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7 Screening of Manitoba Resource Options

7.0 Chapter Overview

Previously***, Chapter 4 – The Need for New Resources*** described how Manitoba Hydro establishes the need for new supply resources in order to meet the electricity demands of Manitoba Hydro's domestic and firm export customers. As part of the resource planning process, Manitoba Hydro monitors a wide range of resource supply options and maintains an inventory of options which are potentially available to meet future Manitoba needs. ***Chapter 7 – Screening of Manitoba Resource Options*** describes the process of screening resource technologies and options and establishes the portfolio of resource options that is used by Manitoba Hydro in determining development plans.

This chapter considers those technologies that are available for utility-scale generation. Detailed information on resource technologies is available in ***Appendix 7.1 Emerging Energy Technology Review*** and ***Appendix 7.2 – Range of Resource Options.***

7.1 Resource Technology Screening

Screening of different resource technologies begins with a high-level review that identifies the resource technologies most suitable for further evaluation. Sixteen resource technologies potentially suitable for utility-scale generation are considered and discussed in this section.

7.1.1 Resource Technology Characteristics

This section provides a general description of 15 characteristics associated with each resource technology.

These characteristics form the basis for the criteria used in screening the full range of resource technologies to a select number for further consideration. A comparative summary of descriptive characteristics for the resource technologies is provided in Table 7.1: Screening Characteristics of Resource Technologies. The characteristics are grouped into the following conventional categories:

- technical
- environmental
- social and policy
- economic.

Table 7.1 SCREENING CHARACTERISTICS OF RESOURCE TECHNOLOGIES

SCREENING CHARACTERISTICS OF RESOURCE TECHNOLOGIES

🟥 Screened Out | 🟨 Some Concern | 🟩 Minimal Concern or Positive

Utility Scale Resource Technologies		Characteristics															Screening Summary
		Technical					Environmental					Social & Policy			Economic		
		Maturity of Technology	Technical Challenges in Manitoba	Ease of Integration into System	Intermittency	Seasonality	Water Quality Impacts	Hazardous Air Pollutants	Greenhouse Gas Emissions	Land Use Impacts	Wildlife Species of Interest	Proximity to Load Center	Regulatory Constraints	Social Acceptability	Manitoba Delivered Fuel Costs	Forecast USA Unit Costs ($/MW.h)	
DSM	Additional DSM	🟩 increasingly customer dependant	🟨 uncertainty in market potential	🟨 unknown	🟨 unknown	🟨 unknown	🟩 program specific	🟩 program specific	🟩 none	🟩 none	🟩 none	🟩 reduction at load centre	🟩 none	🟩 not polled	🟩 no fuel cost	🟨 not included in AEO 2013	✓
Hydro	Hydro with Storage	🟩 >100 years of experience	🟨 long construction schedule	🟩 no issues	🟩 none	🟨 reservoir storage management	🟨 shoreline erosion	🟩 none	🟩 minimal reservoir GHG	🟨 flooded area	🟨 sturgeon caribou	🟨 northern generation southern load	🟨 lengthy approval process	🟩 strongly support	🟩 stable water rentals	🟩 use AEO 2013 Hydro plant type	✓
	Run-of-River Hydro	🟩 >100 years of experience	🟨 long construction schedule	🟩 no issues	🟨 lack of reservoir	🟨 flow dependent	🟨 shoreline erosion	🟩 none	🟩 virtually no GHG	🟨 limited flooding	🟨 sturgeon caribou	🟨 northern generation southern load	🟨 lengthy approval process	🟩 strongly support	🟩 stable water rentals	🟩 use AEO 2013 Hydro plant type	✓
Wind	On-Shore Wind	🟩 newly mature	🟨 blade icing & cold weather operation	🟨 forecast challenges & costs	🟨 highly variable wind speeds	🟨 moderate seasonality	🟩 none	🟩 none	🟩 virtually no GHG	🟨 set backs & land use limitations	🟨 birds & bats	🟩 southern generation potential	🟨 land use setbacks	🟩 strongly support	🟩 no fuel cost	🟩 use AEO 2013 Wind plant type	✓
	In-Lake Wind	🟥 lack of experience	🟥 no experience with lake ice	🟨 forecast challenges & costs	🟨 highly variable wind speeds	🟨 moderate seasonality	🟨 construction phase impacts	🟩 none	🟩 virtually no GHG	🟨 resource user impacts	🟨 birds & fish	🟨 large lakes preferred	🟨 migratory birds & fisheries	🟨 not polled	🟩 no fuel cost	🟥 use AEO 2013 Wind - Offshore plant type	✗ - Very High Unit Costs
Solar	Photovoltaic (Utility Plant Scale)	🟨 potential efficiency improvements	🟨 unproven in Manitoba	🟨 forecast challenges & costs	🟥 cloud cover creates rapid power drop off	🟨 winter energy is 1/2 of summer	🟩 none	🟩 none	🟩 virtually no GHG	🟨 large footprint	🟨 habitat loss	🟨 best resource in SW corner of Manitoba	🟩 none	🟩 strongly support	🟩 no fuel cost	🟥 use AEO 2013 Solar PV plant type	✗ - High Unit Cost & Intermittency
	Solar Thermal	🟨 potential efficiency improvements	🟨 unproven in Manitoba	🟨 forecast challenges & costs	🟨 weather dependant	🟨 winter energy is 1/2 of summer	🟨 potential thermal oil leaks	🟩 none	🟩 virtually no GHG	🟨 large footprint	🟨 habitat loss	🟨 best resource in SW corner of Manitoba	🟩 none	🟩 strongly support	🟩 no fuel cost	🟥 use AEO 2013 Solar THermal plant type	✗ - Very High Unit Costs
Geo.	Enhanced Geothermal System	🟥 lack of experience in Manitoba	🟥 low grade resource requiring deep drilling	🟩 no issues	🟩 none	🟩 winter peaking	🟨 potential fracking impacts	🟩 none	🟩 virtually no GHG	🟩 small surface footprint	🟩 not significant	🟨 best resource in SW corner of Manitoba	🟨 groundwater quality concerns	🟨 not polled	🟩 no fuel cost	🟩 use AEO 2013 Geothermal plant type	✗ - Deep Low Grade Resource
Natural Gas	Simple Cycle Gas Turbine	🟩 >70 years of experience	🟩 not significant	🟩 no issues	🟩 none	🟨 lower summer capacity	🟩 none	🟨 easily mitigated with NOx controls	🟨 hydrocarbon combustion	🟩 small footprint	🟩 not significant	🟩 near southern pipelines	🟨 air emissions	🟨 somewhat support	🟨 2001 to 2009 price volatility	🟨 use AEO 2013 Advanced CT plant type	✓
	Combined Cycle Gas Turbine	🟩 >60 years of experience	🟩 not significant	🟩 no issues	🟩 none	🟨 lower summer capacity	🟨 boiler treatment chemicals	🟨 easily mitigated with NOx controls	🟨 efficient hydrocarbon combustion	🟩 small footprint	🟩 not significant	🟩 near southern pipelines	🟨 air emissions	🟨 somewhat support	🟨 2001 to 2009 price volatility	🟩 use AEO 2013 Advanced CC plant type	✓
Coal	Conventional Pulverized Coal Generation	🟩 >100 years of experience	🟨 emissions & waste management	🟨 cold start ramp times	🟩 none	🟩 not significant	🟨 mercury arsenic selenium	🟨 mercury & air toxics	🟥 restricted by legislation	🟨 fuel storage & ash disposal	🟨 deleterious substances to fish or fish habitat	🟨 likely located in southern Manitoba	🟥 restricted operations	🟥 strongly oppose	🟨 transportation costs	🟨 use AEO 2013 Conventional Coal plant type	✗ - Regulatory Constraints
	Integrated Gasification Combined Cycle	🟥 only 2 plants in North America	🟨 complex chemical systems	🟨 cold start ramp times	🟩 none	🟨 lower summer capacity	🟨 mercury arsenic selenium	🟨 easily mitigated with NOx controls	🟨 syngas combustion	🟨 fuel storage & waste disposal	🟨 deleterious substances to fish or fish habitat	🟨 likely located in southern Manitoba	🟥 restricted operations	🟨 not polled	🟨 transportation costs	🟨 use AEO 2013 Advanced Coal with CCS	✗ - Regulatory Constraints
Nu.	Nuclear Power Plant	🟩 >60 years of experience	🟨 fuel & waste management	🟥 huge individual units	🟩 none	🟩 not significant	🟥 radioactive wastes	🟩 none	🟩 virtually no GHG	🟨 1 kilometer exclusion zone	🟩 not significant	🟩 southern generation potential	🟥 complex & lengthy approval process	🟥 strongly oppose	🟨 limited supply market	🟨 use AEO 2013 Advanced Nuclear plant type	✗ - Difficult Integration into System
Biomass	Agricultural Crop Residue	🟩 mature Rankine technology	🟨 long-term biomass fuel storage	🟨 cold start ramp times	🟩 none	🟨 limited by annual crop harvest	🟨 combustion ash & boiler chemicals	🟨 NOx & air toxics	🟨 fuel collection & transport	🟨 fuel storage & ash disposal	🟨 deleterious substances to fish or fish habitat	🟩 southern generation potential	🟨 air emissions	🟨 not polled	🟥 collection & transportation costs	🟨 use AEO 2013 Biomass plant type	✗ - High Collection & Transportation Costs
	Wood Based Fuel	🟩 mature Rankine technology	🟨 long-term biomass fuel storage	🟨 cold start ramp times	🟩 none	🟨 limited by annual forest harvest	🟨 combustion ash & boiler chemicals	🟨 NOx & air toxics	🟨 fuel collection & transport	🟨 fuel storage & ash disposal	🟨 deleterious substances to fish or fish habitat	🟨 located adjacent to boreal forest	🟨 air emissions & allowable cut limits	🟨 not polled	🟥 collection & transportation costs	🟨 use AEO 2013 Biomass plant type	✗ - High Collection & Transportation Costs
Imp.	Imports	🟩 large well established market	🟩 tie line limits	🟩 no issues	🟩 not significant	🟩 not significant	🟨 regional impacts outside of Manitoba	🟨 regional impacts outside of Manitoba	🟨 regional impacts outside of Manitoba	🟨 new transmission right-of-ways	🟩 not significant	🟨 non-Manitoba generation	🟨 transmission right-of-way approvals	🟨 not polled	🟩 no fuel cost	🟨 projected market prices	✓

