	31,083	22,379	7,878	0.8	6,300	$214	$11.30
Olav Haavaldsrud Timber Company Ltd.	224,598	19,077	13,736	4,835	0.8	3,900	$180	$9.50
Levesque Plywood Ltd.	253,446	5,069	5,069	1,285	0.8	1,000	$199	$10.50
Levesque Plywood Ltd.	188,409	3,768	75	955	0.8	800	$199	$10.50
Chapleau District								
Tembec Industries Inc.	377,361	29,039	20,908	7,360	0.8	5,900	$228	$12.00
Weyerhaeuser Company Ltd.							$228	$12.00
Domtar Inc.	373,980	28,828	20,756	7,306	0.8	5,800	$228	$12.00
Pineal Lake Lumber Company Ltd.	16,055	2,253	1,622	571	0.8	500	$228	$12.00
Devon Mills Ltd.	3,692	685	493	174	0.8	100	$228	$12.00
Sault Ste. Marie District								
Boniferro Mill Works Ltd.	47,528	5,425	3,906	1,375	0.8	1,100	$239	$12.60
Flakeboard Company Ltd.	561,579	11,232	11,232	2,847	0.8	2,300	$239	$12.60
Midway Lumber Ltd.	92,236	9,280	6,682	2,352	0.8	1,900	$258	$13.60
Birchland Veneer Ltd.	8,996	180	180	46	0.8	0	$258	$13.60
Timmins District								
Gogama Forest Products Ltd.	322,842	25,592	18,427	6,486	0.8	5,200	$258	$13.60
Domtar Inc.	441,442	32,971	23,739	8,356	0.8	6,700	$258	$13.60
Little John Enterprises Ltd.	5,463	941	678	239	0.8	200	$258	$13.60
Tembec Industries Inc.	471,193	34,759	25,027	8,809	0.8	7,000	$258	$13.60
Grant Forest Products	961,166	19,223	19,223	4,872	0.8	3,900	$258	$13.60
Cochrane District								
Tembec Industries Inc.	397,634	30,296	21,813	7,678	0.8	6,143	$246	$12.90
Norboard Industries Inc.	164,338	3,287	3,287	833	0.8	666	$246	$12.90

Figure 8. The amount (A) and delivered cost (B) of waste bark available to the Atikokan GS



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5. Landfilled Wood Waste

5.1 Introduction

There is a significant amount of wood waste landfilled in on- or off-site dumps tied to sawmilling operations in northwestern Ontario. Indeed, FBi estimates that almost 105,000 BDT/yr of waste bark is disposed of by sawmills in the region (i.e. theoretical pool of mill wood waste, Table 23A). This fresh material represents a viable source of biomass, however, the amount of landfilled wood waste that could be recovered and used for fuel is limited by decay, contamination, and high moisture content. The combined costs of mining, cleaning and drying these wood wastes would significantly increase their per unit energy cost.

5.2 Approach

FBi has modelled the amount of landfilled wood waste using data received from the Ontario Ministry of the Environment on the location, size and status of mill dump sites in the Thunder Bay region (Mr. R. Purdon, Ministry of the Environment, personal communication). Tables 36 and 37 give the locations, owners and sizes of active and inactive wood waste sites in the region. Biomass in inactive wood waste sites was not included here since all of these landfills have been out of use for at least 10 years.

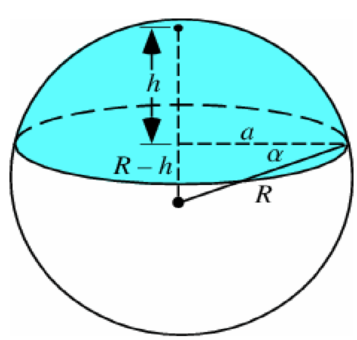
Table 36 identifies roughly 130 ha of active wood waste sites in the region. We assume a total area of 200 ha to account for missing data. The amount of biomass in these dumps can be estimated by grouping them into a single large landfill with a radius of 643 m an average depth of 20 m:

$$\pi a^2 = 200 \text{ ha} = 2{,}000{,}000 \text{ m}^2;\ \therefore\ a = 800 \text{ m and } h = 20 \text{ m}$$

The volume of material is estimated using the volume equation for a spherical cap (Figure 8):

$$V = 1/6\pi h(3a^2 + h^2)$$

Figure 9. Finding the volume of a spherical cap



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It is assumed that half of this material is useful as a fuel, with a bulk density of 400 kg/m^3 and a moisture content of 50%.

5.3 Findings

The total volume of such a wood waste landfill is estimated at 20 million m^3. Multiplying this by its bulk density and accounting for moisture gives a theoretical pool of 4 million BDT. By applying an availability factor of 0.5 (decay, contamination, recoverability) roughly 2 million BDT of fuel-quality biomass is stored in the hypothetical landfill.

Table 36. Location, owner and size of active wood waste sites in the Thunder Bay region

Location	Site Owner	Size
Atikokan	Proboard Inc.	Landfill Area 1.5 ha; Total Area 8.5 ha
Hutchinson Twp	Atikokan Forest Products Ltd.	Landfill Area 6 ha; Total Area 95 ha
Daley Twp	Longlac Wood Industries Inc.	Landfill Area 19.4 ha; Total Area 50 ha
Dorion	Bowater	
Exton	Nakina Forest Products	Landfill Area 9.9 ha; Total Area 62.8 ha
Graham Twp	Bowater	
Graham Twp	Bowater	
Graham Twp	Buchanan Forest Products Ltd.	Landfill Area 1 ha; Total Area 68 ha
Houghton Lake	Bowater	
Ledger Twp	Jim Nichols Trucking Ltd.	Landfill Area 3 ha; Total Area 8 ha
Daley Twp	Long Lake Forest Products Inc.	Landfill Area 10 ha; Total Area 70 ha
McGregor Twp	Bowater	Landfill Area 6.5 ha
Marathon	Marathon Pulp Inc.	
Marathon	Marathon Pulp Inc.	Landfill Area 6.5 ha; Total Area 16.3 ha
Nakina	Kimberly-Clark	
Nipigon	Weyerhaeuser Company Ltd.	Landfill Area 0.3 ha; Total Area 0.4 ha
Nipigon	NORAMPAC INC	
Red Rock	NORAMPAC INC	Landfill Area 7 ha; Total Area 17 ha
Red Rock	NORAMPAC INC	Total Area 4.4 ha
Thunder Bay	Abitibi-Consolidated Ltd.	Landfill Area 16.3 ha; Total Area 21.6 ha
Thunder Bay	Northern Sawmils	35,000 m^3
Thunder Bay	Bowater	
Terrace Bay	Kimberly-Clark	Landfill Area 30.7 ha; Total Area 87.9 ha
Unorganized Twp	Bowater	
Unorganized Twp	Bowater	
Unorganized Twp	Domtar Forest Products	Landfill Area 1 ha; Total Area 2 ha
Unorganized Twp	Great West Timber Ltd.	Landfill Area 1 ha; Total Area 2 ha
Upsala	Upsala Forest Products Ltd.	Landfill Area 2.3 ha; Total Area 10 ha
Upsala	Upsala Forest Products Ltd.	Landfill Area 3.8 ha; Total Area 12.4 ha
Upsala	Bowater	Landfill Area 0.6 ha; Total Area 38.4 ha

Source: Ontario Ministry of the Environment

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Table 37. Location, owner and size of inactive wood waste sites in the Thunder Bay region

Location	Site Owner	Size
Caramat	Buchanan Forest Products Ltd.	Landfill Area 0.5 ha; Total Area 2.7 ha
Coldwell Twp	Great West Timber Ltd.	
Daley Twp	Longlac Wood Industries Ltd.	Landfill Area 2.6 ha
Graham Twp	Bowater	
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 0.01 ha; Total Area 0.25 ha
Longlac	Kimberly-Clark	Landfill Area 9.5 ha; Total Area 19.8 ha
Marathon	Marathon Pulp Inc.	Landfill Area 15 ha; Total Area 16 ha
Nelson Lake	Bowater	
Savant Lake	Bowater	Landfill Area 0.65 ha; Total Area 19.6 ha
Thunder Bay	Great West Timber Ltd.	Landfill Area 4 ha; Total Area 9.7 ha
Thunder Bay	Thunder Bay Hydrol	
Thunder Bay	Bowater	Landfill Area 33.6 ha
Terrance Bay	Kimberly-Clark	
Terrance Bay	Kimberly-Clark	
Unorganized Twp	Abitibi-Consolidated Ltd.	Landfill Area 0.1 ha; Total Area 0.8 ha
Unorganized Twp	Buchanan Forest Products Ltd.	Landfill Area 0.5 ha
Unorganized Twp	Buchanan Forest Products Ltd.	Landfill Area 0.5 ha

Source: Ontario Ministry of the Environment

Based on this analysis, the 30 active wood waste sites in the Thunder Bay region together contain some 2 million BDT of biomass that could be mined, processed and burned to generate electricity at the Atikokan GS.

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6. Fuel Grade Peat

6.1 Introduction

Peat is defined as the accumulating mass of dead sphagnum in an environment that prevents or slows decomposition owing to a high water table. Peat deposits occur in bogs, fens, swamps and marshes and the material can be harvested for a variety of uses. It is estimated that there are 3 trillion m^3 or 510 billion tonnes of peat in Canada (Daigle and Gautreau-Daigle, 2001). In Canada, peat moss is harvested and sold to the horticultural industry or for household use.

Fuel-grade peat is defined as peat with an energy density exceeding 17.4 GJ/BDT and with less than 15% ash content on a dry basis. In Finland, Sweden, Ireland, Russia, Estonia and Latvia fuel-grade peat is harvested, processed and burned to generate electricity in steam-powered generators.

Between 1982 and 1985, the Peatland Inventory Project of the Ontario Geological Survey (OGS) undertook the survey of peatlands across almost 88,000 km^2 of northwestern Ontario (Riley and Michaud, 1989). The overall intent of the inventory was to characterize and map the peat resource in the region (Figure 10). The work is summarized as follows:

- Carried out reconnaissance field investigations of designated peatlands, in order to assess or confirm which sites should be surveyed in detail;
- Carried out detailed field investigations of designated peatlands in which the peat type, humification stratigraphy, area, volume and other relevant information was evaluated;
- Mapped all designated peatlands on the basis of airphoto interpretation and field work into major types (i.e. bog, fen, swamp, marsh);
- Estimated regional peat volumes by extrapolating measured average peat depths for each peatland type, derived from detailed field studies.

Overall, the regional volume of *in situ* peat was estimated at 12.6 billion m^3, corresponding to 1.1 billion BDT of material. Roughly 54% of the total volume of peat was in bogs and fens, which tend to be ideal for harvesting operations because of their depth and accessibility. Bogs and fens in the region were estimated to contain 595 million BDT of peat, around 39% or 232 million BDT of which was of fuel-grade in deposits greater than 2 m in depth. The study authors recommend that half of this volume should be discounted due to land use conflicts and the non-continuity, small size, and poor accessibility of peatlands. What remains is an amount of fuel-grade peat with the energy equivalent of 330 million barrels of crude oil.

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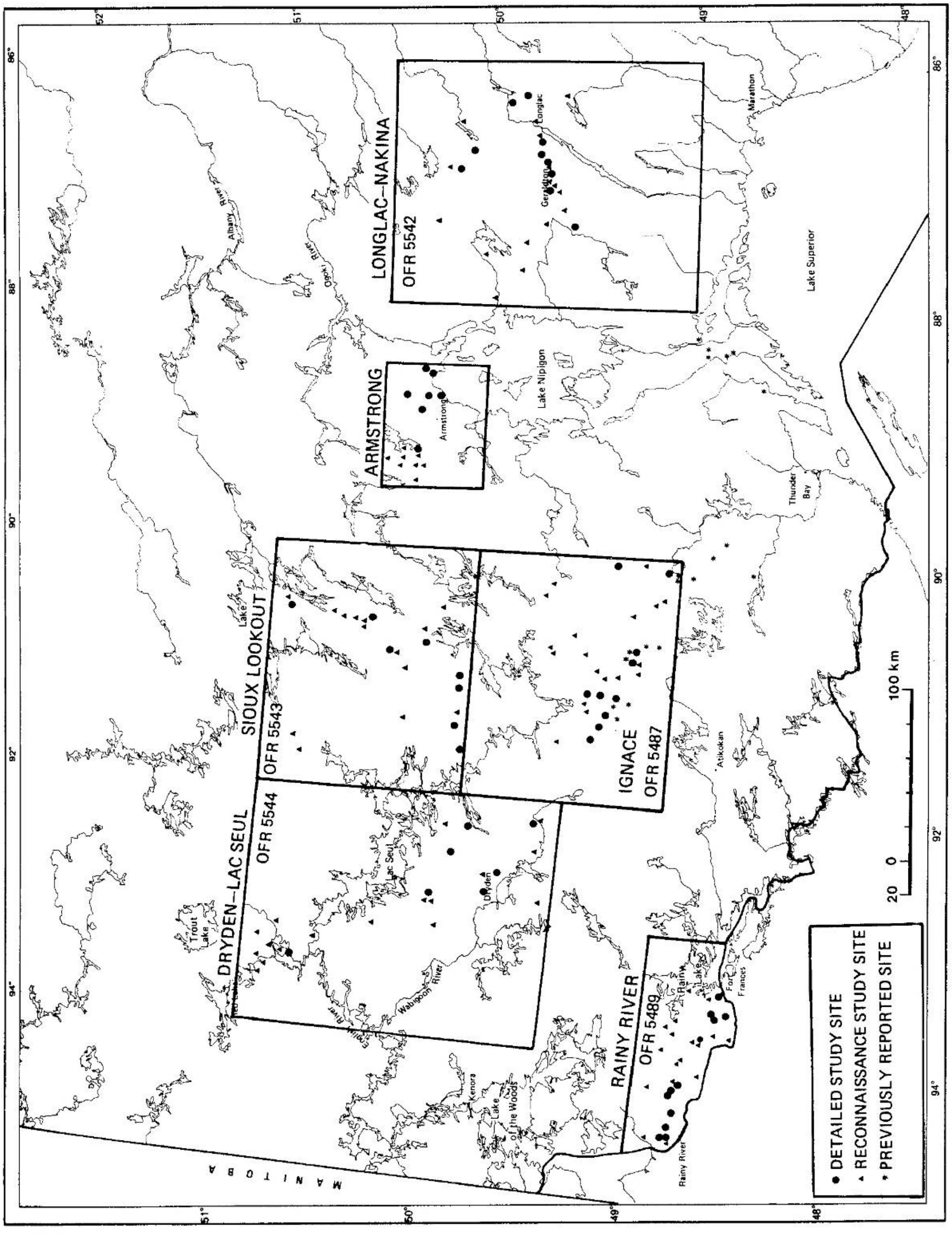
Figure 10. Areas surveyed in the Peatland Inventory Project of the Ontario Geological Survey. From Riley and Michaud (1989)



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The regional peat resource figures and detailed survey data provided by the inventory points towards a vast and almost entirely unexploited material resource.

The area, volume and mass of fuel-grade peat in the 6 study areas surveyed by the OGS are given in Table 38. Over 700,000 ha of peatlands containing roughly 400 million BDT of fuel-grade peat were identified in the OGS inventory. Approximately 21% of all fuel-grade peat deposits mapped were located in the Ignace study region which is in close proximity to the Atikokan GS (Figure 10).

Table 38. The fuel-grade peat resource in the Northwestern Ontario study areas surveyed by the OGS

	Rainy River	Dryden - Lac Seul	Sioux Lookout	Ignace	Armstrong	Longlac - Nakina	TOTAL
Total Peatland Area (ha)	116,000	84,000	95,000	194,000	10,000	202,000	701,000
Total Volume of Fuel-Grade Peat ($x10^6$ m^3)	1,800	1,100	1,500	1,700	50	1,900	8,050
Total Mass of Fuel-Grade Peat ($x10^6$ BDT)	90	50	70	80	3	100	393

There are two factors to consider in setting the acceptable level of fuel peat harvest in Ontario:

Annual Allowable Harvest (AAH)

AAH is analogous to the Annual Allowable Cut (AAC) used in forest management planning. The AAH for Ontario is equal to the amount of peat that accumulates each year in the province and by harvesting the AAH a constant peat resource can be maintained.

Taking an AAH approach to determining the sustainable production level for fuel peat in northern Ontario requires a comprehensive database on peatlands and peat resources. Except for the detailed resource evaluation undertaken in 2005 by PRL in the Upsala area (DST, 2005), the only substantial body of information on Ontario peat resources is the results of the Ontario Peatland Inventory Project conducted by the Ontario Geological Survey between 1981-1985 (Riley and Michaud, 1989). This inventory was intended to provide information on the possible energy and horticultural potential of the resource and to assist the government of Ontario in land use planning and resource management.

A preliminary provincial study estimated that Ontario's peatlands cover approximately 22 million hectares including about 9.9 million hectares south of the southern limit of discontinuous permafrost (Monenco, 1981). Because of this vast area and the time and resources available to the OGS, the 1981-1985 inventory was conducted at only a reconnaissance level (Telford, 1983). In northwestern Ontario, for example, the inventory surveyed only 72,600 ha of an estimated 700,000 ha of peatlands in the region (Riley and Michaud, 1989).

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The OGS inventory did include detailed field investigations of a few selected peatlands to evaluate peat humification stratigraphy, peat volumes, elevations, drainage, surficial vegetation and other relevant information that was used to extrapolate results across the broader area. However, none of these investigations approached the level of detail now required to define “indicated” or “measured” resources as currently required for public disclosure by Ontario companies. Work by PRL on its property near Upsala has identified about 22 million tonnes of fuel-grade peat (10% moisture level) according to regulated procedures. In addition, forested areas that were often avoided by the OGS inventory were found to contain large peat resources (DST, 2005). This suggests that, on the whole, results of the OGS inventory are significantly underestimated.

In its response to recommendations of the Environmental Commissioner of Ontario (ECO, 2005), MNR states that it “recognizes the economic benefits of a peat harvesting industry” and that “MNR will be reviewing options for managing peat harvesting”. As the database on the northern peatlands is improved, the AAH approach could be a tool for ensuring sustainable use of this important renewable resource. However, application of the AAH approach, at this time, to development of the peat resources of northern Ontario is considered provisional only.

