Needs For and Alternatives To

APPENDIX 7.2

Range of Resource Options

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APPENDIX – 7.2

RANGE OF RESOURCE OPTIONS

1. INTRODUCTION

As part of the resource planning process, Manitoba Hydro monitors a variety of resource supply options which are potentially available to meet future Manitoba needs. The inventory consists of a range of 17 different technologies suitable for utility scale generation. Each technology type includes a number of individual resource options potentially available for development. Each of these resource technologies and options possess their own unique technical, environmental, socioeconomic and economic characteristics. This document provides a description and overview of each resource technology including a summary of key characteristics. Following the resource technology descriptions are reference data sheets summarizing a broad range of resource characteristics for individual resource options.

1.1 LEVELIZED COST OF ENERGY (LCOE)

Levelized cost is a standard measure of the cost of constructing and operating a generating resource over its life. While it is a useful measure for comparing or screening of technologies, it should be noted that levelized cost does not indicate the value of the generation, but is a relative measure of the cost associated with a unit of energy. For the purpose of high-level screening, levelized costs for new generation were obtained from the U.S. Energy Information Administration (EIA) 2013 Annual Energy Outlook Early Release.

Figure Appendix 7.2-1 shows the levelized cost ranges for resource technologies as provided in the EIA Annual Energy Outlook 2013. Figure Appendix 7.2-2 reflects the levelized cost based on potential development of resource technologies in Manitoba as provided in Section 3 and presented in 2014$.

Figure - Appendix 7.2-1. **TYPICAL LEVELIZED COST OF NEW GENERATION BY RESOURCE**

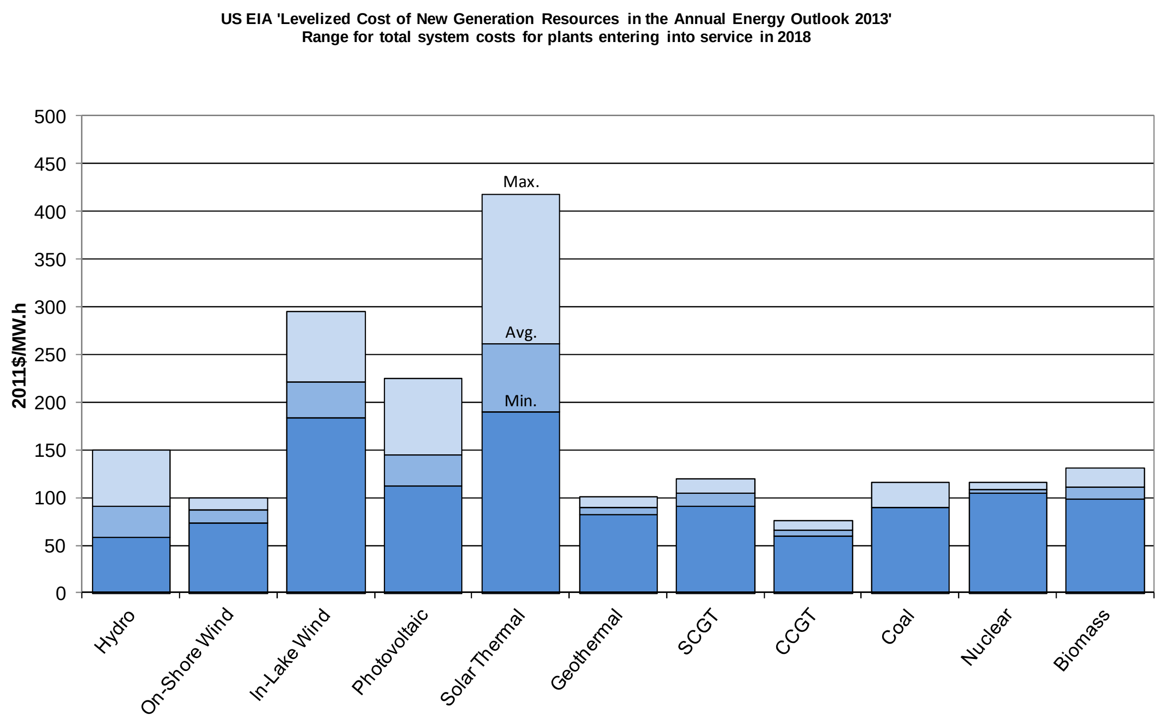

Figure - Appendix 7.2-2. **LEVELIZED COST OF RESOURCE TECHNOLOGIES DEVELOPED IN MANITOBA**

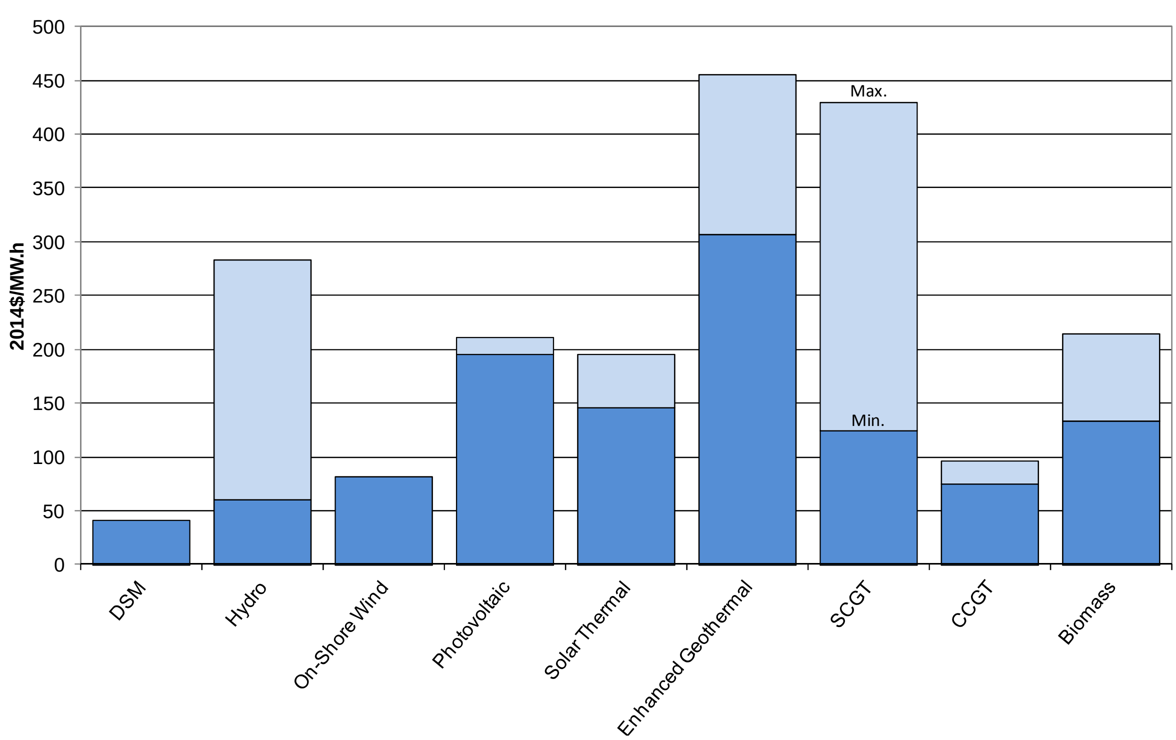

Table Appendix 7.2-1 presents a summary of the resource options included in the Range of Supply Options that are characterized as dispatchable. Dispatchability relates to the ability of a resource to be turned on/off or adjusted by the operator in order to meet varying electricity demand. Options such as hydroelectric and most thermal options are considered to be dispatchable. In addition to the calculated LCOE values for the dispatchable options, the table also contains other important metrics such as rated capacity, net system capacity and lifetime capacity factor.

Table Appendix 7.2-2 lists those resource options included in the Range of Supply Options that are characterized as non-dispatchable. Wind and solar options with or without energy storage capabilities are considered non-dispatchable.

1.2 SUMMARY OF RESOURCE OPTIONS LCOE

Table Appendix 7.2-1. **LCOE SUMMARY OF DISPATCHABLE RESOURCE OPTIONS (2012$)**

Resource Options	Category	Rated Capacity	Net System Capacity	Lifetime Capacity Factor	Levelized Cost without Transmission (CAD 2012$ at 5.05%)	Levelized Cost with Transmission (CAD 2012$ at 5.05%)
DISPATCHABLE RESOURCES						
Keeyask Generating Station	Hydro-electric	695 MW	630 MW	80%		$58/MW.h
Less Sunk to 2014 06 30						
Conawapa Generating Station	Hydro-electric	1485 MW	1300 MW	57%		$64/MW.h
Less Sunk to 2014 06 30						
Gillam Island Generating Station	Hydro-electric	1080 MW	850 MW	60%		$108/MW.h
Birthday Rapids Generating Station	Hydro-electric	380 MW	290 MW	60%		$155/MW.h
Red Rock Generating Station (Low Head)	Hydro-electric	250 MW	230 MW	65%		$163/MW.h
Bladder Rapids Generating Station	Hydro-electric	510 MW	500 MW	65%		$103/MW.h
Whitemud Generating Station	Hydro-electric	310 MW	290 MW	65%		$141/MW.h
First Rapids Generating Station	Hydro-electric	210 MW	195 MW	75%		$122/MW.h
Manasan Generating Station (Low Head)	Hydro-electric	70 MW	60 MW	90%		$195/MW.h
Manasan Generating Station (High Head)	Hydro-electric	270 MW	250 MW	65%		$128/MW.h
Birchtree Generating Station	Hydro-electric	290 MW	255 MW	70%		$147/MW.h
Kepuche Generating Station	Hydro-electric	210 MW	190 MW	65%		$123/MW.h
Early Morning Generating Station	Hydro-electric	80 MW	60 MW	90%		$215/MW.h
Notigi Generating Station	Hydro-electric	120 MW	100 MW	85%		$85/MW.h
Granville Generating Station	Hydro-electric	120 MW	120 MW	65%		$188/MW.h
Bonald Generating Station	Hydro-electric	110 MW	110 MW	65%		$277/MW.h
Heavy Duty Combined Cycle Gas Turbine	Thermal - Natural Gas	320 MW	308 MW			
Greenfield High CF Case				70%	$72/MW.h	$73/MW.h
Greenfield Low CF Case				35%	$93/MW.h	$95/MW.h
Brownfield High CF Case				70%	$72/MW.h	$73/MW.h
Brownfield Low CF Case				35%	$93/MW.h	$94/MW.h
Heavy Duty Simple Cycle Gas Turbine	Thermal - Natural Gas	216 MW	209 MW			
Greenfield High CF Case				20%	$120/MW.h	$124/MW.h
Greenfield Low CF Case				5%	$256/MW.h	$272/MW.h
Brownfield High CF Case				20%	$120/MW.h	$121/MW.h
Brownfield Low CF Case				5%	$256/MW.h	$261/MW.h
Aeroderivative Simple Cycle Gas Turbine	Thermal - Natural Gas	51 MW	47 MW			
Greenfield High CF Case				20%	$157/MW.h	$161/MW.h
Greenfield Low CF Case				5%	$412/MW.h	$429/MW.h
Brownfield High CF Case				20%	$157/MW.h	$158/MW.h
Brownfield Low CF Case				5%	$412/MW.h	$418/MW.h
Wood Waste-Fired Generation	Thermal - Biomass	15 MW	13.2 MW	0.83		
Low Fuel Cost Case						$179/MW.h
High Fuel Cost Case						$206/MW.h
Wood Waste-Fired Generation	Thermal - Biomass	30 MW	27 MW	83%		
Low Fuel Cost Case						$128/MW.h
High Fuel Cost Case						$155/MW.h
Agricultural Crop Residue-Fired Generation	Thermal - Biomass	15 MW	13.2 MW	83%		
Low Fuel Cost Case						$180/MW.h
High Fuel Cost Case						$196/MW.h
Agricultural Crop Residue-Fired Generation	Thermal - Biomass	30 MW	27 MW	83%		
Low Fuel Cost Case						$129/MW.h
High Fuel Cost Case						$145/MW.h
Subcritical Pulverized Coal Generation	Thermal - Coal	583 MW	550 MW	85%		
EIA Low LCOE Case for 2012						$110/MW.h
EIA High LCOE Case for 2012						$138/MW.h
Supercritical Pulverized Coal Generation	Thermal - Coal	580 MW	550 MW	85%		
EIA Low LCOE Case for 2012						$110/MW.h
EIA High LCOE Case for 2012						$138/MW.h
Integrated Gasification Combined Cycle	Thermal - Syngas	770 MW	640 MW	80%		
EIA Low LCOE Case for 2012						$124/MW.h
EIA High LCOE Case for 2012						$150/MW.h
Integrated Gasification Combined Cycle & CCS	Thermal - Syngas	745 MW	556 MW	80%		
EIA Low LCOE Case for 2012						$155/MW.h
EIA High LCOE Case for 2012						$191/MW.h
Nuclear Power Plant	Thermal - Nuclear	1350 MW	1350 MW	90%		
EIA Low LCOE Case for 2012						$130/MW.h
EIA High LCOE Case for 2012						$144/MW.h
Enhanced Geothermal System Generation	Renewable - Geothermal	2 MW(e)	1.9 MW(e)	≈90%	NOTE: 2 MW (electrical) & 20 MW (heating)	
Low Capital Cost Case					$294/MW.h	
High Capital Cost Case					$437/MW.h	

Table Appendix 7.2-2. **LCOE SUMMARY OF NON-DISPATCHABLE RESOURCE OPTIONS (2012$)**

Resource Options	Category	Rated Capacity	Net System Capacity	Lifetime Capacity Factor	Levelized Cost without Transmission (CAD 2012$ at 5.05%)	Levelized Cost with Transmission (CAD 2012$ at 5.05%)
NON-DISPATCHABLE RESOURCES						
Solar Photovoltaics - Fixed Tilt	Renewable - Solar	20 MW	0 MW	≈20%	≈$203/MW.h	
Solar Photovoltaics - Single Axis Tracking	Renewable - Solar	20 MW	0 MW	≈26%	≈$187/MW.h	
Solar Photovoltaics - Dual Axis Tracking	Renewable - Solar	20 MW	0 MW	≈28%	≈$193/MW.h	
Solar Parabolic Trough (No Thermal Storage)	Renewable - Solar	50 MW	0 MW	≈26%		
Low Capital Cost Case					$140/MW.h	
High Capital Cost Case					$187/MW.h	
Solar Parabolic Trough (6-hour Thermal Storage)	Renewable - Solar	50 MW	0 MW	≈40%		
Low Capital Cost Case					$144/MW.h	
High Capital Cost Case					$175/MW.h	
Generic On-Shore Wind (100 MW)	Renewable - Wind	100 MW	0 MW	≈40%		
Low Capital Cost Case					$62/MW.h	$67/MW.h
High Capital Cost Case					$99/MW.h	$108/MW.h
Generic On-Shore Wind (65 MW)	Renewable - Wind	65 MW	0 MW	≈40%	$78/MW.h	$83/MW.h
Generic In-Lake Wind	Renewable - Wind	100 MW	0 MW	≈43%		
Low Capital Cost Case					$132/MW.h	$140/MW.h
High Capital Cost Case					$225/MW.h	$233/MW.h

1.3 NFAT PREFERRED RESOURCE OPTIONS - SUMMARY OF CHARACTERISTICS

Following a general review of resource options conducted annually for the resource planning process and a more comprehensive screening exercise undertaken for the NFAT process, 16 resource options were recognized and chosen for additional study. The 16 resource options include 12 hydroelectric options, three thermal options and a wind resource option. Table Appendix 7.2-3, Table Appendix 7.2-4, and Table Appendix 7.2-5 respectively summarize important characteristics for these resources. LCOE values in these tables are reported in 2014$ as required for NFAT analysis purposes while LCOE values contained in the resource option summary sheets are reported in 2012$.

Table Appendix 7.2-3. **NFAT PREFERRED HYDROELECTRIC RESOURCE OPTIONS**

		Resource Timing	Stage of Preparation	Resource Lead Time (Years)	Technical Characteristics	Nominal Capacity (MW)	Dependable Energy (GW.h)	Environmental Characteristics	Flooded Area (km 2)	Wildlife Species of Interest	Economic Characteristics	Base Cost (2014$ Billion)	Levelized Cost (2014$/MW.h)	Considered for Further Evaluation
Hydro Resource Options	Keeyask GS		V	7		695	3000		45	Yes		3.5	60	✓
	Conawapa GS		IV	13		1485	4650		5	Yes		5.7	67	✓
	Notigi GS*		IV	10		120	650		0	No		1.0	88	✗
	Gillam Island GS		II	19		1080	3800		12	Yes		7.2	113	✗
	First Rapids GS		II	14		210	1000		55	Yes		2.1	127	✗
	Manasan GS		II	14		270	1200		150	Yes		2.9	134	✗
	Whitemud GS		II	14		310	1000		11	Yes		3.1	146	✗
	Birthday GS		II	14		380	1100		70	Yes		3.8	161	✗
	Red Rock GS		II	14		250	800		35	Yes		3.0	170	✗
	Granville GS		II	14		120	300		11	Yes		1.8	196	✗
	Early Morning GS		II	14		80	400		12	Yes		1.5	224	✗
	Bonald GS		I	16		110	300		80	Yes		2.3	289	✗

Stage I - Inventory   Stage II - Feasibility   Stage III - Concept   Stage IV - Pre-Investment
Stage V - Final Design, Construction & Commissioning

Notes:

- Levelized costs are calculated using a real discount rate of 5.05%.
- Levelized costs are based on remaining estimated capital costs going forward from June 2014. All costs (incurred or estimated) prior to June 2014 are considered as sunk.
- Descriptions of the stages of preparation are included in Appendix B

  *Although Notigi is identified at a Stage IV— Preparation level, studies were suspended in 2002.
- Energy values do not require transmission loss adjustment for supply & demand tables.

Table Appendix 7.2-4. **NFAT PREFERRED THERMAL RESOURCE OPTIONS**

		Resource Timing	Resource Lead Time (Years)	Technical Characteristics	Nominal Capacity (MW)	Dependable Energy (GW.h)	Heat Rate (mmBTU/MW.h)	Fleet History	Quick Start	Environmental Characteristics	GHG Emissions (CO2e/MW.h)	Economic Characteristics	Base Costs (million 2014$)	Levelized Costs (2014$/MW.h)	Considered for Further Evaluation
Natural Gas	GE 7FA Heavy Duty CCGT		3-5		308	2460	6652	Yes	No		342		399	75 - 97 [1]	✓
Natural Gas	GE 7FA Heavy Duty SCGT		3-5		209	1688	9906	Yes	No		506		161	125 - 266 [2]	✓
Natural Gas	GE LM6000PH Aeroderivative SCGT		3		47	387	9475	Yes	Yes		506		71	163 - 430 [2]	✓

1 Based on 70% to 35% capacity factor range.
2 Based on 20% to 5% capacity factor range.

Notes:

- Energy values require 10% transmission loss adjustment for supply & demand tables.

Table Appendix 7.2-5. **NFAT PREFERRED WIND RESOURCE OPTION**

		Resource Timing	Resource Lead Time (Years)	Technical Characteristics	Nominal Capacity (MW)	Winter Capacity (MW)	Dependable Energy (GW.h)	Capacity Factor	Environmental Characteristic	Wildlife Species of Interest	Economic Characteristics	Base Costs (million 2014$)	Levelized Costs (2014$/MW.h)	Considered for Further Evaluation
Wind	Generic Wind Farm		3-5		65	0	194	40%		Yes		163	82	✓

Notes:

- Energy values require 10% transmission loss adjustment for supply & demand tables.

2. RESOURCE TECHNOLOGIES

2.1 DEMAND SIDE MANAGEMENT

Manitoba Hydro's demand side management (DSM) initiative, "POWER SMART", consists of energy conservation and load management activities designed to capture energy efficiency and economic opportunities in an effort to meet the energy needs of Manitoba in a more sustainable manner, while assisting customers in using energy more efficiently and reducing their energy bills. DSM encompasses a range of market-based conservation programs and activities. By the end of 2012/13, Power Smart is estimated to have achieved an annual load reduction of 1,990 GW.h and 586 MW (at generation) [1].

Manitoba Hydro's strategy for DSM involves a continued long-term commitment to pursuing all cost effective energy efficiency opportunities and continually monitoring the market for emerging trends and opportunities which may become economically viable. As opportunities are identified as being economic, these opportunities are included into the Corporation's DSM plan. The 2013 – 2016 Power Smart Plan projects energy savings of 1,552 GW.h/year and 490 MW by 2027/28. Combined with energy savings achieved to date, total electricity savings through DSM of 3, 113 GW.h and 846 MW will be realized by 2027/28.

Compared to other resource technologies, DSM results in no flooding, negligible to no air emissions while having a positive global environmental impact. In the latter regard, energy conserved in Manitoba as a result of DSM efforts can be sold in largely fossil fuel generation based export market thus displacing the use of fossil fuels those regions.

One of the main considerations with DSM is that without regulation or legislation, achieving energy reduction targets is strongly dependent upon market acceptance and voluntary action. The savings potential is estimated based on a variety of assumptions in addition to market availability and adoption forecasts including natural technological development, anticipated customer energy usage/savings and market cost projections. As a result of these factors, expected energy savings from DSM do not have the same future certainty of supply as would the development of a physical resource. A summary of the perceived advantages and challenges to implementation of DSM options is provided in Table Appendix 7.2-6.

[1] Interim estimate as of March 31, 2013.

Table Appendix 7.2-6. **ADVANTAGES AND CHALLENGES SUMMARY OF DSM OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Demand Side Management	• Program specific environmental benefits • Current low cost • Modular packages • Postpone the need for new construction	• As technologies/measures are adopted, the next level of incremental DSM savings is diminishing in scale. • Dependent upon customer behavior and market conditions. • Delivery uncertainty exists for each product and program within the portfolio.

2.2 HYDRO WITH STORAGE AND RUN-OF-RIVER HYDRO

Both of these resource technologies utilize the conversion of potential energy to kinetic energy as water undergoes a decrease in elevation to generate electricity. A typical generating station consists of a dam across a river to control water flows, a powerhouse with a generator, and a spillway. Water behind the dam is channeled into the powerhouse through a draft tube and onto a turbine. As the water is pushed down through the draft tube it passes through the turbine, causing it to rotate. The rotating turbine is connected to a generator which rotates to produce electricity.

In order to operate a dam safely, spillways are used to allow water to bypass around the generating station during times of high river flows when there is too much water for the generating station to utilize. Additionally, hydro with storage options have large reservoirs in order to moderate the seasonal effects of natural water flows while run-of-river options have no reservoirs and are subject to natural variations. Most Manitoba Hydro stations operate somewhere within this range and can be described as a modified run-of-river as individually, they have limited storage capabilities.

The design of individual hydroelectric generating stations is based on site specific assumptions related to the volume of stream flow, reservoir storage, change in elevation and geological conditions. Within the station, hydro turbines are typically fixed blade propellers that have an optimal operating range of approximately 95% of maximum output. This type of turbine represents the majority of turbines currently used within the Manitoba Hydro system. Alternatively, turbines can be of variable pitch blade design that allows the turbine to operate more efficiently over a wider range of elevations and flows. As a result of operating flexibility these unit are very good in peaking operations. The only station currently utilizing this type of turbine in Manitoba is at the Grand Rapids Generating Station.

The availability of storage reservoirs within the hydro system allows generation, in the form of water, to be "stored" during off-peak periods and generated later during high value periods. Manitoba is a winter peaking region, yet river flows are highest in during spring runoff when electricity demand is generally at or near its lowest. Manitoba Hydro’s generation planning criteria requires that the system be planned to supply the firm energy demand in the event of the lowest recorded coincident water supply conditions are repeated.

Hydroelectric generating stations typically have very high availability rates (approximately 98% at Manitoba Hydro’s Lower Nelson generating stations) and very low operating and maintenance costs (approximately $70,000 per year for a 100 MW unit operating on the Lower Nelson). In Manitoba, water rentals are paid to the provincial government on an annual basis and are based on the quantity of energy generated from each plant. While operating costs are low, hydroelectric generating stations are typically very costly to construct.

Hydro plants have very long useful service lives. Some of Manitoba Hydro’s generation stations are approaching 100 years of service life. For analysis purposes, the life of a new hydroelectric generation station is assumed to be 67 years which reflects combination of the different service lives of the mechanical and electrical equipment and the service lives of the concrete and earthen structures.

The potential environmental implications of large hydroelectric facilities due to flooding and water regime and habitat changes require extensive environmental reviews which can impact the extent and duration of the regulatory review and approval processes.

Project summaries for hydro resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-1 and Figures 7.2-2 in Section 1 of this appendix. A summary of the perceived advantages and challenges to implementation of hydroelectric resource options is provided in Table Appendix 7.2-7.

Table Appendix 7.2-7. **ADVANTAGES AND CHALLENGES SUMMARY OF HYDROELECTRIC RESOURCES OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Hydro with Storage and Run-of-River Hydro	• Easily dispatched as required • Reliable • Long life (over 60 years) • Low life-cycle emissions • Reservoirs provide energy storage	• Potential seasonal fluctuations • Long lead times to implement • Sites are usually not located near load center • Costs associated with environmental mitigation and regulatory approvals

2.3 HYDROELECTRIC RESOURCES AVAILABLE TO MANITOBA HYDRO

Current hydroelectric inventories identify a remaining total of 8200 MW of undeveloped hydroelectric potential of varying sizes in Manitoba. These sites are located across the various river systems in Manitoba and due to accessibility and other factors can have considerably different development potential.

In 1977 Manitoba Hydro, the governments of Manitoba, Canada and the Northern Flood Committee signed "The Northern Flood Agreement". The purpose of the agreement was to define a procedure for settlement of claims and compensation for the adverse affects of the Churchill River Diversion and of the Lake Winnipeg Regulation projects. Subsequently in 1997, the Province signed the Manitoba Treaty Land Entitlement Framework Agreement (MFA) that specifies a process by which an affected First Nation may make entitlement land selection. Under the MFA, land that is, or potentially will be, required by Manitoba Hydro for future power developments may not be selected by an Entitlement

First Nation. The MFA gives Manitoba Hydro the right to place easements on land in areas of interest based on the elevation of proposed water level changes caused by hydroelectric projects. The sites identified by Manitoba Hydro are based on the concept of full reach development of rivers on which development has already occurred. The original MFA list of 16 sites has changed over time and is currently comprised of 12 potential sites along the Nelson, Rat/Burntwood and Churchill Rivers, totaling 4700 MW of undeveloped hydroelectric potential.

In 1984 the federal, provincial and territorial governments created the Canadian Heritage Rivers System (CHRS) to conserve rivers with outstanding natural, cultural and recreational heritage. Hydroelectric development on rivers with a heritage designation is in conflict with the intent and purpose of a heritage river declaration. Heritage river declarations impacting potential hydro power development in Manitoba include the Bloodvein River in 1987, the Seal River in 1992, and the Hayes River in 2006. As potential hydroelectric sites located on designated heritage rivers are not being perused at this time, the result is a reduction in the number of sites available for future hydro power development.

Many other sites of small and medium sizes have been inventoried but are not being pursued at this time. Their relative small size and remoteness from the transmission grid make most of them uneconomical to develop when compared to other available sites. Together with the heritage river designations these un-pursued potential sites total 3500 MW. Sixteen partially developed or undeveloped, preferred options currently remain available to Manitoba Hydro for future consideration and are listed in Table Appendix 7.2-8

Table Appendix 7.2-8. **LONG LIST OF PREFERRED HYDROELECTRIC SITES CURRENTLY AVAILABLE**

Notigi Generating Station	Red Rock Generating Station
Early Morning Generating Station	Bladder Generating Station
Kepuche Generating Station	Birthday Generating Station
Birchtree Generating Station	Keeyask Generating Station
Manasan Generating Station (high head)	Conawapa Generating Station
Manasan Generating Station (low head)	Gillam Island Generating Station
First Rapids Generating Station	Bonald Generating Station
Whitemud Generating Station	Granville Generating Station

The potential options listed in Table Appendix 7.2-8 are not all mutually exclusive to one another. Some options are potential alternative developments for a particular river reach. The lower reach of the Burntwood River has three different development options available; Manasan GS high head, Manasan GS low head along with Kepuche GS, or Birchtree GS. The upper reach of the Nelson River has two separate development options available; Whitemud GS and Red Rock GS or Bladder GS. Once the Wuskwatim GS low head was developed it allowed for the potential development of Early Morning GS upstream of the generating station. Taking these multiple site development options into account the list was reduced to 12 potential sites, as shown in Table 7.2-9, for consideration in the high level screening within the NFAT submission..

Table Appendix 7.2-9. **LIST OF PREFERRED HYDROELECTRIC SITES FOR HIGH LEVEL SCREENING**

Notigi Generating Station	Birthday Generating Station
Early Morning Generating Station	Keeyask Generating Station
Manasan Generating Station (high head)	Conawapa Generating Station
First Rapids Generating Station	Gillam Island Generating Station
Whitemud Generating Station	Bonald Generating Station
Red Rock Generating Station	Granville Generating Station

2.4 ON-SHORE WIND AND IN-LAKE WIND

These resource technologies utilize wind to rotate the blades of a turbine that is connected, via a gearbox, to a generator to produce electricity. A typical wind turbine assembly includes a generator, gearbox and controls, all of which are housed in a nacelle located at the top of the turbine tower. The amount of wind energy transferred to a turbine is proportional to the sweeping area of the blades and the cube of the wind speed. The current energy efficiency of wind turbines is about 50% out of a possible 59% maximum. Typical utility-scale wind farms consist of multiple three-bladed wind turbines (1.5 MW to 3.0 MW unit size) broadly spaced throughout a large footprint.