7.1.1.1 Technical Characteristics

Maturity of Technology

For this analysis, maturity of technology is represented as the extent of industry experience with the implementation and operation of a particular technology. The higher the level of industry experience the lower the level of risk and concern with implementing the technology.

Technical Challenges in Manitoba

For this analysis, technical challenges are defined in the context of project development in Manitoba. Technical challenges include the availability of the resource, physical environment conditions including Manitoba's northern climate, level of technical experience in Manitoba, length of implementation time and waste stream management.

Ease of Integration into System

This characteristic measures the complexity of integrating a specific resource technology into Manitoba Hydro's existing system. The factors considered include intermittency, size and dispatchability. Most available technologies pose no significant integration issues.

For example, the intermittency of wind only becomes an issue when the amount of wind variability exceeds the amount of load variability that occurs moment by moment. When wind variability significantly exceeds that amount, additional reserves are required, increasing the cost of integrating those additional wind resources.

Technologies that employ large individual units that are designed for base load operation over long periods of time pose an economic challenge. Such units are difficult to integrate into the current hydraulic system since they lack the dispatchability needed to complement the variability in water flows and loads. Integration of large units is possible as long as additional interconnection capability is provided to manage the increased amounts of surplus energy generated. In addition, a large unit may require Manitoba Hydro to increase the amount of contingency reserves available to it. Adding six 100 megawatt (MW) hydro units would require one-sixth the reserves as one 600 MW unit.

Intermittency

An intermittent resource technology is one that is not continuously available and cannot be dispatched to meet the demand of a power system.

Seasonality

"Seasonality" refers to those factors that affect the production capability on a season-by-season basis. Seasonality may impact production efficiencies as well as have an effect on a technology's fuel availability.

7.1.1.2 Environmental Characteristics

Water Quality Impacts

This characteristic captures a range of potential environmental effects impacting either surface or groundwater. Adverse surface water impacts may include increased turbidity due to erosion, thermal plumes or the discharge of combustion by-products such as mercury, arsenic or selenium. Adverse impacts to groundwater are typically associated with uncontrolled spills or leaks of process chemicals or by-products.

Hazardous Air Pollutants

Hazardous air pollutants are the by-products of combustion. Contaminants of concern for an individual resource technology may include nitrogen oxides, sulfur oxides, carbon monoxide, particulate matter (including respirable particles), mercury, arsenic and lead.