For the purpose of this report, we have elected to determine whether the proposal to harvest 1,000,000 BDT of peat per annum fits within the concept of AAH for Ontario. Using the rough data available to us we have determined an AAH level for Ontario. Given that in Ontario there are around 20 billion BDT of fuel grade peat in 22 million ha of peatlands that, on average, accumulate carbon at the rate of 20 g C m^{-2} yr^{-1} (Gorham, 1991). Given that peat is 50% C on a dry basis, peatlands in Ontario accumulate roughly 8.8 million BDT/yr. In theory, 8.8 million BDT/yr would be the maximum provincial AAH.

Note that we are using this concept as a rough landscape model for the potential of harvesting peat at the landscape level. To our knowledge this concept has not been advanced in any other jurisdictions and it is not a component of policies in Ontario. As well, the AAH concept is only of value as long as fuel peat is considered a renewable resource. Should it be classified a mineral resource, then there is no constraints on its harvest as long as the harvest meets environmental impact guidelines, including post harvest reclamation and environmental protection.

Conversion to More Productive Ecosystems

Forest ecosystems are significantly more productive than peatland ecosystems and therefore sequester carbon at a much faster rate. Net primary productivity in the boreal forest of northwestern Ontario averages 400-500 g C m^{-2} yr^{-1} which is 20-25 times that of bogs and fens in the region. Harvesting peatlands for fuel and reclaiming them as faster growing ecosystems would increase carbon storage in Ontario’s forests. This could assist in meeting Kyoto commitments as well as support the forest industry by providing additional sources of fiber.

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6.2 Approach

The amount and delivered cost of fuel-grade peat with distance from the Atikokan GS was modelled using parameters taken from the OGS report and from land classification data obtained from the Ontario Ministry of Natural Resources for each FMU in northwestern Ontario (Mr. D. Rouillard, Ministry of Natural Resources, personal communication). Only fuel-grade peat in bogs and fens were included in the analysis since they tend to be larger, deeper deposits well-suited for resource development. Table 39 lists the area of peatlands as bogs and fens in FMU's in the northwest region.

By definition, fuel-grade peat has an energy density of over 17 GJ/BDT, humification levels of H4 or greater and ash contents below 15%. A total of 39% of all peat samples analyzed in the OGS inventory met these criteria. As such, a value of 39% was used here as the percentage of fuel-grade peat in bogs and fens. Table 40 is an example of how the total fuel-grade peat resource was calculated using data for the Sapawe FMU.

The total fuel-grade peat resource (BDT) in FMU's in northwestern Ontario was found using:

$$FGP = PA \times d \times \%FG \times \%DW$$

where *FGP* is the total amount of fuel-grade peat (BDT);
PA is peatland area (m^2), taken from OMNR data;
d is the average deposit depth (m) as reported by Riley and Michaud (1989);
%FG = 39% is the percentage of fuel-grade peat, as reported by Riley and Michaud (1989);
%DW = 9% is the percent dry weight of *in situ* peat.

The total resource was discounted by a factor of 0.5 to approximate the available resource as per Riley and Michaud (1989).

The following scenario was assumed for the harvest, processing and transport of fuel-grade peat from the field to the Atikokan GS:

- Peat is wet-harvested using an excavator at $11/BDT (Mr. S. Golod, Peat Resources Ltd., personal communication);
- Peat is mechanically dewatered, dried and pelletized at field processing stations at $38.50/BDT (Mr. S. Golod, Peat Resources Ltd., personal communication);
- Peat pellets are trucked to the Atikokan GS at $0.129/BDT-km.

Note that costs associated with preparing peatlands for harvest (i.e. clearing of trees, removal of surface layers) were not modelled in this analysis.

The distance class matrix given in Table 30 was used to calculate trucking costs.

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Table 39. Area (ha) of peatlands in northwestern Ontario FMU's based on Landsat land classification data

Peatland Type	Armstrong	Black Sturgeon	Caribou	Crossroute	Dog River - Mattawin	Dryden	English River
Open Bog	3,800	1,200	2,700	11,900	10,600	1,200	9,200
Treed Bog	9,700	5,700	10,900	46,100	51,300	2,700	25,600
Open Fen	2,800	2,300	2,100	2,800	2,700	300	2,000
Treed Fen	4,400	700	3,000	10,100	18,400	1,600	4,400
TOTAL	20,700	9,900	18,700	70,900	83,000	5,800	41,200

Peatland Type	Kenogami	Kenora	Lac Seul	Lake Nipigon	Lakehead	Ogoki	Pic River Ojibway
Open Bog	7,500	7,900	1,300	1,300	600	6,600	0
Treed Bog	53,100	20,000	15,600	17,900	5,600	55,000	1,100
Open Fen	5,200	400	1,000	4,400	100	9,000	0
Treed Fen	85,000	5,200	9,500	4,700	1,000	33,000	0
TOTAL	150,800	33,500	27,400	28,300	7,300	103,600	1,100

Peatland Type	Red Lake	Sapawe	Spruce River	Trout Lake	Wabigoon	Whiskey Jack	TOTAL
Open Bog	1,200	700	6,000	3,700	2,400	2,000	82,000
Treed Bog	5,800	3,000	24,300	25,500	10,500	10,400	399,500
Open Fen	100	100	700	1,200	600	200	38,100
Treed Fen	5,000	900	2,200	18,800	3,100	5,600	216,700
TOTAL	12,100	4,700	33,200	49,200	16,600	18,200	**736,200**

Source: Ontario Ministry of Natural Resources

Table 40. Calculating the total fuel-grade peat resource in bogs and fens in the Sapawe FMU

Peatland Type	Area (m^2)	Depth (m)	Total Volume (m^3)	% Fuel Grade	Fuel-Grade Volume (m^3)	Fuel-Grade Mass (BDT)
Open Bog	6,926,000	2.90	20,085,000	39%	7,833,000	705,000
Treed Bog	30,158,000	2.70	81,427,000	39%	31,757,000	2,858,000
Open Fen	1,496,000	2.60	3,890,000	39%	1,517,000	137,000
Treed Fen	8,950,000	2.20	19,690,000	39%	7,679,000	691,000
TOTAL	47,530,000		125,092,000		48,786,000	4,391,000

6.3 Findings

The distribution and delivered cost of fuel-grade peat in bogs and fens for the FMU's treated in this study with distance from the Atikokan GS is shown in Figure 12.

Figure 12 shows the distribution of the available fuel-grade peat resource in bogs and fens for the FMU's treated in this study with distance from the Atikokan GS. The

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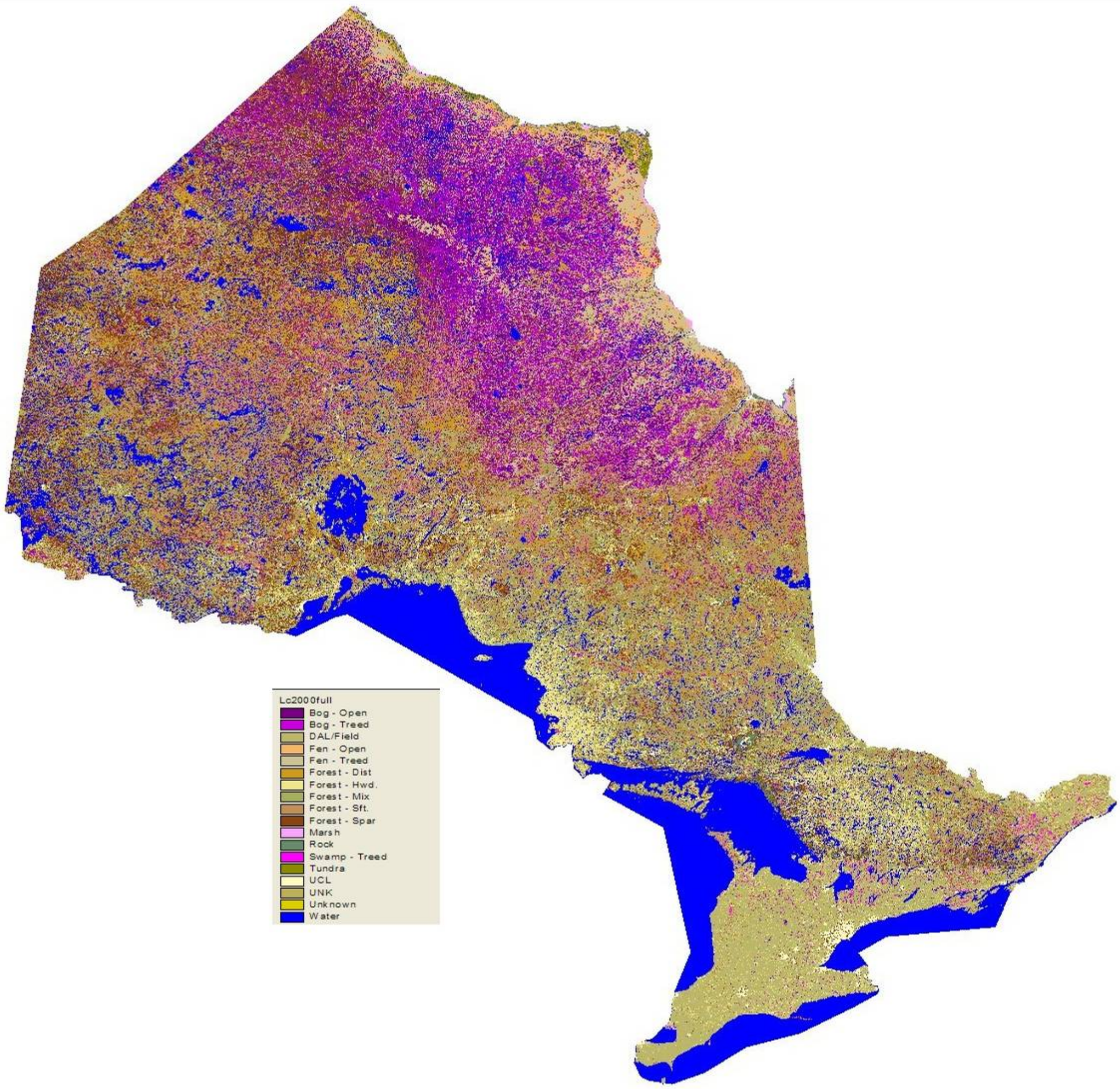
amount is estimated at 332 million BDT, around 50% of which (i.e. 167 million BDT) is found within 300 km of the Atikokan GS.

Figure 11. Landsat land classification image of Ontario. From the Ontario Ministry of Natural Resources



We have estimated an available fuel-grade peat resource in excess of 100 million BDT within 200 km of the Atikokan GS (Figure 12). The landed cost of this material is modeled at $65-$96/BDT or $3.60-$5.40/GJ (Table 23C, D).

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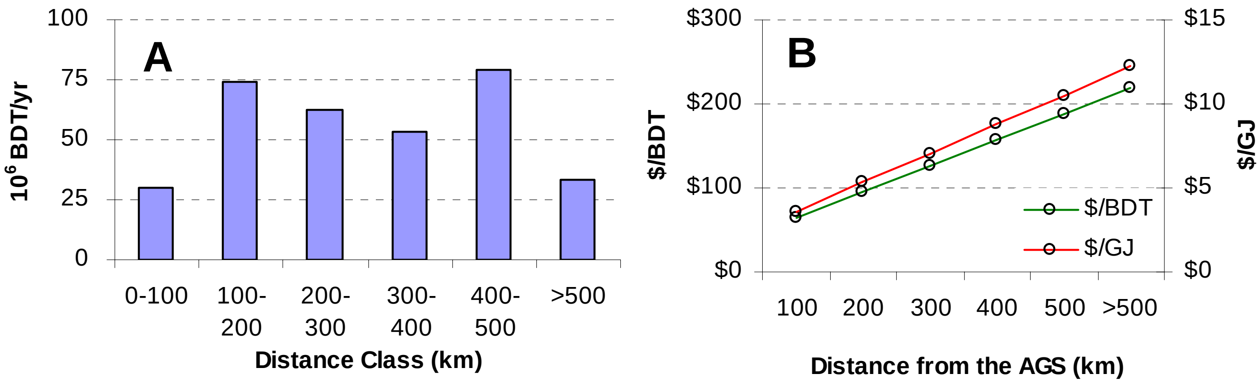
Figure 12. The amount (A) and delivered cost (B) of fuel-grade peat in bogs and fens in northwestern Ontario FMU's



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7. Dedicated Energy Plantations

7.1 Introduction

Energy crops are grown as a substitute for fossil fuels for use in power stations and heating systems. Crops commonly grown for fuel in Europe and the US include perennial grasses such as switchgrass, reed canary grass and elephant grass and fast-growing varieties of poplar and willow.

Aside from being a fuel source, energy plantations can increase carbon sequestration in soils and can be grown on marginal or idle agricultural lands. As such, they offer incentives in terms of reducing atmospheric CO_2 and stimulating rural economies

In Canada, short-rotation willow (SRW) plantations can produce between 5-12 BDT/ha-yr of biomass over 10-20 years. Fully-loaded production costs for Ontario are modelled at $112-$160/BDT as per 1995 (Samson et al., 1999).

7.2 Approach

The amount of biomass as SRW was estimated based on farm data for the Thunder Bay and Rainy River districts obtained from the Ministry of Agriculture, Food and Rural Affairs (OMAFRA, 2001a,b).

The land base for SRW production was modelled assuming that 10% of the total area of improved pasture, unimproved pasture and other land in the Districts of Thunder Bay and Rainy River would be converted to SRW. Yields of 7 BDT/ha-yr and production costs of $108/BDT were used (Samson et al., 1999).

Growing regions in Thunder Bay and Rainy River District were classified with distance from the Atikokan GS (Table 41, Figure 13). A value of $0.129/BDT-km was used to estimate transportation costs.

Table 41. Distance class matrix used in calculating the delivered cost of short-rotation willow biomass to the Atikokan GS

OMAFRA District	% of Forest Management Unit in Distance Class					
	0-100 km	100-200 km	200-300 km	300-400 km	400-500 km	>500 km
Thunder Bay	0%	100%	0%	0%	0%	0%
Rainy River	0%	90%	10%	0%	0%	0%

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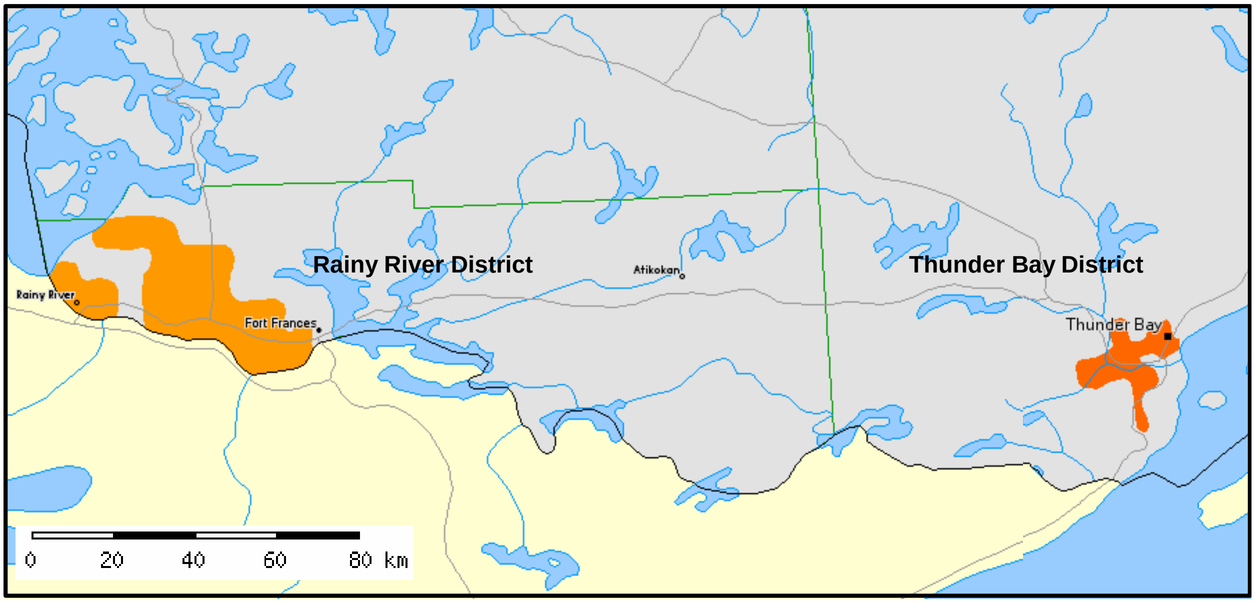
Figure 13. Growing regions in Thunder Bay and Rainy River Districts for energy crops. From The Atlas of Canada



7.3 Findings

Table 42 summarizes the potential for biomass production as SRW in the Thunder Bay and Rainy River Districts.

Table 42. The amount of biomass as short-rotation willow that could be grown on pasture and marginal lands in the Thunder Bay and Rainy River Districts assuming a conversion rate of 10%, a growth increment of 7 BDT/ha-yr and a harvest period of 4 years

OMAFRA District	BDT/yr of biomass available with distance (km) from AGS						TOTAL
	0-100	100-200	200-300	300-400	400-500	>500	
Thunder Bay	0	9,000	0	0	0	0	9,000
Rainy River	0	33,300	3,700	0	0	0	37,000

If 10% of the agricultural land treated here were converted to SRW producing 7 BDT/ha-yr every 4 years, the amount of biomass available at the end of the harvest cycle would be 46,000 BDT, all grown within 300 km of the Atikokan GS (Figure 15A).

The delivered cost of this biomass would range from $155 to $186/BDT or $8.10 to $9.80/GJ assuming an energy density of 19 GJ/BDT (Figure 14B). As such, SRW biomass would not be a cost-effective feedstock compared to lignite at this point in time.