Manitoba has a reasonably good wind resource with the potential to develop several thousand MW's of wind generation. There are currently areas within the province with suitable wind quality to achieve capacity factors of approximately 40%. If tower heights continue to rise and turbine efficiencies continue to improve additional sites could also achieve capacity factors above 40% in southern Manitoba.

Wind generation is an intermittent resource with both seasonal and daily variability, typically producing more energy during off-peak periods, and has virtually no dependable capacity. As a result, additional fast ramping generation or energy storage is required to provide firming capacity and dispatchability. Hydroelectric generating facilities can provide such fast ramping firming capability as well as storing wind energy within reservoirs. Utilizing hydro reservoirs to store wind generation or to time shift wind generation towards peak demand, comes with a cost against other possible revenue options available to hydro generation. Measures such as improved wind forecasting, wind ramp-up predictability, and sub-hourly scheduling can reduce associated integration costs for additional wind capacity.

Sub-zero weather presents operating challenges do to the limitations of the mechanical and fluid components located within the nacelle. Standard turbines can operate at temperatures down to approximately -20^{o}C at which beyond which operation is restricted to prevent long term damage. Additional cold weather packages can be installed that allows a turbine to safely operate down to -30^{o}C before needing to cease operations. Such packages include changing fluids and additional electric heaters within the nacelle representing a small heating load.

Current trends for utility-scale, onshore, wind turbine generators are horizontal axis units of 1.5 to 3.0 MW in capacity with hub heights ranging from 60 to 140 meters. Units as large as 8.0 MW are in development for European offshore applications.

In general, wind power is not suitable for baseload as it usually has capacity factors below 38% and is difficult to forecast. Installed costs for wind range from $2,100 to $2,600/kW with annual O&M costs ranging from: $50 to $60/kW. The rotor blades, generator and tower represent three quarters of the capital cost and present the highest potential for reduction of LCOE in the future.

The competitive position of wind generation remains heavily dependent upon North American governments promoting wind generation through feed-in-tariffs, tax credits, renewable portfolio standards, and climate change legislation.

Project summaries for the following wind resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-2 and Figures 7.2-2 in Section 1 of this appendix:

- Generic On-Shore Wind (100 MW)
- Generic On-Shore Wind (65 MW)
- Generic In-Lake Wind (100 MW)

A summary of the perceived advantages and challenges to implementation of wind resource options is provided in Table Appendix 7.2-10.

Table Appendix 7.2-10. **ADVANTAGES AND CHALLENGES SUMMARY OF WIND RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
On-Shore Wind and In-Lake Wind	• No fuel costs • Short construction time • Modular • Low life-cycle emissions • Costs expected to decline • Ease of permitting • Local benefits to communities	• Diffuse, intermittent resource • Not suitable for baseload • Prone to lightning strikes • Highly dependent on commodity prices • Cold weather issues

2.5 SOLAR PHOTOVOLTAIC

Solar Photovoltaics (PV) are solid state semiconductor devices that transform light energy from the sun directly into electrical energy.

Through a process called doping, different impurities are added to materials such as silicon, resulting in positive and negative electrical charges. The atom collision from photons in sunlight provides the necessary energy to free a trapped electron in the doped material, which then may flow through a wire creating an electric current. The DC energy created can be directly utilized, converted into AC, or stored in a battery for future usage. Individual solar cells are relatively small and are connected together to form modules, that make up larger panels, which are placed in arrays. Stations typically consist of many solar arrays connected together in a solar “farm”. To optimize energy production arrays can be oriented towards the sun, utilize lenses to concentrate the solar energy, or utilize mechanical tracking systems to follow the suns daily path across the sky.

During operations no combustion or other chemical reactions are involved resulting in an emission-free energy resource. No water is consumed other than for periodic cleaning.

Solar resources are seasonal, intermittent and variable depending on the time of day, the angle of the sun, geographical location, and cloud cover. The low power-to-size ratio of the arrays leads to significant spatial requirements for large-scale operations. Backup generation or storage system is usually required for loads demanding a constant supply to provide power during times of little or no sunlight. Southern Manitoba has a good quality solar resource with Direct Normal Irradiation (DNI) values of approximately 75% that of central California.

Solar electricity is currently the most expensive form of generation, but represents the greatest resource potential for all forms of renewable generation. Capital costs are expected to continue to decline, on average, at the historical rate of about 8% per year, while panel efficiencies are expected to rise above 50% from the commercially available 20% panels today. The falling price trend for PV module costs with rising system efficiencies has continued since 1998 and is projected to extend to 2030. In real terms, it is projected that Total Plant Costs will drop by over 50% by 2020 and 75% by 2030, making this option increasingly competitive in the future.

The current competitive position of solar generation remains heavily dependent upon North American governments promoting solar generation through feed-in-tariffs, tax credits, renewable portfolio standards, and climate change legislation.

Project summaries for the following photovoltaic resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-2 and Figures 7.2-2 in Section 1 of this appendix:

- Solar PV - Fixed Tilt (20 MW)
- Solar PV - Single Axis Tracking (20 MW)
- Solar PV - Dual Axis Tracking (20 MW)

A summary of the perceived advantages and challenges to implementation of solar photovoltaic resource options is provided in Table Appendix 7.2-11.

Table Appendix 7.2-11. **ADVANTAGES AND CHALLENGES SUMMARY OF SOLAR PV RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Solar Photovoltaics	• Costs projected to decline • Low maintenance • No noise, no emissions • Modularity provides ability to expand • No fuel costs • Generation can be located near load • Can be used as building material • Can be physically oriented toward system electrical peaks	• Currently a high cost resource • Highly variable and intermittent • Storage required to provide power during times of no sunlight • Low efficiencies • Low power to size ratio • Aesthetics may cause siting difficulties

2.6 SOLAR THERMAL

Solar thermal refers to the process of harnessing heat energy from the sun. An active solar heating system uses pumps to circulate air or liquid to collect and transfer heat energy from a high temperature solar collector. A passive solar system does not include any electrical or mechanical equipment to transfer or convert heat and are typically described as low temperature solar collectors. High temperature solar thermal technology can be used for heating applications or to produce electricity, and typically utilize mirrors to concentrate heat from the sun. The heat can be used to boil water to drive a steam turbine. By heating a gas, solar radiation can also be used to drive a piston. The mechanical energy of the moving turbine or piston drives a generator to produce electrical energy. Generating stations consist of many solar collector arrays connected together in a solar “farm” linked with a thermal plant. To optimize energy production arrays can be oriented towards the sun, utilize mechanical tracking systems to follow the sun, or even be coupled with other secondary heating sources, such as fossil fuels.

Southern Manitoba possesses one of the strongest solar resources in Canada. Concentrated Solar Power (CSP), which is also known as Solar Thermal, is historically the most attractive styles of harnessing the sun’s energy on a utility scale. CSP is an intermittent power source, and is not suitable for base load purposes without large scale thermal storage which is currently not economical for utility scale generation.

Addition of thermal storage allows this technology to provide some dispatchability as it allows the solar plants to provide firm power even during non-solar and cloudy periods. In addition thermal storage also allows the solar field to be oversized to increase the plant’s annual capacity factor to about 50%. Thermal storage capability is reported as a number of hours. Currently thermal storage at solar, parabolic trough, power plants range from 3 to 12 hours.

The collector system in most solar thermal power plants is manufactured primarily of common and inexpensive materials. However, a significant portion of the cost evolves from the vast collector system which is required to harness solar rays. Therefore, the development of less expensive and more efficient collectors would likely have the highest impact on CSP economics. The levelized cost of the collector system in a solar thermal project is nearly 50%. Solar thermal projects have been abandoned in a number of cases, due to a recent decline in the cost of solar photovoltaics.

Current CSP systems require either oil or molten salt as a heat transfer fluid. The potential leakage of the oil is a concern for environmental contamination. The American Society of Mechanical Engineers is currently conducting research into the usage of direct steam generation and supercritical CO2 Brayton cycle may prove to significantly reduce the cost of solar thermal projects. A direct steam system or S-CO2 would reduce the risk of fire, environmental contamination, capital costs and heat losses.

Manitoba Hydro is currently working with Red River College (RRC) and the University of Manitoba to establish a R&D solar trough field at RRC to investigate the suitability of CSP in southern Manitoba. The direct normal irradiance (DNI) is a measure of the energy intensity that strikes a given area over time. Manitoba receives between 1800 and 2400 kW.h/m2-yr which is approximately three quarters of the DNI in California. Given the lower DNI available in Manitoba, a 1000 MW CSP plant would be expected to occupy between 30 and 40 square kilometres of landscape.

Project summaries for the following solar thermal resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-2 and Figures 7.2-2 in Section 1 of this appendix:

- Solar Parabolic Trough (no thermal storage) (50 MW)
- Solar Parabolic Trough (6-hour thermal storage) (50 MW)

A summary of the perceived advantages and challenges to implementation of solar thermal resource options is provided in Table Appendix 7.2-12.

Table Appendix 7.2-12. **ADVANTAGES AND CHALLENGES SUMMARY OF SOLAR THERMAL RESOURCE OPTIONS**

Technology	**Perceived Advantages**	**Perceived Challenges**
Solar Thermal **or** **Concentrated Solar Power**	• Potential cost effective electric heat replacement • No fuel costs • Small systems can be located close to user • Scalable and modular • Low life-cycle emissions • Life span up 30 years • Low maintenance • Common materials	• Currently a high cost resource • Larger footprint on utility scale at 3 to 5 hectares/MW • Storage systems have significant capital cost and may result in complex system designs • Potential freezing of heat transfer or storage medium • Potential environmental impacts from oil leakage

2.7 ENHANCED GEOTHERMAL SYSTEM

This resource option utilizes heat originating from earth's core to generate electricity. Wells are drilled 2 to 10 km deep to reach geothermal heat sources containing subsurface temperatures ranging from 150 to 200°C. The thermal energy contained in the subsurface rocks can be extracted by creating or accessing a system of enhanced, connected fractures through which water can be circulated by injection wells. While in contact with the deep subsurface bedrock the water is heated then returned to the surface from production wells to form a closed loop heat recovery system. Steam separated from the circulating subsurface water can be converted into electricity using a conventional Rankin cycle generator or utilized in a combined heat and power system (CHP).

EGS geothermal power plants operating with closed-loop circulation have extremely low Greenhouse Gas (GHG) and other air emissions with most associated with the construction and from maintenance vehicles. The main air emission from generation is associated with cooling water evaporation if open-loop cooling is required, and may include hydrogen sulphide (H_2S) and ammonia (NH_3).

There are industry and environmental concerns with micro tremors and the potential to contaminate ground water via the enhancement of fracture connectivity of the underground rock reservoir ("fracking"), between the injection and production well networks.

Geothermal systems perform better in winter due to the improved performance of heat exchange components. The greatest potential geothermal resource is in the south east corner of Manitoba where the resource has the potential to produce 100 kg/s at 150°C from a 6 km depth, which is equivalent to a capacity of approximately 40 MW. Shallower regions in Manitoba could produce 10 kg/s at 80°C, which would be equivalent to only 2 MW. A production well flow rate of 25 kg/s at 200°C at less than 4 km depth is the suggested minimum required capacity for current economic viability. Given the hottest geothermal areas in Manitoba and the associated lower grade heat to electricity efficiency of about 10%, the best case LCOE is expected to be 270 $/MW.h. It is estimated that this LCOE could potentially be halved within the next 10 to 20 years given advancements in drilling technology and extraction methods.

Most geothermal power plants have an average capacity of 50 MW, however geothermal options are scalable and suitable for base load purposes with capacity factors over 90%.

The largest financial hurdle with implementing EGS in Manitoba is related to the high drilling costs for deep wells of approximately $15 M per well based on current conventional petroleum drilling technologies. A system with 2 or 3 deep-wells is likely necessary to yield a plant with a 2 to 4 MW capacity.

Project summaries for the following enhanced geothermal resource option is provided in Section 3 of this appendix while its levelized costs appear in both tabular and graphical formats in Tables 7.2-1 and Figures 7.2-2 in Section 1 of this appendix:

- Enhanced Geothermal System (2 MWe)

A summary of the perceived advantages and challenges to implementation of an EGS resource options is provided in Table Appendix 7.2-13.

Table Appendix 7.2-13. **ADVANTAGES AND CHALLENGES SUMMARY OF ENHANCED GEOTHERMAL SYSTEM RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Enhanced Geothermal Systems (EGS)	• Potential cost effective electric heat replacement • No fuel costs • Small systems can be located close to user • Suitable for baseload • Low life-cycle emissions • Life span up to 30 years • Winter peaking	• Low grade resource in Manitoba • High drilling costs • Fracking presents potential water contamination issues • Maintenance costs higher than conventional thermal

2.8 SIMPLE CYCLE GAS TURBINES

Simple Cycle Gas Turbines (SCGT) are a type of internal combustion engine with an upstream rotating compressor, a combustion chamber and a downstream turbine. Fuel is mixed with air and ignited in the combustion chamber, with the products of the combustion forced into the turbine section. The products of combustion are directed through nozzles onto the turbine's blades causing the turbine to spin. The spinning turbine is then connected to a generator to produce electricity. Simple cycle gas turbines are typically fueled by natural gas or kerosene based fuels.

SCGTs are a supply option that includes attributes of modularity; low to moderate capital cost; short lead times from the date of project commitment (3 to 5 years); compact size; siting flexibility; and excellent operational flexibility. SCGTs are available in a variety of configurations ranging from sub-megawatt to 470 MW in size. SCGT power plants can consist of one to several turbine generator units. This variety allows plant capacity to be more exactly matched to system requirements than larger hydro options and thereby minimizing capital investment in excess of system needs.

The two main types of SCGTs in use today are the heavy duty frame units and the smaller, more modular aeroderivative units. The heavy-duty frame units are characterized by lower capital costs per kW and lower maintenance costs. Aeroderivative SCGT units operate with higher pressure ratios and are more efficient (i.e. have a lower heat rate) and are more compact than larger styled frame-type units. Because of the lighter construction, aeroderivative units provide superior operational flexibility with rapid start capability, short run-up and rapid cool-down capabilities. The modularity of the aeroderivative units allows for the swapping out of major components or the entire engine for major maintenance, thereby shortening maintenance outages.

Units with quick-start capability that can ramp quickly to full load are suitable as emergency backup and can also provide regulation or shaping services for varying loads from intermittent resources such as wind. SCGTs are extensively used for meeting short-term peak load demands and providing grid support functions. However, this resource option is rarely used purely for energy production because of its low efficiency relative to Combined Cycle Gas Turbines (CCGT).

Environmentally, SCGT’s water requirements are minimal and air emissions can be controlled to low levels. Basic NOx (nitrogen oxide) control can be accomplished with the use of "low NOx" combustors or steam injection. Selective catalytic reduction (SCR) controls can further limit NOx emissions as well as carbon monoxide and volatile organic compounds (VOC), particularly at unit start-up. Greenhouse gases are emitted at about one half of the intensity of a typical pulverized coal plant during normal plant operations.

The SCGT resource option is a mature and reliable technology with further increases in gas turbine performance anticipated in the coming decades.

Project summaries for the following simple cycle gas turbine resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-1 and Figures 7.2-2 in Section 1 of this appendix.

- Heavy Duty Simple Cycle Gas Turbine (216 MW)
- Aeroderivative Simple Cycle Gas Turbine (51 MW)

A summary of the perceived advantages and challenges to implementation of simple cycle gas turbines resource options is provided in Table Appendix 7.2-14.

Table Appendix 7.2-14. **ADVANTAGES AND CHALLENGES SUMMARY OF SIMPLE CYCLE GAS TURBINE RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Simple Cycle Gas Turbines (SCGT)	• Proven and reliable technology • Dispatchable resource • Low capital cost • Short construction lead times • Ideal for peaking and quick start operations	• High variable operating cost • Fuel price risk and volatility • Less efficient than CCGT • Air and greenhouse gas emissions

2.9 COMBINED CYCLE GAS TURBINES

Combined Cycle Gas Turbines (CCGT) utilize a natural gas fuelled simple cycle gas turbine (SCGT) along with a heat recovery steam generator utilizing the Rankine cycle. As described above, a SCGT ignites a gas-air fuel mixture that expands and is forced through a turbine to rotate an electric generator. In addition, a second system is combined with the SCGT to capture the waste exhaust heat from the process and uses it in a Rankine cycle generator to convert high pressure water into steam. The expanding steam causes a second turbine that is connected to a generator to rotate and produce additional electricity. Use of the otherwise wasted heat of the turbine exhaust gas yields high thermal efficiency compared to other combustion technologies.

Typical CCGT units operate with natural gas as the operating fuel, but often dual-fuel capability with oil as a backup can be used to increase the availability of the generation when natural gas supplies are curtailed. However, use of distillate fuel oil as a backup fuel has become less common in recent years because of its additional emissions such as sulfur oxides. Inexpensive optional power augmentation for peak period operation can be obtained by use of inlet air chilling and duct firing (direct combustion of natural gas in the HRSG to produce additional steam). CCGTs are economically capable of providing base and intermediate load service with capacity factors commonly ranging from 35% to 65%.

CCGTs are a supply option that includes attributes of high thermal efficiency, low to moderate initial cost, high reliability, lower air emissions, short lead times (3 to 5 years), compact size with siting flexibility, and excellent operational flexibility. CCGTs are available in a variety of configurations ranging from less than 10 MW to over 1000 MW in size.

Environmental effects of combined cycle power plants are relatively minor. The principal environmental concerns associated with the operation of combined cycle gas turbine plants are emissions of NOx and CO_2 (carbon dioxide). Nitrogen oxide abatement is accomplished by use of “dry low-NOx” combustors and SCRs within the HRSG. Limited quantities of ammonia are released by operation of the NOx selective catalytic reduction system. Carbon monoxide and VOC emissions are typically controlled by use of an oxidation catalyst within the HRSG. Greenhouse gases are emitted at less than 40% of a typical pulverized coal plant during normal operations.

Water consumption for power plant condenser cooling appears to be an issue of increasing importance in North America. Water consumption can be reduced by use of dry (closed-cycle) cooling, though at added cost and reduced efficiency. In the future, it appears likely that an increasing number of new projects will use dry cooling.

The high thermal efficiency of combined cycle units could position this technology to displace conventional coal-fired plants throughout North America, if significant universal carbon dioxide caps or penalties were established.

Project summaries for a combined cycle gas turbine resource options is provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-1 and Figures 7.2-2 in Section 1 of this appendix.

A summary of the perceived advantages and challenges to implementation of combined cycle gas turbines resource options is provided in Table Appendix 7.2-15.

Table Appendix 7.2-15. **ADVANTAGES AND CHALLENGES SUMMARY OF COMBINED CYCLE GAS TURBINE RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Combined Cycle Gas Turbines (CCGT)	• Proven and reliable technology • Dispatchable resource • More efficient than SCGT • Well suited for either intermediate or baseload service • Greater than 60% reduction in CO_2 emission intensity per MW.h than a conventional coal plant	• Fuel price risk and volatility • Some air and greenhouse gas emissions

2.10 CONVENTIONAL PULVERIZED COAL

Pulverized coal-fired power plants are a mature and proven technology that has been in use for over a century and is the major source of electrical power in the US. Coal is ground to a dust-like consistency, blown into a boiler and burned. Heat from the burning coal generates steam that is used to drive a steam turbine-generator. The process known as the Rankine cycle uses the combustion of fuel and oxygen within a boiler to generate heat. Demineralized water is pumped through pipes within the boiler where it is heated to create steam. During the process of converting the liquid into gas, the fluid expands considerably creating a force that is used to rotate a turbine. The rotating turbine which is connected to a generator then produces electricity. The steam is condensed back into a liquid by reducing its temperature with cooling water and is then repressurized, reheated and reused in the boiler in a continuous cycle.

There are no seasonality or intermittency issues associated with this resource option. The most prominent operational flexibility consideration for this option is the ramp time (approximately 8 hours) required to achieve full load from a cold start state.

Pulverized coal-fired boilers can be operated either under subcritical steam conditions with thermal efficiencies of about 37% or supercritical conditions with thermal efficiencies of 37% to 40%. The latest European advancements in pulverized coal-fired generation are the deployment of "ultra-supercritical" units with thermal efficiencies of 41% to 43%.

The Province of Manitoba has restricted power generation from the use of coal to the support of emergency operations after January 1, 2010 with *The Climate Change and Emissions Reductions Act*. Similarly, the permitting of new coal-fired facilities in North America has become increasingly difficult over the past few years. Recent regulatory trends outside of Manitoba in Canada and the US concerning air emissions require that new pulverized coal-fired units incorporate flue gas desulfurization (FGD) systems to control SO_2 (sulfur dioxide) emissions; selective or non-selective catalytic (SCR/SNCR) reduction to control NO_x emissions; and either electrostatic precipitators (ESP) or filter fabric baghouses to control particulate emissions. Additional environmental controls are also required to control mercury emissions. Uncontrolled air emissions would typically include NO_x, SO_2, particulate matter (PM), volatile organic compounds (VOC) and mercury. Greenhouse gas emissions from a conventional pulverized coal plant are approximately equal to 1 tonne of CO_{2e} per MW.h of generated energy.

Environmentally compliant, pulverized coal-fired power plants have high capital costs and lengthy construction periods relative to other generating options and are best suited to baseload duty. Cycling and load following operations are typically detrimental to the economics of large coal units because of costly increased maintenance requirements.

All coal-fired generation facilities in Manitoba to date have utilized imported coals, initially Lignite from Saskatchewan and more recently sub-Bituminous coal from Montana. Recent discoveries (2009 to 2011) of thick seams of bituminous grade coal southwest of The Pas have created significant exploration interest in the Canadian mining sector.

Although use of this technology is currently restricted in Manitoba, summaries for coal based resource options are provided in this report to allow comparison of resource options available to Manitoba Hydro to coal based technologies operating in other jurisdictions. Project summaries for the following conventional pulverized coal resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Tables 7.2-1 and Figures 7.2-1 in Section 1 of this appendix.

- Subcritical Pulverized Coal Generation (583 MW)
- Supercritical Pulverized Coal Generation (580 MW).

A summary of the perceived advantages and challenges to implementation of pulverized coal resource options is provided in Table Appendix 7.2-16.

Table Appendix 7.2-16. **ADVANTAGES AND CHALLENGES SUMMARY OF CONVENTIONAL PULVERIZED COAL RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Pulverized Coal	• Proven and reliable technology • Dispatchable resource • Abundant, low cost fuel • Less fuel price volatility than natural gas • Well suited for baseload operations	• Significant particulate and air emissions • Significant GHG emissions • Significant capital investment • Growing lack of public and regulatory acceptance • Lengthy siting and environmental approval process • Combustion residues (ash)

2.11 INTEGRATED GASIFICATION COMBINED CYCLE

Integrated Gasification Combined Cycle (IGCC) technology produces a low energy, synthetic gas (syngas), typically from coal, which is used in an efficient, combined cycle gas turbine for power generation. Pulverized coal is blended with oxygen and water to produce a slurry that is fed into a gasifier which produces heat and raw synthetic gas (syngas). The cooled and treated syngas is then fed into the combustion chamber of a gas turbine modified to combust low calorific value syngas and generates electricity. Exhaust heat from the turbine is captured by a heat recovery steam generators (HRSG) which is used to power a steam turbine to generate additional electricity.

The IGCC process is a relatively new technology with only three full-scale power plants currently operating in the USA, none of which have deployed carbon capture processes. Coal gasification itself is an old technology dating back to the early nineteenth century to produce "town gas" for heating and illumination. It is believed that approximately 90% of CO_2 produced in the gasifier can be separated from the syngas for commercial scale carbon sequestration. Commercial development of this technology is not expected before the mid-2020s.

The Province of Manitoba has restricted power generation from the use of coal to the support of emergency operations after January 1, 2010 with *The Climate Change and Emissions Reductions Act*. This may limit the development of this resource technology in Manitoba.

As this is a new technology, industry lacks experience with this option's reliability or its ongoing operation and maintenance issues. The general industry consensus is that capital and operation and maintenance costs will be at least 25% higher than that of a supercritical coal plant. There are no seasonality or intermittency issues associated with this resource option.

Project summaries for the following resource options are provided in Section 3 of this appendix while levelized costs for these options appear in

Project summaries for the following IGCC resource options are provided in Section 3 of this appendix while their levelized costs appear in tabular format in Tables 7.2-1 in Section 1 of this appendix.

- Integrated Gasification Combined Cycle (770 MW)
- Integrated Gasification Combined Cycle with Carbon Capture and Storage (745 MW)

A summary of the perceived advantages and challenges to implementation of integrated gasification combined cycle resource options is provided in Table Appendix 7.2-17.

Table Appendix 7.2-17. **ADVANTAGES AND CHALLENGES SUMMARY OF INTEGRATED GASIFICATION COMBINED CYCLE RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Integrated Gasification Combined Cycle (IGCC)	• Dispatchable resource • Abundant, low cost fuel • Less fuel price volatility than natural gas • Well suited for baseload operations • Potentially lower greenhouse gas emissions if CO_2 is captured and stored	• New, largely unproven technology with only a few operating plants • Higher capital investment than conventional coal • Complex operating technology • Process wastes (solids and liquids)

2.12 NUCLEAR POWER PLANT

Nuclear power plants utilize the fission of radioactive material such as uranium, thorium or plutonium as a fuel to generate electricity. The difference between a nuclear power plant and a conventional steam turbine plant is in the way in which steam is created. In a conventional steam turbine plant, steam is created via combustion in a boiler. In a nuclear power plant, steam is created via the heat released by a controlled nuclear reaction. The reaction creates tremendous amounts of thermal energy which is then captured by tubes containing pressurized water. The thermal energy from the reaction then converts the pressurized water into steam, which is used to rotate a turbine and a generator. Other than the method by which heat is created, the remaining components of a nuclear plant are the same as those of a conventional steam turbine plant.

Nuclear power plants supply 15% of Canada's current electrical generation totaling 13,553 MW, while worldwide it provides 13-14% totaling 370,000 MW. Conventional nuclear generation is a mature and proven technology and could be an attractive future source of dependable capacity and baseload low-carbon energy that is largely immune to high natural gas prices and climate policies. Nuclear plants have thermal efficiencies in the 30% to 35% range. This resource technology is best suited for baseload duty. Cycling and load following operations are typically detrimental to the economics of large nuclear units and such services increase maintenance requirements and costs considerably.

Nuclear power's limited operational flexibility and large individual units, in the order of 1000 MW, can present system integration challenges with relatively smaller systems, such as Manitoba Hydro's predominantly hydroelectric system. Large individual, must-run, units would not easily accommodate periods of low load. In addition, one large nuclear unit, representing approximately 10 – 20% of Manitoba Hydro's current capacity, would provide significant operational challenges during any extended maintenance period.

Nuclear capital costs are difficult to forecast, as no new "greenfield" nuclear facilities have been built in the US since the 1980s. In the past decade, nuclear generating units have had very high capital cost estimates and are believed to have lengthy siting, permitting and construction periods relative to other generation options.

Motivated by improved plant designs, need for new low-carbon baseload resources, and financial incentives of the US. Energy Policy Act of 2005, nuclear development activity has resumed in the US with the Nuclear Regulatory Commission's approval of a two-reactor expansion at a nuclear power station plant in Georgia. This is the first approval for new reactors since 1978. Development and design work is also underway on a highly modular, light water design using standard 40-megawatt modules that could be added to plants to obtain a desired capacity.

Nuclear waste disposal continues to be a significant issue facing the industry as there is currently no operational, long-term storage facility in North America. Manitoba's High-Level Radioactive Waste Act R10 may prohibit development of nuclear generation facilities in the province due to the prohibition of storage of high-level radioactive wastes in Manitoba.

Project summaries for a Nuclear Power Plant is provided in Section 3 of this appendix their levelized costs appear in both tabular and graphical formats in Table 7.2-1 and Figure 7.2-1 in Section 1 of this appendix.

A summary of the perceived advantages and challenges to implementation of nuclear resource options is provided in Table Appendix 7.2-18.

Table Appendix 7.2-18. **ADVANTAGES AND CHALLENGES SUMMARY OF NUCLEAR RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Nuclear	• Reliable baseload power • Low life-cycle emissions • Proven fuel reserves • Technically feasible • Long life, 60 years • No seismic risk in Manitoba • Canadian designs available	• Societal concerns about safety and security • Radioactive waste disposal is a major issue • Generation not used for following changes in load • Advanced technologies decades away

2.13 BIOMASS ENERGY

Biomass materials such as waste wood, landfill gas, agricultural waste, crop residues or dedicated energy crops can be converted into heat, electricity, or both. There are three main types of conversion technologies:

- Combustion - the burning of biomass for heat
- Thermochemical – uses heat and pressure to break down biomass into combustible gases or liquids
- Biochemical – uses microorganisms to break down biomass into viable fuels and chemicals.

Conventional steam-electric plants with or without cogeneration will be the chief technology for future electricity generation using crop or wood residues. Solid-fuel biomass fired power plants can utilize processes such as direct combustion or gasification. Direct combustion of biomass utilizes mature steam turbine plant technology involving a traditional four component process including a stoker-fired boiler, a turbogenerator, a condenser, and a boiler feed pump. A stoker-fired boiler has the flexibility to combust variably sized biomass having variable moisture content. This plant configuration can also be easily adapted to allow co-firing with other fuels such as natural gas.