Greenhouse Gas Emissions

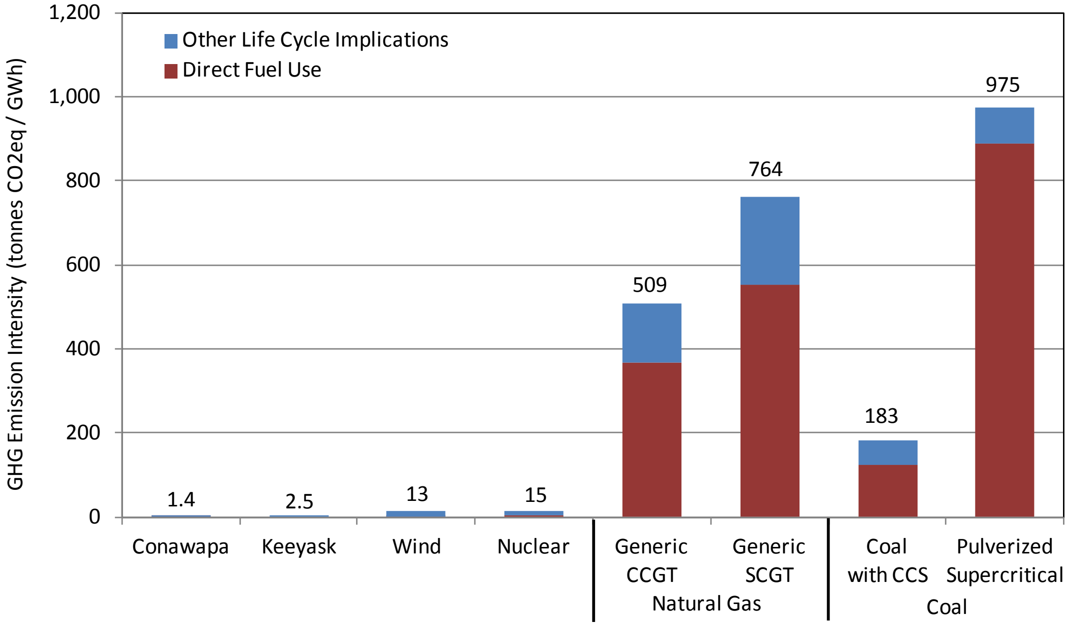
This characteristic represents the greenhouse gases (GHG) emissions associated with the life cycle of a particular electric generation technology from construction, operation and decommissioning. Renewable resource options produce minimal GHG emissions, typically during construction phase, while all forms of conventional thermal generation, with the exception of nuclear, produce GHGs.

Error! Reference source not found. Figure 7.1 provides a comparison of the life-cycle GHG emissions for several generation technologies and uses the Keeyask Generating Station (G.S.) and Conawapa G.S. as examples for the hydro technology. The source document for this figure is appended as ***Appendix 7.3 – Life Cycle Greenhouse Gas Assessment Overview.***

One of the key results of a life-cycle GHG assessment is to show a levelized GHG comparison including all life-cycle components between different technologies. The life-cycle assessment encompasses cradle-to-grave calculations of activities for a project inclusive of:

- construction components – raw material extraction, production and transportation
- construction activities – primarily vehicle fuel
- site-specific land-use changes including reservoir emissions
- operation and maintenance activities
- decommissioning GHG emission implications.

Figure 7.1 COMPARISON OF LIFE CYCLE GHG EMISSIONS FOR ELECTRICITY GENERATION



The life-cycle GHG emission intensity for thermal generation options is dominated by the use of direct fuel (coal and natural gas), while the life-cycle GHG footprint for renewable options is dominated by construction and land-use change GHG emissions. As shown in **Error! Reference source not found.**Figure 7.1, the GHG emission intensity from the 100-year life of the Keeyask G.S. is 2.5 CO_{2e} (carbon dioxide equivalent) tonnes/GWh (gigawatt-hour); while a conventional pulverized coal generating station has a GHG emission intensity approaching 1,000 CO_{2e} tonnes/GWh and a Combined Cycle Gas Turbine (CCGT) generating station has a GHG emission intensity of 509 CO_{2e} tonnes/GWh. This means that a conventional pulverized coal generating station operating for less than 100 days would have the equivalent GHG emissions from the entire 100-year life of the Keeyask G.S. Similarly, a highly efficient CCGT generating station would emit an equivalent amount of GHG emissions in less than one year compared to the 100-year values from the Keeyask G.S.

Land-Use Impacts

Land-use impacts represent the physical footprint of a resource option as well as other associated land-use limitations such as flooded areas, buffer or set-back limits, adjacent land use restrictions and lands impacted by disposal of waste such as ash from coal plants. A small physical footprint having no post-decommissioning land-use restrictions would have the least land-use impacts. For example, a small, natural gas-fired combustion turbine with a small physical footprint will have no perpetual land use restrictions following its decommissioning.

Wildlife Species of Interest

This characteristic represents specific at-risk species—or other regionally important wildlife species noted in either Canada's *Species at Risk Act* or Manitoba's *The Endangered Species Act*—that could potentially be affected by the development of a resource technology at a specific location. Broader groupings of species that may be adversely impacted by significant habitat loss or alteration are also considered.

7.1.1.3 Social and Policy Characteristics

Proximity to Load Centre

This characteristic is a proxy for a combination of different issues such as associated right-of-way issues, construction challenges encountered in isolated areas as well as post-construction line losses. Distances to potential new facilities are estimated from the Dorsey Converter Station and are grouped into five categories: 0 to 100 kilometers (km); 100 to 250 km; 250 to 500 km; 500 to 900 km; and greater than 900 km. Shorter distances are of less concern.

Regulatory Constraints

Regulatory constraints can severely restrict or prohibit the development of a technology based on federal or provincial governments’ policy perspectives or enacted laws and regulations. In some cases, the regulatory approval process itself can become an impediment to development. Policy areas such as land use, environmental emissions and impacts on wildlife may become a regulatory constraint requiring mitigation or compensation for any individual resource technology within the planning horizon.

Social Acceptability

Two public opinion polls conducted by Ipsos and the Innovative Research Group in April 2011 were used to gauge Canadian public opinion regarding six methods of producing electricity (solar, wind, hydro-electric, natural gas, nuclear and coal). Polling results plus inferences drawn from the data are used to populate this characteristic. The degree of respondent support corresponds to the level of acceptance of individual resource technologies.

7.1.1.4 Economic Characteristics

Manitoba Delivered Fuel Costs

Delivered fuel costs refers to the current and future cost of fuel and associated transportation for each technology. This characteristic includes the effect of the recent fuel-price volatility experienced by natural gas as well as rising transportation costs for fuel that have been impacted by petroleum prices. Natural gas and coal fuels require additional management of the fuel delivery system. Transportation services—either by rail for coal or pipeline service for natural gas—need to be addressed in a manner that both maximizes flexibility but also guarantees service.

Forecast U.S. Unit Cost

With the exception of demand side management (DSM) and imports, unit cost is represented by levelized cost. The unit cost of DSM varies by program; information on the cost of additional DSM is not available at this time. The unit cost of imports varies by market and by product and is based on Manitoba Hydro's consensus electricity export price forecast.

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 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 obtained from the U.S. Energy Information Administration (EIA) 2013 Annual Energy Outlook Early Release (AEO) were sorted into three categories as follows:

- less than $100/megawatt-hour (MWh),
- $100 - $130/MWh, and
- greater than $130/MWh.