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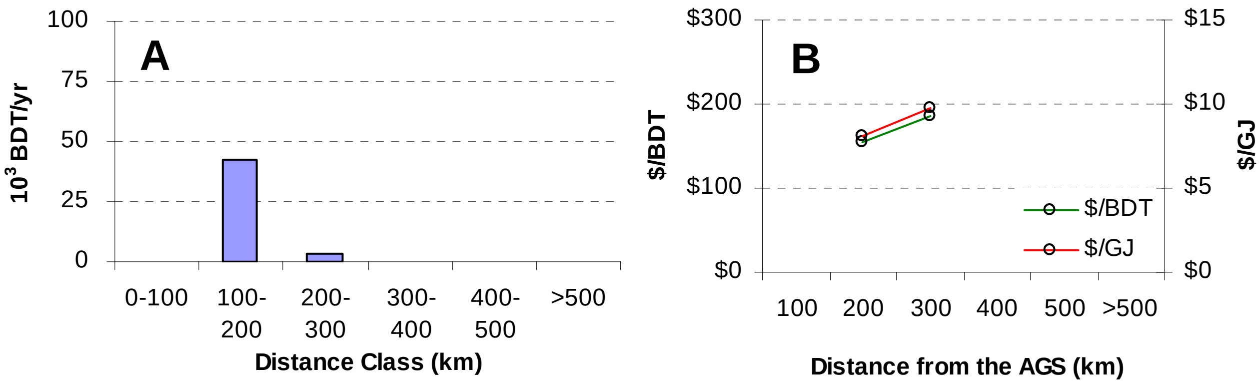
Figure 14. The amount (A) and delivered cost (B) of short-rotation willow biomass available to the Atikokan GS



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8. Municipal Solid Waste

8.1 Introduction

As of January 2003, the disposal of 100% of waste generated in the City of Toronto is provided under contract with Republic Services' Carleton Farms Landfill located in Michigan. Disposal capacity has been secured to December 31, 2020. The current cost for haulage and disposal is $50.54/tonne and $53.64/tonne for municipal and commercial tonnage, respectively (City of Toronto, 2005)

In 2003, the City's Solid Waste Management Services (SWMS) collected some 1.5 million tonnes of solid waste (Table 45), 330,000 tonnes of which was diverted through various curbside diversion programs (Table 46). The remaining 1,130,000 tonnes of waste was shipped to Michigan at the rate of 140 truckloads per day. As such, the City spent in excess of $58 million to dispose of its garbage in 2003. The City has zero landfill capacity and has made a commitment to increase its diversion rate to 100% by the year 2010.

Table 43. Origin of waste collected by Toronto's Solid Waste Management Services in 2003

Stream	%	tonnes
Residential	62%	908,000
Paid Commercial	25%	363,000
Peel Region	7%	102,000
ABCD & Other	4%	58,000
Small Commercial	2%	29,000
	100%	1,460,000

Source: City of Toronto (2005)

Table 44. Waste diverted in Toronto in 2003

Diverted Waste	%	tonnes
Containers/Fibre	51%	146,000
Leaf/Yard Waste	27%	77,000
Organics	18%	52,000
Cardboard	2%	6,000
White Goods	1%	3,000
Household Hazardous Waste	1%	3,000
	100%	287,000

Source: City of Toronto (2005)

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In other jurisdictions (i.e. USA, Germany, Scandinavia, Italy, Japan), municipal solid waste (MSW) is processed into refuse-derived fuel (RDF) that is gasified and/or combusted alone or co-fired with other feedstocks (i.e. coal, woody biomass) in power boilers to generate electricity. RDF refers to solid waste in any form that is used as fuel, however, it is commonly used to refer to solid waste that has been mechanically and thermally processed to produce a storable, transportable, and more homogeneous fuel for combustion. RDF production facilities make RDF in various forms through materials separation, size reduction, and pelletizing. In general, 1 tonne of source-separated MSW becomes 0.7 tonnes of RDF produced through the following steps:

- Refuse reception;
- Preliminary shredding and crushing;
- Magnetic separation;
- Drying;
- Screening and/or air classification;
- Secondary crushing or hammermilling;
- Mixing;
- Baling or Pelletizing.

Non-combustible materials and bulk recyclables are removed, resulting in a material with an increased energy content compared to MSW. An RDF pellet is mostly composed of paper, paperboard and plastic film (UTRC, 2001) (Table 45). It is compressed to a bulk density of 500-600 kg/m^3, has a moisture content of <10% and an energy density of 15-18 GJ/BDT.

Table 45. Typical make-up of an RDF pellet

Fraction	mass %
Paper, Paperboard & Plastic Film	87%
Wood	3%
Glass	3%
Plastic Container	2%
Grit <10 mesh	2%
Dense Plastic	2%
Light Plastic	1%
Aluminium	1%
Ferrous	0.5%

Source: UTRC (2001)

Revenues are generated at RDF processing facilities through MSW tipping fees (i.e. RDF feed material) and the sale of baled recyclables and RDF pellets. As mentioned above, the City of Toronto has committed to increase its waste diversion rate from 32% in 2003 to 100% in 2010 – an increase of 68% over 7 years. Processing Toronto's

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MSW into RDF and shipping the pellets to the Atikokan GS by rail could represent a potential solution to Toronto's garbage problem and to the biomass feedstock issue at the Atikokan GS.

8.2 Approach

In this study, FBi modelled the amount of RDF that could be produced in Toronto based on production and diversion rates reported by the City for 2003 (City of Toronto, 2005) and waste stream composition data (residential + institutional/commercial/industrial) from the Greater Vancouver Regional District (GVRD) (TRI, 2005) (Table 46). Numbers from the GVRD were used since a recent analysis of Toronto's waste stream was not readily available. The following assumptions have been made:

- Production and diversion rates have not changed since 2003;
- Raw MSW has a moisture content of 20%;
- RDF pellets have a density of 500 kg/m^3, a moisture content of 10% and an energy density of 15 GJ/BDT;
- Toronto's garbage from all sources has the same composition as that in the GVRD.

Table 46. Waste stream composition from all sources (residential + institutional/commercial/industrial) for the Greater Vancouver Regional District in 2004

Waste Fraction	%	Waste Fraction	%
Paper & Paperboard	19%	Appliances	5%
Plastics	9%	Hazardous Waste	2%
Organic Waste	45%	Household Hygiene	3%
Metals	4%	Bulky Objects	6%
Glass	1%	Fines	2%
Inorganic Waste	3%		

Source: TRI (2005)

The amount of RDF that could be produced in Toronto was calculated using:

$$RDF = (MSW - DIV - R - NC) \times Yield \times (1 - MC)$$

where *RDF* = mass of RDF in BDT;
MSW = total mass of solid waste collected in Toronto in tonnes (at 20% moisture content);
DIV = mass of solid waste diverted in Toronto in tonnes (at 20% moisture content);
R = mass of recyclable material removed from the MSW stream during RDF processing in tonnes;

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NC = mass of non-combustible material removed from the MSW stream during RDF processing in tonnes;
Yield = RDF processing efficiency = 70%;
MC = moisture content of RDF pellet = 10%.

The landed cost of RDF at the Atikokan GS was taken as the sum of processing and transportation costs by rail. UTRC (2002) reports that in the United States, RDF costs range from $2-5/GJ with a negative cost of up to $4.50/GJ owing to tipping fees paid to the processing facility to accept the RDF feed material (i.e. $60/tonne). Processing costs are further offset by revenues generated from the sale of recyclable material. For the purposes of this report, processing costs were set at $2.50/GJ or $45/BDT, which includes the negative cost of RDF feed material. Capital costs for an RDF facility tied to a biomass integrated combined cycle power plant range from $85 to $140/kW of capacity (UTRC, 2002).

A rail freight quote was sought from CN rail to estimate the cost of shipping RDF from Toronto to the Atikokan GS. CN put forward a rail freight cost of $33.50/tonne of RDF shipped in shipper supplied specialty covered gondola railcars with a payload of 92 tonnes. Note that the quote was supplied to FBi for study purposes only and is subject to change.

8.3 Findings

Our models indicate that in 2003 the City of Toronto diverted roughly 20% of the garbage it collected while the remaining 80% - almost 1.2 million tonnes, was shipped to Michigan for disposal (Table 47). This amount, 1.2 million tonnes, represents the amount of material that could be fed into an RDF processing facility.

Table 47. The fate of Toronto's garbage in 2003

Waste Fraction	%		tonnes	
	Diverted	Michigan	Diverted	Michigan
Paper & Paperboard	7%	12%	104,000	169,000
Recyclable Plastics	1%	1%	18,000	12,000
Non-Recyclable Plastics	0%	9%	0	124,000
Combustible Organics	4%	21%	52,000	300,000
Non-Combustible Organics	5%	16%	77,000	234,000
Metals	2%	2%	31,000	30,000
Glass	0%	1%	0	20,000
Inorganics	0%	3%	0	37,000
Appliances	0.2%	5%	3,000	67,000
Hazardous Waste	0.2%	2%	3,000	23,000
Household Hygiene	0%	3%	0	39,000
Bulky Objects	0%	6%	0	86,000
Fines	0%	2%	0	22,000
	20%	80%	288,000	1,163,000

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Almost half of this material (i.e. 550,000 tonnes) is non-combustible and would be removed during the process along with almost 12,000 tonnes of recyclables. The remaining 600,000 tonnes of solid waste would be shredded, dried and pelletized to give 380,000 BDT of RDF (Table 20B).
Processing costs were modelled at $5/GJ (i.e. $90/BDT of output) and applying a negative cost of $2.50/GJ (i.e. $45/BDT of output due to tipping fees and the sale of recyclables) gave a net processing cost of $45/BDT of RDF produced. Adding this to the freight rate of $37/BDT gives a landed cost of RDF at the Atikokan GS of $82/BDT or $4.60/GJ (Table 23C, D). This is comparable to the unit energy cost of the other feedstocks within 300 km of the Atikokan GS.

Our findings show that RDF from Toronto is an abundant and relatively low-cost feedstock that could, in theory, supply up to 55% of the gross energy input at the Atikokan GS and eliminate over half of Toronto's solid waste surplus.

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Schedule 2

Air Emissions from Using Lignite, Woody Biomass, Fuel Grade Peat or Refuse Derived Fuel at the Atikokan Generating Station

1. Introduction

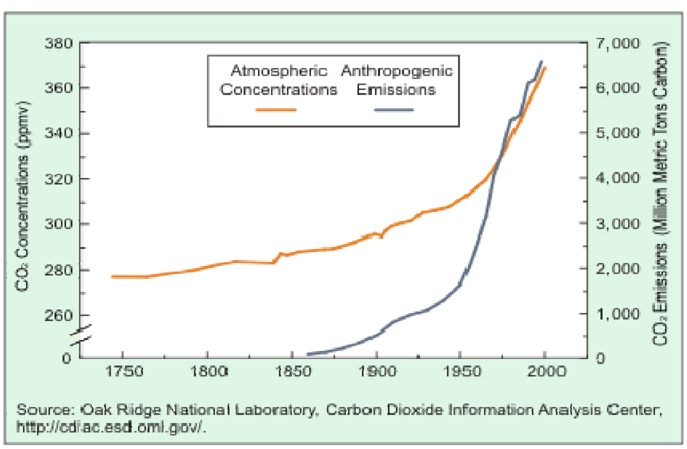
FBi has assessed the potential for greenhouse gas emissions associated with the use of lignite, woody biomass, fuel peat or refuse derived fuel at the Atikokan GS.

Many chemical compounds found in the Earth's atmosphere act as "greenhouse gases." These gases allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth's surface, some of it is absorbed and re-radiated back towards space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap the heat in the atmosphere. This upsets the earth's energy balance – which is good to an extent since, without the natural greenhouse effect, surface temperatures here would be some 33°C cooler. However, it is argued that since the industrial era, human activities have increased greenhouse gas concentrations to a degree where global warming is predicted to seriously impact on the biosphere.

Many gases exhibit these "greenhouse" properties. Some of them occur in nature (water vapor, carbon dioxide, methane, and nitrous oxide), while others are exclusively human-made (like gases used for aerosols such as hairsprays).

Levels of several important greenhouse gases have increased by about 25% since large-scale industrialization began around 150 years ago (Figure 15). During the past 20 years, about three-quarters of human-made carbon dioxide emissions were from burning fossil fuels.

Figure 15. Trends in atmospheric concentrations and anthropogenic emissions of carbon dioxide



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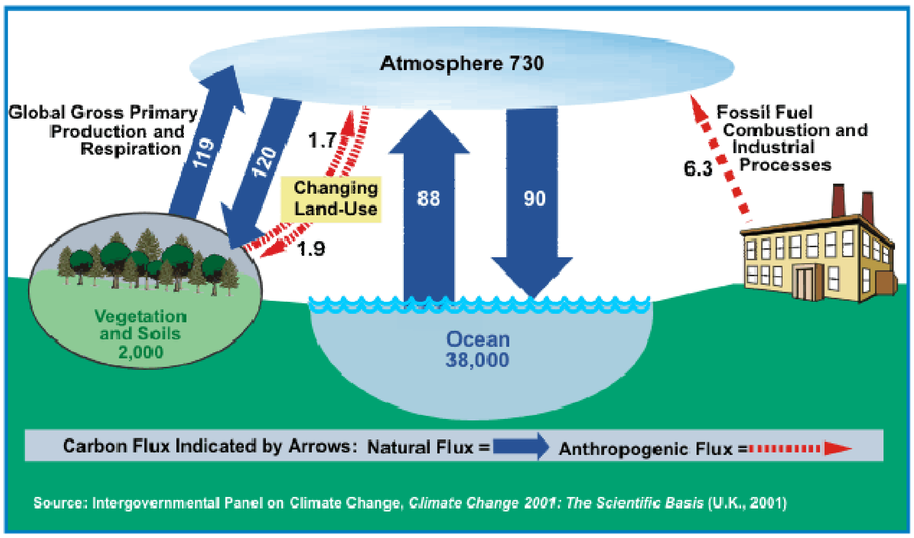
Concentrations of carbon dioxide in the atmosphere are naturally regulated by numerous processes collectively known as the "carbon cycle" (Figure 16). The movement or flux of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the net 6.1 billion metric tons of anthropogenic carbon dioxide emissions produced each year (measured in carbon equivalent terms), an estimated 3.2 billion metric tons is added to the atmosphere annually. This positive imbalance between emissions and absorption results in the accumulation of greenhouse gases in the atmosphere.

Figure 16. The global carbon cycle. Values are in billion tonnes of carbon



The extent to which a given mass of a greenhouse gas contributes to global warming is called its global warming potential (GWP). Not all greenhouse gases have the same GWP – it is a relative scale that compares the gas in question to an equivalent mass of carbon dioxide, which by definition has a GWP of 1 (Table 48).

GWP is based on a number of factors, including the radiative efficiency, or heat-absorbing ability of each gas relative to that of carbon dioxide, as well as the decay rate of each gas relative to that of carbon dioxide.

The Intergovernmental Panel on Climate Change (IPCC) provides the generally accepted values for GWP, which changed slightly between 1996 and 2001. According to IPCC (2001), GWP is calculated using:

$$GWP\left(x\right) = \frac{\int_0^{TH} a_x \cdot \left[x\left(t\right)\right] dt}{\int_0^{TH} a_r \cdot \left[r\left(t\right)\right] dt}$$

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where TH is the time horizon over which the calculation is considered;

a_x is the radiative efficiency due to a unit increase in atmospheric abundance of the substance in W m^{-2} kg^{-1}; and

x(t) is the time-dependent decay in abundance of the substance following an instantaneous release of it at time t=0. The denominator contains the corresponding quantities for the reference gas, which is CO_2

Table 48. Global warming potential (100 year time horizon) and duration of stay for some greenhouse gases

Compound	GWP	Residency (yr)
Carbon dioxide	1	250-400
Methane	23	12
Nitrous oxide	310	120
CFC-12	6,100-7,200	102
HCFC-22	1,300-1,400	12
Tetrafluoromethane	6,500	50,000
Sulfur hexafluoride	23,900	3,200

In practice, assessing the life-cycle emissions for a biomass feedstock involves preparing an account of the different sources of greenhouse gases over the course of its lifetime. In this way, carbon accounting is analogous to a bank account with debits and credits.

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2. Life-Cycle Emissions for Lignite Coal

2.1 Introduction

Life-cycle air emissions for lignite include those that occur as a result of mining and processing activities, transportation by rail and combustion in the boiler. Air, water and land releases of the following list of compounds are monitored at the Atikokan GS:

Table 49. Compounds monitored at the Atikokan GS

Compounds Monitored at the AGS		
Carbon Dioxide	Particulate Matter	Cadmium
Methane	PM2.5	Chromium
Nitrous Oxide	PM10	Iron
Carbon Monoxide	Dioxins & Furans	Lead
Nitrogen Oxides	Formaldehyde	Lithium
Sulphur Dioxides	Hexachlorobenzene	Manganese
Hydrogen Chloride	HFC-134a	Mercury
Hydrogen Fluoride	Aluminum	Titanium
Sulphuric Acid	Arsenic	Phosphorus
VOC	Boron	

For the purposes of this report, life-cycle air emissions of CO_2, N_2O, NO_x, SO_x and PM were modelled for lignite based on recent consumption patterns at the Atikokan GS (Table 19).

2.2 Approach

When data was available, emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), sulphur dioxides (SO_x) and particulate matter (PM) made during the mining, transportation and combustion of lignite were added together to give an estimate of life-cycle emissions based on annual consumption at the Atikokan GS.

Methane trapped in coal deposits is released to the atmosphere when it is mined and then crushed. Environment Canada reports a fugitive emission factor of 0.06 kg CH_4/tonne lignite for lignite mining operations in Saskatchewan. This emission factor was multiplied by the average annual amount of lignite consumed at the Atikokan GS to estimate the amount of CH_4 lost to the atmosphere as a result of extraction and processing.

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Since 2000, an average of 640,000 tonnes of lignite has been shipped each year in coal cars from the mine in Estevan, SK, to the Atikokan GS – a distance of roughly 1,100 km by rail. Emissions during the transport of lignite come from diesel locomotives, which burn diesel at the rate of 4.91 L/1000 revenue tonne-km (RTK) of freight. Emissions were estimated as a function of the amount of diesel fuel burned which was found using:

FU = *FCR* x *mass of lignite (tonnes)* x *distance (km)*

where *FU* is fuel use in L; and
FCR is the fuel consumption rate of 4.91 L/1000 RTK

Based on this, almost 3.5 million L of diesel is burned each year in delivering lignite to the Atikokan GS. The following emission factors were used to estimate emissions related to shipping lignite to the Atikokan GS (Environment Canada, 2002, 2005).

Table 50. Emission factors for diesel rail transportation

Emission Factor (g/L diesel)					
CO_2	CH_4	N_2O	SO_x	NO_x	PM
2,730	0.15	1.10	2.54	58.81	1.30

Source: Environment Canada (2002, 2005)

Stack emissions of CO_2, N_2O, NO_x, SO_x, PM and Hg are measured at the Atikokan GS (Table 51) and, as such, in-house emission factors can be calculated for these compounds (Table 52).