Biomass is often shredded into small pieces to allow the biomass to be dried uniformly, which increases the combustion efficiency. Some biomass materials have caused significant problems in test burns by either plugging fuel handling systems (bark wood waste) or plugging boilers (soybeans). The optimal size for a biomass fired electrical generating station is most likely in the 15 to 30 MW range due to a balance between economy-of-scale and the cost of collecting and transporting the fuel from locations remote from the plant site. Currently the cost of energy produced from this form of technology is not yet competitive with other forms of generation and is strongly dependent upon the volatile price of transportation fuels.

In theory, this form of energy production can be considered carbon neutral since it replaces the natural release of CO_2 from biological decay by utilizing the material for energy production and releasing CO_2 during combustion. Irrespective of the carbon neutral theory, this resource produces CO_2 and other hazardous air pollutants comparable to that of coal-fired generation. Additional emissions result from fuel used during the collection and transportation of crop residues.

The principal barriers to development of solid-fuel biomass plants are capital costs, availability of cogeneration load and ensuring an adequate, stable, and economic supply of fuel. Modular biogasification plants are under development and may be introduced within the next several years. With the development of bioenergy industries, there is the potential for increased competition and prices for biomass feedstocks in Manitoba.

The potential generation of all major biomass resources in Manitoba is estimated to be 630 MWe. Since biomass resources are highly distributed, up to 40% of the levelized cost of energy (LCOE) is based on collection and transportation costs. The magnitude of the potential for competitive industries such as bio-fuels and bio-fibres is currently unknown.

Project summaries for the following biomass resource options are provided in Section 3 of this appendix while their levelized costs appear in both tabular and graphical formats in Table 7.2-1 and Figures 7.2-1 and 7.2-2 in Section 1 of this appendix.

- Wood Waste-Fired Generation (15 MW)
- Wood Waste-Fired Generation (30 MW)
- Agricultural Crop Residue-Fired Generation (15 MW)

- Agricultural Crop Residue-Fired Generation (30 MW)

A summary of the perceived advantages and challenges to implementation of biomass resource options is provided in Table Appendix 7.2-19.

Table Appendix 7.2-19. **ADVANTAGES AND CHALLENGES SUMMARY BIOMASS RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Biomass Energy	• Dispatchable and suitable for base load • Suitable conversion technologies are inexpensive and mature • May spur development and relations with rural communities • Captured landfill gas reduces GHG emissions	• LCOE highly dependent on transportation fuel costs • Usually carbon positive • Hazardous air emissions comparable to coal • Magnitude of competition for feedstock with other industries is unknown • Some resources seasonal and drought sensitive • Labour intensive • Moisture content can vary • Limited resource in Manitoba • Family farms typically not large enough for MW projects

2.14 CONTRACTUAL IMPORT AGREEMENTS

Imports are an option to meet either capacity or energy needs. Given Manitoba Hydro's strong connection to the large U.S. market, imports for both capacity and energy needs are available with short lead times and are available for various durations to meet short-term and long-term requirements.

When considering imports for capacity purposes, a critical consideration is that Manitoba experiences a winter peak demand while most U.S. utilities have their peak demand during the summer season. This means that there is likely to be a large pool of surplus U.S. capacity available to Manitoba Hydro in the winter season if suitable transmission arrangements can be made on a firm basis for the delivery of energy associated with the capacity.

Generally Manitoba Hydro has entered into capacity exchange arrangements with U.S. suppliers to acquire winter capacity at no cost. In exchange for the rights to winter capacity, Manitoba Hydro agrees to supply an equivalent amount of capacity to the supplying utility during the summer season: i.e., a seasonal diversity arrangement. If existing firm import and export transmission exists between Manitoba Hydro and the U.S. utility, both companies can meet their capacity needs with no capital expenditures. If there is insufficient firm transmission, then it would be cost-effective to build or buy the necessary transmission service when the cost of the transmission service is less than the cost of acquiring a capacity resource.

When considering imports for dependable energy requirements, a critical consideration is whether the supplying region has surplus energy available during the period when Manitoba Hydro is experiencing dependable flow conditions. For example, because Saskatchewan and northwestern Ontario share the same watersheds and have significant hydro resources on the same river systems as Manitoba Hydro it is extremely likely that these regions will be short of energy during dependable flow conditions. Conversely, because hydro is a very small component of the generation fleet in the region of the U.S. from which Manitoba Hydro purchases energy (1% of total annual generation), shared drought conditions in Manitoba Hydro's watersheds and those of the U.S. Midwest will not noticeably reduce the supply of energy available for purchase by Manitoba Hydro. Even severe drought conditions extending beyond Manitoba and into the U.S. Midwest that potentially impact the supply of energy by affecting cooling or boiler makeup water requirements of U.S. Midwest thermal generating stations would not be expected to have a material impact in the overall availability of energy for purchase.

Manitoba Hydro's long-term firm import limit on the existing transmission lines from the U.S. is 700 MW. This import limit will not change until new transmission interconnections are built or existing transmission interconnections are upgraded.

Generation from the MISO market, on average across all generation types, results in significant amounts of CO2 and other hazardous air emissions on a per unit (MW.h) basis. The MISO region is coal-dominated, generating 75% of its electrical energy from coal in 2011, while natural gas-fired and oil generation represents 5%, wind generation 5%, and nuclear generation 13%. The share of energy generated using coal in the U.S. is on the decline. Coal-fired generation last provided a 50% share across the U.S. in 2005 and is expected to be 40% in 2013 according to the U.S. DOE EIA. In the absence of additional stringent coal regulations or very high carbon prices, the EIA is still projecting coal to generate a significant proportion of electricity within U.S. and particularly in the Midwest through 2030.

Manitoba Hydro can access the supply of surplus energy through market purchases and energy and/or capacity contracts. Firm transmission service is required to ensure the energy can be delivered to Manitoba on a firm basis.

Since Manitoba Hydro generally has surplus energy available and cannot predict when it may need to purchase energy, Manitoba Hydro does not contract for fixed blocks of fixed-price electricity imports. Rather, the arrangements made with suppliers provide Manitoba Hydro with the assurance that the energy will be there when needed but also with the flexibility to buy it when most economical, utilizing the storage capability of the hydraulic system to reshape the supply to serve load requirements. When Manitoba Hydro enters a drought period, in which purchased power and a fixed price and delivery schedule are desired, those arrangements can be made at that time.

Manitoba Hydro does not have firm import transmission with either Ontario or Saskatchewan and, as such, does not plan on firm imports from these markets to address the resource diversity issue discussed above.

A summary of the perceived advantages and challenges to implementation of import resource options is provided in Table Appendix 7.2-20.

Table Appendix 7.2-20. **ADVANTAGES AND CHALLENGES SUMMARY IMPORT RESOURCE OPTIONS**

Technology	Perceived Advantages	Perceived Challenges
Contractual Import Agreements	• Highly flexible short notice resource • Short or long term purchases • Diversity exchanges between winter & summer peaking regions • Diversity between hydro and thermal based systems	• Prices subject to prevailing market conditions • Transmission limits on existing lines • Upgrades or new lines required to increased limits

3. RESOURCE OPTIONS

This section is composed of information sheets for 37 individual resource options. A range of descriptive, technical, economic, environmental, socio-economic and summary characteristics are included for each information sheet. In broad terms there are 16 hydro resource options; 12 thermal resource options; and 9 emerging technology options presented for reference purposes in this section.

3.1 HYDROELECTRIC RESOURCE OPTIONS

The following sixteen (16) resource option data sheets present important performance characteristics and metrics for hydroelectric resource options.

Keeyask Generating Station

Resource Type**:** Hydroelectric   Level of Study: Stage V – Final Design, Construction & Commissioning

Location:

Located between Gull and Stephens Lakes approximately 180 km northeast of Thompson, 60 km northeast of Split Lake, and 30 km west of the town of Gillam.

River Reach: Lower Nelson River

Description:

Principal structures will consist of a powerhouse with seven turbines, other equipment for generating electricity and a service bay complex, a seven-bay spillway, three dams, two dykes and a reservoir. The spillway will manage surplus river flows, and the dams and dykes will contain the reservoir created upstream of the principal structures.

Permanent supporting infrastructure will include a north and south access road (the north access road is being constructed under the Keeyask Infrastructure Project), a transmission tower spur, communications tower, some borrow areas, excavated-material placement areas, boat launches, a portage and public-safety measures. Once the Project is constructed, the north and south access roads will be connected with the Project and will be integrated into the provincial highway network.

Temporary support infrastructure will include: the main camp, contractor work areas, a landfill, water- and sewage-treatment facilities, an explosives magazine, cofferdams, rock groins and an ice boom.

Technical Characteristics

Keeyask Generating Station

Nameplate Rating: 695 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	695 MW	630	630
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	3003	4430	6080

Average Capacity Factor: 80%

Full Supply Level: 159 m

Gross Head: 19.2 m

Expected Average Flow: 3125 m3/s

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect with Nelson River system flow mangement and reservoir storage.

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	6
Minimum Time to Earliest ISD *(years)*	7

Typical Asset Life: 67 years

Economic Characteristics

Keeyask Generating Station

Levelized Cost (*P_{50} Estimate*):

Less Sunk to 2014 06 30 with Outlet Transmission - $58 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Less Sunk to 2014 06 30 with Outlet Transmission - $3324 CAD (2012$)

Expected Accuracy Range of Cost Estimate: -10% to +15%

Overnight Capital Cost ($/kW): $5300 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage V – Final Design, Construction & Commissioning
AACEI Estimate Classification	Class 3

Estimating Technique: Detailed Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$17.86 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.00%	16.16%	6.57%	7.13%	11.25%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
14.80%	17.84%	12.50%	8.89%	4.85%

Environmental Characteristics

Keeyask Generating Station

Impacted Land Area:

Estimated Flooded Area - 45 increasing to 53 sq km (4500 to 5300 ha)

GS Footprint - 214 ha

Additional Impacted Area - 9302 ha

Flooded Area Intensity: 6.5 increasing to 7.6 ha/MW

Total Reservoir Area: 93 sq km

Additional Linear Development: 38 km

Distance from Load Center: 720 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 0.07 to 2.22 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: Upstream of the project there will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury. Project effect on downstream water quality is expected to be generally small to negligible.

Higher Priority Wildlife Species of Interest: sturgeon, caribou & nesting habitat

Long Term Legacy Issues: Perpetual care and maintenance commitment of dam structure or the existing water regime for environmental and safety reasons.

Socio-Economic Characteristics

Keeyask Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Fox Lake Cree Nation, Gillam, Ilford, Tataskweyak Cree Nation, York Factory First Nation, War Lake First Nation

Resource Management Area: Split Lake RMA

Existing Agreements: Joint Keeyask Development Agreement (JKDA), Northern Flood Agreement (NFA), Impact Settlent Agreement (ISA), Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	4480 Person-Years
Operating Phase	58 FTE
Combined Phases *(over full service life)*	8400 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$9.0 million CAD (2012$)/year
Estimated Capital Taxes	$17.3 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$27.7 million CAD (2012$)/year
Estimated List Total	$54.0 million CAD (2012$)/year

Summary Characteristics

Keeyask Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Manitoba Hydro and the Keeyask Cree Nations (KCN) of Tataskweyak Cree Nation (TCN), War Lake First Nation, Fox Lake Cree Nation, and York Factory First Nation negotiated and ratified the Joint Keeyask Development Agreement (JKDA) which was signed on May 29, 2009. The JKDA is a legal agreement between Manitoba Hydro and the KCN which outlines the partnership arrangements with regard to development, ownership, and operation of the Keeyask Generation Station (GS). Following the signing of the JKDA, further negotiations with the KCN resulted in the Keeyask Infrastructure Agreement (KIP). The benefits of the KIP included enhanced employment and business opportunities for the KCN, as well as reduced risk of delays in the construction schedule. Construction of the KIP including the North Access Road, a bridge over Looking Back Creek, and start up camp infrastructure began in January of 2012. Construction of the Generating Station is scheduled to start in June 2014 subject to regulatory approvals.

The final Environmental Licence for the Keeyask Infrastructure Project (KIP) was received March 11, 2011. The Board of Manitoba Hydro approved the Infrastructure Project June 23, 2011, the infrastructure Agreement was signed by all parties on June 28, 2011 and work started on January 16, 2012. The Keeyask GS Project Description document was filed with the Federal Major Projects Management Office in July 2011 and this commenced the federal regulatory process. The Environmental Act Proposal

Form was filed with Manitoba Conservation in December 2011. This commenced the provincial regulatory process. The application for the Keeyask Project Interim Water Power License was submitted to the Province early in 2012.

Manitoba Hydro and the four KCN jointly developed the Environmental Impact Statement (EIS) for the Generation Project which was filed on July 6, 2012. The partners are now working together to respond to Requests for Additional Information from Provincial and Federal Government reviewers and the public. To date TAC and Public Reviewers Round 1 and 2 Information Requests (IRs) were filed in November 2012 and April 2013 respectively; and we are currently working on responding to the round 3 IRs.

On November 16, 2012 the province officially asked the Clean Environment Commission (CEC) to hold public hearings on the proposed Keeyask G.S. The Keeyask CEC Hearings are anticipated to begin on September 30, 2013 in northern Manitoba to facilitate local participation, and to continue in Winnipeg throughout mid-October and early November 2013. Once the hearings are complete, the commission has three months to issue their report and recommendations to the Minister. Manitoba Hydro staff and the four KCNs (the Partnership) filed the CEC Response to IRs Round 1 on July 15, 2013 and are awaiting Round 2 questions scheduled to arrive by the end of July 2013. A KCN pre-hearing committee was established to provide the coordination of responses to questions from governments, the public and the CEC; develop a shared understanding of the overall strategy for the hearings; facilitate KCN witness development and orientation; and, coordinate the implementation of Round 3 of the Keeyask Public Involvement Program (currently in progress). The Keeyask Partnership is working to develop a supplemental filing to the EIS which includes draft versions of the Environmental Protection Plans and the Keeyask Environmental Management plans.

Manitoba Hydro negotiates Transition funding budgets with each of the KCNs from the period of JKDA signing to the start of construction when Implementation Funding occurs. Reimbursing the reasonable costs of these communities for activities during the transition period ensures that the KCNs are able to participate effectively in the transition period activities (described above), and that Manitoba Hydro continues to strengthen its working relationship with each of the Keeyask Cree Nations.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Keeyask Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

BC Hydro (2009). “Peace River Site C Hydro Project, Stage 2 Report: Consultation and Technical Review” Fall 2009.

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International Renewable Energy Agency (2012c). "Renewable Energy Technologies: Cost Analysis Series, Hydropower". June 2012.

Keeyask Hydropower Limited Partnership (2012). "Keeyask Generation Project Environmental Impact Statement". June 2012.

Moonmaw, W. et al. (2011). Annex II: Methodology. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. 2011.

Northwest Power and Conservation Council (2005). “The Fifth Northwest Electric Power Conservation Plan”, May 2005.

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PacifiCorp (2008). 2008 Integrated Resource Plan. May 2008.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Conawapa Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 4 - Pre-investment

Location:

Located on the lower Nelson River approximately 30 km downstream of the existing Limestone G.S. and 74 km upstream of the potential Gillam Island G.S. site. The site is accessible by existing roads and is 90 km northeast of the town of Gillam.

River Reach: Lower Nelson River

Description:

Principal structures will consist of a powerhouse with ten turbines and generators, other equipment for generating electricity, a service bay complex, a control room, a seven-bay spillway, a spillway energy dissipater, two dams, and a reservoir. The spillway will manage surplus river flows, and the dams will contain the reservoir created upstream of the principal structures.

Permanent supporting infrastructure will include the existing Conawapa access road, a transmission tower spur, Generation Outlet Transmission lines, a staffhouse, water and sewer support systems, some borrow areas, excavated-material placement areas, mitigation measures, boat launches, a portage and public-safety measures. The following permanent supporting infrastructure; the construction power line and station and the communication tower will be constructed by Keewatinoow and also used by Conawapa for construction and operation.

Temporary support infrastructure will include: camp areas, Manitoba Hydro and contractor work areas, water- and sewage-treatment facilities, haul roads, south side winter trail, an explosives magazine, cofferdams, and a rock groin.

Technical Characteristics

Conawapa Generating Station

Nameplate Rating: 1485 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	1485 MW	1300	1395
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	4650	7000	9700

Average Capacity Factor: 57%

Full Supply Level: 57.2 m

Gross Head: 32.0 m

Expected Average Flow: 3200 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Modified Run-of-River
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect with upstream Nelson River system flow management

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	4
Construction Phase: Final Design, Procurement & Construction *(years)*	8.5
Minimum Time to Earliest ISD *(years)*	12.5

Typical Asset Life: 67 years

Economic Characteristics

Conawapa Generating Station

Levelized Cost (*P_{50} Estimate*):

Less Sunk to 2014 06 33 with Outlet Transmission - $64 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Less Sunk to 2014 06 33 with Outlet Transmission - $65493CAD (2012$)

Expected Accuracy Range of Cost Estimate: -15% to +20%

Overnight Capital Cost ($/kW): $3700 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 4 - Pre-investment
AACEI Estimate Classification	Class 3

Estimating Technique: Detailed Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$10.28 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
6.55%	12.48%	4.37%	11.97%	19.10%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
17.05%	12.10%	8.33%	5.44%	2.62%

Environmental Characteristics

Conawapa Generating Station

Impacted Land Area:

Estimated Flooded Area - 5.1 sq km (510 ha)

GS Footprint - 164 ha

Additional Impacted Area - 1381 ha

Flooded Area Intensity: Less than 1 ha/MW

Total Reservoir Area: 37.4 sq km

Additional Linear Development: 7 km

Distance from Load Center: 780 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 0.1 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be negligible impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon & caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Conawapa Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Fox Lake Cree Nation, Gillam

Resource Management Area: Fox Lake RMA, York Factory First Nation RMA, Split Lake RMA

Existing Agreements: Impact Settlent Agreement (ISA), Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	6650 Person-Years
Operating Phase	61 FTE
Combined Phases *(over full service life)*	10,700 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$12.8 million CAD (2012$)/year
Estimated Capital Taxes	$28.6 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$45.8 million CAD (2012$)/year
Estimated List Total	$87.2 million CAD (2012$)/year

Summary Characteristics

Conawapa Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

There has been a delay in meeting with the First Nations on the income package while internal review of the preferred aboriginal participation arrangement takes place. Progress has been slower than desired due to competing priorities (Wuskwatim financials, IHA Audit, PUB hearings, obligation to communicate current state Keeyask financials to the Cree Nation Partners (CNP) before discussing them with Fox Lake). It is now anticipated that the details of the preferred arrangement will be shared with the First Nations in January 2013.

With the lower priority assigned to Conawapa, the Project Team continues to encounter difficulties obtaining environmental, engineering and Development Arrangement support required to complete scheduled tasks. If the priority of Conawapa work is not elevated, the schedule will continue to slip.

There has been a delay in meeting with the First Nations on the income package while internal review of the preferred aboriginal participation arrangement takes place. Progress has been slower than desired due to competing priorities (Wuskwatim financials, IHA Audit, PUB hearings, obligation to communicate current state Keeyask financials to the Cree Nation Partners (CNP) before discussing them with Fox Lake). It is now anticipated that the details of the preferred arrangement will be shared with the First Nations in January 2013.

With the lower priority assigned to Conawapa, the Project Team continues to encounter difficulties obtaining environmental, engineering and Development Arrangement support required to complete scheduled tasks. If the priority of Conawapa work is not elevated, the schedule will continue to slip.

Direct employment estimates were revised upwards in July 2013 from 6650 to 7118 but have not been incorporated into these data sheets.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Conawapa Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

BC Hydro (2009). “Peace River Site C Hydro Project, Stage 2 Report: Consultation and Technical Review” Fall 2009.

BC Hydro (2012). “BC Hydro Draft 2012 Integrated Resource Plan: 2010 Resource Options Report Resource Options Database (RODAT) Summary Sheets” June 2012.

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Moonmaw, W. et al. (2011). Annex II: Methodology. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. 2011.

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PacificCorp (2007), ”2007 Integrated Resource Plan”, May 2007.

PacifiCorp (2008). 2008 Integrated Resource Plan. May 2008.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Gillam Island Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 2 - Feasibility

Location:

Located on the Nelson River between the Hudson Bay and the Conawapa G.S. site. It is at the upstream boundary of the Nelson River Estuary tidal zone and 104 km downstream of the existing Limestone G.S. and 132 km northeast of the town of Gillam.

River Reach: Lower Nelson River

Description:

The conventional concept presented here has 11 vertical-shaft, fixed-blade propeller units. The intake and powerhouse structure would be in the 400 m wide channel on the north side, downstream end, of Gillam Island. The spillway and main earth dam would cross the 1,000 m wide channel on the south side near the upstream end of Gillam Island. The seven bay concrete overflow spillway would be controlled by vertical lift gates. This general arrangement, selected in 1977, is referred to as Axis G-4.

Gillam Island is the furthest downstream site being considered for the hydroelectric development of the Nelson River. Gillam Island G.S. together with the potential Conawapa G.S. would complete the hydroelectric development of the Nelson River downstream of the existing Limestone G.S.

Technical Characteristics

Gillam Island Generating Station

Nameplate Rating: 1080 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	1080 MW	850	900
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	3200	4900	not available

Average Capacity Factor: 60%

Full Supply Level: 27.5 m

Gross Head: 23.2 m

Expected Average Flow: 3200 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Modified Run-of-River
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect with upstream Nelson River system flow management

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	9
Construction Phase: Final Design, Procurement & Construction *(years)*	10
Minimum Time to Earliest ISD *(years)*	19

Typical Asset Life: 67 years

Economic Characteristics

Gillam Island Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $108 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $6863 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $6350 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$10.28 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

<u>Fuel Supply Description</u>:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
5.91%	9.74%	1.95%	4.49%	5.01%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
14.01%	19.49%	17.61%	12.13%	9.66%

Environmental Characteristics

Impacted Land Area:

Estimated Flooded Area - 12 sq km

Flooded Area Intensity: 1 ha/MW

Total Reservoir Area: 70 sq km

Additional Linear Development: 78 km

Distance from Load Center: 830 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 0.4 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon, caribou, polar bears & beluga whales

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Gillam Island Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Fox Lake Cree Nation

Resource Management Area: York Factory First Nation RMA, Fox Lake Cree Nation RMA

Existing Agreements: Impact Settlent Agreement (ISA), Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	5300 Person-Years
Operating Phase	50 FTE
Combined Phases *(over full service life)*	8700 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$7.5 million CAD (2012$)/year
Estimated Capital Taxes	$34.3 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$54.9 million CAD (2012$)/year
Estimated List Total	$105.6 million CAD (2012$)/year

Summary Characteristics

Gillam Island Generating Station

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Gillam Island G.S. is in the Stage II – Feasibility level of study. The latest comprehensive planning report is from 1982. As such, the development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

The Gillam Island G.S. powerhouse discharge capability has been revised this year from 4,800 m3/s, which the 1982 studies were based on, to 5,300 m3/s, to make it consistent with the current concept for Conawapa. This is subject to change with further studies and with the final design of Conawapa.

Gillam Island is situated in an area that contains a number of different environmental issues that would potentially need to be addressed prior to development. A new national park (Wapusk) and two new wildlife management areas (Churchill Wildlife Management Area and Kaskatamagan Wildlife Management Area) have been established in the vicinity in the last 10 years.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Gillam Island Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

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Birthday Rapids Generating Station

Resource Type: Hydroelectric

Level of Study: Stage 2 - Feasibility

Location:

Located 10 km downstream of Birthday Rapids, 20 km downstream of Clark Lake, 25 km downstream of Split Lake and 25 km upstream of Gull Rapids and the potential Keeyask G.S. It is 50 km east of the town of Gillam with Provincial Road 280 from Split Lake to Gillam 10 km to the north of Birthday Rapids.

River Reach: Lower Nelson River

Description:

The Birthday G.S. concept consists of a low head powerhouse utilizing 9 horizontal axis bulb turbine units and a concrete overflow spillway with 7 bays controlled by vertical lift gates. Concrete transition structures together with earth dams and dykes complete the concept.

The Birthday G.S. together with the Keeyask G.S. would complete the development of the Lower Nelson River between Split Lake and Stephens Lake.

Technical Characteristics

Birthday Rapids Generating Station

Nameplate Rating: 380 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	380 MW	310	350
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1100	1800	not available

Average Capacity Factor: 60%

Full Supply Level: 168.5 m

Gross Head: 9.2 m

Expected Average Flow: 3050 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Little seasonality affect with Nelson River system flow mangement and reservoir storage.

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

<u>Planning Phase:</u> Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8
<u>Construction Phase:</u> Final Design, Procurement & Construction *(years)*	6
Minimum Time to Earliest ISD *(years)*	14

Typical Asset Life: 67 years

Economic Characteristics

Birthday Rapids Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $156 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $3684 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $9700 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$35.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
1.96%	5.62%	2.95%	4.02%	7.33%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
10.58%	26.45%	19.82%	13.18%	8.08%

Environmental Characteristics

Birthday Rapids Generating Station

Impacted Land Area:

Estimated Flooded Area - 70 sq km

Flooded Area Intensity: 18 ha/MW

Total Reservoir Area: not available

Additional Linear Development: 10 km

Distance from Load Center: 710 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 7.1 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Birthday Rapids Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Fox Lake Cree Nation, Gillam, Ilford, Tataskweyak Cree Nation, York Factory First Nation, War Lake First Nation

Resource Management Area: Fox Lake RMA, York Factory First Nation RMA, Split Lake RMA

Existing Agreements: Northern Flood Agreement (NFA),Impact Settlent Agreement (ISA), Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3700 Person-Years
Operating Phase	40 FTE
Combined Phases *(over full service life)*	6400 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$3.0 million CAD (2012$)/year
Estimated Capital Taxes	$18.4 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$29.5 million CAD (2012$)/year
Estimated List Total	$53.6 million CAD (2012$)/year

Summary Characteristics

Birthday Rapids Generating Station

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Birthday Rapids G.S. planning is in a Stage II – Feasibility level of studies. The latest comprehensive report is from 1991 and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Concepts for the Birthday Rapids G.S. need to be re-evaluated to incorporate the current design of the Keeyask G.S., as well as the body of technical knowledge gained from the Keeyask G.S. planning studies.

The tail water level has been revised from that reported in the 1991 studies, based on an assumed Keeyask G.S. FSL of 157.0 m, to reflect the current Keeyask G.S. design FSL of 159.0 m.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Birthday Rapids Generating Station

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Red Rock Generating Station (Low Head)

Resource Type**:** Hydroelectric Level of Study: Stage 2 - Feasibility

Location:

Located 1 km downstream of the Red Rock Rapids on the upper Nelson River between Cross Lake and Sipiwesk Lake. It is about 20 km northwest of the outlet of Cross Lake and approximately 30 km northwest of the community of Cross Lake, 39 km west of Wabowden and 35 km north of the Jenpeg G.S.

River Reach: Upper Nelson River

Description:

The option presented here is that of a two site development of the remaining hydroelectric potential of the Upper Nelson River along with Whitemud G. S.

The potential Red Rock G.S. axis for the powerhouse and spillway is approximately 1 km downstream of Red Rock Rapids in the Red Rock channel of the Upper Nelson River. The powerhouse is a low head design similar to that at Jenpeg utilizing an integral concrete intake section. Red Rock G.S. would have six horizontal shaft bulb units. The powerhouse and spillway are separated by a concrete non-overflow dam. The spillway is of low ogee crest design regulated by eight vertical lift gates. The discharge capacity of the spillway at full supply level is 7,700 m3/s. A 5.6 km long dyke is incorporated into the concept to minimize flooding. A closure dam would be located approximately 9.5 km southwest of the powerhouse in the Manitou channel which carries a portion of the flow of the Nelson River around Bear Island into Sipiwesk Lake.

Technical Characteristics

Red Rock Generating Station (Low Head)

Nameplate Rating: 250 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	250 MW	not available	not available
NET SYSTEM ENERGY *(GW.h/year)*	Under Dependable Flow Conditions	Under Average Flow Conditions	Under Maximum Flow Conditions
	730	1280	not available

Average Capacity Factor: 65%

Full Supply Level: 195.1 m

Gross Head: 9.3 m

Expected Average Flow: 2000 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Not determined

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	5
Minimum Time to Earliest ISD *(years)*	13.5

Typical Asset Life: 67 years

Economic Characteristics

Red Rock Generating Station (Low Head)

Levelized Cost (*P_{50} Estimate*):

With Transmission - $163 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $2922 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $11,700 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$35.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.54%	7.04%	3.83%	10.39%	15.09%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
22.22%	20.28%	12.98%	5.38%	0.26%

Environmental Characteristics

Red Rock Generating Station (Low Head)

Impacted Land Area:

Estimated Flooded Area - 35 sq km

Flooded Area Intensity: 14 ha/MW

Total Reservoir Area: not available

Additional Linear Development: 26 km

Distance from Load Center: 540 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 5.8 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon, caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Red Rock Generating Station (Low Head)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Cross Lake First Nation, Cross Lake Community, Norway House Cree Nation, Norway House Community, Paint & Liz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: Cross Lake Registered Trapline Zone

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3300 Person-Years
Operating Phase	30 FTE
Combined Phases *(over full service life)*	5300 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$2.4 million CAD (2012$)/year
Estimated Capital Taxes	$12.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$23.4 million CAD (2012$)/year
Estimated List Total	$39.7 million CAD (2012$)/year

Summary Characteristics

Red Rock Generating Station (Low Head)

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Red Rock G.S. is in the Interim Stage II – Feasibility level of study. The latest comprehensive planning report is from 1983. As such, the development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Further study is required of the three development options available to optimize the development of this reach. The cost estimate reflected in this summary reflects the total cost of developing this generating station as a stand-alone project.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Red Rock Generating Station (Low Head)

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

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Bladder Rapids Generating Station

Resource Type**:** Hydroelectric Level of Study: Stage 2 - Feasibility

Location:

Located approximately 12 km northwest of the outlet of Cross Lake and 27 km north of Manitoba Hydro's Jenpeg G.S. on the Nelson River.