Figure 7.2 TYPICAL LEVELIZED COST OF NEW GENERATION BY RESOURCE

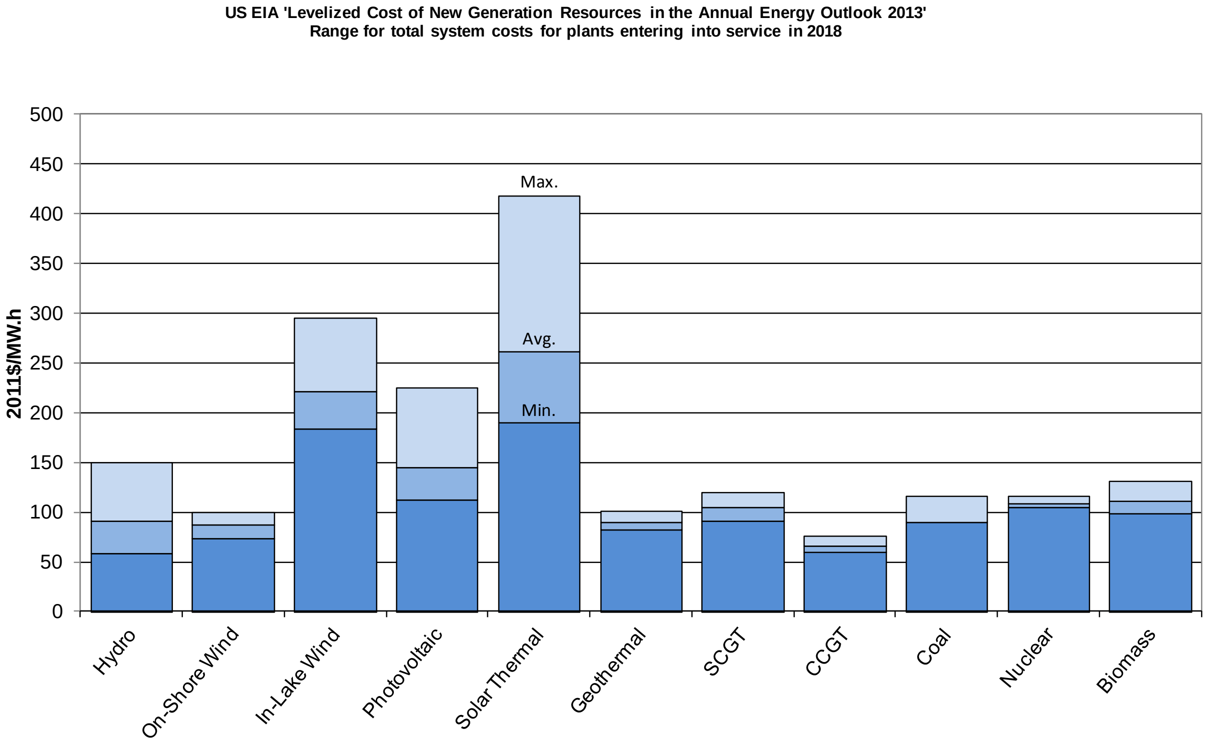
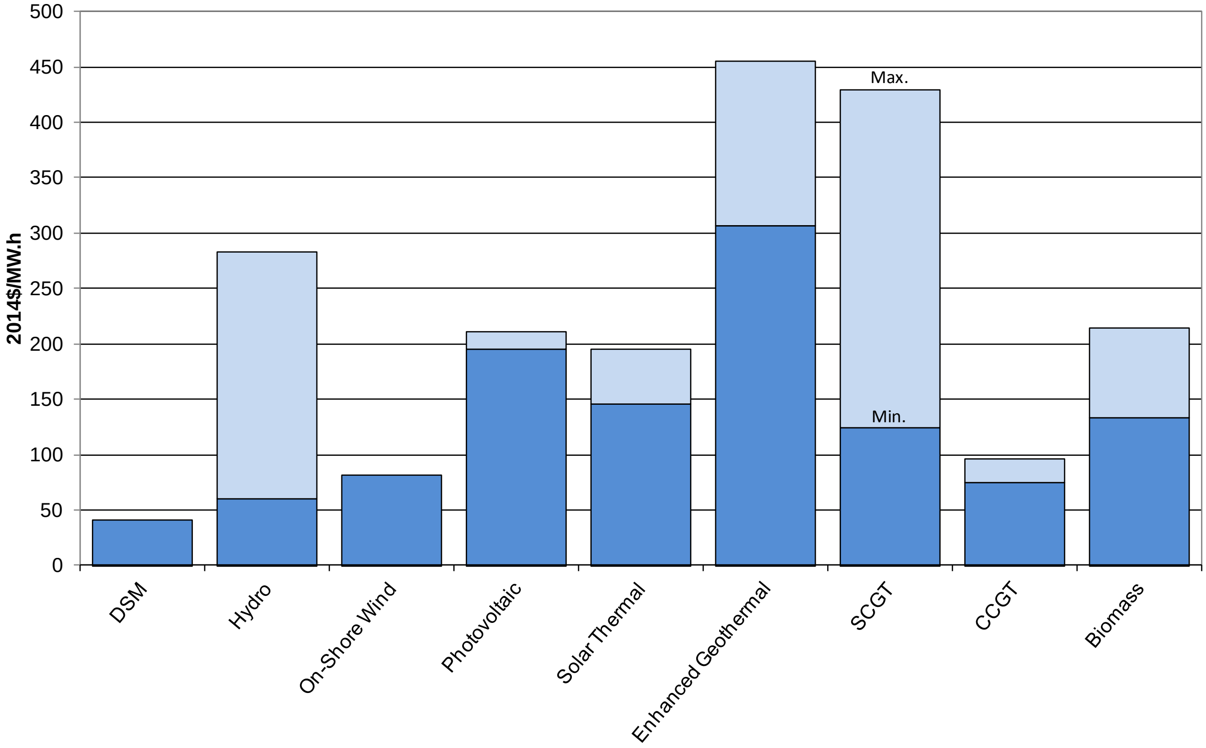


Figure 7.2 above shows the levelized cost ranges for resource technologies as provided in the EIA Annual Energy Outlook 2013. Additional information on resource technologies that have the potential to be developed in Manitoba is provided in ***Appendix 7.2 Range of Resource Options*** and further information on emerging technologies is provided in ***Appendix 7.1 Emerging Energy Technology Review***.

Figure 7.3 shows the levelized cost ranges based on potential development of resource technologies in Manitoba.

Figure 7.3 LEVELIZED COST OF RESOURCE TECHNOLOGIES DEVELOPED IN MANITOBA



Note: Values reflect losses to bring energy to market.

7.1.2 Screening Process

The high-level screening of technologies uses a general characterization to determine whether a technology will proceed to the next stage of evaluation. As shown in Table 7.1, there are three possible outcomes from screening: screened out (red), some concern (yellow), minimal concern or positive (green). If a characteristic for a particular technology receives a "screened out" outcome, that technology does not advance to the next stage and is depicted by an "X" in the Screening Summary column of Table 7.1. A technology will otherwise advance to the next stage of evaluation.