Table 51. Annual air emissions for compounds monitored at the Atikokan GS

Year	Lignite Use (tonnes)	Annual Emissions (tonnes)					
		CO_2	N_2O	NO_x	SO_x	PM	Hg
2004	715,000	1,178,000	10.8	3,790	6,430	43.6	0.04
2003	655,000	996,000	9.8	3,150	6,450	40.6	0.04
2002	572,000	889,000	8.6	2,620	4,930	26.5	0.04
2001	557,000	847,000	5.0	2,450	4,480	n/a	0.04
2000	669,000	1,019,000	n/a	2,840	4,810	n/a	0.04

Source: Ontario Power Generation

Table 52. Emission factors based on measurements at the Atikokan GS

CO_2		CH_4		N_2O		NO_x		SO_x		PM		Hg	
g/kg	kg/MWh	g/kg	g/MWh	g/kg	g/MWh	g/kg	g/MWh	g/kg	g/MWh	g/kg	g/MWh	mg/kg	mg/MWh
1,556	1,090	0.02	15	0.01	9	5	3,290	9	6,010	0.06	41	0.06	42

Source: Ontario Power Generation, Environment Canada (2005)

An emission factor of 0.022 g CH_4/kg for methane from coal combustion as reported by Environment Canada (Environment Canada, 2005) was used here.

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The annual emission of each compound was found by multiplying the average amount of lignite burned at the Atikokan GS between 2000 and 2004 by the emission factor for the compound (Table 52).

2.3 Findings

Table 53 summarizes the lifecycle emissions resulting from the mining, transport and combustion of lignite at the Atikokan GS.

Table 53. Lifecycle emissions resulting from the generation of electricity using lignite at the Atikokan GS

Component	tonnes/yr				kg/yr
	CO_2e	NO_x	SO_x	PM	Hg
Mining	880	n/a	n/a	n/a	n/a
Rail Transport	10,630	9	200	4	n/a
Combustion	986,000	2,960	5,400	37	38
TOTAL	997,510	2,969	5,600	41	38

With respect to greenhouse gas emissions, the Atikokan GS releases roughly 1 million tonnes of CO_{2e} to the atmosphere every year based on global warming potentials of 1, 23 and 310 for CO_2, CH_4 and N_2O, respectively. Overall this gives a life-cycle emission factor of 1,580 kg CO_{2e}/tonne of lignite burned or 1,110 kg CO_{2e}/MWh based on a net generation of 900,000 MWh/yr at the Atikokan GS.

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3. Life-Cycle Emissions for Fuel-Grade Peat

3.1 Introduction

Northern peatlands cover approximately 3.5 million km^2, store between 220 and 460 billion tonnes of carbon (C) and currently accumulate C and emit methane (CH_4) to the atmosphere (Gorham, 1991; Turunen et al., 2002). Collectively, northern peatlands are a key component of the global C cycle and, because they act as a source and sink of C, have both cooling and warming impacts on the climate system. In recent years the C balance of peatlands has been studied to help identify their potential role in global climate change.

Northern peatlands have low rates of net primary productivity (NPP) and decomposition compared to other ecosystems (Lafleur et al., 2001). However, over millennia timescales NPP (i.e. production of biomass) in peatlands has persistently exceeded decomposition. As a result, peatlands have sequestered C to the tune of 20 to 30 g C m^{-2} yr^{-1} over the past 5,000 to 10,000 years (Gorham, 1991). Globally, this translates into an accumulation of 70 to 100 million tonnes of C each year. Indeed, peatlands are a substantial reservoir of C in the boreal and subarctic regions, constituting at least one fifth of the world's total soil C pool (Post et al., 1982) - an amount equivalent to roughly half the amount of CO_2 in the atmosphere (Houghton et al., 1990).

In addition to their role as a C sink, most northern peatlands emit CH_4. Collectively they are a significant source of CH_4 to the atmosphere, accounting for 3-5% of global CH_4 emissions (Prather et al., 2001). These emissions are highly variable in space and time due to the complex interaction of factors that influence the production and transport of CH_4 within a peat deposit. CH_4 losses from peatlands normally comprise less than 10% of the annual net C flux to the atmosphere (Alm et al., 1997).

Ultimately, CH_4 emissions result from the decomposition of litter and accumulated peat in the absence of oxygen (O_2), that is, below the water table. The position of the water table strongly influences the amount of CH_4 released from peatlands in that it controls the thickness of the aerobic surface layer. When the water table is low, CH_4 may be oxidized to CO_2 by methanotrophic bacteria before it reaches the atmosphere. Alternatively, when at the soil surface the water table acts as a barrier to gas diffusion and can therefore slow the rate of CH_4 loss.

Fluxes of CO_2 and CH_4 on peatlands show great variability (Table 54 and 55), which complicates attempts at modelling their net C balance. Figure 17 illustrates the flow of C in peatland ecosystems.

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Table 54. CH_4 flux measurements on peatlands

Annual CH_4 Emission	Peatland Type & Location	Reference
Daily Fluxes		
0.7-28 mg CH_4 m^{-2} d^{-1}	Undisturbed peatland - Minnesota	Moore & Knowles (1989)
3.5-67.5 mg CH_4 m^{-2} d^{-1}	Undisturbed bog - Minnesota	Dise et al. (1993)
11-866 mg CH_4 m^{-2} d^{-1}	Undisturbed bog - New Hampshire	Crill (1991)
94 mg CH_4 m^{-2} d^{-1}	Beaver pond - Canada	Roulet et al. (1997)
Annual Fluxes		
0.7-20 g CH_4 m^{-2} y^{-1}	Undisturbed fen - Canada	Moore & Roulet (1995)
7.8-13.6 g CH_4 m^{-2} y^{-1}	Undisturbed bog - Canada	SENES (2005)
0-70 g CH_4 m^{-2} y^{-1}	Undisturbed peatland - Minnesota	Crill et al. (1992)
1.8 g CH_4 m^{-2} y^{-1}	Undisturbed bog - Ireland	European Commission (1999)
2-40 g CH_4 m^{-2} y^{-1}	Undisturbed mire - Sweden	Nilsson et al. (2001)
4.6 g CH_4 m^{-2} y^{-1}	Overview of bog & fen values	Rivers et al. (1998)
8 g CH_4 m^{-2} y^{-1}	Undisturbed bog - Finland	Nykanen et al. (1998)
13.5 g CH_4 m^{-2} y^{-1}	Undisturbed peatland - Sweden	Crill et al. (2000)
19 g CH_4 m^{-2} y^{-1}	Undisturbed fen - Finland	Nykanen et al. (1998)

Table 55. CO_2 flux measurements on peatlands

Net Ecosystem Exchange of CO_2	Peatland Type & Location	Reference
Daily Fluxes		
-1.7 g CO_2 m^{-2} d^{-1}	Bog - Midsummer - Canada	Neumann et al. (1994)
+0.3 g CO_2 m^{-2} d^{-1}	Fen - May to September - Canada	Lafleur et al. (1997)
-2.7 g CO_2 m^{-2} d^{-1}	Fen - May to September - Ontario	Joiner et al. (1999)
-2.7 g CO_2 m^{-2} d^{-1}	Fen - May to October - Sask.	Suyker et al. (1997)
+5.7 g CO_2 m^{-2} d^{-1}	Beaver pond - May to September	Roulet et al. (1997)
+0.9 g CO_2 m^{-2} d^{-1}	Bog - May to October - Minnesota	Shurpali et al. (1995)
-0.4 g CO_2 m^{-2} d^{-1}	Bog - May to October - Minnesota	Shurpali et al. (1995)
-6 g CO_2 m^{-2} d^{-1}	Bog - June to October - Siberia	Schulze et al. (1999)
Annual Fluxes		
-248 g CO_2 m^{-2} y^{-1}	Bog - Ontario	Lafleur et al. (2001)
-278 g CO_2 m^{-2} y^{-1}	Bog - Ontario	Lafleur et al. (2003)
-254 g CO_2 m^{-2} y^{-1}	Bog - Ontario	Lafleur et al. (2003)
-251 g CO_2 m^{-2} y^{-1}	Bog - Ontario	Lafleur et al. (2003)
-37 g CO_2 m^{-2} y^{-1}	Bog - Ontario	Lafleur et al. (2003)
-62-96 g CO_2 m^{-2} y^{-1}	Mire - Finland	Turunen et al. (1999)
-75 g CO_2 m^{-2} y^{-1}	Mire - Finland	Crill et al. (2000)
-51 g CO_2 m^{-2} y^{-1}	Fen - Sweden	Uppenberg et al. (2001)
-62 g CO_2 m^{-2} y^{-1}	Mire - Sweden	Uppenberg et al. (2001)
-77 g CO_2 m^{-2} y^{-1}	Bog - Sweden	Uppenberg et al. (2001)
-19 g CO_2 m^{-2} y^{-1}	Bog - Ireland	European Commission (1999)

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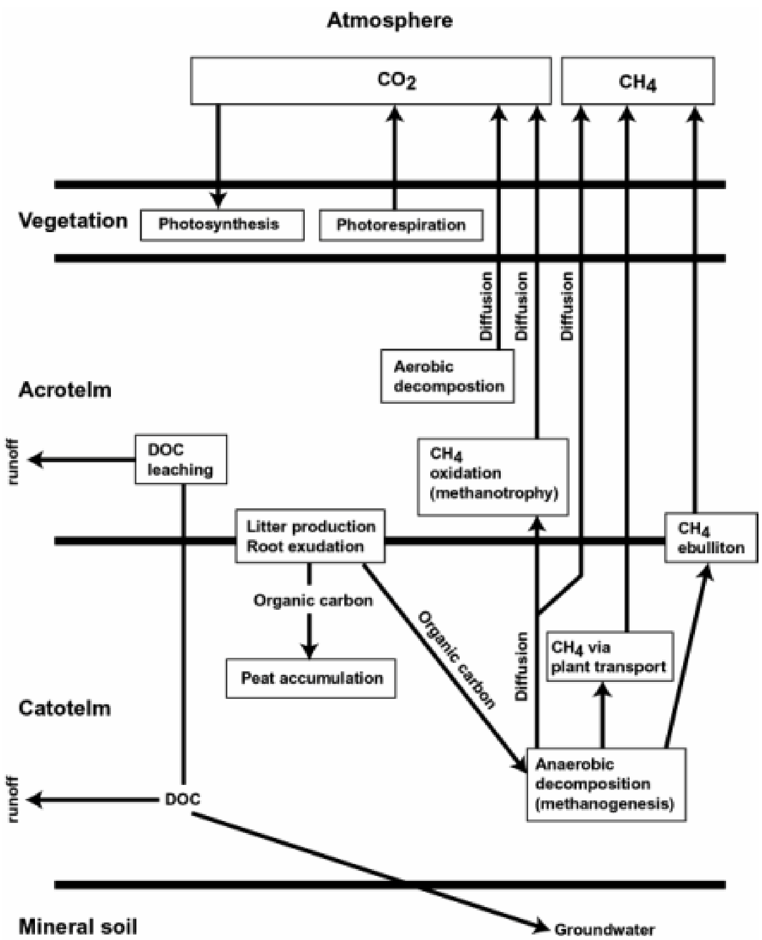
Figure 17. The C cycle in peatland ecosystems



Peatlands develop either through the infilling of shallow lakes or by accumulation on poorly drained lands. With time, the accumulation of plant debris changes the environmental conditions of the ecosystem, causing a shift from aquatic to semi-aquatic habitats to fen that can then evolve to a bog environment with increasing peat thickness.

An undisturbed peat bog is composed of two distinct soil layers, the acrotelm and the catotelm (Figure 18). The catotelm is the bottom layer of peat composed of relatively decomposed and compacted material that is permanently below the water table and therefore saturated. Conditions here are anaerobic, microbial activity is repressed and peat decomposition therefore occurs very slowly. The acrotelm overlies the catotelm, and is the living layer of peat bogs. Water table fluctuations in the acrotelm bring about periodic alternations in oxygen status that favours microbial activity compared to the catotelm.

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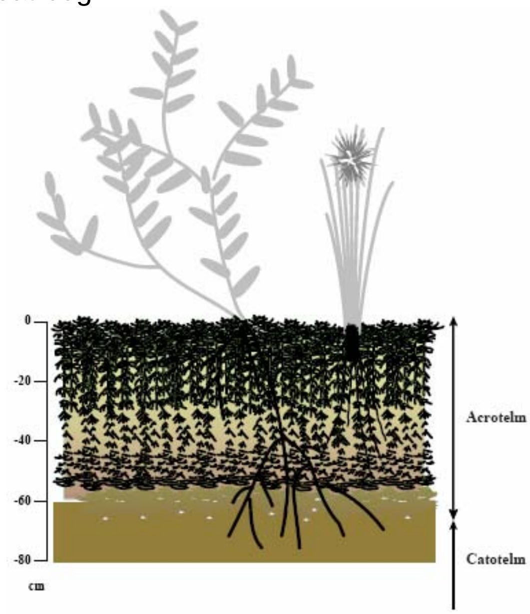
Figure 18. The structure of an undisturbed peat bog



It is argued that the accumulation of peat has a theoretical limit – that peatlands are not permanent net carbon sinks. Eventually, the rate of decay in the ever-increasing mass of peat in the catotelm will equal the rate of biomass production in the acrotelm and a steady-state will be achieved. The long-term apparent rate of C accumulation (LORCA) in northern peatlands since the last deglaciation is estimated at 20-30 g C m^{-2} y^{-1} based on core samples. Research done on bogs in eastern Canada (Ontario, Quebec, New Brunswick, Nova Scotia, PEI) indicates that recent C accumulation rates (RERCA) are up to 8 times that of the LORCA (Turunen et al., 2004). The C accumulation rate in eastern Canadian bogs over the last 150 years ranged from 40 to 117 g C m^{-2} yr^{-1}, with an average of 73 g C m^{-2} yr^{-1}. This is similar to results from Finland (40-81 g C m^{-2} yr^{-1}) (Tolonen and Turunen, 1996; Pitkanen et al., 1999) and elsewhere in North America (31-93 g C m^{-2} yr^{-1}) (Wieder et al.,1994; Turetsky et al., 2000). It appears that northern peatlands are currently sequestering more C than in the distant past. This increase has been attributed to climate variability, nitrogen deposition and response to elevated CO_2 in the atmosphere (Turunen et al., 2004).

Harvesting peat for fuel alters the C balance of peatland ecosystems and their net emission of greenhouse gases to the atmosphere. The change is calculated as the difference in emissions between utilized and virgin peat deposits. From a life-cycle perspective for dry-harvested peatlands this is found using:

Net emissions = (emissions from drained peat before extraction + emissions from extraction and processing of peat + emissions from transport of peat + emissions from combustion of peat + emissions from after-treatment) – (emissions from virgin peatland)

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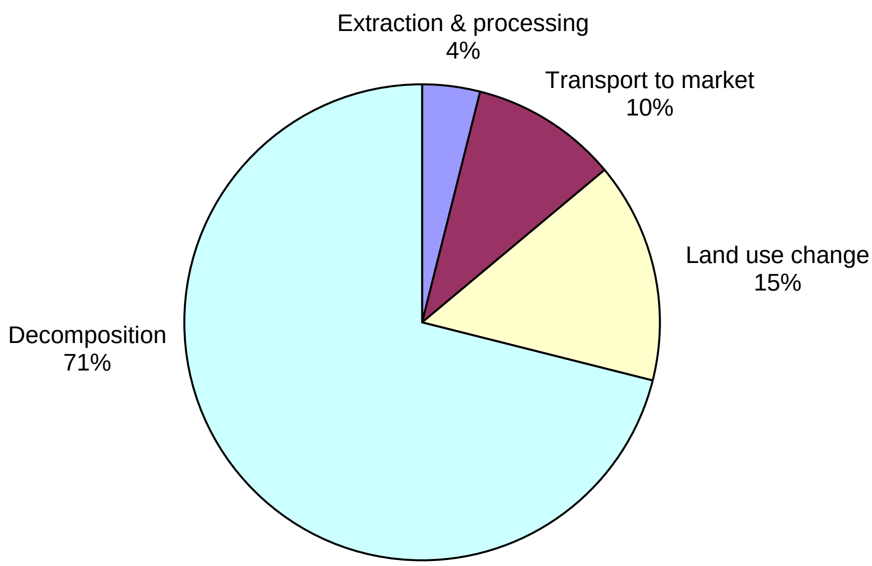
To prepare a peatland for dry-harvesting it is drained, cleared of vegetation and levelled. This alters net greenhouse gas emission in two ways:

- Draining the site enhances oxygen diffusion into the surface layer, thereby increasing the rate of aerobic decomposition. This tends to increase CO_2 emissions and decrease CH_4 emissions (Martikainen, 1996; Sundh et al., 2000; Waddington et al., 2002)
- By removing the living biomass from the peatland surface, CO_2 uptake falls to zero (Waddington and Warner, 2001).

The diesel-powered vehicles and equipment used to extract, process and transport peat emit greenhouse gases and burning peat to generate electricity releases vast amounts of CO_2 to the atmosphere.

Canada harvested roughly 1.3 million tonnes of peat (at 45% moisture content) from 12,420 ha (i.e. ~105 t/ha) in 2000, mainly for horticultural uses (Statistics Canada, 2002). Cleary et al. (2005) performed a life-cycle analysis to examine the net emission of greenhouse gases from the Canadian peat industry. Emissions from land use change, extraction and processing, transport to market and decomposition were considered in the study (Figure 19). In 2000, the peat extraction life-cycle emitted 0.89 million tonnes of CO_{2e}, which translates into 1.24 tonnes CO_{2e}/BDT of harvested peat. They concluded it would take approximately 2000 years to restore the C pool to its original size if peatland restoration is successful and the cutover peatlands once again become a net carbon sink.

Figure 19. Contribution of land-use change, extraction and processing, transport and decomposition to the life cycle of peat extraction in Canada from 1990 to 2000 (from Cleary et al., 2005)



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Life-cycle emissions from fuel peat industries are obviously higher as a result of peat combustion. A life-cycle analysis of fuel peat utilization in Sweden that accounted for greenhouse gas emissions from draining (year 0-5), harvesting (year 6-25) and burning (year 6-25) peat estimated a net emission of 265 kg CO_{2e}/m^2 of harvested peatland (Uppenberg et al., 2001). Assuming a harvest depth of 1 m, a wet bulk density of 1,040 kg/m^3 and a dry weight of 9% this gives a net emission of 2.83 tonnes CO_{2e}/ BDT of harvested peat. This is over twice the emission intensity of the Canadian horticultural peat industry.

Cutover peatlands can be restored by re-establishing a plant cover dominated by peatland species and re-wetting harvested sites by raising and stabilizing the water table near the surface. CO_2 and CH_4 flux measurements taken on restored bogs in eastern Canada have demonstrated that restored peatlands can return to being net carbon sinks after as little as 5 years.