River Reach: Upper Nelson River

Description:

The option presented here is that of a single site development of the remaining hydroelectric potential of the upper Nelson River and is an alternative to developments at Whitemud and Red Rock.

The Bladder Rapids G.S. axis for the powerhouse is located approximately 0.8 km downstream of Bladder Rapids at the mouth of the Leaf River on the west bank of the Nelson River. Approximately 2 km of the Leaf River would be diverted to the west to a new channel to accommodate the construction of the powerhouse. The main dam is located in the channel of the Nelson River between Herb's Bay and Weed Bay about 6.4 km upstream of Bladder Rapids. The Spillway channel is cut through the west bank of the river beside the main dam.

The concept consists of a 7-unit powerhouse of conventional design utilizing vertical axis propeller turbines. The spillway is an ogee crest design located beside the main dam in a 600 m long channel cut though the west bank. The main dam would be a rockfill structure. In addition, 20 km of dyking would be required in low lying areas to contain the forebay.

Technical Characteristics

Bladder Rapids Generating Station

Nameplate Rating: 510 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	510 MW	not available	not available
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1750	3000	not available

Average Capacity Factor: 65%

Full Supply Level: 207.3 m

Gross Head: 18.4 m

Expected Average Flow: 2000 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Not determined

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	10
Construction Phase: Final Design, Procurement & Construction *(years)*	5
Minimum Time to Earliest ISD *(years)*	15

Typical Asset Life: 67 years

Economic Characteristics

Bladder Rapids Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $102 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $4164 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $8200 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$17.86 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.79%	5.52%	1.74%	3.59%	9.86%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
18.08%	21.63%	18.21%	12.78%	5.79%

Environmental Characteristics

Bladder Rapids Generating Station

Impacted Land Area:

Estimated Flooded Area - 60 sq km

Flooded Area Intensity: 12 ha/MW

Total Reservoir Area: not available

Additional Linear Development: 19 km

Distance from Load Center: 540 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 4.3 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon, caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Bladder Rapids Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Cross Lake First Nation, Cross Lake Community, Norway House Cree Nation, Norway House Community, Paint & Liz Lake Provincial Parks, Thicket Portage, Wabowden

Resource Management Area: Cross Lake Registered Trapline Zone

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3600 Person-Years
Operating Phase	35 FTE
Combined Phases *(over full service life)*	5900 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$5.2 million CAD (2012$)/year
Estimated Capital Taxes	$20.8 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$33.3 million CAD (2012$)/year
Estimated List Total	$64.1 million CAD (2012$)/year

Summary Characteristics

Bladder Rapids Generating Station

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Bladder Rapids G.S. is in Stage II – Feasibility level of study. The latest comprehensive report is from 1978. As such, the development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Further study is required of the three development options available to optimize the development of this reach. The cost estimate reflected in this summary reflects the total cost of developing this generating station as a stand-alone project.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Bladder Rapids Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

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PacifiCorp (2008). 2008 Integrated Resource Plan. May 2008.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Whitemud Generating Station

Resource Type**:** Hydroelectric Level of Study: Stage 2 - Feasibility

Location:

Located on the upper Nelson River at Whitemud Falls just downstream of the outlet of Cross Lake.

River Reach: Upper Nelson River

Description:

The option presented here is that of a two site development of the remaining hydroelectric potential of the Upper Nelson River along with Red Rock G. S.

The Whitemud concept consists of a low head powerhouse utilizing 6 horizontal axis bulb turbines. A concrete overflow spillway with 6 bays is controlled by vertical lift gates. The discharge capacity of the spillway at full supply level is 7,050 m3/s. Earth dams and dykes as required to contain the forebay complete the concept.

Technical Characteristics

Whitemud Generating Station

Nameplate Rating: 310 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	310 MW	not available	not available
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	900	1620	not available

Average Capacity Factor: 65%

Full Supply Level: 207.5 m

Gross Head: 11.4 m

Expected Average Flow: 2000 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Not determined

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	6
Minimum Time to Earliest ISD *(years)*	14.5

Typical Asset Life: 67 years

Economic Characteristics

Whitemud Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $141 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $3019 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $9700 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$35.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.91%	6.94%	3.52%	8.77%	6.47%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
15.30%	22.66%	18.99%	10.10%	4.34%

Environmental Characteristics

Whitemud Generating Station

Impacted Land Area:

Estimated Flooded Area - 11 sq km

Flooded Area Intensity: 4 ha/MW

Total Reservoir Area: 615 sq km

Additional Linear Development: 27 km

Distance from Load Center: 530 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 1.5 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon, caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Whitemud Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Cross Lake First Nation, Cross Lake Community, Norway House Cree Nation, Norway House Community, Paint & Liz Lake Provincial Parks, Thicket Portage, Wabowden

Resource Management Area: Cross Lake Registered Trapline Zone

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3100 Person-Years
Operating Phase	30 FTE
Combined Phases *(over full service life)*	5100 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$2.9 million CAD (2012$)/year
Estimated Capital Taxes	$15.1 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$24.2 million CAD (2012$)/year
Estimated List Total	$44.7 million CAD (2012$)/year

Summary Characteristics

Whitemud Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)*:

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

Whitemud G. S. is in a Stage II – Feasibility level of study. The latest comprehensive report is from 1985. As such, the development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Further study is required of the three development options available to optimize the development of this reach. The cost estimate reflected in this summary reflects the total cost of developing this generating station as a stand-alone project.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Whitemud Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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NorthWestern Energy Corporation (2010). "2009 Electric Default Supply Resource Planning and Procurement Plan". June 2010.

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PacifiCorp (2008). 2008 Integrated Resource Plan. May 2008.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

First Rapids Generating Station

Resource Type**:** Hydroelectric	Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River, 35 km upstream of Split Lake. Thompson is 70 km southwest of First Rapids (85 km by road).

River Reach: Burntwood River

Description:

The powerhouse would utilize four vertical-shaft propeller units and umbrella type generators. The spillway would have three bays with vertical lift-gates. Dams and 1.5 km of dykes, all embankment structures, contain the forebay. A plant discharge of 1,250 m3/s, with four units, is representative of a peaking mode of operation.

Technical Characteristics

First Rapids Generating Station

Nameplate Rating: 210 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	210 MW	195	210
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1000	1300	not available

Average Capacity Factor: 75%

Full Supply Level: 188.5 m

Gross Head: 19.0 m

Expected Average Flow: 950 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect managed with reservoir storage

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	5.5
Minimum Time to Earliest ISD *(years)*	14

Typical Asset Life: 67 years

Economic Characteristics

First Rapids Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $122 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $2053 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $9800 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$41.68 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.67%	8.69%	3.17%	5.66%	12.29%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
15.12%	21.50%	15.19%	12.32%	3.40%

Environmental Characteristics

First Rapids Generating Station

Impacted Land Area:

Estimated Flooded Area - 55 sq km

Flooded Area Intensity: 26 ha/MW

Total Reservoir Area: 120 sq km

Additional Linear Development: 9 km

Distance from Load Center: 680 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 9.0 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

First Rapids Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Paint & Liz Lake Provincial Parks, Pikwitonei, Tataskweyak Cree Nation, Thicket Portage, Thompson, York Factory First Nation

Resource Management Area: Split Lake RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	2200 Person-Years
Operating Phase	30 FTE
Combined Phases *(over full service life)*	4200 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Similar
Northern Manitoba Employment	Similar
Aboriginal Employment	Similar

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Similar
Northern Manitoba Purchases	Similar
Aboriginal Business Purchases	Similar

Provincial Development Revenues:

Water Rentals Under Average Flows	$2.3 million CAD (2012$)/year
Estimated Capital Taxes	$10.3 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$16.4 million CAD (2012$)/year
Estimated List Total	$31.0 million CAD (2012$)/year

Summary Characteristics

First Rapids Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

First Rapids planning is in a Stage II – Feasibility level of study. The latest comprehensive study was carried out in 1978. Since 1978, studies in areas such as river hydraulics and environmental assessment were carried out for the Burntwood River, and for the Wuskwatim G.S. that will be of value to future studies of First Rapids. The development concept presented here is representative of the alternatives studied in 1978 and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

First Rapids Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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Manasan Generating Station (Low Head)

Resource Type**:** Hydroelectric   Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River upstream of the confluence with the Manasan River at the location of Manasan Falls and the Manasan Falls ice control structure. Birchtree Lake is upstream and Apussigamisi Lake is downstream. The site is 6 km southwest of Thompson (15 km by road).

River Reach: Burntwood River

Description:

The Manasan option represented here is that of a two site development with a FSL of 197.5 m and is commonly referred to as the Low Head option. This option includes a development at Kepuche to fully develop the reach between Manasan Falls and Wuskwatim.

The general arrangement for this option has the powerhouse and spillway located on the south bank next to Manasan Falls. The approach channel of both the powerhouse and the spillway takes advantage of the existing bypass channel of the Manasan ice control structure. The concrete structures are arranged with the spillway located closest to the river and joined to the powerhouse with a non-overflow dam. Concrete transitions connect the south end of the powerhouse complex to a low dike on the south side of the river, and the north end of the spillway to the main dam.

The powerhouse would have three horizontal shaft turbine and generator units. It would have the service bay on the south side, and it would be founded on sound bedrock. Bulb units were chosen because of the low head available. The spillway would consist of a three bay concrete sluiceway founded on bedrock, with individual vertical lift gates for each bay. Partly because the City of Thompson is downstream, the spillway has been designed to handle an inflow design flood equal to the probable maximum flood. The main dam would make use of the existing rock fill groins. Large rock would be placed between the existing groins to effect closure. The rock fill embankment would be completed to the same height as the existing groins, an approximate elevation of 199.6 m.

Technical Characteristics

Manasan Generating Station (Low Head)

Nameplate Rating: 70 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	70 MW	60	70
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	400	500	not available

Average Capacity Factor: 90%

Full Supply Level: 197.5 m

Gross Head: 7.9 m

Expected Average Flow: 950 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Little seasonality affect managed by upstream flow management

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8
Construction Phase: Final Design, Procurement & Construction *(years)*	4.5
Minimum Time to Earliest ISD *(years)*	12.5

Typical Asset Life: 67 years

Economic Characteristics

Manasan Generating Station (Low Head)

Levelized Cost (*P_{50} Estimate*):

With Transmission - $194 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $1279 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $18,300 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$75.23 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
1.27%	7.40%	2.60%	4.66%	10.56%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
12.39%	23.94%	22.66%	12.77%	1.75%

Environmental Characteristics

Manasan Generating Station (Low Head)

Impacted Land Area:

Estimated Flooded Area - 15 sq km

Flooded Area Intensity: 21 ha/MW

Total Reservoir Area: 46 sq km

Additional Linear Development: 15 km

Distance from Load Center: 640 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 6.4 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Manasan Generating Station (Low Head)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: near Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	1900 Person-Years
Operating Phase	20 FTE
Combined Phases *(over full service life)*	3200 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$0.9 million CAD (2012$)/year
Estimated Capital Taxes	$6.4 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$10.2 million CAD (2012$)/year
Estimated List Total	$18.3 million CAD (2012$)/year

Summary Characteristics

Manasan Generating Station (Low Head)

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Manasan planning is in Stage II – Feasibility. The latest comprehensive study was carried out in 1996. Since 1996, studies in areas such as river hydraulics and environmental assessment were carried out for Wuskwatim that will be of value to future studies of Manasan. The development concept reported here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Manasan Generating Station (Low Head)

Avista Corporation (2009). "Electric Integrated Resource Plan". August 2009.

BC Hydro (2006). "BC Hydro 2005 Integrated Resource Plan: Project and Program Database." 2006 Revision.

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PacifiCorp (2008). 2008 Integrated Resource Plan. May 2008.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Manasan Generating Station (High Head)

Resource Type: Hydroelectric Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River upstream of the confluence with the Manasan River at the location of Manasan Falls and the Manasan Falls ice control structure. Birchtree Lake is upstream and Apussigamisi Lake is downstream. The site is 6 km southwest of Thompson (15 km by road).

River Reach: Burntwood River

Description:

The Manasan option represented here is that of a single site development with a FSL of 211.8 m and is commonly referred to as the High Head option.

The main dam and the principal concrete structures are aligned along a gently sloped bedrock ridge, which crosses the Burntwood River at the point of Manasan Falls. The main dam closes off the existing Burntwood River channel at the location of Manasan Falls. The spillway is located on the north bank of Manasan Falls, close to the Burntwood River, where it could conveniently serve for diversion during closure of the river. The spillway consists of three bays with vertical lift gates, and has a discharge capacity of 2,480 m3/s. The powerhouse is located 250 m further into the north bank of the Burntwood River, enabling the tailrace to discharge downstream of a constriction in the Burntwood River channel. North and south dykes as well as remote saddle dykes are required to contain the forebay.

Technical Characteristics

Manasan Generating Station (High Head)

Nameplate Rating: 270 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	270 MW	250	270
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1200	1600	not available

Average Capacity Factor: 65%

Full Supply Level: 211.8 m

Gross Head: 21.8 m

Expected Average Flow: 950 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect managed with reservoir storage

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8
Construction Phase: Final Design, Procurement & Construction *(years)*	5.5
Minimum Time to Earliest ISD *(years)*	13.5

Typical Asset Life: 67 years

Economic Characteristics

Manasan Generating Station (High Head)

Levelized Cost (*P_{50} Estimate*):

With Transmission - $128 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $2770 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $10,200 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$29.17 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.18%	6.46%	3.70%	7.47%	10.78%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
24.30%	18.63%	15.55%	9.72%	1.21%

Environmental Characteristics

Manasan Generating Station (High Head)

Impacted Land Area:

Estimated Flooded Area - 150 sq km

Flooded Area Intensity: 56 ha/MW

Total Reservoir Area: 190 sq km

Additional Linear Development: 15 km

Distance from Load Center: 640 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 20.0 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Manasan Generating Station (High Head)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: near Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3000 Person-Years
Operating Phase	25 FTE
Combined Phases *(over full service life)*	4700 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$3.0 million CAD (2012$)/year
Estimated Capital Taxes	$13.8 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$22.2 million CAD (2012$)/year
Estimated List Total	$41.4 million CAD (2012$)/year

Summary Characteristics

Manasan Generating Station (High Head)

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

Manasan planning is in Stage II – Feasibility. The latest comprehensive study was carried out in 1996 with prior studies in 1985 and 1986. Since 1996, studies in areas such as river hydraulics and environmental assessment were carried out for Wuskwatim that will be of value to future studies of Manasan. The development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Manasan Generating Station (High Head)

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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BC Hydro (2009). “Peace River Site C Hydro Project, Stage 2 Report: Consultation and Technical Review” Fall 2009.

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Birchtree Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River just upstream of Birchtree Lake and approximately 14 km from Thompson.

River Reach: Burntwood River

Description:

The arrangement represented here has the powerhouse and spillway located on the north bank, with the spillway closest to the river channel. The powerhouse would have four vertical shaft fixed blade propeller units with a plant discharge capacity of 1,400 m3/s. The intake would be close coupled to the powerhouse. The spillway would consist of a three bay ogee profile concrete structure founded on bedrock. Each bay would have vertical lift gates. The spillway in this design was sized for passing an inflow design flood equal to the probable maximum flood.

The main dam consists of sections that connect the powerhouse to the north bank, the powerhouse to the spillway, and the spillway to the south bank. The main dam is an earth embankment structure, founded on bedrock, with heights up to 43 m, due to a trough in the bedrock at the center of the channel. Extensive saddle dams and dykes, up to 20 m in height above ground level, are required to contain the forebay for this arrangement.

Technical Characteristics

Birchtree Generating Station

Nameplate Rating: 290 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	290 MW	255	280
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1230	1600	not available

Average Capacity Factor: 70%

Full Supply Level: 215.0 m

Gross Head: 23.3 m

Expected Average Flow: 950 m3/s

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect managed with reservoir storage

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	5.5
Minimum Time to Earliest ISD *(years)*	14

Typical Asset Life: 67 years

Economic Characteristics

Birchtree Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $148 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $3108 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $10,700 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$35.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
1.94%	5.11%	2.64%	6.44%	12.78%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
25.42%	19.31%	15.59%	9.99%	0.78%

Environmental Characteristics

Birchtree Generating Station

Impacted Land Area:

Estimated Flooded Area - 70 sq km

Flooded Area Intensity: 24 ha/MW

Total Reservoir Area: 100 sq km

Additional Linear Development: 10 km

Distance from Load Center: 640 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 9.3 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Birchtree Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	3900 Person-Years
Operating Phase	25 FTE
Combined Phases *(over full service life)*	5600 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	More
Aboriginal Employment	More

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	More
Aboriginal Business Purchases	More

Provincial Development Revenues:

Water Rentals Under Average Flows	$2.9 million CAD (2012$)/year
Estimated Capital Taxes	$15.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$24.9 million CAD (2012$)/year
Estimated List Total	$45.8 million CAD (2012$)/year

Summary Characteristics

Birchtree Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Birchtree planning is in a Stage II – Feasibility level of studies. The latest comprehensive study was carried out in 1996. Since 1996, studies in areas such as river hydraulics and environmental assessment were carried out for Wuskwatim that will be of value to future studies of Birchtree. The development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Birchtree Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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Kepuche Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River at Kepuche Falls, 50 km from Thompson.

River Reach: Burntwood River

Description:

The option presented here is of a two site development along with a low head Manasan to fully develop the reach between Manasan Falls and Wuskwatim.

The powerhouse, spillway and transitions are located on the south bank, where bedrock is either exposed or has been located by drilling. The proposed arrangement of the structures consists of a spillway located closest to the river, with the powerhouse adjoining it. The powerhouse is a close coupled intake/powerhouse arrangement with the service bay on the side furthest from the river. A road along the top of the structures would provide permanent access, and would connect to the road on the north side of the Burntwood River which was built for Wuskwatim.

The powerhouse would have four vertical shaft fixed blade propeller units with a plant discharge capacity of 1,400 m3/s. The spillway would consist of a three bay ogee profile concrete structure founded on bedrock, with individual vertical lift gates for each bay. The main dam extends across the river from the spillway on the south bank to a point on the north bank at which the ground profile becomes almost level at elevation 215 m. Low embankments complete the dam on each side of the river. With the exception of two small freeboard dykes, saddle dyking is not required.

Technical Characteristics

Kepuche Generating Station

Nameplate Rating: 210 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	210 MW	190	190
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	900	1100	not available

Average Capacity Factor: 65%

Full Supply Level: 215.5 m

Gross Head: 17.2 m

Expected Average Flow: 1400 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace to no seasonality affect managed with reservoir storage

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8
Construction Phase: Final Design, Procurement & Construction *(years)*	5.5
Minimum Time to Earliest ISD *(years)*	13.5

Typical Asset Life: 67 years

Economic Characteristics

Kepuche Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $122 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $1789 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $8500 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$35.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
1.79%	6.29%	3.98%	9.53%	13.11%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
19.70%	18.77%	15.86%	10.85%	0.13%

Environmental Characteristics

Kepuche Generating Station

Impacted Land Area:

Estimated Flooded Area - 14 sq km

Flooded Area Intensity: 7 ha/MW

Total Reservoir Area: 23 sq km

Additional Linear Development: 10.5 km

Distance from Load Center: 630 km

<u>Operating Phase Emissions:</u>

- **Greenhouse Gas Emissions:** 2.7 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

<u>Typical Life Cycle Emissions for Resource Technology:</u>

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Kepuche Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	2400 Person-Years
Operating Phase	25 FTE
Combined Phases *(over full service life)*	4100 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Similar
Northern Manitoba Employment	Similar
Aboriginal Employment	Similar

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Similar
Northern Manitoba Purchases	Similar
Aboriginal Business Purchases	Similar

Provincial Development Revenues:

Water Rentals Under Average Flows	$2.1 million CAD (2012$)/year
Estimated Capital Taxes	$8.9 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$14.3 million CAD (2012$)/year
Estimated List Total	$26.9 million CAD (2012$)/year

Summary Characteristics

Kepuche Generating Station

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Kepuche planning is in a Stage II – Feasibility level of study. The latest comprehensive study was carried out in 1996 with prior studies in 1976 and 1977. Since 1996, studies in areas such as river hydraulics and environmental assessment were carried out for Wuskwatim that will be of value to future studies of Kepuche. The development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Kepuche Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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Early Morning Generating Station

Resource Type**:** Hydroelectric Level of Study: Stage 2 - Feasibility

Location:

Located on the Burntwood River, upstream of Wuskwatim G.S. and downstream of the Notigi control structure. The site is 2 km upstream of Wuskwatim Lake and is 4 km downstream of Early Morning Rapids.

River Reach: Burntwood River

Description:

The concept reported here consists of a three unit powerhouse utilizing horizontal axis bulb turbines. Adjacent to the powerhouse is a three bay spillway with vertical lift gates, a two part dam (right and left) and no dykes. The proposed Early Morning G.S. plant discharge of 1,050 m3/s reported here is representative of a run of river mode of operation, similar to Wuskwatim.

Technical Characteristics

Early Morning Generating Station

Nameplate Rating: 80 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	80 MW	60	80
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	400	500	not available

Average Capacity Factor: 90%

Full Supply Level: 243.2 m

Gross Head: 8.5 m

Expected Average Flow: 900 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Some seasonality affect managed by upstream flow management

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	5.5
Minimum Time to Earliest ISD *(years)*	14

Typical Asset Life: 67 years

Economic Characteristics

Early Morning Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $215 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $1409 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $17600 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$75.23 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.97%	8.26%	2.93%	7.27%	5.48%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
14.34%	26.29%	19.20%	11.72%	1.55%

Environmental Characteristics

Early Morning Generating Station

Impacted Land Area:

Estimated Flooded Area - 12 sq km

Flooded Area Intensity: 15 ha/MW

Total Reservoir Area: 215 sq km

Additional Linear Development: 25 km

Distance from Load Center: 630 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 4.8 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Early Morning Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Pikwitonei, Thicket Portage, Thompson, Wabowden

Resource Management Area: Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	2000 Person-Years
Operating Phase	20 FTE
Combined Phases *(over full service life)*	3300 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$0.9 million CAD (2012$)/year
Estimated Capital Taxes	$7.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$11.3 million CAD (2012$)/year
Estimated List Total	$20.0 million CAD (2012$)/year

Summary Characteristics

Early Morning Generating Station

<u>Non-Site Specific</u> Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)*:

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Investigations into the Early Morning G.S. started in 1977 when two alternative axes were examined: the first at Early Morning Rapids and the second 4 km downstream. The site downstream of Early Morning Rapids was the preferred site as it provided shorter approach and tailrace channel modifications and better topographic conditions. The development concept presented here is intended to be representative and is not necessarily the optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: Combine with pumped storage

References

Early Morning Generating Station

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Notigi Generating Station

Resource Type: Hydroelectric

Level of Study: Stage 4 - Pre-investment

Location:

Located at the site of the existing Notigi control structure, 105 km west of the City of Thompson. Nisichawayasik Cree Nation (NCN) at Nelson House is downstream of Notigi and is 45 km from Notigi by road.

River Reach: Burntwood River

Description:

The Notigi Generating Station would utilize the existing main dam, saddle dams and control structure, with Notigi Lake functioning as the immediate forebay. The discharge currently passing through the Notigi Control Structure would be used to generate electricity from two horizontal bulb turbines that would be installed in the proposed powerhouse, located directly north of the main dam. The PR 391 roadway would be realigned at the site and routed across the powerhouse intake deck.

Technical Characteristics

Notigi Generating Station

Nameplate Rating: 120 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	120 MW	100	120
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	650	830	not available

Average Capacity Factor: 85%

Full Supply Level: 258.5 m

Gross Head: 12.9 m

Expected Average Flow: 900 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Little seasonality affect managed by upstream flow management

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	5
Construction Phase: Final Design, Procurement & Construction *(years)*	5
Minimum Time to Earliest ISD *(years)*	10

Typical Asset Life: 67 years

Economic Characteristics

Notigi Generating Station

Levelized Cost (P_{50} *Estimate*):

With Transmission - $85 CAD (2012$)/MW.h @ 5.05%

Base Estimate (P_{50} *Estimate*):

With Transmission - $935 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -15% to +20%

Overnight Capital Cost ($/kW): $7800 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 4 - Pre-investment
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$33.88 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.00%	3.43%	2.32%	2.88%	5.15%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
21.04%	25.28%	25.01%	14.89%	0.00%

Environmental Characteristics

Notigi Generating Station

Impacted Land Area:

Estimated Flooded Area - 0 sq km

Flooded Area Intensity: 0 ha/MW

Total Reservoir Area: 0 sq km

Additional Linear Development: 0 km

Distance from Load Center: 670 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 0.0 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: caribou

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Notigi Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Granville Lake, Nelson House Community, Nisichawayasihk Cree Nation, Paint & LIz Lake Provincial Parks, Thompson

Resource Management Area: Nelson House RMA

Existing Agreements: Burntwood/Nelson River Agreement

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	1800 Person-Years
Operating Phase	15 FTE
Combined Phases *(over full service life)*	2800 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$01.6 million CAD (2012$)/year
Estimated Capital Taxes	$4.7 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$7.5 million CAD (2012$)/year
Estimated List Total	$14.9 million CAD (2012$)/year

Summary Characteristics

Notigi Generating Station

Non-Site Specific Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Planning studies for the Notigi Control Structure in 1973 selected the site and general arrangement to accommodate a future powerhouse in the north abutment. The Notigi Control Structure was commissioned in 1977 as a component of the Churchill River Diversion. In 1978 a development study was undertaken to investigate an option with a powerhouse located in the river channel with four vertical-axis units. Studies in 1992 included a similar concept but with two or three horizontal-bulb turbines. Studies in 1995 and 1996 recommended that the optimum alternative was the development of a powerhouse located in the north abutment. Stage IV Engineering studies were initiated in 1999 but were subsequently suspended in 2002 to concentrate efforts on the Wuskwatim, Keeyask, and Pointe du Bois projects.

An in-service date for the Notigi G.S. has not been identified. The minimum time to first power (the first unit in service) is ten years. Five years is the estimated minimum time required to complete planning studies, site investigations, community consultations and all regulatory processes for licensing. Five years is the time reflected in the existing construction schedule from the start of construction to the first unit in service.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Notigi Generating Station

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Granville Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 2 - Feasibility

Location:

Located at Granville Falls on the upper Churchill River, 10 km upstream (south) of Granville Lake and 25 km downstream (north) of Twin Falls and Highrock Lake. The closest road access is Provincial Road 391 from Thompson to Leaf Rapids which is 20 km to the east of the site.

River Reach: Churchill River

Description:

The concept reported here consists of a conventional powerhouse constructed in the main channel and a spillway constructed in a channel excavated in the east bank. The reservoir would be impounded by a dam between the powerhouse and spillway and by dyking as necessary. The powerhouse would have four vertical shaft units. The five bay ogee spillway would be controlled by vertical lift gates. The main dam would be a zoned earthfill embankment. Two to five km of dykes and saddle dams would be necessary.

Technical Characteristics

Granville Generating Station

Nameplate Rating: 120 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	120 MW	not available	not available
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	300	700	not available

Average Capacity Factor: 65%

Full Supply Level: 207.7 m

Gross Head: 11.0 m

Expected Average Flow: 800 m3/s

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Not determined

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	8.5
Construction Phase: Final Design, Procurement & Construction *(years)*	5
Minimum Time to Earliest ISD *(years)*	13.5

Typical Asset Life: 67 years

Economic Characteristics

Granville Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $188 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $1753 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $14,600 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$33.88 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
2.22%	7.65%	3.18%	7.98%	14.78%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
7.21%	16.49%	23.51%	16.03%	0.94%

Environmental Characteristics

Granville Generating Station

Impacted Land Area:

Estimated Flooded Area - 11 sq km

Flooded Area Intensity: 9 ha/MW

Total Reservoir Area: not available

Additional Linear Development: 20 km

Distance from Load Center: 710 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 3.4 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO_2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Granville Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Granville Lake, Leaf Rapids, Lynn Lake, Nelson House Community, Nisichawayasihk Cree Nation, Pukatawagan

Resource Management Area: Pukatawagan Registered Trapline Zone

Existing Agreements: None

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	2200 Person-Years
Operating Phase	25 FTE
Combined Phases *(over full service life)*	3900 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$1.3 million CAD (2012$)/year
Estimated Capital Taxes	$8.8 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$14.0 million CAD (2012$)/year
Estimated List Total	$25.1 million CAD (2012$)/year

Summary Characteristics

Granville Generating Station

Non-Site Specific Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Granville Falls G.S. is in the Stage II – Feasibility level of study. The latest comprehensive study was carried out in 1977. This study concluded that Granville Falls could be developed to a maximum FSL of 280.4 m but a FSL of 276.1 m would result in minimal environmental impact.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Granville Generating Station

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Bonald Generating Station

Resource Type: Hydroelectric | Level of Study: Stage 1 - Inventory

Location:

Located on the Upper Churchill River 10 km northwest of the community of Pukatawagan. The Bonald Rapids are on a narrow portion of the Churchill River that has Pukatawagan Lake on the downstream side and Sisipuk Lake on the upstream side.