7.1.2.1 Selected Resource Technologies

The screening process resulted in the following resource technologies advancing to the next stage of evaluation:

- additional DSM
- hydro – with Storage and Run-of-River
- wind – On-Shore
- natural Gas-Fired – Simple Cycle and Combined Cycle Gas Turbines
- imports.

The following is a summary of the key characteristics of the selected resource technologies.

Additional Demand Side Management

Manitoba Hydro's 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.

As indicated in ***Chapter 4 –The Need for New Resources***, the 2012 Load Forecast reflects the expected load reductions as a result of past DSM programs. By the end of 2012/13, Power Smart is estimated to have achieved an annual load reduction of 1,990 GWh and 586 MW (at generation)[1]. Manitoba's net load is determined by subtracting the DSM energy savings from the corporation's electric load forecast.

Compared to other generation technologies in Table 7.1, DSM results in no flooding, no air emissions and has a positive global environmental impact. In the latter regard, energy

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

conserved in Manitoba as a result of DSM efforts can be sold to export market customers, thus displacing the use of fossil-fuel based generation in those regions. DSM may also have a net positive impact on the environment by deferring the need for new electricity infrastructure in Manitoba. However, this deferral may increase overall GHG if the deferred generation is hydro.

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. Also, in addition to market availability and adoption forecasts, the savings potential is estimated based on a variety of assumptions that include natural technological development, anticipated customer energy usage/savings and market cost projections. As a result, expected energy savings from DSM do not have the same future certainty of supply as would the development of a physical resource.

In the screening process, additional DSM did not receive a “screened out” outcome for any of the 15 characteristics as shown in Table 7.1.

Hydro – with Storage and Run-of-River

From a technical perspective, hydro-electric generation is a mature, dependable technology that easily integrates into Manitoba Hydro’s existing system. Approximately 4,700 MW of developable hydro-electric potential remains within the province including the proposed Keeyask and Conawapa projects.

From an environmental perspective, hydro-electric generation is a renewable resource that has virtually no hazardous air pollutants or GHG emissions. Specific hydro developments do have the potential to impact aquatic and terrestrial species. Hydro with storage can typically result in a significant amount of flooding, while run-of-river hydro results in comparatively less flooding. From a social and policy perspective, hydro-electric generation is a long lead-time resource that has a lengthy approval process. Major hydro-electric resources are located in northern

Manitoba which is distant from the load centre. According to Canadian public opinion, hydro-electric generation is generally viewed favourably.

From an economic perspective, hydro-electric generation is a long-lived resource with high upfront investment but very low and stable operating costs over the long-term, resulting in a levelized cost that falls within the range of other technologies selected for the next stage of evaluation.

In the screening process, hydro with storage and run-of-river hydro did not receive a “screened out” outcome for any of the 15 characteristics as shown in Table 7.1.

Wind – On-Shore

From a technical perspective, traditional on-shore wind is an established technology and a good-quality wind resource exists within Manitoba. Wind is an intermittent resource that is highly variable, is challenging to accurately forecast and can result in system integration issues. The integration issues become more significant with higher proportions of wind in a system, resulting in the requirement for additional dispatchable capacity resources.

From an environmental perspective, wind generation is a renewable resource that has virtually no hazardous air pollution and no GHG emissions. However, there are potential negative impacts on various avian species.

From a social and policy perspective, wind generation is a short lead-time resource that has typically experienced short regulatory approval processes. According to Canadian public opinion, wind is generally viewed favourably.

From an economic perspective, wind generation has significant upfront investment costs but low operating costs over its approximate 20-year operating life. The unit cost of wind generation falls within the range of other technologies selected for the next stage of evaluation. The unit cost for wind generation does not include costs required to compensate for the intermittency.

In the screening process, On-shore wind did not receive a "screened out" outcome for any of the 15 characteristics as shown in Table 7.1.

Natural Gas-Fired – Simple Cycle and Combined Cycle Gas Turbines

From a technical perspective, natural gas-fired generation (simple cycle and combined cycle gas turbines) uses modular, low capital cost technologies that are mature and well established. Natural gas-fired generation is a short lead-time resource that is relatively easy to install and integrate into the existing Manitoba Hydro system, provided that natural gas supply is readily available.

From an environmental perspective, simple cycle gas turbine (SCGT) units emit minor amounts of hazardous air emissions and produce approximately half as much carbon dioxide (CO_2) as coal-based generation. The dual-stage combined cycle gas turbine (CCGT) units require a higher capital investment compared to simple cycle gas turbines but are larger and more efficient, resulting in a lower unit cost of energy. CCGT emit no meaningful amount of hazardous air emissions and produce approximately one-third of the CO_2 of coal-based generation.

From a social and policy perspective, natural gas-fired generation is a shorter lead-time resource that has typically experienced modest regulatory approval processes. According to Canadian public opinion, natural gas-fired generation is generally viewed favourably. There is ongoing concern with respect to GHG emissions, affecting the social acceptance and potential cost of this technology.

From an economic perspective, the majority of the cost of natural gas-fired generation is a result of the cost of fuel, which in recent years has been highly volatile as discussed in ***Chapter 3 – Trends and Factors Influencing North American Electricity Supply***. Recently, as a result of the adoption of innovative technological advancements in natural gas exploration and extraction, the current and forecast price of natural gas is very low, resulting in a highly competitive operating cost for natural gas-fired generation. However, there is general expectation that the price of natural gas will increase.

In the screening process, SCGT and CCGT did not receive a “screened out” outcome for any of the 15 characteristics as shown in Table 7.1.

Imports

Given Manitoba’s predominantly hydro system, resource diversity can be achieved by building resources in Manitoba or through the purchase of imports from a non-hydro based region or a combination of both. For planning purposes, under low flow or dependable flow conditions, imports in the 2020 timeframe represent in the order of 10% of Manitoba Hydro’s total supply. The primary source of imports to Manitoba is the Midcontinent Independent System Operator, Inc.(MISO) market.

From a technical perspective, imports, utilizing existing or new transmission lines, are a flexible resource option that can be called upon whenever required and on short notice. Imports provide Manitoba Hydro with supply diversity by drawing from the MISO market, consisting primarily of coal-fired, natural gas-fired, nuclear and wind generation.

From an environmental, social and policy perspective, generation from the MISO market—on average across all generation types—results in significant amounts of CO_2 and other hazardous air emissions on a per-unit (MWh) basis. Imports are also dependent on transmission interconnections; new interconnections require both a willing counterparty as well as approvals from U.S. and Canadian regulatory bodies.

From an economic perspective, the cost of market-based energy can vary by time of day and by season. Manitoba Hydro is not committed to purchase any quantity of imports at any specific time of day or year, and therefore has the flexibility to import when most effective for Manitoba Hydro's overall system operations.

In the screening process, imports did not receive a "screened out" outcome for any of the 15 characteristics as shown in Table 7.1.