3.2 Approach

In this study, estimates of life-cycle emissions of greenhouse gases from peatlands harvested for fuel were compared to that of an equivalent area of virgin peatland.

To maintain current gross production at the Atikokan GS, roughly 569,000 BDT of fuel-grade peat would have to be burned each year. Assuming a harvest depth of 2 m, a wet bulk density of 1,040 kg/m^3 and a dry weight of 9% gives an annual harvest area of 300 ha/yr – around 2% of the area of peatland currently under production by the Canadian horticultural peat industry.

Emissions were modelled over a 20-year extraction cycle with the following assumptions:

- Years 1 to 19: 300 ha of peatland are drained each year;
- Years 2 to 20: 569,000 BDT of fuel-grade peat is dry-harvested using the vacuum method from 300 ha each year;
- Years 2 to 20: 300 ha of peatland are abandoned at the end of each harvest season and begin the restoration process following a lag time of 1 year. For example, a cutover harvested by winter 2006 would lay abandoned for 1 year and enter restoration in spring 2008;
- Fluxes of -27 g CO_2 m^{-2} yr^{-1} and 4 g CH_4 m^{-2} yr^{-1} were used for undisturbed peatlands (Gorham, 1991). Based on this and a GWP of 23 for CH_4 (100-year time horizon), undisturbed peatlands are a net source of greenhouse gases at 65 g CO_{2e} m^{-2} yr^{-1};
- Fluxes of 600 g CO_2 m^{-2} yr^{-1} and 2.1 g CH_4 m^{-2} yr^{-1} were used for peatlands draining prior to extraction (Sundh et al., 2000);
- Fluxes of 1,019 g CO_2 m^{-2} yr^{-1} and 1.9 g CH_4 m^{-2} yr^{-1} were used for peatlands under extraction (as per Cleary et al., 2005);

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- Fluxes of 1,107 g CO_2 m^{-2} yr^{-1} and 1.7 g CH_4 m^{-2} yr^{-1} were used for abandoned cutover peatlands (as per Cleary et al., 2005);
- N_2O emissions from undisturbed, draining, harvested and abandoned peatlands were negligible (Cleary et al., 2005);
- Greenhouse gas emissions from peat stockpiles and drainage ditches were not accounted for;
- According to Uppenberg et al. (2001), working machines and transports combine give an emission of 17 kg CO_{2e}/BDT of harvested peat. We have modelled transport emissions at 7.8 kg CO_{2e}/BDT. As such, emissions from working machines (i.e. harvesting/processing equipment) is estimated as the balance at 9.2 kg CO_{2e}/BDT;
- Harvested peatlands fall within 200 km of the Atikokan GS, with an average trucking distance of 100 km. Harvested peat is pelletized (500 kg/m^3; 20% moisture) at on-site processing stations and hauled by B-train chip vans with a payload of 40 tonnes to the Atikokan GS. Greenhouse gas emissions from trucking were calculated as a function of diesel consumption (i.e. 0.396 L/km) using emission factors of 2,730 g CO_2/L, 0.12 g CH_4/L and 0.08 g N_2O/L (Environment Canada, 2005). A GWP of 310 was used for N_2O (100-year time horizon);
- Emission factors of 1,530 kg CO_2/BDT, 85 g CH_4/BDT and 102 g N_2O/ BDT were used for the combustion of peat (Uppenberg et al., 2001).

3.3 Findings

Over its 20-year life-cycle, the fuel-grade peat harvesting operation modelled here would emit roughly 18 million tonnes of CO_{2e}, giving an emission intensity of 1,570 kg CO_{2e}/BDT of peat burned at the Atikokan GS. For the amount of peat required to maintain a net generation of 900,000 MWh/yr at the Atikokan GS this gives 990 kg CO_{2e}/MWh, which is 10% less than the emission intensity for lignite (1,110 kg CO2e/MWh).

Over 94% of emissions result from the burning of peat with roughly 5% being lost from cutover peatlands under restoration (Table 56, Figure 20).

Cumulative emissions from an equivalent area of virgin peatland (i.e. 5,700 ha) totalled 75,000 tonnes CO_{2e} or 0.4% of emissions from using peat for fuel. Although the effect is negligible, these losses are avoided by mining peatlands and can therefore be subtracted from the life-cycle emission intensity of using peat for fuel.

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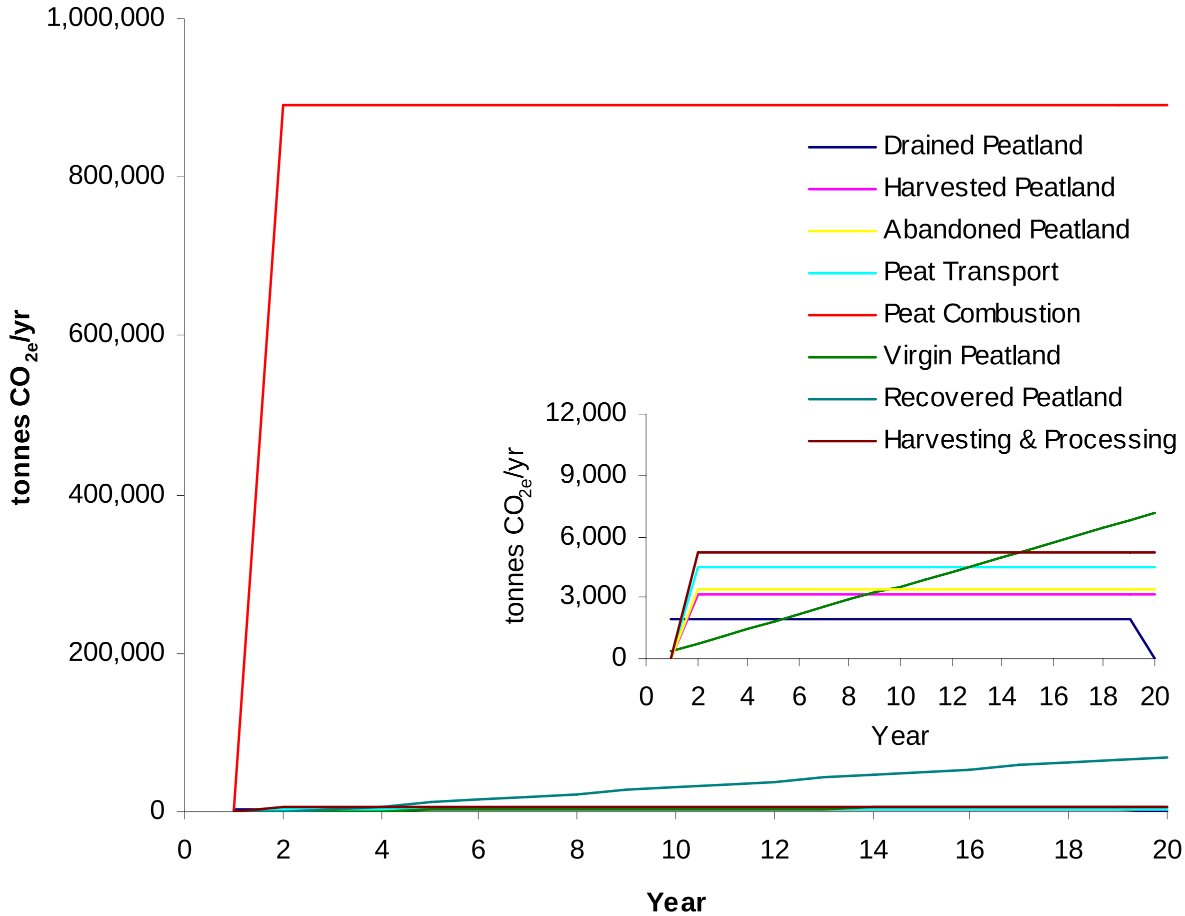
Table 56. Breakdown of the life-cycle emissions of greenhouse gases from the 20-year fuel-grade peat harvesting operation

	Emissions ($t\ CO_{2e}$)	%
Drained Peatland	37,000	0.2%
Harvested Peatland	61,000	0.3%
Extraction & Processing	65,000	0.4%
Abandoned Peatland	662,000	4%
Restored Peatland	99,000	1%
Transport	84,000	0.5%
Combustion	16,904,000	94%
TOTAL	17,912,000	100%
Virgin Peatland	75,000	

Figure 20. Life-cycle emissions of greenhouse gases from a 20-year fuel-grade peat harvesting operation



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4. Combustion Emissions for Woody Biomass & Refuse Derived Fuel

4.1 Introduction

Various boiler firing configurations are used for burning woody biomass, including Dutch ovens, fuel cell ovens, and spreader-stoker, suspension-fired and fluidized bed combustors (FBC).

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during wood residue combustion. Nearly all of the fuel carbon (~98%) in wood residue is converted to CO_2 during the combustion process. This conversion is relatively independent of firing configuration. Although the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the fuel carbon not converted to CO_2, due to incomplete combustion, is entrained in the bottom ash. CO_2 emitted from the combustion of woody biomass is generally not counted as greenhouse gas emissions because it is considered part of the short-term CO_2 cycle of the biosphere.

Formation of N_2O during the combustion process is governed by a complex series of reactions and depends on many factors. For example, N_2O formation is minimized when combustion temperatures are kept high (above 800°C) and excess air is kept to a minimum (<1%).

Methane emissions are highest during periods of low-temperature combustion or incomplete combustion, such as the start-up or shut-down cycle for boilers. Typically, conditions that favour formation of N_2O also favour emissions of CH_4.

The major emission of concern from wood boilers is particulate matter (PM). These emissions depend primarily on the composition of the residue fuel burned, and the PM control device. Oxides of nitrogen (NO_x) may also be emitted in significant quantities when certain types of wood residue are combusted or when operating conditions are poor.

For stoker and FBC boilers, overfire air ports may be used to lower NO_x emissions by staging the combustion process. Where NO_x emission limits are very low, selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR) systems can be applied. Both are post-combustion NO_x reduction techniques in which ammonia or urea are injected into the flue gas to reduce NO_x to nitrogen (N_2) and water. Overall reduction efficiencies increase with the ratio of ammonia-to-NO_x and range between 35-75%.

Table 57 lists emission factors for greenhouse gases and other pollutants released during the combustion of wet woody biomass in a system with and without emission controls. Here, emission control technologies include wet flue gas desulfurization, selective catalytic reduction, and improved electrostatic precipitators.

Table 57. Emission factors for greenhouse gases and other pollutants for wood-fired boilers with and without emission controls

	CO_2e kg/MWh	NO_x g/MWh	SO_X g/MWh	PM g/MWh	Hg mg/MWh
Uncontrolled	1,130 a	1,000 b	110 b	1490 b	16 b
Controlled	1,130	300 c	22 d	89 e	4 f

[a] Environment Canada (2005)
[b] EPA (1995a)
[c] Selective catalytic reduction - NOx reduction efficiency of 67%
[d] Wet flue gas desulfurization - SOx reduction efficiency of 80%
[e] Electrostatic precipitator - PM reduction efficiency of 94%
[f] Electrostatic precipitator - Hg reduction efficiency of 75%

Refuse derived fuel (RDF) is municipal solid waste (MSW) that has been processed by removing some or all of the non-combustibles (i.e. metals, glass, grit) and shredding and/or pelletizing the combustible fraction such that it can be effectively fired in a boiler, either alone or with other feedstocks. Today, RDF is normally burned in spreader-stoker or fluidized bed combustors with the largest systems capable of handling up to 3,000 tonnes/day of processed fuel.

The greenhouse gases CO_2, CH_4 and N_2O are all produced during the combustion of RDF and depending on the characteristics of the RDF and conditions in the combustor the following pollutants can be emitted:

- Particulate matter (PM) – Under normal combustion conditions solid fly ash formed from inorganic, non-combustible materials in RDF are released into the flue gas. Most PM is effectively removed in the air pollutant collection device downstream of the combustor.

- Carbon monoxide (CO) – CO emissions result when all of the carbon in the RDF is not oxidized to CO_2. CO concentration in the flue-gas is a good indicator of combustion efficiency and can be regulated by controlling the amount of air in the combustion zone.

- Nitrogen oxides (NO_x) – Nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O) - collectively termed NO_x, are produced in all fuel-air combustion processes through the oxidation of nitrogen in the RDF and the fixation of atmospheric nitrogen (N_2) in the combustion air.

- Acid gases (SO_2, HCl) – The chief acid gases produced in the combustion of RDF are hydrogen chloride and sulphur dioxide and levels directly relate to the chlorine and sulphur content of the RDF (i.e. in paper and plastic), which can vary considerably. Other gases present in much lower concentrations include

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hydrogen fluoride, hydrogen bromide and sulphur trioxide. Acid gas concentrations are considered to be independent of combustion conditions and can be effectively reduced using emission control systems.

- Toxic organics - Organic compounds such as chlorinated dibenzodioxins/chlorinated dibenzofurans (CDDs/CDFs), chlorobenzene, polychlorinated biphenyls, chlorophenols, and polyaromatic hydrocarbons, are present in municipal solid waste and therefore in RDF. These compounds can be released during the combustion and post-combination processes and exist in the vapor phase or can be condensed or absorbed on fine particulate matter. Control of organics is accomplished through proper design and operation of both the combustor and air pollutant control devices.

- Metals - Metals are present in a variety of MSW streams, including paper, newsprint, yard wastes, wood, batteries, and metal cans. Metal concentrations in RDF are highly variable and are emitted from RDF combustors in association with particulate matter (i.e. arsenic, cadmium, chromium, lead, nickel) and as vapors, such as mercury. Most metals condense onto fly ash particles and can be effectively removed (i.e. >98%) by a particulate matter control device. Mercury is not adsorbed unless the C content of the fly ash is high and it exists as a gas at operating temperatures typical of pollution control devices. Mercury levels can be significantly reduced using mercury control technologies.

Table 58 lists emission factors for greenhouse gases and other pollutants released during the combustion of raw RDF (i.e. at 20-30% moisture content) with and without emission controls. Reliable emission factors for nitrous oxide and methane could not be found for RDF-fired boilers.

A wide variety of control technologies are used to reduce emissions from RDF-fired boilers. The control of PM, along with metals that have adsorbed onto the PM, is usually accomplished by way of an electrostatic precipitator or fabric filter. Acid gas emissions (SO_2, HCl) are controlled by spray drying, wet scrubber or dry sorbent injection technologies, followed by a high-efficiency PM control device. Nitrogen oxide levels are reduced through combustion controls such as staged combustion, low excess air and flue gas recirculation or by add-on controls that include selective non-catalytic reduction, selective catalytic reduction and natural gas re-burning.

Mercury can be controlled through the use of activated carbon filters or by injecting activated carbon or sodium sulfide (Na_2S) into the flue gas upstream of the acid gas control system. With activated carbon injection, mercury is adsorbed onto the carbon particle, which is then captured in the PM control device with removal efficiencies of 50-99%. Injecting sodium sulfide into cooled flue-gas forces solid mercuric sulfide to precipitate out which can be collected by the PM control device.

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Table 58. Emission factors for greenhouse gases and other pollutants for RDF-fired boilers with and without emission controls

	CO_2e kg/MWh	NO_x g/MWh	SO_X g/MWh	PM g/MWh	Hg mg/MWh
Uncontrolled	1,100 a	2,070 a	1,610 a	28,650 a	1,970 a
Controlled	1,100	680 b	322 c	1,720 d	490 e

[a] EPA (1995b)

[b] Selective catalytic reduction - NOx reduction efficiency of 67%

[c] Wet flue gas desulfurization - SOx reduction efficiency of 80%

[d] Electrostatic precipitator - PM reduction efficiency of 94%

[e] Electrostatic precipitator - Hg reduction efficiency of 75%

4.2 Approach

Unabated emissions of greenhouse gases and other pollutants from the direct-firing of woody biomass and RDF were calculated based on the emission factors listed in Tables 57 and 58 and the amount of woody biomass or RDF required to maintain the gross energy input to the Atikokan GS (i.e. 10 million GJ/yr). These emissions were compared to those released by burning lignite and natural gas. Note that the Atikokan GS currently has low NO_x burners and an electrostatic precipitator to control emissions of NO_x and particulate matter. The plant lacks air emission control devices for acid gases and mercury.

4.3 Findings

Table 59 summarizes emissions of greenhouse gases and other pollutants from burning lignite at the Atikokan GS and hypothetical emissions for natural gas, woody biomass and RDF based on an equivalent energy input (i.e. 10 million GJ/yr). As mentioned above, the Atikokan GS uses low NO_x burners and an electrostatic precipitator to condition flue gases. Emission factors used for natural gas are for small (i.e. <300 MW), 2x1 combined cycle system with low NOx burners and a conversion efficiency of 48% (HHV basis). Emission factors for woody biomass and RDF are for systems equipped with wet flue gas desulfurization, selective catalytic reduction, and enhanced electrostatic precipitator technologies.

Table 59. Annual emissions of greenhouse gases and other pollutants using lignite, natural gas, woody biomass or refuse derived fuel as feedstocks at the Atikokan GS

Fuel Source	CO_2e		NOx		SOx		PM		Hg	
	t/yr	kg/MWh	t/yr	g/MWh	t/yr	g/MWh	t/yr	g/MWh	kg/yr	mg/MWh
Fossil										
Lignite	986,000	1,100 a	2,960	3,290 a	5,400	6,000 a	37	41 a	38	42 a
Natural Gas	489,000	380 b	100	110 b	3	3.4 b	49	54 b	0	0 b
Controlled										
Woody Biomass	1,021,000	1,130	300	330	20	22	80	89	4	4
Refuse Derived Fuel	993,000	1,100	610	680	290	322	1,550	1,720	440	490

[a] in-house measurements at the Atikokan GS

[b] DSS and RWDI (2005)

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Schedule 3

Economic Modeling of Production Costs Associated with the Various Project Proposals

1. Introduction

At the request of the Steering Committee, FBi developed a financial model to estimate the levelized unit energy cost (LUEC, $/MWh) at the Atikokan GS based on the feedstock strategies, boiler technologies and emission controls associated with the proposals examined in this study:

Case Study 1: Atikokan Power Corporation – owner/operator of the facility using woody biomass feedstocks and fluidized bed combustion technology.