River Reach: Churchill River

Description:

The concept reported here consists of a conventional powerhouse and a spillway constructed in a low spot in the north bank (access is assumed to be from the north). The reservoir would be impounded by a dam across the main channel and by dyking as necessary. The powerhouse would have four vertical shaft units. The five bay ogee spillway would be controlled by vertical liftgates. The main dam would be a zoned earthfill embankment. Less than 1 km of dykes and saddle dams would be necessary. Multiple potential axes exist in the narrow channel in the vicinity of Bonald Rapids. The axis for the concept represented in this report is at the rapids.

Technical Characteristics

Bonald Generating Station

Nameplate Rating: 110 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	110 MW	not available	not available
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	300	600	not available

Average Capacity Factor: 65%

Full Supply Level: 284.4 m

Gross Head: 10.7 m

Expected Average Flow: 750 m3/s

Power Generation Flexibility:

- **Fuel Type:** Renewable - Water
- **Mode of Operation:** Baseload & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Not determined

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Labour intensive, lengthy, construction phase

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	9
Construction Phase: Final Design, Procurement & Construction *(years)*	7
Minimum Time to Earliest ISD *(years)*	16

Typical Asset Life: 67 years

Economic Characteristics

Bonald Generating Station

Levelized Cost (*P_{50} Estimate*):

With Transmission - $277 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

With Transmission - $2188 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $19,900 CAD (2012$)/kW

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Factored Estimate

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$33.88 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Excellent: renewable, abundant and reliable
- **Supply Risk:** Periodic Risk of Drought
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Low
- **Transportation Pricing Trends:** None
- **Fuel Price:** $3.3426 CAD (2012$)/MW.h

REC Premium Marketability: Low

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
4.99%	10.96%	7.35%	6.90%	10.23%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
13.20%	21.50%	17.42%	7.35%	0.10%

Environmental Characteristics

Bonald Generating Station

Impacted Land Area:

Estimated Flooded Area - 80 sq km

Flooded Area Intensity: 73 ha/MW

Total Reservoir Area: not available

Additional Linear Development: 35 km

Distance from Load Center: 700 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** 28.5 kg/MW.h
- **Hazardous Air Pollutant Emissions:** None

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 3 to 7 kg CO2e/MWh

Water Pollutants: There will be varying impacts on suspended sediment, dissolved oxygen, nutrients and metals, including mercury.

Higher Priority Wildlife Species of Interest: sturgeon

Long Term Legacy Issues: Perpetual maintenance commitment of dam structure for environmental and safety reasons

Socio-Economic Characteristics

Bonald Generating Station

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Granville Lake, Pukatawagan

Resource Management Area: Pukatawagan Registered Trapline Zone

Existing Agreements: Not determined

Aboriginal Participation Interest: Positive

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(3000 hrs per PY basis)*	2200 Person-Years
Operating Phase	25 FTE
Combined Phases *(over full service life)*	3900 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenues:

Water Rentals Under Average Flows	$1.1 million CAD (2012$)/year
Estimated Capital Taxes	$10.9 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$17.5 million CAD (2012$)/year
Estimated List Total	$30.4 million CAD (2012$)/year

Summary Characteristics

Bonald Generating Station

Non-Site Specific Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Medium

Energy Security Concerns: Very Low

Environmental Concerns: NA – Site Specific

Outlook for Manitoba Hydro:

Bonald G.S. is in a Stage I – Inventory level of study. No comprehensive studies have been carried out. A 1989 field reconnaissance report noted that relocating the upstream site on the upper Churchill River from Bloodstone Falls to Bonald Rapids would still develop the full potential of the reach, given the reduction of the Granville Falls FSL to 273.7 m to minimize changes in natural lake levels at Pukatawagan. A 2003 memorandum identified a FSL of 284.4 m for Bonald. This FSL inundates to the tailrace of the Island Falls G.S. in Saskatchewan. This development concept with a FSL of 284.4m is presented here and is representative of potential alternatives, not the final or optimum concept. Further technical, environmental, social, and economic studies are required.

Regulatory Environment: Lengthy approvals process

Option Enhancement Opportunities: not available

References

Bonald Generating Station

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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3.2 THERMAL RESOURCE OPTIONS

The following twelve (12) resource option data sheets present important performance characteristics and metrics for thermal resource options.

Heavy Duty Combined Cycle Gas Turbine

Resource Type: Thermal - Natural Gas-fired Level of Study: Stage 2 - Feasibility

Location:

Development of this option as a brownfield project at either the Brandon or Selkirk Generating Stations could be relatively uncomplicated. This option could also be developed as a greenfield project in southern Manitoba within proximity of a suitable natural gas supply source.

Description:

A heavy duty, Combined Cycle Gas Turbine (CCGT) power plant consists of one or more gas turbine generators equipped with heat recovery steam generators (HRSG) to capture heat from hot exhaust gases from the gas turbine. Steam produced in the HRSG powers a steam turbine generator to produce additional electric power. Use of the otherwise wasted heat of the turbine exhaust gas yields high thermal efficiency compared to other combustion technologies.

Technical Characteristics

Heavy Duty Combined Cycle Gas Turbine

Nameplate Rating: 320 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	308	325	291
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	2460	945 to 1890	89

Capacity Factor Range under Average Flow Conditions: 35 to 70%

HHV Heat Rate: 6652 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Natural Gas
- **Mode of Operation:** Intermediate & Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Trace seasonality affect caused by differences in summer and winter air density.

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2-4
Minimum Time to Earliest ISD *(years)*	3-5

Typical Asset Life: 30 years

Economic Characteristics

Heavy Duty Combined Cycle Gas Turbine

Levelized Cost (*P_{50} Estimate*):

Greenfield with Transmission - $73 to $95 CAD (2012$)/MW.h

Brownfield with Transmission - $73 to $94 CAD (2012$)/MW.h

Without Transmission - $72 to $93 CAD (2012$)/MW.h

All calculated @ 5.05% under average flow conditions with an average $14.55 CAD (2012$) per tonne GHG price.

Base Estimate (*P_{50} Estimate*): $383 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $1240 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Equipment Factored

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$20.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$3.50CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Imported from Alberta
- **Quality:** Very Good: Fossil-based, consistent quality, abundant & reliable
- **Supply Risk:** Disruption in pipeline supply
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High
- **Transportation Pricing Trends:** Increasing Pipeline Tolls and Tarrifs
- **Price Forecast:** $2.62 USD (2011$)/mmBTU in 2012 rising to $7.83 USD (2011$)/mmBTU in 2040 from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
32.0%	46.0%	20.5%	1.5%	0.0%

Environmental Characteristics

Heavy Duty Combined Cycle Gas Turbine

Impacted Land Area:

GS Footprint – 2.8 ha

Additional Impacted Area – None

Total Impacted Area – 2.8 ha

Additional Linear Development: Varies by site. May range from 2 to 55 km.

Distance from Load Center: Varies by site. May range from 40 to 180 km.

Operating Phase Emissions:

Emissions controlled by Dry Low NOx combustor emissions and reported at full load conditions.

- **Greenhouse Gas Emissions:** 342 kg/MW.h
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	**NO_x**	**CO**	**SO_x**	**PM_{10}**	**Hg**
(kg/MW.h)	0.10	0.05	0.002	0.02	Absent

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 422 to 548 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	**Estimated Demand**
HRSG & STG steam & wet cooling tower demands.	9.2 cu. m/MW.h

Water Pollutants: Spill or leak of oxygen scavenging chemicals associated with cooling towers most likely source of any contamination.

Water Pollutant	**As**	**Se**	**Oxygen Scavengers**	**Thermal Plume**
Release Potential	None	None	Low	Negligible with cooling tower

Solid Waste Production Rate: No waste ash

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Abandoned buried utility corridors

Socio-Economic Characteristics

Heavy Duty Combined Cycle Gas Turbine

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**

Population centers near Brandon; or Selkirk; or near major natural gas pipelines.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Alberta

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	329 Person-Years
Operating Phase	94 FTE
Combined Phases *(over full service life)*	3100 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	$3.2 to $6.5 million CAD (2012$)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$2.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$3.2 million CAD (2012$)/year
Estimated List Total	$8.4 to $11.7 million CAD (2012$)/year

Summary Characteristics

Heavy Duty Combined Cycle Gas Turbine

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Low

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

The heavy duty combined cycle gas turbine option is best used as a generating asset with a high capacity factor. Currently the heavy duty CCGT is a very competitive option in relation to hydraulic generation, though hydraulic generation is still preferred. The heavy duty CCGT will continue to be considered for integration into the Manitoba Hydro generation portfolio in the future and will likely be constructed if a need for baseload generation arises which cannot be supplied by a hydraulic asset.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Heavy Duty Combined Cycle Gas Turbine

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Heavy Duty Simple Cycle Gas Turbine

Resource Type**:** Thermal - Natural Gas-fired Level of Study: Stage 2 - Feasibility

Location:

Development of this option as a brownfield project at either the Brandon or Selkirk Generating Stations could be relatively uncomplicated. This option could also be developed as a greenfield project in southern Manitoba within proximity of a suitable natural gas supply source.

Description:

In a Simple Cycle Gas Turbine (SCGT), natural gas and pressurized air are combusted, producing a hot pressurized gas which is expanded through a turbine, connected to a generator producing electrical energy. The heavy duty SCGT is built with the sole purpose of generating electricity in an industrial setting. This differs from an aeroderivative SCGT, which was first produced with the intention of propelling an aircraft. The heavy duty SCGT is characterized by a heavy and robust design, a low $/kW installed cost basis and lower heat rate than both aeroderivative SCGT's and CCGT's.

Technical Characteristics

Heavy Duty Simple Cycle Gas Turbine

Nameplate Rating: 216 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	209	223	196
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	1688	92 to 368	92

Capacity Factor Range under Average Flow Conditions: 5 to 20%

HHV Heat Rate: 9906 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Natural Gas
- **Mode of Operation:** Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Little seasonality affect caused by differences in summer and winter air density.

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2-4
Minimum Time to Earliest ISD *(years)*	3-5

Typical Asset Life: 30 years

Economic Characteristics

Heavy Duty Simple Cycle Gas Turbine

Levelized Cost (*P_{50} Estimate*):

Greenfield with Transmission - $124 to $272 CAD (2012$)/MW.h

Brownfield with Transmission - $121 to $261 CAD (2012$)/MW.h

Without Transmission - $120 to $256 CAD (2012$)/MW.h

All calculated @ 5.05% under average flow conditions with an average $14.55 CAD (2012$) per tonne GHG price.

Base Estimate (*P_{50} Estimate*): $154 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $740 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Equipment Factored

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$16.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$4.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Imported from Alberta
- **Quality:** Very Good: Fossil-based, consistent quality, abundant & reliable
- **Supply Risk:** Disruption in pipeline supply
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High
- **Transportation Pricing Trends:** Increasing Pipeline Tolls and Tarrifs
- **Price Forecast:** $2.62 USD (2011$)/mmBTU in 2012 rising to $7.83 USD (2011$)/mmBTU in 2040 from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
0.0%	39.0%	53.0%	8.0%	0.0%

Environmental Characteristics

Heavy Duty Simple Cycle Gas Turbine

Impacted Land Area:

GS Footprint – 1.7 ha

Additional Impacted Area – None

Total Impacted Area – 1.7 ha

Additional Linear Development: Varies by site. May range from 2 to 55 km.

Distance from Load Center: Varies by site. May range from 40 to 180 km.

Operating Phase Emissions:

Emissions controlled by Dry Low NOx combustor emissions and reported at full load conditions.

- **Greenhouse Gas Emissions:** 506 kg/MW.h
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.15	0.07	0.003	0.03	Absent

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 422 to 548 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Dry Low NOx Combustor	Negligible

Water Pollutants: Virtually none

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	None	None	None	None

Solid Waste Production Rate: No waste ash

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Abandoned buried utility corridors

Socio-Economic Characteristics

Heavy Duty Simple Cycle Gas Turbine

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**

Population centers near Brandon; or Selkirk; or near major natural gas pipelines.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Alberta

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	116 Person-Years
Operating Phase	52 FTE
Combined Phases *(over full service life)*	1660 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	$0.5 to $1.9 million CAD (2012$)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.8 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.3 million CAD (2012$)/year
Estimated List Total	$2.6 to $4.0 million CAD (2012$)/year

Summary Characteristics

Heavy Duty Simple Cycle Gas Turbine

Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Low

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

The heavy duty simple cycle gas turbine is best used as a generating asset with a low capacity factor. Today the heavy duty CCGT is a very competitive capacity option in relation to hydraulic generation, though hydraulic generation is still preferred. The heavy duty SCGT will continue to be considered for integration into the Manitoba Hydro generation portfolio in the future and will likely be constructed if a need for capacity arises which cannot be supplied by a hydraulic asset.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Heavy Duty Simple Cycle Gas Turbine

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Aeroderivative Simple Cycle Gas Turbine

Resource Type: Thermal - Natural Gas-fired   Level of Study: Stage 2 - Feasibility

Location:

Development of this option as a brownfield project at either the Brandon or Selkirk Generating Stations could be relatively uncomplicated. This option could also be developed as a greenfield project in southern Manitoba within proximity of a suitable natural gas supply source.

Description:

The GE LM6000 Simple Cycle Gas Turbine is an aero-derivative gas turbine, with a ten minute start time. Their small size allows for flexibility in site selection with the basic requirements consisting of access to an adequate natural gas supply and to the transmission grid. World-wide most of the over 700, in-service, LM6000s are operated as peaking facilities, their low heat rate also makes them available as a baseload resource if required to operate as such.

The smaller LM6000 can be selected as a resource over a larger, heavy duty SCGT as its size provides the additional flexibility of locating multiple, smaller units at one facility, providing increased overall availability. These units can also be distributed in a number of locations over a larger area, providing not only energy, but also grid support near larger load centres.

The configuration of emission controls for this turbine allows both a wet low NOx combustor plus selective catalytic reduction.

Technical Characteristics

Aeroderivative Simple Cycle Gas Turbine

Nameplate Rating: 51 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	47	50	42
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	387	21 to 82	21

Capacity Factor Range under Average Flow Conditions: 5 to 20%

HHV Heat Rate: 9475 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Natural Gas
- **Mode of Operation:** Peaking
- **Dispatch & Deployment Speed:** Dispatchable - Medium (in minutes)
- **Intermittency:** None
- **Seasonality:** Little seasonality affect caused by differences in summer and winter air density.

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2
Minimum Time to Earliest ISD *(years)*	3

Typical Asset Life: 30 years

Economic Characteristics

Aeroderivative Simple Cycle Gas Turbine

Levelized Cost (*P_{50} Estimate*):

Greenfield with Transmission - $161 to $429 CAD (2012$)/MW.h

Brownfield with Transmission - $158 to $418 CAD (2012$)/MW.h

Without Transmission - $157 to $412 CAD (2012$)/MW.h

All calculated @ 5.05% under average flow conditions with an average $14.55 CAD (2012$) per tonne GHG price.

Base Estimate (*P_{50} Estimate*): $68 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -30% to +50%

Overnight Capital Cost ($/kW): $1450 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 2 - Feasibility
AACEI Estimate Classification	Class 4

Estimating Technique: Equipment Factored

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$25.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$4.50 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Imported from Alberta
- **Quality:** Very Good: Fossil-based, consistent quality, abundant & reliable
- **Supply Risk:** Disruption in pipeline supply
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High
- **Transportation Pricing Trends:** Increasing Pipeline Tolls and Tarrifs
- **Price Forecast:** $2.62 USD (2011$)/mmBTU in 2012 rising to $7.83 USD (2011$)/mmBTU in 2040 from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
0.0%	39.0%	53.0%	8.0%	0.0%

Environmental Characteristics

Aeroderivative Simple Cycle Gas Turbine

Impacted Land Area:

GS Footprint – 0.8 ha

Additional Impacted Area – None

Total Impacted Area – 0.8 ha

Additional Linear Development: Varies by site. May range from 2 to 55 km.

Distance from Load Center: Varies by site. May range from 40 to 180 km.

Operating Phase Emissions:

Emissions controlled by Dry Low NOx combustor emissions and reported at full load conditions.

- **Greenhouse Gas Emissions:** 506 kg/MW.h
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.23	0.95	0.003	0.03	Absent

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 422 to 548 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Dry Low NOx Combustor	Negligible

Water Pollutants: Virtually none

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	None	None	None	None

Solid Waste Production Rate: No waste ash

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Abandoned buried utility corridors

Socio-Economic Characteristics

Aeroderivative Simple Cycle Gas Turbine

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**

Population centers near Brandon; or Selkirk; or near major natural gas pipelines.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Alberta

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	65 Person-Years
Operating Phase	52 FTE
Combined Phases *(over full service life)*	1610 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	$0.1 to $0.4 million CAD (2012$)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.4 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.6 million CAD (2012$)/year
Estimated List Total	$1.1 to $1.4 million CAD (2012$)/year

Summary Characteristics

Aeroderivative Simple Cycle Gas Turbine

Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Low

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

The aeroderivative simple cycle gas turbine is best used as a capacity resource when only a small number of MW's are required. The aeroderivative SCGT is not currently required in the long term plan. The aeroderivative SCGT will continue to be considered for integration into the Manitoba Hydro portfolio in the future and will likely be constructed if a small need for capacity arises which cannot be supplied by a hydraulic asset.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Aeroderivative Simple Cycle Gas Turbine

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Wood Waste-Fired Generation (15 MW)

Resource Type: Thermal - Biomass-fired Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Minitonas for analysis purposes.

Description:

Wood waste combustion generation utilizes mature steam turbine plant technology, involving a traditional four component process including a wood waste fired boiler, a turbogenerator, a condenser, and a boiler feed pump. The boiler typically has the flexibility to combust various types of biomass having variable moisture content. This plant configuration can also be easily adapted to allow co-firing with other fuels such as natural gas.

Technical Characteristics

Wood Waste-Fired Generation (15 MW)

Nameplate Rating: 15 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	13.2	≈13.2	≈13.2
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	103	not determined	not determined

Capacity Factor Range under Average Flow Conditions: 83% for dependable energy generation

HHV Heat Rate: 12,240 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Renewable - Wood Waste Biomass
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established Elsewhere

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 40 years

Economic Characteristics

Wood Waste-Fired Generation (15 MW)

Levelized Cost (*P_{50} Estimate*):

Without Transmission - $179 to $206 CAD (2012$)/MW.h @ 5.05% under baseload operations with no GHG price.

Base Estimate (*P_{50} Estimate*): Without Transmission - $91 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $6100 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2011

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$400.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Renewable, process waste product, moisture content may vary.
- **Supply Risk:** Collection is weather dependant and impacted by price of diesel.
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High (due to collection costs)
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** Low price: $73 CAD ($2012) per oven-dried tonne
- High price: $110 CAD ($2012) per oven-dried tonne

REC Premium Marketability: Moderate

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
2.0%	39.0%	53.0%	6.0%	0.0%

Environmental Characteristics

Wood Waste-Fired Generation (15 MW)

Impacted Land Area:

GS Footprint – ≈ 15 ha

Additional Impacted Area – Not Determined

Total Impacted Area – ≈ 15 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Minitonas as proxy. 340 km

Operating Phase Emissions:

Emissions controlled with SNCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 24 kg/MW.h (carbon neutral)
- 1170 kg/MW.h (w/CO2)

- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.95	-	0.18	0.19	Negligible

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** > 0 to 37 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & dry or wet cooling tower demand.	0.2 (dry tower) to 3.4 (wet tower) cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Negligible	Negligible	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 34 to 62 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Wood Waste-Fired Generation (15 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Swan River.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	240 Person-Years
Operating Phase	90 FTE
Combined Phases *(over full service life)*	3800 to 4000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Likely carbon premium exempt
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.7 million CAD (2012$)/year
Estimated List Total	$1.2 million CAD (2012$)/year

Summary Characteristics

Wood Waste-Fired Generation (15 MW)

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Low

Energy Security Concerns: Very Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

Wood waste fired generation is best used as a generating asset with a high capacity factor in a close vicinity to the fuel source. Today the circumstances that would make wood waste fired generation attractive to Manitoba Hydro do not exist. Wood-waste fired generation will continue to be considered for integration into the Manitoba Hydro portfolio.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Well suited for combined heat & power (CHP) co-generation applications and can also be easily adapted to allow co-firing with other fuels such as natural gas.

References

Wood Waste-Fired Generation (15 MW)

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Wood Waste-Fired Generation (30 MW)

Resource Type: Thermal - Biomass-fired Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Minitonas for analysis purposes.

Description:

Wood waste combustion generation utilizes mature steam turbine plant technology, involving a traditional four component process including a wood waste fired boiler, a turbogenerator, a condenser, and a boiler feed pump. The boiler typically has the flexibility to combust various types of biomass having variable moisture content. This plant configuration can also be easily adapted to allow co-firing with other fuels such as natural gas.

Technical Characteristics

Wood Waste-Fired Generation (30 MW)

Nameplate Rating: 30 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	27	≈27	≈27
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	211	not determined	not determined

Capacity Factor Range under Average Flow Conditions: 83% for dependable energy generation

HHV Heat Rate: 11,968 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Renewable - Wood Waste Biomass
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established Elsewhere

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 40 years

Economic Characteristics

Wood Waste-Fired Generation (30 MW)

Levelized Cost (*P_{50} Estimate*):

Without Transmission - $128 to $155 CAD (2012$)/MW.h @ 5.05% under baseload operations with no GHG price.

Base Estimate (*P_{50} Estimate*): Without Transmission - $123 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $4100 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$220.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Renewable, process waste product, moisture content may vary.
- **Supply Risk:** Collection is weather dependant and impacted by price of diesel.
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High (due to collection costs)
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** Low price: $73 CAD ($2012) per oven-dried tonne
- High price: $110 CAD ($2012) per oven-dried tonne

REC Premium Marketability: Moderate

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
2.0%	39.0%	53.0%	6.0%	0.0%

Environmental Characteristics

Wood Waste-Fired Generation (30 MW)

Impacted Land Area:

GS Footprint – ≈ 30 ha

Additional Impacted Area – Not Determined

Total Impacted Area – ≈ 30 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Minitonas as proxy. 340 km

Operating Phase Emissions:

Emissions controlled with SNCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 23 kg/MW.h (carbon neutral)
- 1150 kg/MW.h (w/CO2)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.95	-	0.18	0.19	Negligible

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** > 0 to 37 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & dry or wet cooling tower demand.	0.2 (dry tower) to 3.4 (wet tower) cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Negligible	Negligible	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 30 to 60 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Wood Waste-Fired Generation (30 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Swan River.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	330 Person-Years
Operating Phase	90 FTE
Combined Phases *(over full service life)*	3800 to 4000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Likely carbon premium exempt
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.6 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.0 million CAD (2012$)/year
Estimated List Total	$1.6 million CAD (2012$)/year

Summary Characteristics

Wood Waste-Fired Generation (30 MW)

Resource Technology Energy Market Externalities

(Published analysis by Deutsche Bank Climate Change Advisors):

Health Concerns: Very Low

Safety Concerns: Low

Energy Security Concerns: Very Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

Wood waste fired generation is best used as a generating asset with a high capacity factor in a close vicinity to the fuel source. Today the circumstances that would make wood waste fired generation attractive to Manitoba Hydro do not exist. Wood-waste fired generation will continue to be considered for integration into the Manitoba Hydro portfolio.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Well suited for combined heat & power (CHP) co-generation applications and can also be easily adapted to allow co-firing with other fuels such as natural gas.

References

Wood Waste-Fired Generation (30 MW)

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Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Agricultural Crop Residue-Fired Generation (15 MW)

Resource Type: Thermal - Biomass-fired Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Portage la Prairie for analysis purposes.

Description:

Agricultural crop residue combustion generation utilizes mature steam turbine plant technology involving a traditional four component process including a agricultural crop residue fired boiler, a turbogenerator, a condenser, and a boiler feed pump. The boiler typically has the flexibility to combust various types of biomass having variable moisture content. This plant configuration can also be easily adapted to allow co-firing with other fuels such as natural gas.

Technical Characteristics

Agricultural Crop Residue-Fired Generation (15 MW)

Nameplate Rating: 15 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	13.2	≈13.2	≈13.2
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	103	not determined	not determined

Capacity Factor Range under Average Flow Conditions: 83% for dependable energy generation

HHV Heat Rate: 12,240 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Renewable - Agricultural Crop Residue Biomass
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established Elsewhere

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 40 years

Economic Characteristics

Agricultural Crop Residue-Fired Generation (15 MW)

Levelized Cost (*P_{50} Estimate*):

Without Transmission - $180 to $196 CAD (2012$)/MW.h @ 5.05% under baseload operations with no GHG price.

Base Estimate (*P_{50} Estimate*): Without Transmission - $91 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $6100 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2013

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$400.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Renewable, harvest waste product, moisture content may vary.
- **Supply Risk:** Collection is weather dependant and impacted by price of diesel.
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High (due to collection costs)
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** Low price: $74 CAD ($2012) per oven-dried tonne
- High price: $96 CAD ($2012) per oven-dried tonne

REC Premium Marketability: Moderate

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
2.0%	39.0%	53.0%	6.0%	0.0%

Environmental Characteristics

Agricultural Crop Residue-Fired Generation (15 MW)

Impacted Land Area:

GS Footprint – ≈ 15 ha

Additional Impacted Area – Not Determined

Total Impacted Area – ≈ 15 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Portage la Prairie as proxy. 70 km

Operating Phase Emissions:

Emissions controlled with SNCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 24 kg/MW.h (carbon neutral)
- 1470 kg/MW.h (w/CO2)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.95	-	0.18	0.19	Negligible

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** > 0 to 37 kg CO_2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & dry or wet cooling tower demand.	0.2 (dry tower) to 3.4 (wet tower) cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Negligible	Negligible	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 33 to 98 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Agricultural Crop Residue-Fired Generation (15 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Portage la Prairie.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	240 Person-Years
Operating Phase	90 FTE
Combined Phases *(over full service life)*	3800 to 4000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

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Manitoba Purchases	Less
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Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Likely carbon premium exempt
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.7 million CAD (2012$)/year
Estimated List Total	$1.2 million CAD (2012$)/year

Summary Characteristics

Agricultural Crop Residue-Fired Generation (15 MW)

Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Low

Energy Security Concerns: Very Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

Agricultural crop residue-fired generation is best used as a generating asset with a high capacity factor in a close vicinity to the fuel source. Today the circumstances that would make agricultural crop residue-fired generation attractive to Manitoba Hydro do not exist. Crop-waste fired generation will continue to be considered for integration into the Manitoba Hydro portfolio.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

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Resource Type: Thermal - Biomass-fired   Level of Study: Stage 1 - Inventory

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Description:

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Technical Characteristics

Agricultural Crop Residue-Fired Generation (30 MW)

Nameplate Rating: 30 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	27	≈27	≈27
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	211	not determined	not determined

Capacity Factor Range under Average Flow Conditions: 83% for dependable energy generation

HHV Heat Rate: 11,968 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Renewable - Agricultural Crop Residue Biomass
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established Elsewhere

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 40 years

Economic Characteristics

Agricultural Crop Residue-Fired Generation (30 MW)

Levelized Cost (*P_{50} Estimate*):

Without Transmission - $129 to $145 CAD (2012$)/MW.h @ 5.05% under baseload operations with no GHG price.

Base Estimate (*P_{50} Estimate*): Without Transmission - $123 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $4100 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2014

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$220.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Renewable, harvest waste product, moisture content may vary.
- **Supply Risk:** Collection is weather dependant and impacted by price of diesel.
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High (due to collection costs)
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- **Price Forecast:** Low price: $74 CAD ($2012) per oven-dried tonne
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REC Premium Marketability: Moderate

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0.0%	0.0%	0.0%	0.0%	0.0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
2.0%	39.0%	53.0%	6.0%	0.0%

Environmental Characteristics

Agricultural Crop Residue-Fired Generation (30 MW)

Impacted Land Area:

GS Footprint – ≈ 30 ha

Additional Impacted Area – Not Determined

Total Impacted Area – ≈ 30 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Portage la Prairie as proxy. 70 km

Operating Phase Emissions:

Emissions controlled with SNCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 23 kg/MW.h (carbon neutral)
- 1440 kg/MW.h (w/CO2)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.95	-	0.18	0.19	Negligible

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** > 0 to 37 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & dry or wet cooling tower demand.	0.2 (dry tower) to 3.4 (wet tower) cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Negligible	Negligible	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 32 to 95 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Agricultural Crop Residue-Fired Generation (30 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Portage la Prairie.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	330 Person-Years
Operating Phase	90 FTE
Combined Phases *(over full service life)*	3800 to 4000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Likely carbon premium exempt
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$0.6 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.0 million CAD (2012$)/year
Estimated List Total	$1.6 million CAD (2012$)/year

Summary Characteristics

Agricultural Crop Residue-Fired Generation (30 MW)

Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Low

Energy Security Concerns: Very Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

Agricultural crop residue-fired generation is best used as a generating asset with a high capacity factor in a close vicinity to the fuel source. Today the circumstances that would make agricultural crop residue-fired generation attractive to Manitoba Hydro do not exist. Crop-waste fired generation will continue to be considered for integration into the Manitoba Hydro portfolio.

Regulatory Environment: Increasing stringent air emission control regulations are likely.

Option Enhancement Opportunities: Well suited for combined heat & power (CHP) co-generation applications and can also be easily adapted to allow co-firing with other fuels such as natural gas.