7.1.2.2 Resource Technologies Not Selected

The screening process resulted in eliminating the remaining resource technologies that were considered in Table 7.1. The technologies not selected were:

- Wind - In-Lake Wind
- Solar – Solar Photovoltaic and Solar Thermal
- Enhanced Geothermal Systems
- Coal – Conventional Pulverized Coal and Integrated Gasification Combined Cycle
- Nuclear Power Plants
- Biomass – Agricultural Crop Residue and Wood Based Fuel Biomass.

The following is a brief summary of the key characteristics of the resource technologies that were not selected.

In-Lake Wind

In-lake wind shares common attributes with on-shore wind. This resource technology was screened out primarily due to energy costs. In-lake wind costs are significantly higher than land-based alternatives.

Development of in-lake wind resources in Manitoba is significantly more technically challenging than on-shore wind due to issues such as winter ice floes. Additional issues include potential adverse impacts affecting existing commercial and recreational lake users. As well, there is a lack of experience within North America in developing in-lake wind resources.

Solar Photovoltaic

Solar photovoltaic is an established technology with significant opportunity for potential technological improvement. A good-quality potential solar resource exists within southern Manitoba. This resource technology was screened out because:

- energy costs for solar photovoltaic were significantly higher than other resource options costs (although costs have recently been trending downwards)
- solar photovoltaic is an intermittent resource that is highly variable and, as a result of its reliance on direct sunlight, there is potential for significant instantaneous drops in power output due to the unpredictable nature of localized cloud cover.

Solar Thermal

Solar thermal is in advanced stages of development and still has a high cost of energy production relative to other resource options. Solar thermal is considered an intermittent resource as it is dependent upon daily weather. It is less intermittent than solar photovoltaic since it is not impacted instantaneously by cloud cover.

From a technical perspective, Manitoba peak load occurs in the winter when solar intensity is weak. In addition, peak load can occur after sunset.

This resource technology was screened out due to the energy costs for solar thermal being significantly higher than other resource options.

Enhanced Geothermal Systems

An enhanced geothermal system is a proven technology but suitable geothermal heat gradients required for these systems remain unproven in Manitoba. As a result, this technology did not advance to the next stage of evaluation. The production of geothermal-based energy utilizes conventional steam-based generation technology but there remain significant technological and economic challenges in drilling to the 2-10 km depth required.

Conventional Pulverized Coal

Environment Canada's *Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations* (2012) established a performance standard for new coal-fired generating units after 2015 of an annual average intensity of 375 tonnes of CO_{2e} per GWh. The Province of Manitoba, under *The Climate Change and Emissions Reductions Act,* is phasing out the use of coal for generation except to support emergency operations. As a result, coal-fired generation as a technology has been eliminated from consideration for the next stage of evaluation.

Coal - Integrated Gasification Combined Cycle

Integrated gasification combined cycle is an evolving technology that is technically complex with only a few utility-scale examples constructed in North America. While combustion of coal-derived synthetic gas produces a significantly cleaner air emissions profile, the Province of Manitoba, under the *Climate Change and Emissions Reductions Act,* is phasing out the use of coal for generation except to support emergency operations. As a result, this technology has been eliminated from consideration for the next stage of evaluation.

Nuclear Power Plants

Nuclear power plants require high up-front capital investment. The limited operational flexibility and large individual unit-size of nuclear power plants together with their baseload mode of operation, would not integrate well with the relatively small size of Manitoba Hydro's existing system. Nuclear power plant development, based on proven technology, has large individual units typically sized between 600 and 1,200 MW. Nuclear power plants have little operational flexibility resulting in high capacity factors, meaning that there is little opportunity to vary the level of production to suit the needs of the Manitoba system. Although the nuclear industry is addressing this through the development of advanced small sized reactors (less than 300 MW unit capacities in size) they have not yet been commercially deployed in North America and will not be for a number of years.

In addition, *The Manitoba High-Level Radioactive Waste Act* prohibits the long-term storage of high level radioactive waste in Manitoba. As a result, nuclear power plants have been eliminated from further evaluation on the basis of system integration issues and on the basis of the provincial legislation related to the storage of radioactive waste in Manitoba.

Agricultural Crop Residue Biomass & Wood-Based Fuel Biomass

Agricultural crop residue biomass and wood-based fuel biomass are adaptations of conventional steam-based generation. Currently, the cost of energy produced from these forms of technology are not yet competitive with other forms of generation and are highly dependent upon the uncertain price of transportation fuels. On this basis, these technologies have been eliminated from consideration for the next stage of evaluation.

7.2 Resource Options Screening

The next step in the screening process is the selection of specific resource options from each of the resource technologies identified in Section 7.1.2.1. The process for selecting resource options involves comparing the characteristics of the resource technologies—the results of this comparison identifies the resource options for the next stage of analysis.

7.2.1 Additional DSM Screening

Manitoba Hydro’s strategy for DSM involves a continued long-term commitment to pursuing all cost-effective energy efficiency opportunities and to continually monitoring the market for emerging trends and opportunities which may become economically viable. As new opportunities are identified as being economic, these opportunities are included into Manitoba Hydro's DSM plan (e.g. the recently announced Power Smart Community Geothermal program, which will be added to the next update of Manitoba Hydro's DSM plan).

To assist in identifying the available DSM potential in Manitoba, the corporation recently engaged a consultant to undertake a DSM potential study. As the results of this study were not available in time to be incorporated into the 2012 main NFAT analysis, a DSM sensitivity and a DSM stress test are included, based on 2013 planning assumptions and preliminary projections from the DSM Potential Study, in ***Chapter 12 – Economic Evaluations - 2013 Update on Selected Development Plans***

As noted in ***Chapter 4 – The Need for New Resources***, Section 4.2.2 and provided in ***Appendix 4.3 – Demand Side Management Potential Study***, the DSM Potential Study examines the "market potential" and "achievable potential" of existing energy-efficient technologies which are economic in Manitoba and for those technologies that may be on the horizon. The preliminary high-level projections from the study were used to frame threshold levels of additional DSM over and above the 2012 base DSM forecast. These preliminary thresholds are incorporated into the analysis in ***Chapter 12 – Economic Evaluations - 2013 Update on Selected Development Plans*** as a sensitivity of 1.5 times the base DSM plan, and as a stress test of 4 times the DSM base forecast. Table 7.2 shows a comparison of the current approved Power Smart Plan and the final findings of the DSM Potential Study. As shown by Table 7.2 the thresholds incorporated into the analysis presented in ***Chapter 12 – Economic Evaluations - 2013 Update on Selected Development Plans*** remain reasonable.