Case Study 2: Triangle Energy Group – owner/operator of the facility using woody biomass feedstocks and a whole-tree combustion technology;

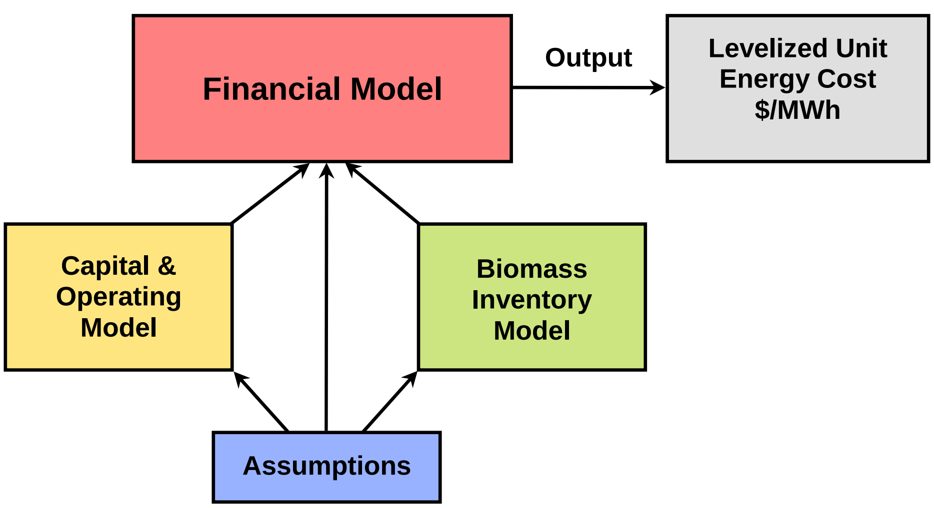
Case Study 3: Peat Resources Ltd. – supplier of fuel grade peat to the facility;

Case Study 4: Municipal Solid Waste from Toronto – a source of refuse derived fuel to the facility fired in combination with woody biomass procured from the region.

2. Approach

Overall, the economic model estimates the levelized unit energy cost at the Atikokan GS based on feedstock and project capital assumptions unique to each proposal.

Figure 21. Structure of the financial model used in the study



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The fundamental assumptions made in the model fall under the following categories:

1) ***Feedstock Properties*** - green moisture content (%), energy density (GJ/BDT);

2) ***Generation Station Properties***

    a) *Plant Factors* – gross generation (MWh/yr), combined parasitic load and forced unit outage factor (%), net generation (MWh/yr); service life (20 years);
    b) *Labour Factors* – staffing (#), labour rate ($/yr), labour overhead (%);
    c) *Maintenance Factors* – maintenance on original building (% of capital), new boiler technologies and equipment (% of capital);
    d) *Other Factors* – consumables ($/MWh of net generation), capital cost variance factor (%), operating cost variance factor (%).

Project capital cost was taken as the cost of retrofitting the existing boiler and to implement stringent emission controls, namely wet flue gas desulfurization, selective catalytic reduction, and electrostatic precipitators. LUEC was calculated as a function of project capital cost (i.e. debt interest, amortization), operation and maintenance costs (including an operating variance) and feedstock costs. Feedstock costs were determined based on the biomass inventory and delivered cost data presented in Schedule 1 (Table 23).

The capital requirement for each proposal was assumed to be 100% debt financed over 20 years at a rate of 5%. An inflation rate of 2.2% and an income tax rate of 30% were assumed. A social discount rate of 5% was used in calculating net present value and the LUEC in terms of net generation. For all scenarios, a combined parasitic load and forced unit outage factor of 10% was applied to a gross generation of 1 million MWh to give a net generation of 900,000 MWh/yr.

Note that a salvage value and decommissioning costs were not included in the modelling exercise.

3. Findings

Table 60 summarizes the project capital and LUEC associated with the proposals examined in the study:

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Table 60. Project capital and levelized unit energy cost of power generation for each of the case studies

	Atiokan Power Corporation	Peat Resources Ltd.	Triangle Energy Group	Toronto Garbage
Project Capital Costs - $				
Boiler Retrofits	$100,000,000	$5,000,000	$100,000,000	$100,000,000
Emission Controls	$206,000,000	$206,000,000	$206,000,000	$206,000,000
Project Capital - $/MWh				
with emission controls	$34	$23	$34	$34
without emission controls	$11	$1	$11	$11
Operations & Maintenance - $/MWh				
with emission controls	$31	$26	$31	$31
without emission controls	$28	$23	$28	$28
Fuel - $/MWh	$51	$58	$51	$58
LUEC - $/MWh				
with emission controls	$115	$108	$115	$123
without emission controls	$89	$82	$89	$97

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Schedule 4

Expressions of Interest in Woody Biomass Received by the Ministry of Natural Resources

Table 61. Expressions of interest for logging slash

Distance from Atikokan GS	Expressions of Interest
Less than 100 km from Atikokan GS	Yes
100 to 200 km from Atikokan GS	Yes
200 to 300 km from Atikokan GS	Yes
300 to 400 km from Atikokan GS	Yes
400 to 500 km from Atikokan GS	Yes

Table 62. Expressions of interest for unallocated AAC

Distance from Atikokan GS	Expressions of Interest
Less than 100 km from Atikokan GS	All available timber is allocated
100 to 200 km from Atikokan GS	All available timber is allocated
200 to 300 km from Atikokan GS	All available timber is allocated
300 to 400 km from Atikokan GS	All available timber is allocated
400 to 500 km from Atikokan GS	All available timber is allocated

Table 63. Expressions of interest for mill residues (hog fuel)

Distance from Atikokan GS	Expressions of Interest
Less than 100 km from Atikokan GS	Yes
100 to 200 km from Atikokan GS	Yes
200 to 300 km from Atikokan GS	Yes
300 to 400 km from Atikokan GS	Yes
400 to 500 km from Atikokan GS	Yes

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Schedule 5

Consideration of First Nations Rights for Peat Harvest

On January 16 2006, FBi interviewed Mr. Wayne McLellan of Peat Resources Ltd. regarding local First Nations (FN) interests and whether the rights of FN are considered by the company's proposal to harvest peat from their traditional lands/hunting territories.

Mr. McLellan stated that Mille Lac FN is the only FN which has showed interest in the company's peat harvest plans thus far.

On January 16, 2006, FBi interviewed Mr. Quinton Snider to secure the Band's perspectives on the issue of peat harvesting:

Quentin Snider, Band Administrator
Lac des Mille Lacs First Nation
Thunder Bay Ontario
(807) 622-9835

Mr. Snyder stated that:

Mille Lac First Nation is the only identified FN within the land use permit allocated by the Ontario Ministry of Natural Resources to Peat Resources Ltd. No other band has stepped forward to show interest or voice concerns.

Peat Resources Ltd. has kept a constant line of communication with the band chief and council. Here are some highpoints:

- Peat Resources Ltd. has had over 12 meetings with band officials and is well perceived as a respectful project proponent;
- The great majority of band members are in agreement with the project; and,
- Elders Council is in agreement with the project, under the condition that the company shows that effects on the environment are small and well controlled and that post-harvest land reclamation strategies are in place.

The Band sees the project favorably because:

- This project will create employment in the vicinity of the traditional lands, which will support the establishment of a community—thus far there is no community established on the reserve land;
- This project will attract band members who are now living in various locations across Canada;

This summary document was approved by Mr. Snider on January 17, 2006.

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Schedule 6

Environmental Assessment of a Peat Harvesting and Processing Operation Near Upsala, Ontario

Terms of Reference

Submitted by:

Peat Resources Ltd.

Prepared by:

SENES Consultants Limited
121 Granton Drive, Unit 12
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L4B 3N4

January 2006

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1.0 INTRODUCTION

Peat Resources Limited (PRL) applied to the Ministry of Natural Resources (MNR) in order to harvest peat from a number of bogs in northwestern Ontario. In order for the MNR to grant the “Application to Develop” an environmental assessment (EA) is required. The MNR reviewed two versions of PRL’s Application to Develop (found in Supplementary Document A) in order to determine what Class of EA must be prepared. In the opinion of MNR, due to the complexity of issues and the requirement for specialists in other Ministries to help in the evaluation, an Individual E.A. is required. PRL has voluntarily agreed to conduct an individual EA and the Terms of Reference (ToR) is the first step in this process. As per Section 6(2)(a) of the EA Act, PRL will be submitting a focused EA to the Ministry of the Environment (MOE). Section 6.1(2) of the EA Act identifies the components of the EA that are required.

1.1 PROPONENT

The proponent of this undertaking is Peat Resources Limited (PRL). The company was formed to develop an engineering process to harvest and manufacture peat for use as a high-grade fuel source that can be directly substituted for coal. PRL is proposing to construct and operate a processing facility and enclosed slurry pipelines near Upsala, approximately 130km northwest of Thunder Bay. PRL is a publicly traded company listed on the Toronto Venture Exchange and trades under the symbol “PET”. More information may be found on the PRL website (www.peatresources.com).

1.2 PURPOSE OF THE TERMS OF REFERENCE

This ToR provides the framework for the preparation of an individual environmental assessment (EA) to support the “Application to Develop” a number of peatlands in the Upsala area. This application was made to the Ontario Ministry of Natural Resources in order to harvest fuel grade peat and process it for use in fossil fired generating stations. Development of peat as a fuel source and the conversion of existing coal-fired generating stations in northwestern Ontario would ensure that area residents and local energy intensive industries will continue to have a secure supply of reasonably priced electricity produced in the region. The opportunity also exists to export finished peat pellets to utilities and markets outside of Ontario and Canada.

The ToR establishes PRL's commitment to the preparation of an Individual EA that is consistent with applicable clauses in Ontario's EA Act. Specifically, Section 6.1(2) of the EAA states that "the proponent shall prepare an environmental assessment for an undertaking in accordance with the approved terms of references, which must consist of:

(a) a description of the purpose of the undertaking;
(b) a description of and a statement of the rationale for,
   (i) the undertaking;
   (ii) the alternative methods of carrying out the undertaking; and
   (iii) the alternatives to the undertaking;
(c) a description of,
   (i) the environment that will be affected or that might reasonably be expected to be affected, directly or indirectly;
   (ii) the effects that will be caused or that might reasonably be expected to be caused to the environment; and
   (iii) the actions necessary or that may reasonably be expected to be necessary to prevent, change, mitigate or remedy the effects upon or the effects that might reasonably be expected upon the environment, by the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking;
(d) an evaluation of advantages and disadvantages to the environment of the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking; and
(e) a description of any consultation about the undertaking by the proponent and the results of the consultation.

This ToR has been prepared with regard for the draft "*Guide to Preparing Terms of Reference for Environmental Assessments*" (December 2000) and incorporates comments received from the MOE, other government agencies and the public.

Two other documents have been prepared in support of this Terms of Reference document. They are:

(a) Supplementary Document – Background Information; and

(b) Public Consultation Record.

Document (a) provides a brief description of the opportunity that prompted the proposed undertaking, information about events that triggered the proponent's involvement with the proposed undertaking, a brief description history of what has been previously done and information relating to the existing environment of the study area.

Document (b) outlines consultation activities leading to the identification of public issues for the EA. This includes: identifying all parties consulted during the preparation of environmental studies prior to the project being designated; identifying all parties consulted during Terms of Reference preparation and outlining the consultation activities undertaken.

1.3 COORDINATED FEDERAL/PROVINCIAL EA PROCESS

Federal/Provincial EA Coordination

The undertaking is subject to the requirements of the Ontario Environmental Assessment Act. The requirements of the Canadian Environmental Assessment Act (CEAA) may also apply. PRL intends to work in a coordinated way with the provincial and federal governments, both governments having formally agreed to coordinate their respective EA processes established by the applicable environmental assessment legislation.

Coordinated EA Process

Peat Resources Ltd. will be guided by the federal/provincial coordination process chart as outlined in Appendix A of these terms of reference document. The proposed approach is designed to address the information requirements of both federal and provincial assessment Acts.

Application of the Coordinated EA Process to the Proposed Project

It is recognized by both the Canadian Environmental Assessment Agency and PRL that ongoing dialogue on the information requirements necessary to complete the EA will occur throughout the EA process as more is learned about the specifics of the undertaking. As such, it may be necessary for the proponent to provide additional or more detailed information as the EA proceeds. The intent is to produce a single EA body of documentation on environmental effects to meet all of the information needs of the federal and provincial governments. To the extent practical, federal/provincial information requirements regarding potential factors to be assessed in the context of this study have been integrated. General information requirements under CEAA can be found in Appendix A of these terms of references document.

2.0 BACKGROUND

Recent statements from the Ministry of Energy and the Ontario Power Authority indicate that over 20,000 MW of new generation will be required by 2025 to replace generators being decommissioned or converted to new fuel sources. With the price of energy increasing, biomass sources such as peat are now gaining acceptance as a source of energy able to meet local industrial demand at reasonable prices. Peat is considered a clean alternative fuel source compared to lignite coal since it contains less then one-tenth the sulphur content and only trace amounts of mercury.

Peat has been, and continues to be, used as a fuel source at generating stations throughout the world for many years. There are no electrical generation facilities in Canada using peat as a source of energy, however, an inter-ministerial committee is presently reviewing the conversion of Ontario Power Generation's Atikokan Generating Station to burn peat or other types of biomass. Peat has been successfully tested in a pilot plant in conjunction with Ontario Hydro's Research Division, although to date, biomass energy, be it wood or other organic materials, represents only a small percentage of electrical generation capacity in Ontario compared to total energy output.

PRL was formed in 1980 to explore, develop and market fuel peat as an energy substitute for or with coal in electrical power generating plants. After energy prices fell in the mid-1980's, the feasibility of using peat as a fuel source became uneconomical. The current increase in energy prices has now made the economics of using peat as a fuel practical – it is unlikely that the price of energy being charged to individuals and businesses will decrease in the near future.

PRL has been in discussions with the MNR to identify the environmental regulatory requirements that would apply to the construction and operation of a peat processing facility in northern Ontario. Throughout 2005, subsequent meetings with the MNR, First Nations and the public led to the development of an "Application to Develop" a number of bogs in the Upsala area.

3.0 PURPOSE AND RATIONALE OF THE PROPOSED UNDERTAKING

3.1 PURPOSE AND RATIONALE

The energy supply problem facing north-western Ontario relates to the commitment by the provincial government to remove 525 MW of coal-fired generation by closing Thunder Bay and Atikokan generating stations. This may create energy supply problems for existing industry and new, energy-intensive industries wishing to locate in northwestern Ontario. In addition, the high cost of energy, relative to other jurisdictions in Canada and the United States, is preventing many local industries from expanding and in some cases, such as the pulp and paper mills, has resulted in closure with significant economic impacts to Thunder Bay and NW Ontario. PRL sees their product enabling the coal-fired stations to remain open by converting to peat. PRL's proposed peat harvesting operation near Upsala is strategically located to be a fuel supplier to Ontario Power Authority's Atikokan and Thunder Bay generating facilities, as well as taking advantage of possible United States markets by shipping via Thunder Bay.

While affordable and reliable electricity supply is critical, many of northwestern Ontario's existing and proposed industries also require large quantities of heat (hot water and/or steam) to operate their facilities. These industries typically operate stand-alone boilers to meet their heating requirements. PRL sees a business opportunity for peat to replace the wood fibre required to run these boilers since there is a shortage of local wood fibre in northwestern Ontario.

3.2 DESCRIPTION OF THE PROPOSED UNDERTAKING

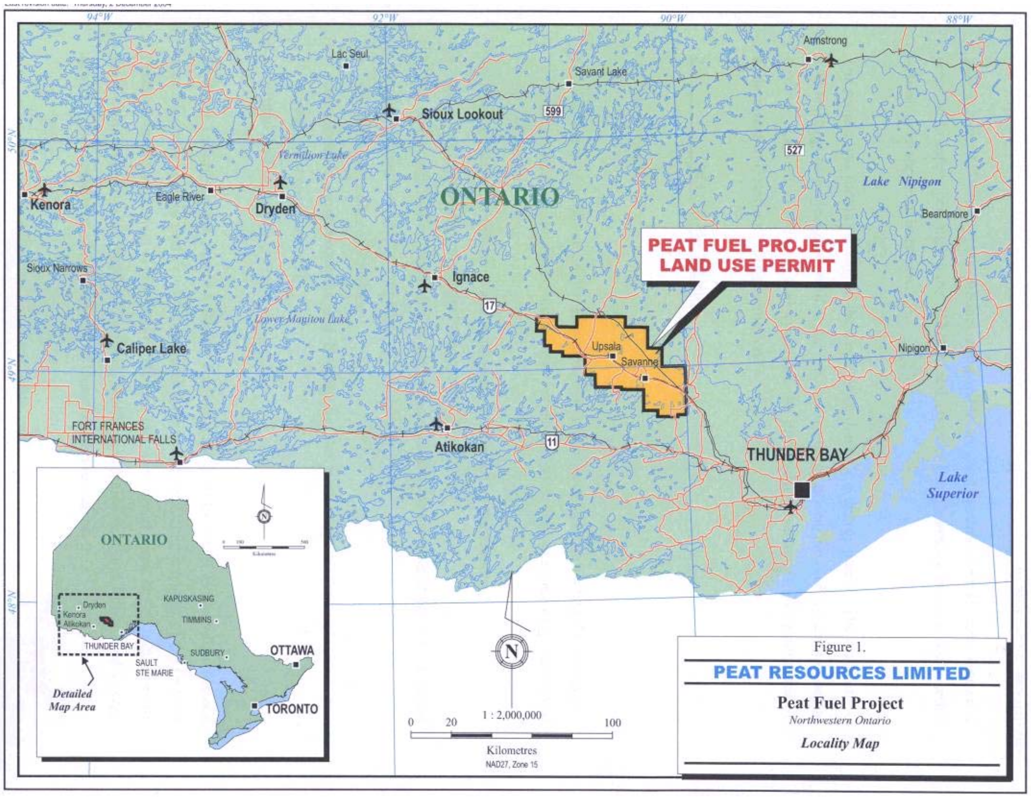
The proposed undertaking is the construction and operation of PRL's peat harvesting facility near Upsala, approximately 130km northwest of Thunder Bay. The proposed project consists of five infrastructure components including:

- A manufacturing plant with a footprint of about 10,000 square feet;
- Two above-ground enclosed slurry pipelines (one for moving the peat to the processing plant and the other for returning water to the bog);
- A water collection and treatment infrastructure
- A peat storage area,
- A loading facility from which to transport the finished peat product; and

A biomass generator (<25MW for power supply and drying system) may be required if studies identify that an adequate supply of power is unavailable. It will not constitute a part of this undertaking and would be classified as a Category A Project under the Electricity Regulation if required.