References

Agricultural Crop Residue-Fired Generation (30 MW)

Avista Corporation (2009). "Electric Integrated Resource Plan". August 2009.

BC Hydro (2006). "BC Hydro 2005 Integrated Resource Plan: Project and Program Database." 2006 Revision.

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Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Subcritical Pulverized Coal Generation

Resource Type: Thermal - Coal-fired Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Brandon for analysis purposes.

Description:

Subcritical pulverized coal combustion generation utilizes mature steam turbine plant technology involving a traditional four component process including a pulverized coal fired boiler, a turbogenerator, a condenser, and a boiler feed pump. A subcritical boiler operates below approximately 19 MPa where a distinction between liquid and gaseous phase of boiler water exists in the steam drum. The lower pressure results in a less complex boiler with lower thermal efficiency than a supercritical boiler.

Air emission control can be achieved with different technologies including Selective Catalytic Reduction (SCR) for NOx control; Flue-gas desulfurization (FGD) for SO2 control; and Activated Carbon Injection (ACI) for mercury control.

Technical Characteristics

Subcritical Pulverized Coal Generation

Nameplate Rating: 583 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	550	≈ 550	≈ 550
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	4100	240	240

Capacity Factor Range under Average Flow Conditions: 85% for dependable energy generation

HHV Heat Rate: 9276 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Coal
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	2
Construction Phase: Final Design, Procurement & Construction *(years)*	4
Minimum Time to Earliest ISD *(years)*	6

Typical Asset Life: 60 years

Economic Characteristics

Subcritical Pulverized Coal Generation

Levelized Cost (*P_{50} Estimate*):

$110 to $138 CAD (2012$)/MW.h Escalated from EIA's LCOE for 2012 in USD (2010$) includes transmission investment.

Base Estimate (*P_{50} Estimate*):

$2000 million CAD (2012$) escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW):

$3440 CAD (2012$)/kw escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$22.83 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$4.20 CAD (2012$)/MW.h/year

<u>Fuel Supply Description:</u>

- **Source:** Likely imported from Montana or Wyoming
- **Quality:** Fair: Fossil-based, quality and chemistry varies by deposit, abundant and reliable
- **Supply Risk:** Long rail haul distances
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Medium to High
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** $13.53 USD (2011$)/short ton in 2012 rising to $29.35 USD (2011$)/short ton in 2040 for WY PRB from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
na	na	na	na	na
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
na	na	na	na	na

Environmental Characteristics

Subcritical Pulverized Coal Generation

Impacted Land Area:

GS Footprint – ≈ 250 ha

Additional Impacted Area – 0

Total Impacted Area – ≈ 250 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Brandon as proxy. 180 km

Operating Phase Emissions:

Emissions controlled with FGD, SCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 918 kg/MW.h (After 2015 restricted to 420 kg/MW.h)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.31	-	0.522	0.07	5.72E-05

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 980 to 1196 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & wet cooling tower demand.	12.3 cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Moderate	Moderate	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 16 to 22 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Subcritical Pulverized Coal Generation

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Brandon.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Wyoming or Montana

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	2500 to 3000 Person-years
Operating Phase	80 FTE
Combined Phases *(over full service life)*	7300 to 7800 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Similar
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Unrestricted: $2.0 to $38.0 million CAD ($2012)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Unrestricted: $2.0 to $34.0 million CAD ($2012)/year
Estimated Capital Taxes	$10.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$16.0 million CAD (2012$)/year
Estimated List Total	$30.0 to $98 .0 million CAD (2012$)/year

Summary Characteristics

Subcritical Pulverized Coal Generation

Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very High

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Very High

Outlook for Manitoba Hydro:

The combustion of coal in Manitoba has encountered considerable oversight and regulatory constraint from the federal and provincial governments since 2008. As a result, the probability of adding new coal-fired generation in the forseable is extremely low. After July 1, 2015 federal regulations have established an annual, intensity performance standard for new coal-fired plants of less than 420 tonnes CO2 emissions from the combustion of fossil fuels for each GWh of electricity produced.

Regulatory Environment: Restricted by Manitoba's "Climate Change and Emissions Reduction Act" and Canada's "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations".

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Subcritical Pulverized Coal Generation

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

BC Hydro (2006). “BC Hydro 2005 Integrated Resource Plan: Project and Program Database.” 2006 Revision.

BC Hydro (2012). “BC Hydro Draft 2012 Integrated Resource Plan: 2010 Resource Options Report Resource Options Database (RODAT) Summary Sheets” June 2012.

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Whitaker, M. et al. (2012). "Life Cycle Greehouse Gas Emissions of Coal-Fired Electricity Generation" in the Journal of Industrial Ecology, Volume 16, Number S1. 2012.

Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Supercritical Pulverized Coal Generation

Resource Type: Thermal - Coal-fired | Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Brandon for analysis purposes.

Description:

Supercritical pulverized coal combustion generation utilizes mature steam turbine plant technology involving a traditional four component process including a pulverized coal fired boiler, a turbogenerator, a condenser, and a boiler feed pump. A supercritical boiler operates above approximately 22 MPa. At these pressures there exists no distinction between liquid and gaseous phase of the boiler fluid. Since no need to separate steam from liquid water is required the supercritical boiler uses once through technology with no steam drum. The supercritical boiler is more complex but also more efficient than the subcritical unit resulting in a more expensive boiler but lower heat rate plant.

Air emission control can be achieved with different technologies including Selective Catalytic Reduction (SCR) for NOx control; Flue-gas desulfurization (FGD) for SO2 control; and Activated Carbon Injection (ACI) for mercury control.

Technical Characteristics

Supercritical Pulverized Coal Generation

Nameplate Rating: 580 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	550	≈ 550	≈ 550
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	4100	240	240

Capacity Factor Range under Average Flow Conditions: 85% for dependable energy generation

HHV Heat Rate: 8721 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Coal
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established

System Integration Considerations: Easily integrated

Technical Challenges: Dust, fire hazard & ash handling

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	2
Construction Phase: Final Design, Procurement & Construction *(years)*	4
Minimum Time to Earliest ISD *(years)*	6

Typical Asset Life: 60 years

Economic Characteristics

Supercritical Pulverized Coal Generation

Levelized Cost (*P_{50} Estimate*):

$110 to $138 CAD (2012$)/MW.h Escalated from EIA's LCOE for 2012 in USD (2010$) includes transmission investment.

Base Estimate (*P_{50} Estimate*):

$2000 million CAD (2012$) escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $3440 CAD (2012$)/kw escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$37.42 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$4.43 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Likely imported from Montana or Wyoming
- **Quality:** Fair: Fossil-based, quality and chemistry varies by deposit, abundant and reliable
- **Supply Risk:** Long rail haul distances
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Medium to High
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** $13.53 USD (2011$)/short ton in 2012 rising to $29.35 USD (2011$)/short ton in 2040 for WY PRB from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
na	na	na	na	na
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
na	na	na	na	na

Environmental Characteristics

Supercritical Pulverized Coal Generation

Impacted Land Area:

GS Footprint – ≈ 250 ha

Additional Impacted Area – 0

Total Impacted Area – ≈ 250 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Brandon as proxy. 180 km

Operating Phase Emissions:

Emissions controlled with FGD, SCR and ACI and lime, flue gas injection prior to bag house capture.

- **Greenhouse Gas Emissions:** 854 kg/MW.h (After 2015 restricted to 420 kg/MW.h)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.29	-	0.258	0.03	2.50E-06

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 781 to 927 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & wet cooling tower demand.	10.8 cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Moderate	Moderate	Low	Negligible with cooling tower

Solid Waste Production Rate: Waste ash - 15 to 21 kg/MW.h

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Supercritical Pulverized Coal Generation

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Brandon.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Wyoming or Montana

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	2500 to 3000 Person-years
Operating Phase	40 to 80 FTE
Combined Phases *(over full service life)*	4900 to 7800 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Similar
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Unrestricted: $2.0 to $35.0 million CAD ($2012)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Unrestricted: $2.0 to $32.0 million CAD ($2012)/year
Estimated Capital Taxes	$10.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$16.0 million CAD (2012$)/year
Estimated List Total	$30.0 to $93.0 million CAD (2012$)/year

Summary Characteristics

Supercritical Pulverized Coal Generation

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very High

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Very High

Outlook for Manitoba Hydro:

The combustion of coal in Manitoba has encountered considerable oversight and regulatory constraint from the federal and provincial governments since 2008. As a result, the probability of adding new coal-fired generation in the forseable is extremely low. After July 1, 2015 federal regulations have established an annual, intensity performance standard for new coal-fired plants of less than 420 tonnes CO2 emissions from the combustion of fossil fuels for each GWh of electricity produced.

Regulatory Environment: Restricted by Manitoba's "Climate Change and Emissions Reduction Act" and Canada's "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations".

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Supercritical Pulverized Coal Generation

Avista Corporation (2009). “Electric Integrated Resource Plan”. August 2009.

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Wuskwatim Power Limited Partnership (2012). "Monitoring Overview 2011-2012". 2012.

Integrated Gasification Combined Cycle

Resource Type**:** Thermal - Syngas-fired Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Brandon for analysis purposes.

Description:

Integrated Gasification Combined Cycle (IGCC) uses a gasification process to produce a synthetic gas (syngas) from a wide variety of carbon based fuels, primarily coal. The syngas is used as a fuel source in a conventional combined cycle gas turbine. The waste heat from the turbine exhaust and the gasification process are combined and used to produce steam in the heat recovery steam generator (HRSG). The steam is then passed through a steam turbine where additional electricity is produced. The gasification process also eliminates or significantly reduces most air emissions associated with pulverized coal combustion.

Technical Characteristics

Integrated Gasification Combined Cycle

Nameplate Rating: 770 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	640	≈ 640	≈ 640
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	4500	unknown	unknown

Capacity Factor Range under Average Flow Conditions: 80% for dependable energy generation

HHV Heat Rate: 8922 BTU/kW.h

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Non-Renewable - Synthetic Gas Derived from Coal
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Proven

System Integration Considerations: Easily integrated

Technical Challenges: Complex technical operations

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	2
Construction Phase: Final Design, Procurement & Construction *(years)*	4
Minimum Time to Earliest ISD *(years)*	6

Typical Asset Life: 30 years

Economic Characteristics

Integrated Gasification Combined Cycle

Levelized Cost (*P_{50} Estimate*):

$124 to $150 CAD (2012$)/MW.h Escalated from EIA's LCOE for 2012 in USD (2010$) includes transmission investment.

Base Estimate (*P_{50} Estimate*):

$3000 million CAD (2012$) escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $3896 CAD (2012$)/kw escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$61.63 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$7.15 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Likely imported from Saskatchewan or North Dakota
- **Quality:** Fair: Coal gasification process moderates input fuel variability. Fossil-based, abundant & reliable.
- **Supply Risk:** Long rail haul distances
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Medium to High
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** $13.53 USD (2011$)/short ton in 2012 rising to $29.35 USD (2011$)/short ton in 2040 for WY PRB from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
na	na	na	na	na
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
na	na	na	na	na

Environmental Characteristics

Integrated Gasification Combined Cycle

Impacted Land Area:

GS Footprint – ≈ 500 ha

Additional Impacted Area – 0

Total Impacted Area – ≈ 500 ha

Additional Linear Development: Likely less than 2 km.

Distance from Load Center: Brandon as proxy. 180 km

Operating Phase Emissions:

Process syngas treatment includes control of heavy metals, particulate and acid gases. Tail gas treatment includes control of mercury.

- **Greenhouse Gas Emissions:** 662 kg/MW.h (After 2015 restricted to 420 kg/MW.h)
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.18	-	0.043	0.02	1.92E-06

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 759 to 888 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & wet cooling tower demand.	6.8 cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Moderate	Moderate	Low	Negligible with cooling tower

Solid Waste Production Rate: Not determined.

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Integrated Gasification Combined Cycle

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Brandon.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Wyoming or Montana

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	2400 to 3300 Person-years
Operating Phase	80 to 120 FTE
Combined Phases *(over full service life)*	5000 to 7000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Similar
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Baseload: $30.0 million CAD ($2012)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Baseload: $27.0 million CAD ($2012)/year
Estimated Capital Taxes	$15.0 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$24.0 million CAD (2012$)/year
Estimated List Total	$96.0 million CAD (2012$)/year

Summary Characteristics

Integrated Gasification Combined Cycle

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Not Rated

Safety Concerns: Not Rated

Energy Security Concerns: Not Rated

Environmental Concerns: Not Rated

Outlook for Manitoba Hydro:

Integrated gasification is an advanced process that is still in the early stages of development. As a result integrated gasification is not a being considered for near term generation needs. The technology will conitue to be monitored for future developments.

Regulatory Environment: Restricted by Canada's "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations". May be restricted by Manitoba's "Climate Change and Emissions Reduction Act".

Option Enhancement Opportunities: Combine with future carbon capture and storage technologies

References

Integrated Gasification Combined Cycle

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Integrated Gasification Combined Cycle & CCS

Resource Type**:** Thermal - Syngas-fired

Level of Study: Stage 1 - Inventory

Location:

Proxy project sited near Virden for analysis purposes.

Description:

Integrated Gasification Combined Cycle (IGCC) uses a gasification process to produce a synthetic gas (syngas) from a wide variety of carbon based fuels, primarily coal. The syngas is used as a fuel source in a conventional combined cycle gas turbine. The waste heat from the turbine exhaust and the gasification process are combined and used to produce steam in the heat recovery steam generator (HRSG). The steam is then passed through a steam turbine where additional electricity is produced. The gasification process also eliminates or significantly reduces most air emissions associated with pulverized coal combustion.

Carbon capture and storage (CCS) is the process of capturing a majority of the CO2 from the exhaust stream of the IGCC process and storing it permanently where it cannot re-enter the atmosphere. Underground geological formations are typically used as storage locations.

Technical Characteristics

Integrated Gasification Combined Cycle & CCS

Nameplate Rating: 745 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	556	≈ 556	≈ 556
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	3900	unknown	unknown

Capacity Factor Range under Average Flow Conditions: 80% for dependable energy generation

HHV Heat Rate: 10,505 BTU/kW.h

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Synthetic Gas Derived from Coal
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Demonstration Stage

System Integration Considerations: Easily integrated

Technical Challenges: Complex technical operations

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	2
Construction Phase: Final Design, Procurement & Construction *(years)*	4
Minimum Time to Earliest ISD *(years)*	6

Typical Asset Life: 30 years

Economic Characteristics

Integrated Gasification Combined Cycle & CCS

Levelized Cost (*P_{50} Estimate*):

$155 to $191 CAD (2012$)/MW.h Escalated from EIA's LCOE for 2012 in USD (2010$) includes transmission investment.

Base Estimate (*P_{50} Estimate*):

$4821 million CAD (2012$) escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $6471 CAD (2012$)/kw escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$72.10 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$8.37 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Likely imported from Saskatchewan or North Dakota
- **Quality:** Fair: Coal gasification process moderates input fuel variability. Fossil-based, abundant & reliable.
- **Supply Risk:** Long rail haul distances
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - Medium to High
- **Transportation Pricing Trends:** Impacted by diesel fuel commodity pricing
- **Price Forecast:** $13.53 USD (2011$)/short ton in 2012 rising to $29.35 USD (2011$)/short ton in 2040 for WY PRB from AEO 2013 (Early Release).

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
na	na	na	na	na
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
na	na	na	na	na

Environmental Characteristics

Integrated Gasification Combined Cycle & CCS

Impacted Land Area:

GS Footprint – ≈ 800 ha

Additional Impacted Area – 0

Total Impacted Area – ≈ 800 ha

Additional Linear Development: May include approximately 50 to 100 km of CCS pipeline.

Distance from Load Center: Virden as proxy. 250 km

Operating Phase Emissions:

Process syngas treatment includes control of heavy metals, particulate, acid gases and separation of CO2. Tail gas treatment includes control of mercury.

- **Greenhouse Gas Emissions:** 70 kg/MW.h
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.17	-	0.034	0.02	2.03E-06

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** Not determined

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Replace lost process water & wet cooling tower demand.	9.0 cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	Moderate	Moderate	Low	Negligible with cooling tower

Solid Waste Production Rate: Not determined.

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Ash Lagoon

Socio-Economic Characteristics

Integrated Gasification Combined Cycle & CCS

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Brandon.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Typically imported from Wyoming or Montana

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	4500 to 4800 Person-years
Operating Phase	150 to 170 FTE
Combined Phases *(over full service life)*	5000 to 7000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Baseload: $2.7 million CAD ($2012)/year
Coal Emission Tax equivalent to $10/tonne of GHG	Baseload: $27.6 million CAD ($2012)/year
Estimated Capital Taxes	$24.1 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$38.6 million CAD (2012$)/year
Estimated List Total	$93.0million CAD (2012$)/year

Summary Characteristics

Integrated Gasification Combined Cycle & CCS

Resource Technology Energy Market Externalities
(Published analysis by Deutsche Bank Climate Change Advisors):

Health Concerns: Not Rated

Safety Concerns: Not Rated

Energy Security Concerns: Not Rated

Environmental Concerns: Not Rated

Outlook for Manitoba Hydro:

Integrated gasification is an advanced process that is still in the early stages of development. As a result integrated gasification is not a being considered for near term generation needs. The technology will conitue to be monitored for future developments.

Regulatory Environment: Meets limits of Canada's "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations" but may be restricted by Manitoba's "Climate Change and Emissions Reduction Act".

Option Enhancement Opportunities: None

References

Integrated Gasification Combined Cycle & CCS

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Nuclear Power Plant

Resource Type: Thermal - Nuclear Level of Study: Stage 1 - Inventory

Location:

Proxy project sited within 100 km of Winnipeg adjacent to Lake Winnipeg.

Description:

A nuclear power plant is very similar to conventional coal-fired boiler plant with the exception that heat production occurs in a nuclear reactor rather than in a boiler. The nuclear power plant uses a four component process of a nuclear fueled boiler, turbogenerator, condenser and boiler feed pump. Nuclear power plants are operated as base load units since their extremely low marginal costs of operation conventionally favour maximal operations at all times. A two CANDU 6 reactor facility is described.

Technical Characteristics

Nuclear Power Plant

Nameplate Rating: 1456 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	1332	1332	1332
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	10510	10510	10510

Capacity Factor Range under Average Flow Conditions: 90% for dependable energy generation

HHV Heat Rate: 9666 BTU/kW.h equivalent

Power Generation Flexibility:

- **Fuel Type:** Non-Renewable - Radioactive or fissile materials
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Limited Dispatch Capability
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well-Established Elsewhere

System Integration Considerations: Large sized units create system challenges when taken offline

Technical Challenges: Complex technical operations

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	7
Construction Phase: Final Design, Procurement & Construction *(years)*	4
Minimum Time to Earliest ISD *(years)*	11

Typical Asset Life: 60 years

Economic Characteristics

Nuclear Power Plant

Levelized Cost (*P_{50} Estimate*):

$130 to $144 CAD (2012$)/MW.h Escalated from EIA's LCOE for 2012 in USD (2010$) includes transmission investment.

Base Estimate (*P_{50} Estimate*):

$8715 million CAD (2012$) escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $6455 CAD (2012$)/kw escalated from EIA's 2012 Cost and Peformance Characteristics in USD (2010$)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$92.35 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$2.12 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Likely imported from Ontario
- **Quality:** Good: Highly processed to meet specifications
- **Supply Risk:** Not traded in an organized commodity exchange but in bilateral transactions
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - High
- **Transportation Pricing Trends:** Highly segmented global market
- **Price Forecast:** Not determined.

REC Premium Marketability: None

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
na	na	na	na	na
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
na	na	na	na	na

Environmental Characteristics

Nuclear Power Plant

Impacted Land Area:

GS Footprint – Not Determined

Additional Impacted Area – 1 km exclusion zone

Total Impacted Area – ≈ 300 ha

Additional Linear Development: Not determined.

Distance from Load Center: Brandon as proxy. 180 km

Operating Phase Emissions:

Negligable HAP emissions.

- **Greenhouse Gas Emissions:** negligible
- **Hazardous Air Pollutant Emissions:**

Air Pollutant	NO_x	CO	SO_x	PM_{10}	Hg
(kg/MW.h)	0.003	-	0.007	negligible	negligible

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 8 to 45 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Wet cooling tower demand or once thru cooling flows.	3 to 4 cu. m/MW.h or 100 to 225 cu. m/MW.h

Water Pollutants: Contaminated runoff from process residuals or spills or leaks of process liquids. May be radioactive or non-radioactive depending on type of failure.

Water Pollutant	As	Se	Oxygen Scavengers	Thermal Plume
Release Potential	None	None	Low	Negligible if cooling tower used. High if once-thru cooling used.

Solid Waste Production Rate: Approximately 62 cu. cm/MW.h of low to intermediate-level and 3.5 cu. cm/MW.h of high-level radioactive wastes.

Higher Priority Wildlife Species of Interest: Requires site specific review.

Long Term Legacy Issues: Storage of Low to High-Level Radioactive Wastes

Socio-Economic Characteristics

Nuclear Power Plant

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of WInnipeg.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Negative

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Likely yellowcake from Saskatchewan and processed fuel rod pellets from Ontario

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	7000 to 11,000 Person-years
Operating Phase	400 to 700 FTE
Combined Phases *(over full service life)*	30,000 to 50,000 Person-years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	More
Northern Manitoba Employment	Similar if portion of staff is targeted
Aboriginal Employment	Similar if portion of staff is targeted

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	More
Northern Manitoba Purchases	Similar if purchases are targeted
Aboriginal Business Purchases	Similar if purchases are targeted

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	Not applicable
Coal Emission Tax equivalent to $10/tonne of GHG	Not applicable
Estimated Capital Taxes	$43.6 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$69.8 million CAD (2012$)/year
Estimated List Total	$113.4 million CAD (2012$)/year

Summary Characteristics

Nuclear Power Plant

Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Medium

Safety Concerns: High

Energy Security Concerns: Low

Environmental Concerns: Medium

Outlook for Manitoba Hydro:

Nuclear power plants are expensive to build, difficult to operate and result in long term liability relating to waste products. As a result, nuclear is not being considered for near term generation needs. The technology will conitue to be monitored for future developments.

Regulatory Environment: May be restricted by the High-Level Radioactive Waste Act which limits the storage or disposal of spent fuel in Manitoba.

Option Enhancement Opportunities: Next generation improvements including smaller individual unit sizes.

References

Nuclear Power Plant

Alberta, Government of (2009). "Alberta Nuclear Consultation". April 2009.

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3.3 **EMERGING TECHNOLOGYRESOURCE OPTIONS**

The following nine (9) resource option data sheets present important performance characteristics and metrics for emerging technology resource options.

Solar Photovoltaics - Fixed Tilt

Resource Type**:** Renewable - Solar | Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Melita for analysis purposes.

Description:

Photovoltaic (PV) systems are used to convert sunlight into electricity. The most important component of a PV system is the PV module, which is composed of a number of interconnected solar cells. PV modules are connected together into panels and arrays. A solar array is connected to an inverter that converts the Direct Current (DC) generated by the PV array into Alternating Current (AC) compatible with the electricity supplied to or from the grid.

Fixed tilt PV systems are simple, inexpensive, and reliable. In Manitoba, they can be tilted upward toward the south, at an angle approximately equal to the latitude, to capture more energy through the year. The orientation of the arrays can also be adjusted seasonally to improve system performance.

Technical Characteristics

Solar Photovoltaics - Fixed Tilt

Nameplate Rating: 20 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	20	0	0
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	≈ 35	≈ 35	≈ 35

Capacity Factor Range under Average Flow Conditions: Approximately 20%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Solar Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - cloud cover creates rapid power drop off
- **Seasonality:** Strongly seasonality affected

Maturity of Technology: Proven - anticipate potential efficiency improvements

System Integration Considerations: Intermittency diffcult to forecast contibuting to higher integration costs.

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2
Minimum Time to Earliest ISD *(years)*	3

Typical Asset Life: 20 years

Economic Characteristics

Solar Photovoltaics - Fixed Tilt

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ $203 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*): Without Transmission - $75 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $3750 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$19.70 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Good: Southern Manitoba has solar DNI values of approximately 75% that of central California.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
0%	10%	50%	40%	0%

Environmental Characteristics

Solar Photovoltaics - Fixed Tilt

Impacted Land Area:

GS Footprint – 55 to 60 ha

Additional Impacted Area – None

Total Impacted Area – 55 to 60 ha

Additional Linear Development: Approximately 30 km.

Distance from Load Center: Melita as proxy. 270 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** Negligable HAP emissions.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 29 to 80 kg CO_2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Panel washing	0.04 cu. m/MW.h

Water Pollutants: On-site herbicide use.

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Solar Photovoltaics - Fixed Tilt

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Melita.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	750 Person-Years
Operating Phase	10 FTE
Combined Phases *(over full service life)*	1000 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.4 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.6 million CAD (2012$)/year
Estimated List Total	$1.0 million CAD (2012$)/year

Summary Characteristics

Solar Photovoltaics - Fixed Tilt

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

The falling price trend for PV module costs with rising system efficiencies has continued since 1998 and is projected to extend to 2030. In real terms, it is projected that Total Plant Costs will drop by over 50% by 2020 and 75% by 2030, making this option increasingly competitive in the future.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with energy storage to moderate intermittency.

References

Solar Photovoltaics - Fixed Tilt

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

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Natural Resources Canada (2012). "Photovoltaic Potential and Solar Resource Maps of Canada" Retrieved 2013 02 20. From http://pv.nrcan.gc.ca.

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Solar Photovoltaics - Single Axis Tracking

Resource Type: Renewable - Solar   Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Melita for analysis purposes.

Description:

Photovoltaic (PV) systems are used to convert sunlight into electricity. The most important component of a PV system is the PV module, which is composed of a number of interconnected solar cells. PV modules are connected together into panels and arrays. A solar array is connected to an inverter that converts the Direct Current (DC) generated by the PV array into Alternating Current (AC) compatible with the electricity supplied to or from the grid.

A Single Axis Tracking System is an PV system arrangement that allows multiple rows of solar panels using a single drive unit to track the east-west motion of the sun relative to the earth. This system can increase annual photovoltaic power generation by more than 25% of a simple, fixed-tilt system.

Technical Characteristics

Solar Photovoltaics - Single Axis Tracking

Nameplate Rating: 20 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	20	0	0
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	≈ 46	≈ 46	≈ 46

Capacity Factor Range under Average Flow Conditions: Approximately 26%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Solar Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - cloud cover creates rapid power drop off
- **Seasonality:** Strongly seasonality affected

Maturity of Technology: Proven - anticipate potential efficiency improvements

System Integration Considerations: Intermittency diffcult to forecast contibuting to higher integration costs.

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2
Minimum Time to Earliest ISD *(years)*	3

Typical Asset Life: 20 years

Economic Characteristics

Solar Photovoltaics - Single Axis Tracking

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ $187 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*): Without Transmission - $90 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $4500 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$21.10 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Good: Southern Manitoba has solar DNI values of approximately 75% that of central California.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
30%	30%	30%	10%	0%

Environmental Characteristics

Solar Photovoltaics - Single Axis Tracking

Impacted Land Area:

GS Footprint – 70 to 75 ha

Additional Impacted Area – None

Total Impacted Area – 70 to 75 ha

Additional Linear Development: Approximately 30 km.

Distance from Load Center: Melita as proxy. 270 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** Negligable HAP emissions.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 29 to 80 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Panel washing	0.03 cu. m/MW.h

Water Pollutants: On-site herbicide use.

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Solar Photovoltaics - Single Axis Tracking

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Melita.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	1050 Person-Years
Operating Phase	10 FTE
Combined Phases *(over full service life)*	1300 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.7 million CAD (2012$)/year
Estimated List Total	$1.2 million CAD (2012$)/year

Summary Characteristics

Solar Photovoltaics - Single Axis Tracking

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

The falling price trend for PV module costs with rising system efficiencies has continued since 1998 and is projected to extend to 2030. In real terms, it is projected that Total Plant Costs will drop by over 50% by 2020 and 75% by 2030, making this option increasingly competitive in the future.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with energy storage to moderate intermittency.

References

Solar Photovoltaics - Single Axis Tracking

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

Hazelhurst, Annie (2009). "Economic Analysis of the Solar Industry: Achieving Grid Parity". October 2009.

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U.S. Department of Energy (2010). "Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States, DES 10-59 DOE/EIS-0403". December 2010.

Solar Photovoltaics - Dual Axis Tracking

Resource Type**:** Renewable - Solar | Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Melita for analysis purposes.

Description:

Photovoltaic (PV) systems are used to convert sunlight into electricity. The most important component of a PV system is the PV module, which is composed of a number of interconnected solar cells. PV modules are connected together into panels and arrays. A solar array is connected to an inverter that converts the Direct Current (DC) generated by the PV array into Alternating Current (AC) compatible with the electricity supplied to or from the grid.

Dual axis solar tracking systems follow the sun's trajectory by changing both, the azimuth and the tilt angles, and require two driving motors. They contain more moving parts and are, in general, more expensive than the single axis systems. This system can increase annual photovoltaic power generation by more than 35% of a simple, fixed-tilt system.

Technical Characteristics

Solar Photovoltaics - Dual Axis Tracking

Nameplate Rating: 20 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	20	0	0
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	≈ 49	≈ 49	≈ 49

Capacity Factor Range under Average Flow Conditions: Approximately 28%

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Renewable - Solar Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - cloud cover creates rapid power drop off
- **Seasonality:** Strongly seasonality affected

Maturity of Technology: Proven - anticipate potential efficiency improvements

System Integration Considerations: Intermittency diffcult to forecast contibuting to higher integration costs.