Table 7.2 THRESHOLDS FOR POTENTIAL ADDITIONAL DSM

	Comparison at Forecast Year 2027/28 (at Meter)			
	GWh	% of Power Smart Plan	MW	% of Power Smart Plan
2013-16 Power Smart Plan (2012/13 – 2027/28)	713	100%	154	100%
DSM Potential Study				
Achievable	1135	159%	255	166%
Market	2915	409%	671	436%

Caution must be exercised in interpreting the results of a DSM potential study. The projections represent a high-level assessment of the achievable and market potential with market potential representing absolute level of energy and demand savings that are technically feasible, economically attractive assuming the ideal market conditions. These conditions could be characterized by the presence of a focused and coordinated effort across organizations/governments (federal, provincial and utilities) eliminating all material market barriers to adoption, such as product availability and market capacity, product awareness and knowledge, price differentials, etc.—i.e., the probability of these ideal market conditions being present in combination is doubtful and therefore represents a theoretical limit.

The setting of specific Power Smart targets involves more detailed and market-specific analysis which was beyond the scope of this study. The study does not involve a detailed assessment of each potential energy efficiency opportunity and does not account for the investment or specific strategies required to support the market intervention.

Insights gathered through the study will need to be further investigated to more specifically define the market and potential associated opportunities, determine the feasibility of the opportunities and the most effective and cost-efficient market intervention strategies to create an effective market change over time. As such, caution must be exercised in using the results of the market potential study for planning purposes: the results of the study should only be used for developing a refined DSM plan.

It is recognized that DSM savings are contingent on program participation and do not carry the same degree of certainty that a generation resource provides. While Manitoba Hydro has relied upon DSM to date at the same level of certainty as new generation, this is reasonable provided realistic DSM programming is underlying the targets associated with DSM. It is reasonable to consider this factor in determining the degree to which Manitoba Hydro will rely on DSM targets which may be arbitrary and not based on sound DSM programming.

7.2.2 Hydro Resource Options Screening

Manitoba Hydro has identified a total of 8,200 MW of undeveloped renewable hydro-electric potential of varying sizes and technical difficulties remaining within the province. Many of the smaller sites are uneconomic in comparison to other sites as a result of their relative small size and remoteness from the existing transmission system. Manitoba Hydro’s cooperation with two major government initiatives has eliminated many other potential hydro-electric sites from further consideration.

Under the Treaty Land Entitlement Framework Agreement, Manitoba Hydro agreed to restrict its interest to a total of 16 sites along the Nelson, Burntwood and Churchill rivers including three sites on the Hayes River and Wuskwatim, thereby releasing lands around other sites for selection by First Nations toward fulfillment of their treaty entitlements.

Under the Canadian Heritage Rivers System, which recognizes and conserves rivers of outstanding natural, cultural and recreational heritage, Manitoba Hydro agreed not to pursue development of the three sites on the Hayes River. The 12 remaining sites on the Nelson, Burntwood and Churchill rivers have a hydroelectric potential of 4,700 MW—these sites have been identified as having the highest potential for future development and are listed in Table 7.3.

Hydro-electric generating resources are highly site specific in terms of design, capacity, energy, construction and cost. These factors, as well as a number of other regulatory, technical and environmental considerations, limit the number and location of practical hydro-electric developments within Manitoba. Hydro-electric plants are considered to have high up-front capital costs, low operating costs, require long lead times for development, and can achieve economies of scale if large in size. Hydro-electric plants also tend to provide more significant economic stimulus to Manitoba than many other technologies.

While all sites included in Table 7.3 contain favourable characteristics for development, not all have been investigated to the same degree. The stage of preparation shown in the table represents the level of investigation and study for individual sites from inventory, feasibility, and conceptual design to pre-investment. Inherent in the individual design concepts and overall range of stages—as defined in ***Appendix 7.2 – Range of Resource Options***—are a number of other issues such as environmental concerns, social concerns, economics and system integration.

The stage of development for a particular resource option is driven by the attractiveness of its characteristics, which includes unit cost. Levelized cost is a significant factor at this stage of the screening process.

As demonstrated in ***Chapter 4 – The Need for New Resources***, new resources are required in 2022/23 according to the 2012 planning assumptions. In order to fully approve and develop a resource in time to meet needs and opportunities, only sites suitable in terms of characteristics and stage of preparation are considered for potential use in development plans. Keeyask G.S and Conawapa G.S. are the only two potential hydro-electric sites with suitable characteristics and at a sufficiently advanced stage of preparation.

Table 7.3 HYDRO RESOURCE OPTION CHARACTERISTICS

		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 7.2- Range of Resource Options***
*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.

The following is a summary of the main positive and negative characteristics for the two selected hydro-electric options along with a brief summary of why other sites were not selected for further evaluation at this time.

Keeyask Generating Station

At 695 MW, Keeyask G.S. is the only medium-sized hydro-electric plant available for consideration, and is significantly larger than most other plants but is smaller than Conawapa and Gillam Island. This medium size makes it attractive for balancing the economies of scale with the large increments of new capacity added by very large hydro developments. Developing the site requires a moderate amount of flooding at 45 km^2 and is located in known sturgeon habitat.

The Keeyask Project is at an advanced Stage V— Final Design, Construction and Commissioning level of development. For a more detailed project description for Keeyask, see ***Chapter 2 – Manitoba Hydro's Preferred Development Plan Facilities***.

Conawapa Generating Station

At 1,485 MW, Conawapa is considered a large generating station and would be the largest generating station within the province if developed. Its large size provides a large amount of excess capacity and would require a more significant upfront investment than other hydro generation alternatives. From a levelized-cost perspective, economies of scale result in Conawapa having the second lowest levelized cost of the hydro options.

The development of this station results in the flooding of 5.1 km^2 within the flood plain of its riverbank, but the location is a known sturgeon habitat. At the time of this analysis and based on a 13 year lead time, Conawapa could be in service as early as 2025.

The Conawapa Project is at an advanced Stage IV—Pre-Investment level of development. For a more detailed project description for Conawapa, see ***Chapter 2 – Manitoba Hydro's Preferred Development Plan Facilities***.

Hydro Resource Options Not Selected

After considering the characteristics of resource timing, environmental impact, capacity and energy and economic information, nine of the 12 hydro-electric resource options have been screened out on the basis of their higher levelized cost and on the basis of their state of development being at the Stage II– Feasibility level or less.

The small size of Notigi, combined with a higher levelized cost than that for Keeyask G.S. and Conawapa G.S., results in Notigi receiving no further consideration in this submission.

At 120 MW, Notigi is considered a small generating station located at the site of the existing Notigi control structure. The primary function of this control structure is to regulate water flows into the Burntwood River. As a result, in the winter the capacity of the plant would be significantly reduced due to declining forebay water levels. The capacity of the plant would also be reduced as tailrace water levels rise due to river ice staging. The combined effect is a reduction of approximately 20 MW or 16% of the plant generating capacity. The resulting capacity provided by Notigi would represent less than two years of load growth.

The development of the Notigi site, as a project, would have minimal environmental effects as the forebay, transmission access, the road, and all of the civil structures, with the exception of the powerhouse, are already established. As Notigi would retain its primary function as a control structure, there is no expected change to existing operation and therefore no expected environmental effects.