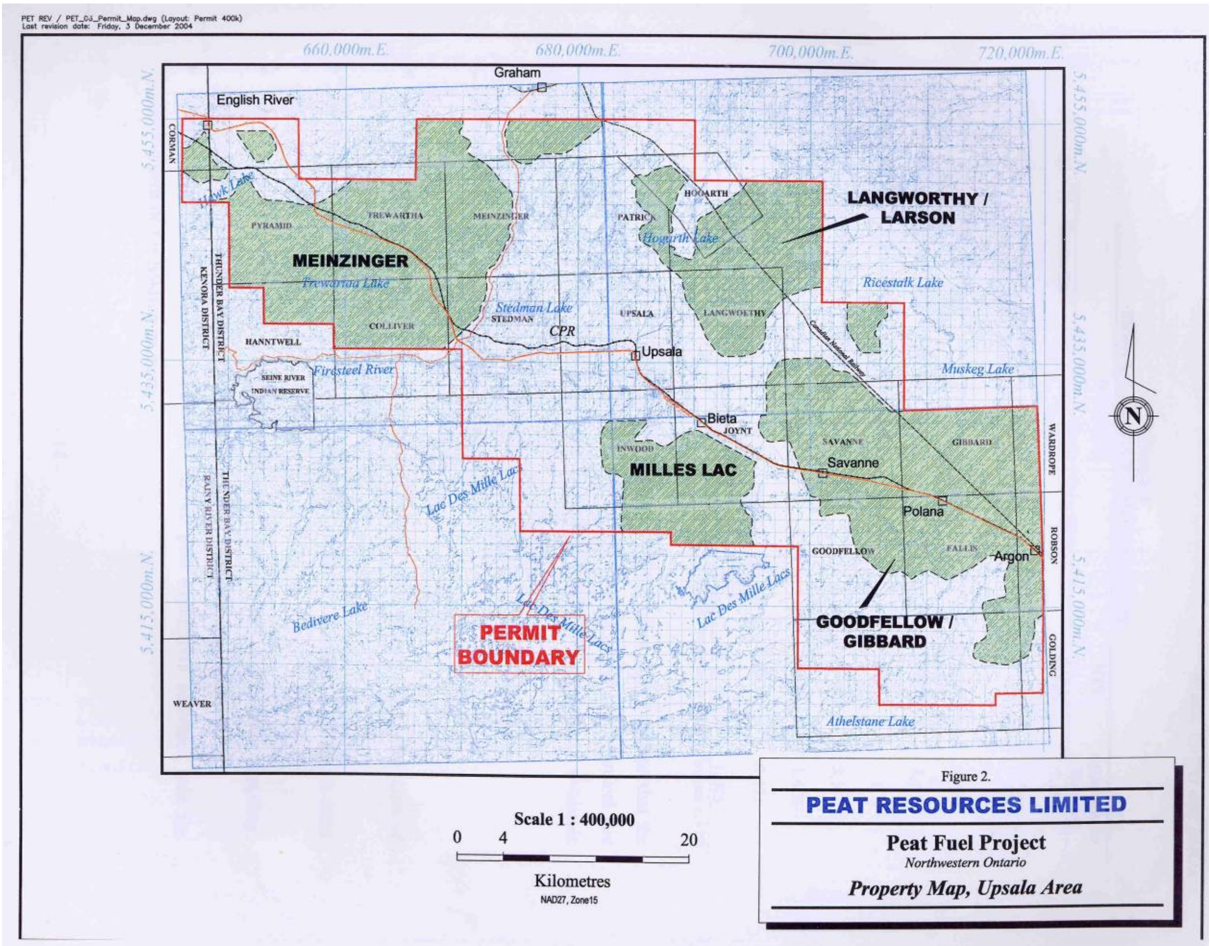
Figure 1 illustrates the regional context within which the original PRL land use permit is located while Figure 2 identifies the detailed permit area. This area was further refined in 2005 to include many of the bogs and bog complexes within the area.

Figure 1: Regional Map of Proposed Project Location



Source: Peat Resources Ltd., 2005.

Figure 2: Property Map of PRL Permitted Peat Lands in Upsala Area



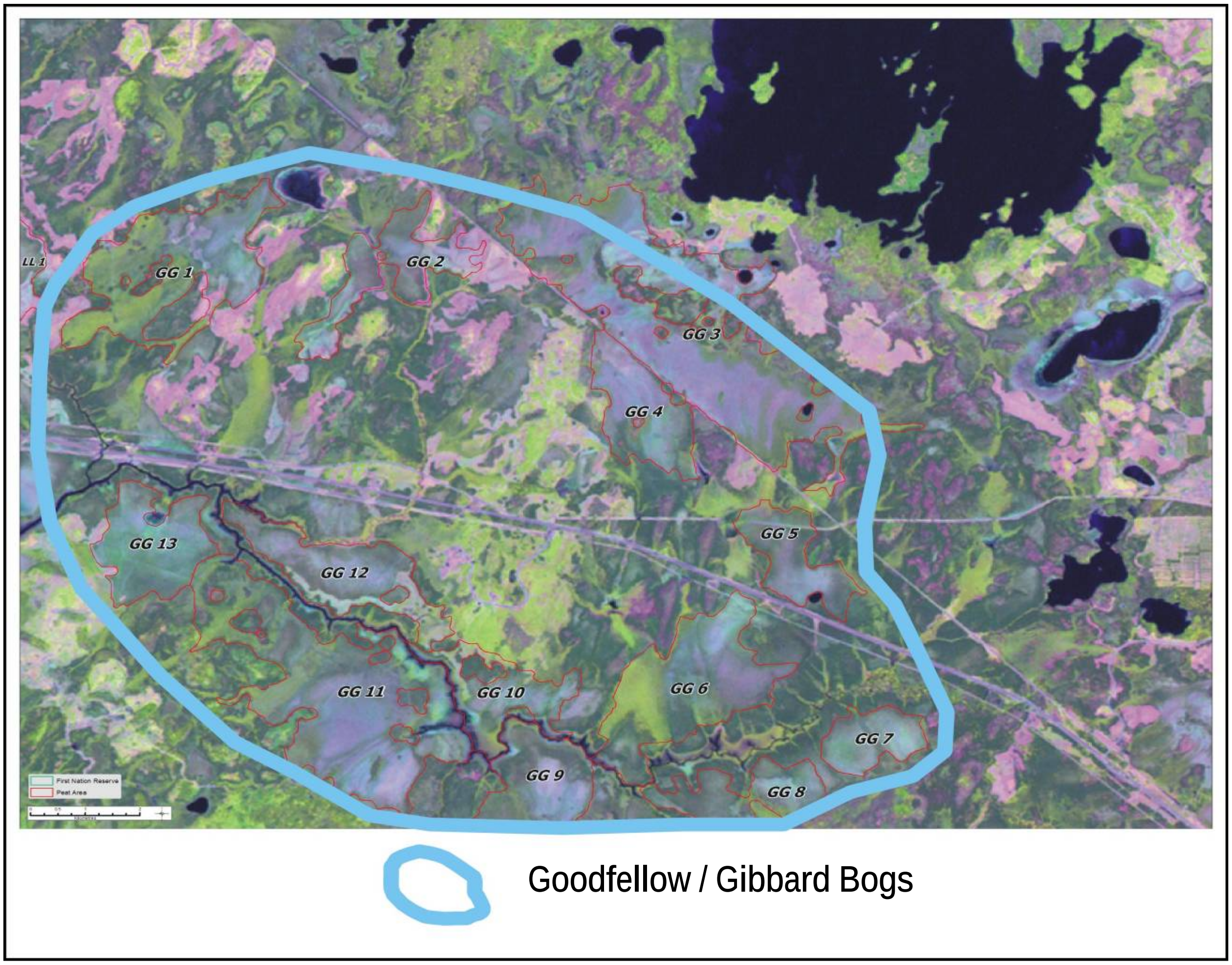
Source: Watts, Griffis and McOuat Limited, Consulting Geologists and Engineers.

Within this permit area, PRL has identified four areas as the principal harvesting location for peat. The names of these development areas are:

Area Name	Area Size (ha.)
Goodfellow/Gibbard (GG)	4,845
Milles Lac (ML)	2,515
Langworthy/Larson (LL)	3,658
Meinzinger (MN)	1,215

Two development areas have been initially slated for development – the Goodfellow/Gibbard area and the Milles Lac area. Figure 3 is a satellite image of the Goodfellow/Gibbard bog located in the southeast corner of the permit block.

Figure 3: Goodfellow/Gibbard Bog Development Area



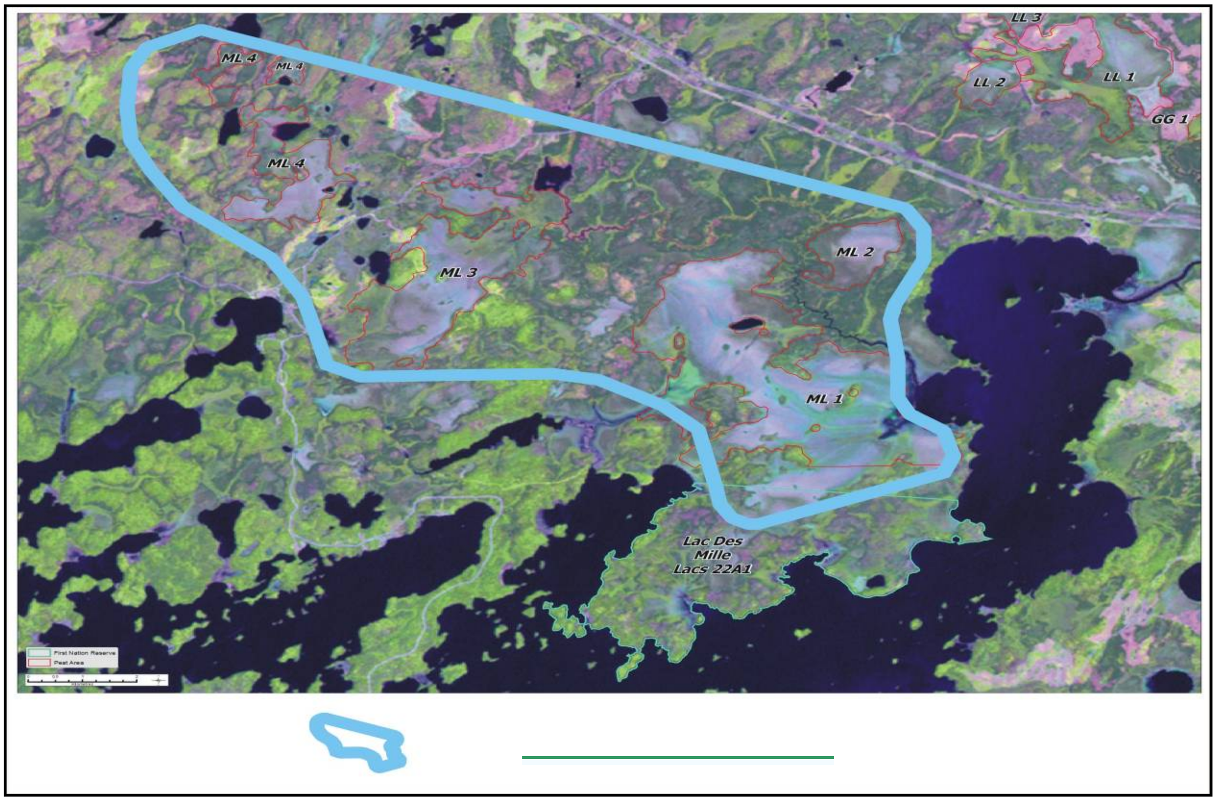
Source: Peat Resource Ltd., 2005.

Figure 4 is a satellite image of Milles Lac bog located west of the Goodfellow/Gillard development area. Milles Lac borders the west-central portion of the permit block. The remaining two development areas (Langworthy/Larson and Meinzinger) may be developed on a phased-in basis to be identified at later date but are not part of this undertaking.

Each processing plant will be capable of producing about 200,000 tonnes of dry (10% moisture) fuel-grade peat per year, which is approximately 3 million tonnes or 3 million cubic meters of wet peat. Approximately 100 ha will be harvested from each area per year, so with the operation having a 20 year planned lifespan, over 2,000 ha will be harvested from each bog complex from initial ground breaking to reclamation.

More information regarding the harvesting and manufacturing processes is found in the background information supplementary document.

Figure 4: Milles Lac Bog Development Area



Source: Peat Resources Ltd., 2005.

The undertaking will provide a positive benefit to the Upsala area and local First Nations in that it will provide numerous jobs and result in developing additional infrastructure in the community. Based on the high demand for electricity and the strategic location of peat supplies to the Atikokan Generating Station, Upsala is an excellent location to source a proposed new fuel for northwestern Ontario.

4.0 ASSESSMENT OF ALTERNATIVES

4.1 ALTERNATIVES TO

PRL wishes to take advantage of a business opportunity to harvest and manufacture peat so that it can be used as a fuel source for thermal power generation. There will be no evaluation of alternatives to this undertaking since PRL is focussed on the harvesting and manufacture of peat for use in thermal generating stations.

4.2 ALTERNATIVE METHODS

Alternative methods are different ways of achieving the same end result (e.g. alternative designs and sites). The EA emanating from the ToR will formally identify, evaluate and document alternative sites, alternative designs and alternative technologies.

Alternative methods will be considered during preparation of the EA. In order to assess alternative methods, a simple comparison will be made between the alternatives. The comparison will be based upon (but not limited to) such factors as cost, technical considerations, ability to meet energy and thermal requirements public acceptance and environmental issues.

During preparation of the EA, once the Alternative Methods have been assessed, and the undertaking has been defined, the following information will be included in the EA:

- The proposed location for the manufacturing plant and the area of land which the facility will occupy;
- A description of the harvesting process, including roads that would be required;
- A description of how the manufactured product will be shipped to market; and
- A description of any other on site activities that is likely to produce contaminants that may have an adverse environmental effect.

5.0 DESCRIPTION OF THE EXISTING ENVIRONMENT AND POTENTIAL EFFECTS

5.1 THE STUDY AREA

Figures 3 and 4 illustrate the specific study areas within which the peat harvesting will be undertaken. The study will encompass a larger area as a result of the positive impact on the economy of Upsala and potentially on the communities of Atikokan, Ignace and Thunder Bay. The study area will be defined in the EA.

5.2 ENVIRONMENTAL COMPONENTS

This section of the ToR outlines the process that will be used to identify and evaluate the environmental impacts of the preferred method for the proposed undertaking. The EAA defines environment as:

- air, land or water;
- plant and animal life, including human life;
- the social, economic and cultural conditions that influence the life of humans or a community;
- any building, structure, machine or other device or thing made by humans;
- any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from human activities; or
- any part or combination of the foregoing and the interrelationships between any two or more of them, in or of Ontario.

The environmental components to be examined will represent the full definition of the environment found in the EA Act. Table 1 provides an overview of the environmental components that will be considered for inclusion in the evaluation of baseline conditions, effects of alternative methods and/or the assessment of effects of the preferred alternative method.

Table 1 – Environmental components to be Studied

Environmental Component	Potential Items to be Studied
Climate	Temperature, precipitation, wind speed and distribution
Air Quality	Methane gas, particulate matter, nitrous oxides, sulphur dioxide, carbon monoxide, ozone
Noise	Ambient noise and noise from the proposed undertaking
Geology / Soils	Stratigraphy, structural properties, contamination
Water Quality	Physical and chemical parameters
Hydrology	Quantity and periodicity
Hydrogeology	Quality and quantity
Biology	Terrestrial and aquatic species and habitats.
Socio-economics	Community profile demographics, land use, aesthetics, employment, solid waste disposal
Cultural	First Nations, built heritage, archaeology

6.0 ENVIRONMENTAL ASSESSMENT WORK PLAN

6.1 OVERVIEW

This section of the ToR outlines, in general terms, the process that will be used to identify and evaluate the environmental impacts of the preferred methods for the proposed undertaking.

The EA Work Plan described in the following sections forms part of the EA ToR as required under the *Environmental Assessment Act*. The approach for the identification, assessment and evaluation of the preferred alternative for the undertaking will be guided by the following major steps:

- confirmation of the study area;
- documentation of existing conditions within the Study Area;
- development of alternative methods of carrying out the undertaking;
- identification of mitigation measures and monitoring programs to reduce the negative effects of the undertaking on the environment;

- analysis and evaluation of alternative methods of carrying out the undertaking based on the residual environmental effects after mitigation measures have been applied ("net effects"); and
- preparation of a rehabilitation plan to enhance the harvested areas once harvesting is complete.

6.2 CONFIRMATION OF THE STUDY AREA

During the preliminary stages of the EA, the appropriateness of the selected Study Area will be reviewed, taking into consideration factors such as the socio-economic study area and the area of direct impact.

6.3 INVENTORY OF EXISTING CONDITIONS

As part of the EA, the existing conditions within the Study Area will be examined in detail and will include an inventory of the natural environment, socio-economic conditions and the cultural environment. The purpose of this exercise is to establish a baseline of conditions and to identify any planned changes to these conditions that are known at the time the EA is conducted. The inventory of existing conditions will build upon the information collected during the development of the Terms of Reference and previous studies conducted within the Study Area. The existing conditions to be further investigated are outlined in the following sections.

6.3.1 Natural Environment

The following natural environmental features will be investigated during the baseline assessment for the EA:

- Geology and soils;
- Groundwater and hydrogeology;
- Surface water quality and quantity (e.g. Regional Storm Floodplain and existing drainage patterns);
- Fisheries and aquatic habitats;
- Wildlife and vegetation resources (e.g. habitat, corridors, migratory bird species,

fisheries, species that are listed as being "at risk" federally, provincially, regionally and/or locally, and Rare Vulnerable, Threatened or Endangered species);

- Environmentally Designated Areas and Natural Heritage Features;
  - Earth and Life Science Areas of Natural and Scientific Interest (ANSIs);
  - Environmentally Significant Areas (ESAs);
  - Provincially and locally significant wetlands;
  - Natural corridors or linkages;
  - Natural heritage system linkages;
- Atmospheric environment (climate, air quality and noise).

A significant amount of primary source information has already been gathered for the study area from exploration activities and environmental studies conducted over the 25 year period from 1980 to 2005. A number of these reports are available on the PRL website (www.peatresources.com).