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	2
Minimum Time to Earliest ISD *(years)*	3

Typical Asset Life: 20 years

Economic Characteristics

Solar Photovoltaics - Dual Axis Tracking

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ $193 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*): Without Transmission - $100 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $5000 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$24.60 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Good: Southern Manitoba has solar DNI values of approximately 75% that of central California.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
30%	30%	30%	10%	0%

Environmental Characteristics

Solar Photovoltaics - Dual Axis Tracking

Impacted Land Area:

GS Footprint – 80 to 85 ha

Additional Impacted Area – None

Total Impacted Area – 80 to 85 ha

Additional Linear Development: Approximately 30 km.

Distance from Load Center: Melita as proxy. 270 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** Negligable HAP emissions.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 29 to 80 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Panel washing	0.03 cu. m/MW.h

Water Pollutants: On-site herbicide use.

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Solar Photovoltaics - Dual Axis Tracking

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Melita.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	1150 Person-Years
Operating Phase	10 FTE
Combined Phases *(over full service life)*	1400 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.8 million CAD (2012$)/year
Estimated List Total	$1.3 million CAD (2012$)/year

Summary Characteristics

Solar Photovoltaics - Dual Axis Tracking

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

The falling price trend for PV module costs with rising system efficiencies has continued since 1998 and is projected to extend to 2030. In real terms, it is projected that Total Plant Costs will drop by over 50% by 2020 and 75% by 2030, making this option increasingly competitive in the future.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with energy storage to moderate intermittency.

References

Solar Photovoltaics - Dual Axis Tracking

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

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Solar Parabolic Trough (No Thermal Storage)

Resource Type**:** Renewable - Solar Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Melita for analysis purposes.

Description:

Solar parabolic trough, power plants consists of a large field of single-axis tracking parabolic trough solar collectors. Each solar collector has a linear parabolic-shaped reflector that focuses the sun's direct beam radiation on a linear receiver located at the focus of the parabola. The collectors track the sun from east to west during the day to ensure that the sun is continuously focused on the linear receiver. A heat transfer fluid (HTF) is heated as it circulates through the receiver and returns to a series of heat exchangers in the power block where the fluid is used to generate high-pressure, superheated steam. The superheated steam is then fed to a conventional reheat steam turbine/generator to produce electricity. The spent steam from the turbine is condensed and cooled in a standard condenser and returned to the heat exchangers via condensate and feedwater pumps to be transformed back into steam. After passing through the HTF side of the solar heat exchangers, the cooled HTF is recirculated back through the solar field.

Technical Characteristics

Solar Parabolic Trough (No Thermal Storage)

Nameplate Rating: 50 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	50	0	0
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	≈ 115	≈ 115	≈ 115

Capacity Factor Range under Average Flow Conditions: Approximately 26%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Solar Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - has weather depedent effects
- **Seasonality:** Strongly seasonality affected

Maturity of Technology: Proven - anticipate potential efficiency improvements

System Integration Considerations: Improved integration of solar energy due to control of working fluid circulation.

Technical Challenges: Less efficient than Solar PV due to heat losses from working fluid.

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 30 years

Economic Characteristics

Solar Parabolic Trough (No Thermal Storage)

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ $140 to $187 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Without Transmission - $175 to $250 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $3500 to $5000 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$64.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Good: Southern Manitoba has solar DNI values of approximately 75% that of central California.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
10%	35%	35%	20%	0%

Environmental Characteristics

Solar Parabolic Trough (No Thermal Storage)

Impacted Land Area:

GS Footprint – 200 to 210 ha

Additional Impacted Area – None

Total Impacted Area – 200 to 210 ha

Additional Linear Development: Approximately 30 km.

Distance from Load Center: Melita as proxy. 270 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** Trace VOC & PM from small-scale boiler needed to maintain system temperatures.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 14 to 32 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Cooling & panel washing	Dry tower - 0.4 to 0.8 cu. m/MW.h Wet tower - 2.5 to 8.0 cu. m/MW.h

Water Pollutants: On-site herbicide use. Spills or leaks of water treatment chemicals, heat transfer fluids (i.e. synthethic oil).

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Solar Parabolic Trough (No Thermal Storage)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Melita.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	350 to 450 Person-Years
Operating Phase	30 to 40 FTE
Combined Phases *(over full service life)*	1250 to 1650 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.9 to $1.3 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.4 to $2.0 million CAD (2012$)/year
Estimated List Total	$2.3 to $3.3 million CAD (2012$)/year

Summary Characteristics

Solar Parabolic Trough (No Thermal Storage)

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

Reductions in initial capital and O&M costs are required to make this option more competitive. Research is continuing to make improvments in the performance of heat transfer fluids (i.e. molten salt).

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with energy storage to moderate intermittency.

References

Solar Parabolic Trough (No Thermal Storage)

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

Hazelhurst, Annie (2009). "Economic Analysis of the Solar Industry: Achieving Grid Parity". October 2009.

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University of Michigan, School of Natural Resources and Environment (2010). "Renewable Energy in the California Desert Mechanisms for Evaluating Solar Development on Public Lands". April 2010.

Solar Parabolic Trough (6-hour Thermal Storage)

Resource Type**:** Renewable - Solar   Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Melita for analysis purposes.

Description:

Solar parabolic trough, power plants consists of a large field of single-axis tracking parabolic trough solar collectors. Each solar collector has a linear parabolic-shaped reflector that focuses the sun's direct beam radiation on a linear receiver located at the focus of the parabola. The collectors track the sun from east to west during the day to ensure that the sun is continuously focused on the linear receiver. A heat transfer fluid (HTF) is heated as it circulates through the receiver and returns to a series of heat exchangers in the power block where the fluid is used to generate high-pressure, superheated steam. The superheated steam is then fed to a conventional reheat steam turbine/generator to produce electricity. The spent steam from the turbine is condensed and cooled in a standard condenser and returned to the heat exchangers via condensate and feedwater pumps to be transformed back into steam. After passing through the HTF side of the solar heat exchangers, the cooled HTF is recirculated back through the solar field.

Addition of thermal storage allows this option to provide some dispatchability as it allows the solar plants to provide firm power even during non-solar and cloudy periods. In addition thermal storage also allows the solar field to be oversized to increase the plant's annual capacity factor to about 50%. Thermal storage capability is reported as a number of hours. Currently thermal storage at a solar parabolic trough, power plant range from 3 to 12 hours.

Technical Characteristics

Solar Parabolic Trough (6-hour Thermal Storage)

Nameplate Rating: 50 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	Nominal	Net Winter Peak	Net Summer Peak
	50	0	0
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	≈ 175	≈ 175	≈ 175

Capacity Factor Range under Average Flow Conditions: Approximately 40%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Solar Energy
- **Mode of Operation:** Shaped must-take generation
- **Dispatch & Deployment Speed:** Partially Dispatchable - dependant on availability of TES
- **Intermittency:** Intermittent - shaped with thermal storage
- **Seasonality:** Strongly seasonality affected

Maturity of Technology: Proven - anticipate potential efficiency improvements

System Integration Considerations: Improved integration of solar energy due to control of working fluid circulation.

Technical Challenges: Less efficient than Solar PV due to heat losses from working fluid.

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	3
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 30 years

Economic Characteristics

Solar Parabolic Trough (6-hour Thermal Storage)

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ \$144 to \$175 CAD (2012\$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Without Transmission - \$300 to \$375 million CAD (2012\$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost (\$/kW): \$6000 to \$7500 CAD (2012\$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$68.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Good: Southern Manitoba has solar DNI values of approximately 75% that of central California.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
10%	35%	35%	20%	0%

Environmental Characteristics

Solar Parabolic Trough (6-hour Thermal Storage)

Impacted Land Area:

GS Footprint – 200 to 210 ha

Additional Impacted Area – None

Total Impacted Area – 200 to 210 ha

Additional Linear Development: Approximately 30 km.

Distance from Load Center: Melita as proxy. 270 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** Trace VOC & PM from small-scale boiler needed to maintain system temperatures.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 14 to 32 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Cooling & panel washing	Dry tower - 0.2 to 0.5 cu. m/MW.h Wet tower - 1.8 to 5.3 cu. m/MW.h

Water Pollutants: On-site herbicide use. Spills or leaks of water treatment chemicals, heat transfer fluids (i.e. synthethic oil).

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Solar Parabolic Trough (6-hour Thermal Storage)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Melita.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	350 to 450 Person-Years
Operating Phase	30 to 40 FTE
Combined Phases *(over full service life)*	1250 to 1650 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$1.5 to $1.9 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$2.4 to $3.0 million CAD (2012$)/year
Estimated List Total	$3.9 to $4.9 million CAD (2012$)/year

Summary Characteristics

Solar Parabolic Trough (6-hour Thermal Storage)

Resource Technology Energy Market Externalities
*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

Reductions in initial capital and O&M costs are required to make this option more competitive. Research is continuing to make improvments in the performance of heat transfer fluids (i.e. molten salt) and associated thermal storage.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with additional energy storage to mitigate intermittency.

References

Solar Parabolic Trough (6-hour Thermal Storage)

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U.S. Department of Energy (2010). "Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States, DES 10-59 DOE/EIS-0403". December 2010.

University of Michigan, School of Natural Resources and Environment (2010). "Renewable Energy in the California Desert Mechanisms for Evaluating Solar Development on Public Lands". April 2010.

Generic On-Shore Wind (100 MW)

Resource Type: Renewable - Wind | Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in St. Joseph for analysis purposes.

Description:

Wind power involves capturing the kinetic energy of moving air and converting it into electricity, generally with 3-bladed Danish design wind turbine generator. The rotor blades impart a torque on the hub of the turbine generator which is housed at the top of a tower. A transformer at the base of the tower steps up the voltage from the turbine generator for transmission through an underground distribution system. Typically, 10 to 15 turbines are tied into this underground distribution system which connects to a nearby substation for the entire on-shore wind farm.

Technical Characteristics

Generic On-Shore Wind (100 MW)

Nameplate Rating: 100 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	100	0	10
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	298	351	351

Capacity Factor Range under Average Flow Conditions: 40%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Wind Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - wind speed variability
- **Seasonality:** Some seasonality affect

Maturity of Technology: Well-Established

System Integration Considerations: Intermittency diffcult to forecast contibuting to higher integration costs.

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1-2
Construction Phase: Final Design, Procurement & Construction *(years)*	2-3
Minimum Time to Earliest ISD *(years)*	3-5

Typical Asset Life: 20 years

Economic Characteristics

Generic On-Shore Wind (100 MW)

Levelized Cost (*P_{50} Estimate*):

With Transmission - $67 to $108 CAD (2012$)/MW.h @ 5.05%

Without Transmission ≈ $62 to $99 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Without Transmission - $160 to $300 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $1600 to $3000 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$39.55 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Southern Manitoba has Wind Power Class ranking of Class 3 to 4 . (NREL Wind Power Classification)
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
0%	3%	95%	2%	0%

Environmental Characteristics

Generic On-Shore Wind (100 MW)

Impacted Land Area:

GS Footprint - 15 to 30 ha;

Additional Impacted Area – 1525 to 4570 ha

Total Impacted Area - 1540 to 4600 ha

Additional Linear Development: Average 29 km.

Distance from Load Center: St. Joseph as proxy. 95 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** No direct air emissions while operating.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 8 to 20 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Periodic blade washing	Negligible

Water Pollutants: Almost no risk of water contamination.

Higher Priority Wildlife Species of Interest: Bird and bat collisions

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Generic On-Shore Wind (100 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**
Population centers in vicinity of St. Joseph.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	50 to 120 Person-Years
Operating Phase	6 to 12 FTE
Combined Phases *(over full service life)*	170 to 360 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.8 to $1.5 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.3 to $2.4 million CAD (2012$)/year
Estimated List Total	$2.1 to $3.9 million CAD (2012$)/year

Summary Characteristics

Generic On-Shore Wind (100 MW)

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Very Low

Outlook for Manitoba Hydro:

Utilizing wind for electric power generation has comparatively high capital costs and low capacity factors. As a result, large scale deployment of wind power is currently not economical in Manitoba without some form of incentives or guarantees. Advancements in the design and construction of wind turbine generators, such as individual wind turbines increasing from 1 to 3 MW in size, have the potential for reducing the cost of utility scale wind and may improve its economics in the near future.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with additional energy storage to mitigate intermittency.

References

Generic On-Shore Wind (100 MW)

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

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U.S. Department of Energy (2012). "2011 Wind Technologies Market Report". August 2012.

University of Michigan, School of Natural Resources and Environment (2010). "Renewable Energy in the California Desert Mechanisms for Evaluating Solar Development on Public Lands". April 2010.

Generic On-Shore Wind (65 MW)

Resource Type: Renewable - Wind

Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in St. Joseph for analysis purposes.

Description:

Wind power involves capturing the kinetic energy of moving air and converting it into electricity, generally with 3-bladed Danish design wind turbine generator. The rotor blades impart a torque on the hub of the turbine generator which is housed at the top of a tower. A transformer at the base of the tower steps up the voltage from the turbine generator for transmission through an underground distribution system. Typically, 10 to 15 turbines are tied into this underground distribution system which connects to a nearby substation for the entire on-shore wind farm.

Technical Characteristics

Generic On-Shore Wind (65 MW)

Nameplate Rating: 65 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	65	0	6.5
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	194	228	228

Capacity Factor Range under Average Flow Conditions: 40%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Wind Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - wind speed variability
- **Seasonality:** Some seasonality affect

Maturity of Technology: Well-Established

System Integration Considerations: Intermittency difficult to forecast contributing to higher integration costs.

Technical Challenges: No major impediments

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1-3
Construction Phase: Final Design, Procurement & Construction *(years)*	2
Minimum Time to Earliest ISD *(years)*	3-5

Typical Asset Life: 20 years

Economic Characteristics

Generic On-Shore Wind (65 MW)

Levelized Cost (*P_{50} Estimate*):

With Transmission - $83 CAD (2012$)/MW.h @ 5.05%

Without Transmission ≈ $78 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*): Without Transmission - $156 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $2400 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$39.55 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Southern Manitoba has Wind Power Class ranking of Class 3 to 4 . (NREL Wind Power Classification)
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
0%	3%	95%	2%	0%

Environmental Characteristics

Generic On-Shore Wind (65 MW)

Impacted Land Area:

GS Footprint – 10 to 20 ha

Additional Impacted Area – 990 to 2980 ha

Total Impacted Area – 1000 to 3000 ha

Additional Linear Development: Average 29 km.

Distance from Load Center: St. Joseph as proxy. 95 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** No direct air emissions while operating.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 8 to 20 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Periodic blade washing	Negligible

Water Pollutants: Almost no risk of water contamination.

Higher Priority Wildlife Species of Interest: Bird and bat collisions

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Generic On-Shore Wind (65 MW)

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**
Population centers in vicinity of St. Joseph.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Positive

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	35 to 80 Person-Years
Operating Phase	4 to 8 FTE
Combined Phases *(over full service life)*	120 to 240 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.7 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$1.1 million CAD (2012$)/year
Estimated List Total	$1.8 million CAD (2012$)/year

Summary Characteristics

Generic On-Shore Wind (65 MW)

Resource Technology Energy Market Externalities

*(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Very Low

Outlook for Manitoba Hydro:

Utilizing wind for electric power generation has comparatively high capital costs and low capacity factors. As a result, large scale deployment of wind power is currently not economical in Manitoba without some form of incentives or guarantees. Advancements in the design and construction of wind turbine generators, such as individual wind turbines increasing from 1 to 3 MW in size, have the potential for reducing the cost of utility scale wind and may improve its economics in the near future.

Regulatory Environment: Must be compatible with local land use plans.

Option Enhancement Opportunities: Combine with additional energy storage to mitigate intermittency.

References

Generic On-Shore Wind (65 MW)

Deutsche Bank Group (2011). "The 2011 Inflection Point for Energy Markets: Health, Safety, Security and the Environment. DB Climate Change Advisors." May 2011.

E3 Energy+Environmental Economics (2012). "WECC capital Cost Recommendations". Prepared for the Western Electricity Coordinating Council. June 2012.

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U.S. Department of Energy (2012). "2011 Wind Technologies Market Report". August 2012.

University of Michigan, School of Natural Resources and Environment (2010). "Renewable Energy in the California Desert Mechanisms for Evaluating Solar Development on Public Lands". April 2010.

Generic In-Lake Wind

Resource Type: Renewable - Wind Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Lake Manitoba for analysis purposes.

Description:

The main differences between offshore and onshore wind turbines are size and foundation requirements. The high cost of offshore wind turbine foundations and sea or lake bottom electric cables results in offshore wind turbines being typically larger than their onshore counterparts as they take advantage of economies of scale. In most cases, submerged cables connect the wind turbines within a project to an offshore substation and from the substation to the mainland. Worldwide, offshore wind farms are currently installed at distances from shore ranging from 0.8 km to 20 km.

Technical Characteristics

Generic In-Lake Wind

Nameplate Rating: 100 MW

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	100	0	10
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	302	377	377

Capacity Factor Range under Average Flow Conditions: 43%

Power Generation Flexibility:

- **Fuel Type:** Renewable - Wind Energy
- **Mode of Operation:** Must-take generation
- **Dispatch & Deployment Speed:** Non-Dispatchable
- **Intermittency:** Intermittent - wind speed variability
- **Seasonality:** Some seasonality affect

Maturity of Technology: Demonstration Stage - lack of North American experience

System Integration Considerations: Intermittency difficult to forecast contributing to higher integration costs.

Technical Challenges: Mitigation of seasonal ice flow consequences

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	2-3
Construction Phase: Final Design, Procurement & Construction *(years)*	2-3
Minimum Time to Earliest ISD *(years)*	4-6

Typical Asset Life: 20 years

Economic Characteristics

Generic In-Lake Wind

Levelized Cost (P_{50} *Estimate*):

With Transmission - $140 to $233 CAD (2012$)/MW.h @ 5.05%

Without Transmission ≈ $132 to $225 CAD (2012$)/MW.h @ 5.05%

Base Estimate (P_{50} *Estimate*):

Without Transmission - $400 to $760 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW): $4000 to $7600 CAD (2012$)/kw

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2012

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$74.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Very Good: Large Manitoba lakes may have Wind Power Class ranking of Class 5 to 6. (NREL Wind Power Classification)
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Very High

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
30%	30%	30%	10%	0%

Environmental Characteristics

Generic In-Lake Wind

Impacted Land Area:

GS Footprint – not determined

Additional Impacted Area – 2000 to 4000 ha

Total Impacted Area – 2000 to 4000 ha

Additional Linear Development: Approximately 125 km.

Distance from Load Center: Lake Manitoba as proxy. 125 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** No direct air emissions while operating.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 10 to 15 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Periodic blade washing	Negligible

Water Pollutants: Almost no risk of water contamination.

Higher Priority Wildlife Species of Interest: Bird and bat collisions

Long Term Legacy Issues: Restoration of lake bottom.

Socio-Economic Characteristics

Generic In-Lake Wind

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:**
Population centers bordering Lake Manitoba.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Neutral

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	140 to 240 Person-Years
Operating Phase	27 to 38 FTE
Combined Phases *(over full service life)*	680 to 1000 Person-Years

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$2.0 to $3.8 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$3.2 to $6.1 million CAD (2012$)/year
Estimated List Total	$5.2 to $9.9 million CAD (2012$)/year

Summary Characteristics

Generic In-Lake Wind

Resource Technology Energy Market Externalities

(Published analysis by Deutsche Bank Climate Change Advisors):

Health Concerns: Low

Safety Concerns: Very Low

Energy Security Concerns: Very Low

Environmental Concerns: Very Low

Outlook for Manitoba Hydro:

There are currently no offshore wind farms installed in North America.

Regulatory Environment: Largely unknown but compliance with the Fisheries and Navigable Waters Protection Acts is fundamental.

Option Enhancement Opportunities: Combine with additional energy storage to mitigate intermittency.

References

Generic In-Lake Wind

BC Hydro (2012). "BC Hydro Draft 2012 Integrated Resource Plan: 2010 Resource Options Report Resource Options Database (RODAT) Summary Sheets" June 2012.

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U.S. Department of Energy (2012a). "U.S. Offshore Wind Market and Economic Analysis". Prepared by Navigant Consulting. November 2012.

Enhanced Geothermal System Generation

Resource Type**:** Renewable - Geothermal Level of Study: Stage 1 - Inventory

Location:

Proxy project sited in Birtle for analysis purposes.

Description:

Enhanced Geothermal Systems (EGS) utilizes the Earth's thermal energy by extracting heat from circulating, high temperature groundwater pumped from deep rock fractures. A typical EGS system extracts heat by drawing groundwater from a production well and returns cooler groundwater back into the producing formation through an injection well. A production well returns either hot water to a power plant where a turbine can be driven to generate electricity. This is done using conventional steam turbine technology. Although the production and injection wells are not directly connected, they are linked through underground permeability of the rock and enhanced ("fracked") transmissibility of rock fractures. Optimum extraction is usually achieved in wet formations, rather than hot dry rock. Generally, the overall thermal extraction process begins at depths between 2 and 10 km below the Earth's surface.

Technical Characteristics

Enhanced Geothermal System Generation

Nameplate Rating: 2 MW (electrical) and 20 MW (heating) from a 3 well system (2 production & 1 injection).

Capacity and Energy (*at Plant*):

CAPACITY *(MW)*	**Nominal**	**Net Winter Peak**	**Net Summer Peak**
	1.9	1.9	1.9
NET SYSTEM ENERGY *(GW.h/year)*	**Under Dependable Flow Conditions**	**Under Average Flow Conditions**	**Under Maximum Flow Conditions**
	15	15	15

Capacity Factor Range under Average Flow Conditions: 90%

<u>Power Generation Flexibility</u>:

- **Fuel Type:** Renewable - Geothermal Energy
- **Mode of Operation:** Baseload
- **Dispatch & Deployment Speed:** Dispatchable - Slow (in hours)
- **Intermittency:** None
- **Seasonality:** None

Maturity of Technology: Well Established Elsewhere

System Integration Considerations: Easily integrated

Technical Challenges: Deep drilling required in Manitoba

Project Lead Time:

Planning Phase: Investigations, Development Arrangements, Preliminary Design & Approvals *(years)*	1
Construction Phase: Final Design, Procurement & Construction *(years)*	30
Minimum Time to Earliest ISD *(years)*	4

Typical Asset Life: 20 years

Economic Characteristics

Enhanced Geothermal System Generation

Levelized Cost (*P_{50} Estimate*):

Without Transmission ≈ $294 to $437 CAD (2012$)/MW.h @ 5.05%

Base Estimate (*P_{50} Estimate*):

Without Transmission - $50 to $75 million CAD (2012$)

Expected Accuracy Range of Cost Estimate: -50% to +100%

Overnight Capital Cost ($/kW):

$25,000 to $37,500 CAD (2012$)/kw (for electrical generation only)

Estimate Classification:

Manitoba Hydro Planning Stage	Stage 1 - Inventory
AACEI Estimate Classification	Class 5

Estimating Technique: Analogy

Year of Current Estimate: 2013

Average Lifetime Operations and Maintenance Costs:

Fixed O&M Costs	$66.00 CAD (2012$)/kW/year
Variable Non-fuel O&M Costs	$0.00 CAD (2012$)/MW.h/year

Fuel Supply Description:

- **Source:** Locally-sourced fuel
- **Quality:** Fair: Average Manitoba geothermal heat flows at or near North American averages. Some areas in the SW corner of Manitoba have higher heat flows.
- **Supply Risk:** None
- **Commodity Pricing Trends:** Post-2001 Fuel Price Volatility - None
- **Transportation Pricing Trends:** None
- **Price Forecast:** None

REC Premium Marketability: Moderate

Construction Period Cash Flows by Percentage:

ISD -11 to -20	ISD -7 to -10	ISD -6	ISD -5	ISD -4
0%	0%	0%	0%	0%
ISD -3	**ISD -2**	**ISD -1**	**ISD**	**ISD +1 to +3**
30%	30%	30%	10%	0%

Environmental Characteristics

Enhanced Geothermal System Generation

Impacted Land Area:

GS Footprint – not determined

Additional Impacted Area – not determined

Total Impacted Area – not determined

Additional Linear Development: Approximately 260 km.

Distance from Load Center: Birtle as proxy. 260 km

Operating Phase Emissions:

- **Greenhouse Gas Emissions:** None
- **Hazardous Air Pollutant Emissions:** If EGS employs a closed groundwater recirculating system there are virtually no direct air emissions released while operating.

Typical Life Cycle Emissions for Resource Technology:

- **Greenhouse Gas Emission Range:** 20 to 57 kg CO2e/MWh

Water Consumption Rates:

Reason for Water Demand	Estimated Demand
Not determined	Not determined

Water Pollutants: Surface spills or leaks of saline groundwater are possible.

Higher Priority Wildlife Species of Interest: Terrestrial habitat disturbance. Species not determined

Long Term Legacy Issues: Restoration of native plant communities after service life.

Socio-Economic Characteristics

Enhanced Geothermal System Generation

Nearby Population Centers (with more than 75 permanent residents within 100 km)**:** Population centers in vicinity of Birtle.

Resource Management Area: Not applicable

Existing Agreements: None

Aboriginal Participation Interest: Neutral

Independent Power Producer (IPP) Interest: Negative

Manitoba Sourced Fuel: Manitoba-based fuel

Estimated Direct Employment:

Construction Phase *(2000 hrs per PY basis)*	Not Determined
Operating Phase	60 to 170 FTE
Combined Phases *(over full service life)*	Not Determined

In-Province Employment Opportunities *(Relative to Wuskwatim):*

Manitoba Employment	Less
Northern Manitoba Employment	Less
Aboriginal Employment	Less

In-Province Business Opportunities *(Relative to Wuskwatim):*

Manitoba Purchases	Less
Northern Manitoba Purchases	Less
Aboriginal Business Purchases	Less

Provincial Development Revenue:

Carbon Shadow Price $10/tonne of GHG forecast	None
Coal Emission Tax (equivalent to $10/tonne of GHG)	None
Estimated Capital Taxes	$0.3 to $0.4 million CAD (2012$)/year
Estimated Provincial Guarantee Fee	$0.4 to $0.6 million CAD (2012$)/year
Estimated List Total	$0.7 to $1.0 million CAD (2012$)/year

Summary Characteristics

Enhanced Geothermal System Generation

Resource Technology Energy Market Externalities *(Published analysis by Deutsche Bank Climate Change Advisors)***:**

Health Concerns: Very Low

Safety Concerns: Low

Energy Security Concerns: Very Low

Environmental Concerns: Low

Outlook for Manitoba Hydro:

Temperatures suitable for electrical energy generation (>150 degress C) would require deep drilling to depths of 6km in the very south western corner of Manitoba and down to 7km depth in a larger area east – south east of Brandon. Geothermal gradients in Manitoba result in deep and expensive drilling costs. Manitoba Hydro's consultant, Dr. Jacek Majorowicz, has estimated that the drilling and fracturing component costs for a 3-well system (1 injection + 2 production) to be in the order of $44M to $68M CAD (2012$). To date, EGS in hot, dry rock resources have not been developed commercially in the United States.

Regulatory Environment: Protection of surface and fresh water aquifers from saline intrusion.

Option Enhancement Opportunities: Advancements in drilling technology.

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Enhanced Geothermal System Generation

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APPENDIX A – RESOURCE OPTIONS DATABASE DEFINITIONS

	Field Name	Sub-Field Name	Definition
Introductory Characteristics	Resource Type		Is described by one the following terms: Demand Side Management; Energy Imports; Hydro-electric; Renewable – Geothermal; Renewable – Solar; Renewable - Wind; Thermal - Biomass-fired; Thermal - Coal-fired; Thermal - Natural Gas-fired; Thermal - Nuclear; or Thermal - Syngas-fired.
	Level of Study		Is described by one of the following terms: Stage I - Inventory; Stage II - Feasibility; Stage 3 - Concept; Stage IV - Pre-Investment; or Stage V - Design Construction & Commissioning.
	Location		Is a brief description of the location of the site or the site proxy for each resource option
	Reach of River		Is used in Hydro Options only and selected from the following list: Burntwood River; Lower Nelson River; Upper Churchill River; Upper Nelson River; or Winnipeg River.
	Description		Is a brief description of a resource option's design or its basic process components.
Technical Characteristics	Nameplate Rating		Is the maximum rated output of a resource option under specific conditions designated by the manufacturer and is expressed in megawatts (MW).
	Capacity	Nominal Capacity	Is the approximate energy producing capacity of a power plant, reported in MW, under specified conditions, usually during periods of highest load.
		Net Winter Peak Capacity	Represents an option's peak capability, reported in MW, under typical winter conditions (typically January). Capacity losses at other plants are netted off against capacity increases from the new option.
		Net Summer Peak Capacity	Represents an option's peak capability, reported in MW, under typical summer conditions (typically July). Capacity losses at other plants are netted off against capacity increases from the new option.
	Net System Energy	Under Dependable Flow Conditions	Represents the energy that a specific hydro option could produce during flows equivalent to the lowest flows of record which corresponds to approximately to the August, 1939 to March, 1941 time period. For non-hydro options this represents the energy that would be required or could be produced under those same conditions. Thermal resources are assumed to operate to their full potential, net of forced outages and maintenance for dependable energy requirements. This metric is reported in units of GW.h/year.
		Under Average Flow Conditions	Represents the energy that a specific hydro option could produce annually during flows equivalent to the average from the full 99-year range of historic flows. For non-hydro options this represents the energy that would be required or could be produced under those same conditions. Currently, thermal resources are assumed to operate at their minimum under average flow conditions. This metric is reported in units of GW.h/year.
		Under Maximum Flow Conditions	Represents the energy that a specific hydro option could produce annually during flows equivalent to the maximum historic flows (2005/06 equivalent). For non-hydro options this represents the energy that would be required or could be produced under those same conditions. Thermal resources are assumed to operate at their minimum under maximum flow conditions. This metric is reported in units of GW.h/year.
	Average Capacity Factor		Reported for Hydro Options only and is the ratio of actual energy produced by an energy generating resource option annually, to the hypothetical maximum possible energy produced during continuous operation. This metric is expressed in terms of percentages.
	Capacity Factor Range under Average Flow Conditions		Is used in the Thermal and the Alternative Energy Options and is the range of ratios of actual energy produced by an energy generating resource option annually, to the hypothetical maximum possible energy produced during continuous operation. In a predominantly hydro system, stream flows can impact the need for non-hydro resource options. This metric is expresses the range of annual Capacity Factors over the asset life of an option that demanded or delivered to the system. It is reported in percentages.
	Full Supply Level		Is the elevation, in metres above sea level, of the normal maximum controlled level of the forebay (reservoir) and is reported for Hydro Options only.
	Gross Head		Reported for Hydro Options only and is the difference in elevation between FSL and the tailwater elevation for open water conditions and all units operating at the Plant Discharge Capacity.

	Field Name	Sub-Field Name	Definition
Technical Characteristics (continued)	Expected Average Flow		Reported for Hydro Options only and is the average of simulated historical flows from the SPLASH system model for 99-years of monthly flows which are capped by the Plant Discharge Capacity.
	HHV Heat Rate		Is used in Thermal Options only and represents the higher heating value (HHV) of the amount of fuel input (in BTUs) required to generate one kWh of electrical energy. BTU/kWh can be converted to kJ/kWh by multiplying by 1.054.
	Power Generation Flexibility	Fuel Type	Is described by one the following terms: Non-Renewable - Coal; Non-Renewable - Natural Gas; Non-Renewable - Radioactive or fissile materials ; Non-Renewable - Synthetic Gas Derived from Coal; Predominantly Coal-based; Renewable - Agricultural Crop Residue Biomass; Renewable - Geothermal Energy; Renewable - Solar Energy; Renewable - Water; Renewable - Wind Energy; or Renewable - Wood Waste Biomass.
		Dispatch & Deployment Speed	Is described by one the following terms: Dispatchable – Fast (in seconds); Dispatchable – Medium (in minutes); Dispatchable – Slow (in hours); or Not Dispatchable.
		Intermittency	Characterizes any energy supply option that is not continuously available due to factors beyond the operator's direct control and cannot be dispatched to meet the demand of a power system. This metric indicates if an option is intermittent or not and briefly describes the causes of an option's intermittency.
		Seasonality	Correlates to seasonal weather patterns and their affect on a resource option's fuel availability and can be measured by the difference between winter and summer peak capacities. It Is described by one the following terms: Strongly Seasonality Affected with a > 51% differential; Seasonality Affected with a 35% to 50% differential; Some Seasonality with a 21% to 34% differential; Little Seasonality with a 11% to 20% differential; or Trace Seasonality with a 0% to 10% differential.
	Maturity of Technology		Represents the stage of technological development for each option, commencing with research and advancing to option deployment. It Is described by one the following terms: Conceptual; Development Stage; Demonstration Stage; Proven; Well Established Elsewhere; or Well Established.
	System Integration Considerations		Corresponds to the ease or the complexity of integrating a specific resource option into Manitoba Hydro's existing system and provides a brief description of integration challenges of an option if present.
	Technical Disadvantages		Characterizes the degree to which a resource option, sited in Manitoba, brings with it large technical challenges and a corresponding need for a large number of specialists to maintain facility operations. If present, a brief description of an option's technical difficulties is provided.
	Project Lead Time	Planning Phase	Estimates the lead time (in years) necessary for the Planning Phase which includes investigations, development arrangements, preliminary design and regulatory approvals.
		Construction Phase	Estimates the lead time (in years) necessary for the Construction Phase which includes final design, procurement and construction.
		Years to Earliest ISD	Represents the number of years necessary to achieve the earliest In-Service Date. It is estimated by adding the lead time estimates for the Planning and Construction Phases.
	Typical Asset Life		Represents the actual number of years of operating or service life that can be expected from a resource option.
Economic Characteristics	Levelized Cost (P50 Estimate)		The present value of the net cost (including capital, operating costs and any other fixed and variable costs) of a particular generation alternative divided by the present value of the average energy produced by that generation alternative over its economic life, expressed in constant Canadian Dollars (CAD) per megawatt hour and linked to a given year.
	Base Estimate (P50 Estimate)		Estimate of project cost with added contingency to obtain a certain confidence level of not overrunning the budget (P50, 50% chance of being over or under). Values are expressed in constant Canadian Dollars (CAD) and are linked to a given year.
	Expected Accuracy Range of Cost Estimate		Represents the anticipated range of accuracy for projects at different stages of development for the estimated base cost. The ranges are as follows: Stage 1 from ±50% to ±40%; Stage 2 from ±40% to ±30%; Stage 3 from ±30% to ±20%; Stage 4 from ±20% to ±10%; and Stage 5 < ±10%.
	Overnight Capital Cost		Describes the cost of building a power plant overnight not including financing costs or escalation. It is reported in units of $/kW expressed in constant Canadian Dollars (CAD) linked to a given year.

	Field Name	Sub-Field Name	Definition
Economic Characteristics (continued)	Estimate Classification	Manitoba Hydro Planning Stage	Is described by one the following terms: Stage 1 – Inventory; Stage 2 – Feasibility; Stage 3 – Concept; Stage 4 - Pre-Investment; or Stage 5 - Design Construction & Commissioning
		AACEI Estimate Classification	Is described by one the following terms: Class 5 - Concept Screening; Class 4 - Study or Feasibility; Class 3 - Budget Authorization or Control; Class 2 - Control or Bid/Tender; or Class 1 - Check Estimate or Bid/Tender.
	Estimating Technique		Is described by one of the following terms: Detailed; Equipment Factored; Parametric; Analogy; or Scaled Operations.
	Year of Current Estimate		Indicates the year the capital cost estimate was made or updated.
	Average Lifetime Operations and Maintenance Costs	Fixed O&M Costs	Typically includes items that do not vary significantly with generation such as general and administration expenses, staffing expenditures, plant support equipment costs and routine maintenance. Values are reported as an annual average cost over the lifetime of the resource and reported in units of CAD (2012$)/kW/year.
		Variable Non-fuel O&M Costs	Typically includes costs that vary with electrical generation such as raw water treatment, disposal of wastes, chemicals, catalysts, lubricants and other consumables. Fuel costs are not imbedded in this metric. This category is reported in units of CAD (2012$)/MW.h/year based on the capacity factor assumptions for a specific resource option.
	Fuel Supply Description	Source	Represents the likely fuel supply source either as a locally-sourced fuel or a fuel imported from another province or state.
		Quality	Is rated based on a subjective evaluation considerations such as renewability, abundance and variability. Additional description may also be included.
		Supply Risk	Briefly describes an important factor that could adversely impact reliable fuel supply for a resource option.
		Commodity Pricing Trends	Is represented by a fuel's post-2001 price volatility and is described in terms of high, medium, low or none.
		Transportation Pricing Trends	Briefly describes an important factor that could adversely impact fuel supply pricing for a resource option.
		Price Forecast	Is the fuel price forecast expressed in constant Canadian Dollars (CAD) and linked to a given year. This metric is used to calculate the Levelized Cost (P50 Estimate) value.
	REC Premium Marketability		Represents the Renewable Energy Credit (REC) potential and is expressed in terms of Very High; High; Moderate; Low; or No Premium.
	Construction Period Cash Flows by Percentage	ISD -11 TO -20	Represents the total percentage of the construction period cash flows expended in years ISD -11 to ISD -20.
		ISD -7 TO -10	Represents the total percentage of the construction period cash flows expended in years ISD -7 to ISD -10.
		ISD -6	Represents the total percentage of the construction period cash flows expended in year ISD -6.
		ISD -5	Represents the total percentage of the construction period cash flows expended in year ISD -5.
		ISD -4	Represents the total percentage of the construction period cash flows expended in year ISD -4.
		ISD -3	Represents the total percentage of the construction period cash flows expended in year ISD -3.
		ISD -2	Represents the total percentage of the construction period cash flows expended in year ISD -2.
		ISD -1	Represents the total percentage of the construction period cash flows expended in year ISD -1.
		ISD	Represents the total percentage of the construction period cash flows expended in the first unit In-Service Date ("ISD") year.
		ISD +1 TO +3	Represents the total percentage of the construction period cash flows expended in years ISD +1 to ISD +3.

	Field Name	Sub-Field Name	Definition
Environmental Characteristics	Impacted Land Area		Reported as hectares (or square kilometres) of land directly impacted by the footprint of a generating facility and any associated flooded areas. Indirectly impacted lands are those areas the beyond primary impacted areas having additional land use restrictions or limitations and are included in estimates of the Total Project Area.
	Flooded Area Intensity		Is used in Hydro Options only and an option's flooded area divided by its nameplate capacity. It is reported in units of ha/MW.
	Total Reservoir Area		Is used in Hydro Options only and is reported in units of square kilometres.
	Additional Linear Development		Represents an option's required linear development including transmission lines, roads or pipelines and is reported in kilometres.
	Distance from Load Center		This metric is a proxy for many issues from length of transmission right-of-ways, associated transmission losses and an option's degree of "remoteness" which impacts construction costs. Load center distance is estimated in units of kilometres from the generating facility site to the Dorsey Converter Station.
	Operating Phase Emissions	Description	Is a brief description used with Thermal Options that describe the operating phase conditions that result in air emissions.
		Greenhouse Gas Emissions	Is an estimate of the GHG emission rate produced at full load during average flow conditions. It is reported in units of kg of CO2e per MW.h.
		Hazardous Air Pollutant Emissions	Is used to describe Hazardous Air Pollutants (HAPs) if emitted during the operational phase of either a Hydro or Alternative Energy Option.
		HAPs - NOx	Is used in the Thermal Options only and Is an estimate of the NOx emission rate produced at full load during average flow conditions. It is reported in units of kg of NOx per MW.h.
		HAPs - CO	Is used in the Thermal Options only and Is an estimate of the carbon monoxide (CO) emission rate produced at full load during average flow conditions. It is reported in units of kg of CO per MW.h.
		HAPs -SOx	Is used in the Thermal Options only and Is an estimate of the SOx emission rate produced at full load during average flow conditions. It is reported in units of kg of SOx per MW.h.
		HAPs - PM10	Is used in the Thermal Options only and Is an estimate of the emission rate of fine particulate matter less than 10 microns in size (PM10) produced at full load during average flow conditions. It is reported in units of kg of PM10 per MW.h.
		HAPs - Hg	Is used in the Thermal Options only and Is an estimate of the mercury emission rate produced at full load during average flow conditions. It is reported in units of kg of Hg per MW.h.
	Typical Life Cycle Emissions for Resource Technology	Greenhouse Gas Emission Range	Provides the 25th to 75th percentile range of Life Cycle GHG emissions for an option's resource technology category as obtained from an external literature review. This metric is measured in units of kg of CO2e per MW.h.
	Water Consumption Rates	Reason for Water Demand	Is a brief description of the processes requiring water and is only used in the Thermal and the Alternative Energy Options.
		Estimated Demand	Is an estimate of the water consumption rate and is only used in the Thermal and the Alternative Energy Options. It is reported in units of cubic metres per MW.h.
	Water Pollutants		Is a brief description of types of contaminants that may be released in either the surface or ground water during facility operations.
	Water Pollutant Release Potential	As	Defines the overall risk potential for the release of Arsenic (As) during facility operations and Is used in Thermal Options only. Release potential is described by one of the following terms: None; Negligible; Low; Moderate; or High.
		Se	Defines the overall risk potential for the release of Selenium (Se) during facility operations and Is used in Thermal Options only. Release potential is described by one of the following terms: None; Negligible; Low; Moderate; or High.
		Oxygen Scavengers	Defines the overall risk potential for the release of oxygen scavenging chemicals during facility operations and Is used in Thermal Options only. Release potential is described by one of the following terms: None; Negligible; Low; Moderate; or High.
		Thermal Plume	Defines the overall risk potential for the release of a thermal plume in a body of water during facility operations and Is used in Thermal Options only. Release potential is described by one of the following terms: None; Negligible; Low; Moderate; or High.
	Solid Waste Production Rate		Is reported for Thermal Options only as a brief description of the type of bulk waste with the greatest concern and an estimated quantity.

	Field Name	Sub-Field Name	Definition
	Higher Priority Wildlife Species of Interest		Is a non-exhaustive list of selected species, including valued environmental components, species-at-risk or of concern that may be impacted at sited, resource options. Also indicates potential impacts for non-sited options having a large footprint or indicates the need for a site specific review for non-sited, small footprint options.
	Long Term Legacy Issues		Is a brief description of remaining issues that will require appropriate remedial actions at the end of asset life.
Socio-Economic Characteristics	Nearby Population Centers		Either lists or describes nearby population centers having more than 75 permanent residents and located within a 100 km radius of a site or a proxy site.
	Resource Management Area		Lists the potentially affected Resource management Area (RMA) or Registered Trap Lines (TRL) from the following list: Cross Lake RTL Zone; Fox Lake RMA; Nelson House RMA; Pukatawagan RTL Zone; Shamattawa RTL Zone; Split Lake RMA; and York Factory RMA. Hydro developments in northern Manitoba are mainly affected.
	Existing Agreements		Lists important, in-place agreements that may impact Manitoba Hydro's development of an option.
	Aboriginal Participation Interest		Is a speculative estimate about potential interest selected from the following list: Positive; Neutral; or Negative.
	Independent Power Producer Interest		Is a speculative estimate about potential interest selected from the following list: Positive; Neutral; or Negative.
	Manitoba Sourced Fuel		Indicates if the fuel for the resource option is derived from within the province or if it is imported from another province or state.
	Estimated Direct Employment	Construction Phase	Is the size of the construction force required to construct the project consistent with the P50 estimate for this resource option. The value of this metric is reported in units of person-years (PY). A PY is equal to one person working 2200 hours per year on-site or 1853 hours per year off-site.
		Operating Phase	Is the annual staffing requirement needed to operate the facility. The value of this metric is reported in units of Full-Time Equivalents (FTE).
		Combined Phases (over full service life)	Is reported in units of person-years (PY) and is equal to the sum of construction phase estimated direct employment plus the product of the operating phase estimated direct employment (in FTEs) times the typical asset life (in years).
	In-Province Employment Opportunities	Manitoba Employment	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.
		Northern Manitoba Employment	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.
		Aboriginal Employment	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.
	In-Province Business Opportunities	Manitoba Purchases	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.
		Northern Manitoba Purchases	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.
		Aboriginal Business Purchases	Compares a resource option's opportunity potential to that of Wuskwatim's reported values. Estimates within ± 25% of Wuskwatim are considered "Similar " to Wuskwatim. The following terms are used for this metric: More; Similar; or Less.

	Field Name	Sub-Field Name	Definition
	Provincial Development Revenues	Water Rentals Under Average Flows	An estimate of the fees paid to the province for generating electricity from water based resources at average flow conditions and at the rate of $3.3426/MW.h. It is presented in equivalent annual payments for a resource.
		Carbon Shadow Price	In lieu of a regulated carbon pricing framework, this is an estimated "shadow price" used in estimating levelized costs or potential provincial development revenues. It is reported in units of $ per tonne of CO2e emitted.
		Coal Emission Tax	Manitoba's Emissions Tax on Coal Act levies a tax of $17.37 per tonne of sub-Bituminous coal burned. This is the equivalent of $9.40/tonne of CO2e emitted and is calculated on that basis for the potential range of energy generated annually from coal-fired generation.
		Estimated Capital Tax	A simplified estimate of capital taxes paid to the province associated with resource development and is based on total capital expenditures and a rate of 0.5%. It is presented in annual payment for a resource.
		Estimated Provincial Guarantee Fee	A simplified estimate of fees paid to the province for guaranteeing debt associated with resource development and is based on total capital expenditures. It is presented in annual payment for a resource.
		Estimated List Total	Is a sum of the following values, if applicable: Water rentals under Average Flows; Shadow Carbon Price; Coal Emission Tax; Estimated Capital Tax; and Estimated Provincial Guarantee Fee.
Summary Characteristics	Resource Technology Energy Market Externalities	Health Concerns	Represents the degree of concern for health-based market externalities as assessed by the Deutsche Bank Climate Change Advisors. This includes broad issues such as breathing disorders, radiation exposure, cancers, heavy metals inhalation or ingestion and vibration health affects. The degree of concern is described by one of the following terms: Very High; High; Medium; Low; or Very Low.
		Safety Concerns	Represents the degree of concern for safety-based market externalities as assessed by the Deutsche Bank Climate Change Advisors. This includes broad issues such as fuel explosions, nuclear failures, unintentional spills or releases, floods and earthquakes. The degree of concern is described by one of the following terms: Very High; High; Medium; Low; or Very Low.
		Energy Security Concerns	Represents the degree of concern for energy security-based market externalities as assessed by the Deutsche Bank Climate Change Advisors. This includes broad issues such as fuel supply abundance or limits, construction materials feedstock limits, terrorism and military costs. The degree of concern is described by one of the following terms: Very High; High; Medium; Low; or Very Low.
		Environment Concerns	Represents the degree of concern for environment-based market externalities as assessed by the Deutsche Bank Climate Change Advisors. This includes broad issues such as air emissions, contamination of land or water, water consumption, radiation leaks, spent fuel storage, fish-kills and bird-kills. The degree of concern is described by one of the following terms: Very High; High; Medium; Low; or Very Low.
	Outlook for Manitoba Hydro		Is a brief description of a likely Manitoba Hydro outlook for the development of a specific site; a site proxy; or a specific resource option. This will change as engineering study and industry experience advances.
	Regulatory Environment		Provides a brief description of the regulatory or public policy factors that are currently influencing the development of a resource option.
	Option Enhancement Opportunities		Briefly describes the potential of enhancing the performance of a specific resource option by combining it with another separate technology (i.e. wind with energy storage technology).
	References		Is a list of references used to populate this resource option record.

APPENDIX B - MANITOBA HYDRO STAGES OF DEVELOPMENT

Project Development

Staged Development Process

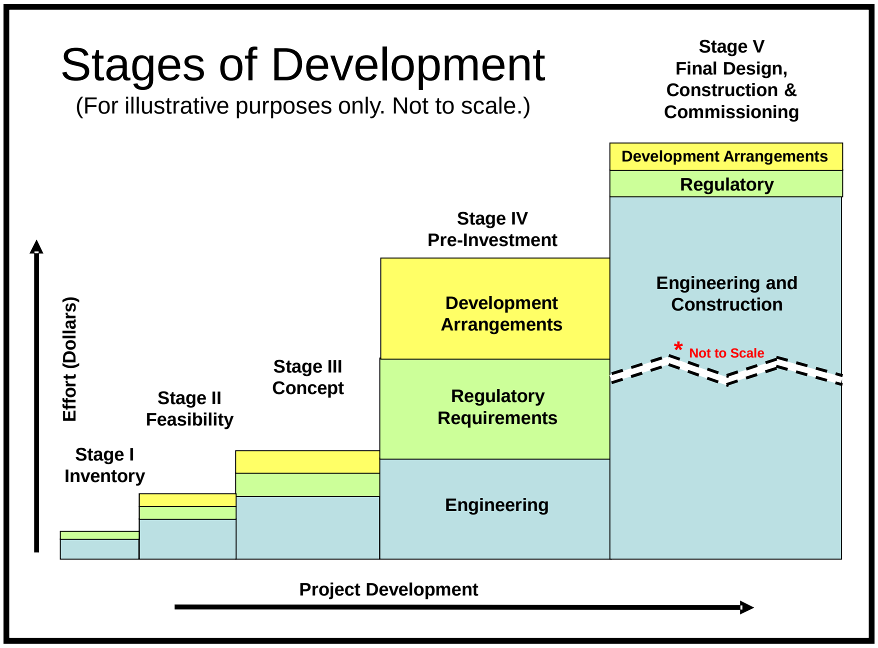
Manitoba Hydro follows the construction industry recognized best practice of using a staged process in planning for and developing new major capital projects. The five stage process provides a structured project planning methodology that brings projects from initial business case to detailed project plan, placing them under increased scrutiny at each stage.

The five stages of the development process are illustrated in Figure B-1 Manitoba Hydro Stages of Development and include the following stages:

- Stage I - Inventory,
- Stage II - Feasibility,
- Stage III - Concept,
- Stage IV - Pre-Investment, and,
- Stage V - Final Design, Construction & Commissioning.

Deliverables specified for a project need to be completed at each stage in order to proceed to the next stage of project development. This process allows for numerous projects to be under consideration at a time. Maintaining an inventory of project options is critical to the evaluation process as different sequences of projects may prove to be more optimal than others depending on the future corporate strategy.

FIGURE B-1 MANITOBA HYDRO STAGES OF DEVELOPMENT



Sustainable development is pursued in all Stages by integrating current economic, environmental, and social considerations. The Stages described here have been in use since the early 1980's and are subject to on-going improvements to adapt them to the best practice of the day. The use of Stages by Manitoba Hydro promotes the efficient development of options by targeting the level of expenditures of cost and effort to the Stage being pursued. As a project advances through each Stage, more effort is expended to refine options. This increases confidence in project characteristics and increases the accuracy of cost estimates.

The Keeyask and Conawapa projects are both in the later phases of the staged development process. Both projects have proceeded past Stage III (of 5 total stages), meaning they are considered primary options for development and licensing activities can begin. With the submission of the EIS, Keeyask has passed Stage IV and is at the beginning of Stage V: Final Engineering & Construction. Conawapa is still in the Stage IV: Pre-Investment phase, with environmental assessment process is on-going. It is at the completion of Stage IV (transition from Stage IV to Stage V) where project sanctioning could occur.

Objectives of Staged Development Process

The objectives of the staged development process are as follows:

- Facilitate comparison amongst all projects under consideration in order to select the most appropriate next new generation source sequence
- Provide a structure that ensures the most appropriate development sequence for new generation sources is selected
- Provide a framework that ensures that deliverables are appropriate to the stage the project is in and that management approvals are obtained before proceeding to the next stage of project development, where increased time and effort will be expended.

Structure of Staged Development Process

Ownership of the staged development process resides with Manitoba Hydro's Executive Committee. They are responsible for advancing projects through the development stages. Within each development stage activities are managed by a multi-disciplinary project management team. Design activities become more detailed and investment is increased as project moves through stages. As such, the composition of this team changes as a project progresses through the development stages.

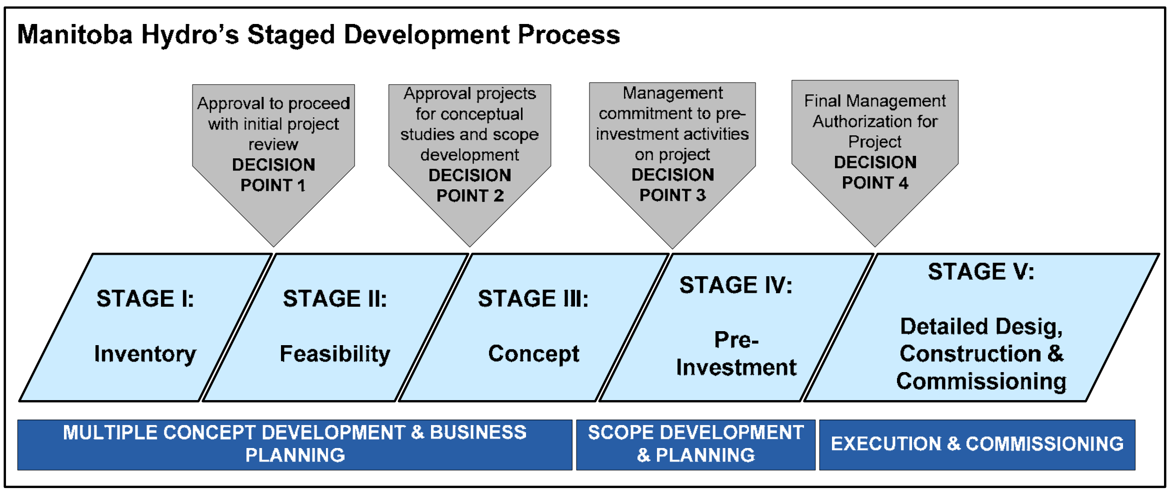
Generally, assuming all required criteria of a stage have been met, movement to the next development stage is driven by resource demands as outlined in Manitoba Hydro's Power Resource Plan and the business case of each specific project. The key decision points within the staged development process are as follows:

- **Decision Point 1:** Decision to progress with feasibility reviews of project alternatives.
- **Decision Point 2:** Decision to progress a specific project (or development sequence) for more detailed analysis and overall concept development.
- **Decision Point 3:** Critical decisions phase where a management commitment is made to pursue pre-investment activities on a specific project or specific development sequence. Approval at Decision Point 3 begins the consultation process and initiates activities to obtain environmental approvals.

- **Decision Point 4:** Critical decisions phase where final management authorization is given to pursue detailed development, construction and commissioning of a specific project or specific development sequence. Final project budget and schedule are established at Decision Point 4 approval.

The staged development process and associated decision points are outlined further in Figure B-2 Manitoba Hydro's Staged Development Process:

FIGURE B-2 MANITOBA HYDRO'S STAGED DEVELOPMENT PROCESS



Stage I – Inventory

The purpose of Stage I is to create an inventory of all potential resource options available, along with key information required to screen them for advancement to Stage II.

Examples of key information identified for hydroelectric options is the location, flow characteristics, potential head, potential capacity, major environmental and social considerations and cost.

Progression to Stage II is based on the generating potential of the project and any potential major environmental and/or First Nations socio-economic issues related to the project.

Stage II – Feasibility

The purpose of Stage II is to prove the feasibility of an option before it is advanced to Stage III.

Multiple variations of locations and configurations of resource options are explored. These variations are evaluated on the basis of energy and capacity costs and their respective environmental and social effects. For hydroelectric options, the fit of the option within the development of other locations on the river is also considered. Nominal amounts of studies are undertaken, most of which are engineering studies. Preliminary field studies and environmental screenings are carried out for issues that may affect the feasibility of the option.

This stage effectively completes the inventory of next plant options. The results of the feasibility assessments from this stage determine which plant studies will be advanced to Stage III.

Stage III – Concept

The purpose of Stage III is to develop alternative concepts for feasible options from Stage II and recommend a preferred concept to advance to Stage IV.

For hydroelectric options the recommendation would include the axis location (within approximately 200m) and the general arrangement of principal structures.

Engineering and field studies are undertaken to evaluate the range of concepts. More thorough assessments of foundation conditions, equipment types and fuel and material sources are undertaken. Environmental and social considerations are integrated into the planning studies to assist in the selection of the preferred concept. Environmental data collection and studies are initiated. Stakeholder interactions and plans for potential development arrangements are begun. Capacity and energy estimates are refined. Construction schedules, cost estimates and cash flows are prepared.

Results of stage III analysis is a determination by management whether or not to make a commitment to pursue the next source of new generation under consideration by advancing it to the next stage of the planning process.

Stage IV – Pre-Investment

The purpose of Stage IV is to advance all facets of the preferred concept so that an investment decision to construct the project can be made.

Studies and field investigations are carried out for the preferred concept to a level of detail that reduces as much uncertainty as practicable. Project parameters are optimized, the concept is finalized, design criteria are set and detail cost estimate is prepared. Environmental assessment studies and measures for mitigating effects are completed. Stakeholders are fully engaged, consultations are carried out, and development arrangements are finalized. Regulatory and licensing processes are initiated and completed by the end of Stage IV.

Some Stage V activities overlap with Stage IV, for example, early involvement of suppliers and contractors to facilitate procurement and contracting strategies. The transitioning and scheduling of Stage IV and Stage V activities are subject to on-going process improvements.

At the end of Stage IV, Manitoba Hydro will be in a position to clearly describe the project in such detail as to comply with all the regulatory and approval requirements. Furthermore, it is at the completion of Stage IV stage where management will provide full authorization to proceed with the final design and construction of the project.

Stage V – Detailed Design, Construction & Commissioning

Stage V includes the final detailed design of the project and all construction & commissioning activities. This is the final stage of project development. Critical activities in Stage V include:

- Finalization of detailed engineering
- Implementation of development arrangements
- Implementation of mitigation, compensation, and environmental monitoring plans Procurement activities on all contracts
- All construction and commissioning activities

At the end of Stage V the new generating asset will be in-service producing power for Manitoba Hydro. Ownership and responsibility for the completed asset is transferred to Operations.

APPENDIX C –AACE COST ESTIMATE CLASSIFICATION SYSTEM

aace International
The Authority for Total Cost Management™

AACE International Recommended Practice No. 69R-12

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE HYDROPOWER INDUSTRY

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. January 25, 2013

Note: As AACE International Recommended Practices evolve over time, please refer to www.aacei.org for the latest revisions.

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January 25, 2013

COST ESTIMATE CLASSIFICATION MATRIX FOR THE HYDROPOWER INDUSTRY

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Table 1 – Cost Estimate Classification Matrix for the Hydropower Industry