Where there are data gaps in existing secondary information supplementary field investigations will be conducted. The scope of field studies will be based on the level of existing information, landowner access permission and sensitivity of the community being considered. The need for an increased level of detail and collection of field data may be required through the progression of the EA Study. As alternatives are developed and refined, and particularly as a preferred alternative is selected, it is anticipated that the collection of more site-specific information will be necessary. If available, site-specific information collected during previous studies will be used. If deemed necessary, further site-specific field characterization will also be conducted.

6.3.2 Socio-Economic Environment

The following components of the socio-economic environment will be further investigated during the EA Study:

- Existing land use and ownership;
- Future land use and in the Study Area and development proposals;

- Ethnic make-up, demographics, education level, employment level, cultural facilities such as churches and recreational facilities;
- Potential Noise Sensitive Areas in accordance with MOE / MTO Noise Protocol;
- Populations that may be sensitive to impacts of the proposed undertaking; and
- Existing and proposed employment and other economic opportunities in the Study Area.

Once the baseline socio-economic conditions have been documented positive and negative effects on the community will be assessed.

6.3.3 Cultural Environment

As part of the review of the cultural environment, an inventory of the following will be carried out:

- First Nations;
- archaeological resources;
- cultural / heritage features.

The baseline assessment for this component of the environment will focus on research that has been conducted to date within the Study Area. All work completed for the inventory of archaeological and cultural / heritage features will comply with the expectations and requirements of the Ministry of Culture. Once the baseline socio-economic conditions have been documented, positive and negative effects on the community will be assessed.

6.4 CONSTRAINT MAPPING

Where appropriate, the information collected during the inventory of existing conditions will be mapped for use during the development of alternative methods to carrying out the undertaking, and the preferred undertaking. The constraint mapping will allow alternatives to be developed that seek to avoid significant / sensitive resource features and other constraint areas to the extent possible. Typical variables to be considered during the mapping exercise include:

- Existing and proposed land use;
- Previously disturbed locations;

- Existing and proposed community features;
- Significant / sensitive habitat areas; and
- Proximity to required utilities.

This map will be updated as additional information is collected during the EA study.

6.5 ANALYSIS AND EVALUATION FRAMEWORK

Judgement of the Project Team regarding the potential effects associated with the project, previous public input on similar undertakings and public consultation will be used to develop a master list of factors for the analysis. These factors will be developed to assist in the identification of the magnitude of the effects and will be used to comparatively evaluate the alternatives to the undertaking and the alternative methods of carrying out the undertaking. While information obtained during the course of preparing Individual EAs may result in changes, it is currently anticipated that the general groupings for analyses will be:

- Natural Environment;
- Socio-Economic Environment;
- Cultural Environment;
- Technical Constraints and Opportunities; and
- Cost.

The EA will describe and assess the environmental effects of the proposed undertaking and alternatives. The study of effects will increase in detail as the study progresses to identify a preferred alternative. Potential effects to be studied include, but are not limited to, those described in Sections 6.5.1 to 6.5.3.

6.5.1 Natural Environment

6.5.1.1 Species and Habitats

Aquatic Resources

MNR resource mapping, watershed and subwatershed studies, air photos, field observation and agency contacts will be used to describe surface water, aquatic and fisheries characteristics within the Study Area and to evaluate potential effects of each alternative. This information will be supplemented by other investigations and reports prepared within the Study Area.

Water body types that will be evaluated during the assessment of fisheries and aquatic habitats include: lakes, rivers, permanent creeks/streams, ponds, intermittent streams and wetlands. The following criteria are proposed for the evaluation of potential impacts of the undertaking on fisheries and aquatic habitats:

- Presence of a Coldwater Community: a waterbody that possesses the physical characteristics capable of supporting coldwater species such as trout or salmon. Coldwater streams usually have sufficient groundwater discharge to maintain year round flow and relatively low water temperatures.
- Presence of a Warmwater Community: a waterbody that supports warmwater fish communities. Fish species commonly designated as warmwater species include Largemouth Bass, Smallmouth Bass Rock Bass, Sunfish, Bullhead, Carp, Northern Pike, Walleye and Yellow Perch. Common warmwater baitfish includes Blacknose Dace, Creek Chub, Common Shiner and Bluntnose Minnow.
- The length of riparian vegetation affected, where riparian vegetation is defined as part of or on the bank of the watercourse.
- Implications for identified rare aquatic species. This is a qualitative assessment based on the disturbance of habitat for rare, vulnerable, threatened or endangered species and other fish species as identified by MNR or other resource groups.

Terrestrial Resources

Information on terrestrial resources will be based on secondary sources (agency/municipal files and mapping), consultant reports, topographic mapping, aerial photography, and field surveys. The following criteria will be used to evaluate impacts to such resources:

- **Presence of Significant floral/faunal communities.** Measures the potential effect on significant communities based on the number of documented sites either severed, encroached on, or in near proximity to the alternative. Investigations will focus on the identification and evaluation of potential impacts based on consideration of ecological factors such as habitat type and disturbance tolerance (e.g. susceptibility to edge effects, hydrological changes etc.).
- **Loss of wildlife habitat**. Measures the area of wildlife habitat (forested vegetation and non-forested successional areas, wetlands, meadows etc.) removed by an alternative. Includes an assessment of significance and sensitivity of wildlife habitat potentially impacted.
- **Encroachment on or severance of ecologically functional wildlife movement areas**. These will be identified during the EA on the basis of documented information, discussion with agency staff, review of mapping and aerial photography, field surveys and professional judgment.
- **Encroachment on, or severance of, important wildlife habitat areas**. These may include identified habitats such as migratory bird habitat or other areas with specific wildlife attributes identified by municipalities, agencies or local naturalist groups. Measure of the number of such areas affected by an alternative, based on the consideration of the wildlife species using those areas and an expected impact zone as determined during the EA.
- **Loss or encroachment on habitat of known rare or Vulnerable, Threatened, Endangered (VTE) Species.** Measures the number of habitat areas supporting documented presence of rare or VTE (Vulnerable, Threatened, Endangered) wildlife species within the study area.

Existing information sources will be reviewed to assess wildlife presence/habitat in the Study Area. Examples of the type of information that will be included are: agency/municipal files and mapping, topographic and aerial photo mapping, Natural Heritage Information Centre databases, bird studies, Canada databases, agency and local naturalist contacts. Supplemental field surveys will also be conducted if deemed appropriate.

6.5.1.2 Surface Water Quality and Quantity

The potential impacts of the alternatives on surface water quality and quantity will be evaluated. Criteria to be used in the evaluation of water quality include physical, chemical and biological parameters. These criteria will be selected to reflect the specific impacts typically associated with the alternatives under investigation. Surface water quantity will be evaluated in terms of the quantity of surface water required to operate the alternatives (e.g. once-through cooling water) and the degree to which the alternative influences surface water flows (e.g. site hydrology). The availability of suitable mitigative measures such as stormwater management facilities to minimize contaminant loadings to watercourses from storm water inputs will also be evaluated.

6.5.1.3 Atmospheric Environment

Air Quality

This factor will identify and evaluate the potential for changes in air quality due to operation of the manufacturing facility. Air quality evaluations that rely on the combustion of fossil fuels will consider, among others, parameters such as CO, NO_x, SO_2 and particulate matter. Evaluation will take into consideration background concentrations, local climatology and atmospheric dispersion to determine the impacts of the alternatives at sensitive receptors. Where applicable, information from existing documentation will be used in the assessment of air quality. Supplemental investigations will be conducted if deemed necessary.

i) The air quality assessment will include atmospheric dispersion modeling to predict off-site impacts. The mathematical models used and the averaging period selected for the assessment will reflect the latest recommendations from the MOE (i.e., the MOE is presently proposing the phase-in, over a three to five year period, of the use of AERMD-PRIME as the default dispersion model of choice).

ii) The air quality assessment will include a review and comparison of air pollution control technology for the proposed facility relative to the latest reasonably achievable control technology (RACT), best available control technology (BACT) and lowest achievable emission rate (LAER) information from the United States Environmental Protection Agency.

iii) A human health risk assessment will be undertaken for this project.

Noise

This factor identifies the effects of predicted noise increases on existing noise sensitive areas and land uses. In situations where there is a potential for alternatives to result in substantive noise impacts, a noise analysis will be carried out in accordance with the MTO / MOE Noise Protocol. The consideration of noise mitigation will also be undertaken according to the MTO / MOE Noise Protocol.

6.5.1.4 Soils, Groundwater and Hydrogeology

Based on a review of currently available and new information, the soils, groundwater and hydrogeology environmental components will be summarized for the Study Area. Factors to be investigated may include, but are not limited to:

- Geotechnical stability;
- Water flow;
- Groundwater resource areas (such as locations with a high water table, recharge areas, significant overburden aquifers, groundwater protection areas); and
- Groundwater discharge area (e.g. excavations or infrastructure that could intercept/interfere with groundwater discharge).

6.5.2 Socio-Economic Environment

The Socio-Economic Environment addresses the effects of the undertaking on the components of the environment that are ‘man-made’ and is a measure of the effects on the community. The effects measured are anticipated to include the effects on: direct and indirect employment, population migration, aesthetics, noise, land use, businesses and community services.

Employment Effects

The proposed undertaking will stimulate direct and indirect employment opportunities for residents within and beyond the Study Area. Additionally, the effect of availability of a supply of reasonably priced power will be assessed on other industry in the study area. Measures for employment effects will be number of jobs created/maintained and the revenue generated for the local economy.

Land Use and Property Effects

Current and projected land use practices within the study area have the potential to be impacted by the proposed undertaking. The assessment of property effects will identify the impact to Crown and private lands and the programs being undertaken thereon.

Community Services

The effects on fire, police, ambulance, hospital, social services education and recreation will be addressed.

Aesthetics/Noise

The effects of the facility to intrude upon the community will be assessed in terms of noise and aesthetics.

Health and Safety

A Human Health Risk Assessment will be undertaken to ensure that the facility does not have the potential to negatively affect people.

6.5.3 Cultural Environment

The Cultural Environment identifies the extent or displacement or disruption of known archaeological or heritage sites. It also examines the potential effects of the facility on First Nation Communities in terms of employment, community services, aesthetics, noise and human health.

Archaeological Resources

The effect of the alternatives on archaeological resources within the Study Area will be determined. An archaeological assessment of the Study Area will be completed as part of the EA Study.

6.6 Identification and Assessment of Alternative Methods

The purpose of this phase will be to develop a reasonable set of alternative methods of carrying out the undertaking and to assess the degree of impact associated with those methods in order to develop an across the board ranking. This could include alternative sites, and alternative technologies to harvest and process the peat. The EA will include the following generic components:

- A description of the environment that will be affected or might reasonably be affected;
- A description of potential effects on relevant environmental components;
- A description of mitigation measures;
- An evaluation of the advantages and disadvantages to the environment; and,
- A determination of "net effects" of the alternative method on the environment.

The level of detail and factors considered will be appropriate for the specific alternative methods under evaluation. The effects of each alternative method on the environment will be compared in a traceable and objective manner using quantitative and qualitative data. Throughout the EA process, the project team will review the analysis framework and, based on the additional information that becomes available, update and refine the assessment methodology. Documentation of the methodology and analysis results will be presented in the EA Report.

As required by the *Environmental Assessment Act*, the alternative with the greatest overall benefit will be selected. In order to select the preferred alternative, appropriate mitigation measures for identified impacts will need to be identified for each of the alternative methods. In addition, the determination of “net effects” (i.e. the effects of an alternative after implementation of mitigation) will be considered in the selection of a preferred alternative method.

As with other key decision stages during the EA process, the public will be given the opportunity to help develop alternative methods. Similarly, the Ministry of the Environment and other agencies will be consulted throughout the process in order to obtain their insight and perspective.

6.7 Refine the Preferred Undertaking

Following public and agency review, the preferred undertaking will be refined and finalized. The purpose of the alternative refinement will be to address comments received on the preferred undertaking.

6.8 Preliminary Design

The purpose of this task is to develop the preferred undertaking to a level of detail so that all of the detailed effects are known and can be documented as part of the EA Study. Once the detail of the effects are known, mitigation measures can be identified including the “net effects”.

6.9 Rehabilitation

Rehabilitation of the harvested areas is a critical component of determining the environmental impact. Various rehabilitation techniques will be reviewed and a preferred rehabilitation plan developed that will achieve maximum benefit in terms of restoring or enhancing the ecological functions and features of the harvested area.

7.0 MONITORING STRATEGY

The EA will include the preparation of a monitoring strategy and schedule for the construction, operation and rehabilitation of the proposed undertaking. The purpose of the monitoring plan will be to confirm the predicted effects identified by the EA and to verify the performance of mitigation measures that have been implemented. A contingency plan will be developed should unanticipated effects be identified through the monitoring program. The monitoring strategy will include compliance monitoring (with the conditions identified in the EA).

8.0 CONSULTATION PLAN

The EA associated with this ToR will include a consultation program based on the following principles:

a) The EA consultation process will be open by making all reasonable efforts to ensure that potentially affected or interested parties are given the opportunity to make their views known;
b) The EA consultation process will be transparent by documenting the consultation process that is carried out for the development of the EA so that the process can be understood and traced;
c) The EA consultation process will be responsive by providing opportunities for stakeholders to comment on the EA at key stages and by ensuring that such comments are addressed in the EA;
d) The EA consultation process will be meaningful by identifying how comments and concerns have been considered throughout the EA process; and
e) The EA consultation process will be flexible by allowing response to new issues that emerge as the EA proceeds.

The EA consultation process will include the following activities:

1. Publishing a notice in the Thunder Bay Chronicle-Journal and on PRL's project web-site announcing the approval of the ToR, commencement of an individual EA and providing

notice of the first Public Information Open House. This Open House will include distribution of information to the public for discussion and comment on the proposed "Alternatives To" and "Alternative Methods". Draft evaluation criteria will also be distributed for discussion and comment. A mechanism will be established for formally submitting public and agency comments.

2. Publishing a notice explaining that a Draft EA Report has been completed and is available for review and comments. The notice will indicate where copies of the Draft EA Report can be viewed, will explain how comments can be submitted for consideration and will specify the deadline for comments (generally 30 days). The mechanism by which the proponent will address the comments will also be indicated.
3. Conducting a second Public Consultation Open House meeting to provide information about the Draft EA Report and seek public comment. These events will be conducted in a central location that is easily accessible by interested parties. Technical/expert staff will be in attendance to answer any questions pertaining to Draft EA Report. The Open House will involve: display boards summarizing the Draft EA Report; a sign-in sheet; summary material for distribution; and formal comment sheets. Formal comments received from the public and corresponding responses from the proponent will be consolidated in a separate document. Comments from the public will be reflected in Final EA Report, as deemed appropriate.

4. Copies of the Draft EA Report, in printed and electronic format, will be placed in locations accessible to the public for viewing. These may include: PRL's offices in Thunder Bay; PRL's project web-site; local libraries; municipal offices; and Ministry of the Environment offices.

5. Following pre-determined comment periods (30 days), the Draft EA Report will be revised if and as necessary to reflect agency/stakeholder comments and concerns and the Final EA Report will be produced. A revised stakeholder list will be prepared following completion of the initial round of agency/stakeholder consultations on the Draft EA Report. Revised lists will be provided to the Ministry of the Environment for its use in the formal EA Review.

6. Upon completion and submittal of the Final EA Report the Ministry of the Environment will conduct its formal review of the EA documentation.

7. Direct contact with the Government Review Team will be maintained by the proponent and/or the EA and Approvals Branch of the MOE. The Government Review Team consists of federal, provincial and municipal agency representatives that have an interest in the project. The following table lists members of the Government Review Team.

8. Direct contact will also be maintained with public interest groups that have expressed an interest in the undertaking. Additional groups will be added throughout the EA process if any are identified and will include Lakehead University, Northwatch, Environment North and the Lake Superior Binational Forum.

9. First Nations will be consulted through discussions with Chief and Council. If requested by Chief and Council, a separate public meeting on Reserve will be held. All First Nation members are invited to the public meeting. The First Nations that have expressed an interest in working with PRL include the Lac Des Mille Lacs First Nation and the Seine River First Nation. Other First Nations that may have an interest will be identified through the E.A. process.

8.1 General Public and Interest Groups

PRL will directly (by internet or e-mail) invite interest groups and the general public to participate in the EA. Those persons will be identified from the public response to the ToR. Additional groups and individuals will be added to the mailing list during the course of the E.A.

8.2 Citizens Advisory Committee

PRL will establish a Citizens Advisory Committee comprised of people in the Upsala area. PRL will provide the Committee with information to review at key milestone dates and will consider the Committee's response prior to finalizing decisions.

8.3 GOVERNMENT REVIEW TEAM

The MOE has established a Government Review Team (GRT) that will review the EA. PRL will provide the GRT with information at key points in the process. The GRT will review this information, as well as the draft EA and provide comments to the MOE as well as to PRL. The GRT consists of federal, provincial and municipal representatives, as well as representatives of First Nations.

9.0 OTHER APPROVALS

In addition to EA approvals required under O.Reg.196/04, applications will be made concurrently, as necessary, under a number of provincial statutes for approval to implement the project covered by this ToR. Such applications may include but are not necessarily limited to:

- Certificates of Approval (Air) to cover air and noise emissions (Section 9, Environmental Protection Act);
- Certificates of Approval (Industrial Sewage) to cover stormwater management (Section 53, Ontario Water Resources Act);
- Building permits to cover construction of any facilities; and
- Application to Develop Crown Lands from the MNR.

10.0 EA PLANNING MILESTONES

The following are key EA planning milestones:

• PRL submits proposed Terms of Reference to Minister	March 1, 2006
• Notification of Terms of Reference Approval	May 1, 2006
• Draft EA available for public/government comment*	July 1, 2006
• Comment period on Draft EA ends	August 1, 2006
• Revision of Draft EA/Issue resolution	September 15, 2006
• Submission of EA to MOE for approval	September 30, 2006
• Government / Public review of EA	October 30, 2006
• Notice of Completion of government EA review	November 15, 2006
• Final public comment period	December 15, 2006
• Minister's review and decision	January 15, 2007

* The number and location of the open houses and presentations associated with the process will be determined based on public feedback received.

11.0 FLEXIBILITY OF THE ToR

Once approved by the Minister of the Environment, this ToR will provide the framework for preparing the EA and will serve as a benchmark for reviewing it. However, given recent precedents regarding Terms of Reference and the broad scope of O.Reg.196/04, this ToR is not intended to present every detail of all activities that will occur when preparing the associated EA. In this regard, PRL is committed to working with the Ministry of Environment and stakeholders to apply the ToR in a manner that reflects the issues associated with the undertaking.