Stage IV engineering studies for Notigi were initiated as far back as 1999 but were suspended in 2002 in order to concentrate efforts on the Wuskwatim, Keeyask, and Pointe du Bois projects. As a result of the engineering and related planning studies being at an early Stage IV level, there is greater uncertainty in the levelized cost estimate for Notigi. The minimum time identified to the earliest in-service date for Notigi is ten years. Given the vintage of the available project information and engineering studies, it is likely that longer than ten years would be required for Notigi's earliest in-service date.

In future studies, Notigi G.S.— along with other plants on the Burntwood River such as First Rapids and Manasan G.S. — will be evaluated in a development plan which would allow for economies of scale in construction.

7.2.3 Natural Gas-Fired Resource Option Screening

In Section 7.1.2 Manitoba Hydro determined that the natural gas-fired generation options suitable for further consideration are SCGT and CCGT.

Natural gas-fired turbines are flexible, modular units that come in a variety of configurations from a number of manufacturers and there is a large fleet of natural gas turbines world-wide. Their prevalence ensures predictable operating and environmental performance characteristics. Units range in size from very small (less than 1 MW) to very large (more than 400 MW). As fossil fuel-based resources, natural gas-fired turbines emit carbon dioxide and minor amounts of nitrous oxide. Considerations for siting include accessibility to gas supply, water supply and transmission interconnections. Natural gas-fired generation is considered to be a shorter lead time-resource option with lower capital costs, with the majority of the cost related to high fuel-based operating costs.

Noteworthy decreases in future costs for combustion turbines are not anticipated; however, innovation in the field of combustion turbine generation will lead to more efficient machines that operate at lower heat rates. These efficiency improvements will be achieved through higher cycle pressure ratios, improved turbo-machinery component efficiencies and higher turbine inlet temperatures.

For planning purposes Manitoba Hydro considered the following gas turbine configurations, representative of the different types of units that are available, for integration into the existing system:

- heavy duty SCGT
- heavy duty CCGT
- aeroderivative SCGT.

The following is a summary of the characteristics for each natural gas-fired resource option and how each option would be utilized.

Heavy Duty Simple-Cycle Gas Turbine

A heavy duty SCGT would be best suited as an addition to Manitoba Hydro's system when there is a requirement for a capacity increment larger than 200 MW and when the resource is intended to operate infrequently. Typically, heavy duty SCGTs are large units with short lead times (3-5 years), low capital costs and high operational costs. Consequently, an SCGT is best used as a capacity resource when operation is intended to be infrequent, typically less than 20% of the total time.

The heavy duty SCGT specified for planning purposes is the General Electric (GE) 7FA. The GE 7FA has a capacity of 209 MW and a mid-efficiency heat rate of 9,906 Btu/kWh (British thermal units/kilowatt-hour). The GE 7FA has been in operation since 1994 and has 740 individual units in operation in both simple and combined cycle configurations, lending confidence to its operation, reliability and maintenance. In the event that development is pursued, actual turbine selection would be based upon its intended operation, design requirements, cost, and availability at the time of purchase.

Heavy Duty Combined Cycle Gas Turbine

A heavy duty CCGT is best suited as an addition to Manitoba Hydro's system when there is a requirement for a large increment of energy and capacity and when the resource is intended to operate more frequently than a SCGT (typically more than 40% of total time). Typically, CCGTs are large units with short lead times (3-5 years) and have higher capital costs and lower operational costs than SCGTs.

The heavy duty CCGT specified for planning purposes is the GE 7FA CCGT. The GE 7FA CCGT has a capacity of 308 MW and a high-efficiency heat rate of 6,652 Btu/kWh. In the event that development is pursued, actual turbine selection would be based upon its intended operation, design requirements, cost and availability at the time of purchase.

Aeroderivative Simple Cycle Gas Turbine

An aeroderivative gas turbine is best suited as an addition to Manitoba Hydro's system when there is a requirement for a small increment of capacity and is intended to operate infrequently. Typically, aeroderivative gas turbines are available as small units with short lead times (approximately three years), higher capital costs and higher operational costs than both the simple cycle and combined cycle GE 7FA units. Thus, an aeroderivative SCGT is best used as a capacity resource when the operation is intended to be infrequent or for quick-start and black-start capabilities.

The aeroderivative SCGT specified for planning purposes is the GE LM6000PH. The GE LM6000PH is based on the CF6 aircraft engine which powers the Boeing 747 aircraft among others. The LM6000PH has a capacity of 47 MW and a mid-efficiency heat rate of 9,475 Btu/kWh. The engine has been in industrial operation since 1992 with a current fleet size of 1,025 units, lending confidence to its operation, reliability and maintenance. In the event that development is pursued, actual turbine selection would be based upon its intended operation, design requirements, cost, and availability at the time of purchase.

Table 7.4 summarizes the characteristics of the natural gas-fired resource options used for planning purposes.

Table 7.4 NATURAL GAS-FIRED RESOURCE OPTION CHARACTERISTICS

		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]	✓
	GE 7FA Heavy Duty SCGT		3-5		209	1688	9906	Yes	No		506		161	125 - 266 [2]	✓
	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.

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

7.2.4 Wind Resource Option Screening

In Section 7.1.2 Manitoba Hydro determined through resource technologies screening, that on-shore wind generation is a short lead-time resource option suitable for further consideration. Large areas in southern Manitoba are both environmentally and technologically suitable for several thousand MWs of wind farm development.

Wind resource options are modular and are made up of multiple units that can be installed to closely match energy resource requirements. In the Manitoba Hydro system, a wind resource option is suitable when there is a requirement for energy only, and not capacity, as Manitoba experiences peak demand in winter. Wind generation is assumed to have a zero winter peak capacity due to the intermittent nature of the resource and the fact that the wind generators cannot be expected to operate reliably at temperatures below -30°C, the kind of temperatures which produce Manitoba peak winter load. This subject is further discussed in ***Appendix 7.4 - Capacity Value of Wind Resources.*** Wind turbine manufacturers have considered operations in extreme temperatures and have defined a cold climate as less than -20°C for more than one hour in nine days per year. Manufacturers' cold weather packages have been developed and can extend the operational range of a turbine typically down to normal ambient temperatures of -30°C.

Wind power cannot be reliably controlled due to fluctuations in wind speed; because of its intermittency wind power alone cannot be relied upon to produce electricity when needed. Other issues typically associated with a wind resource include extremes of wind speed (too low or too high), extreme wind gusts, extreme wind shear, and extreme wind turbulence, as well as lack of wind for periods of time. To accommodate a wind resource, other dispatchable resources that have fast energy ramp-up times such as hydro-electric and natural gas-fired generation are required to back-up wind generation when wind energy production is reduced or not available.

In North America, recent on-shore wind development projects under construction have predominantly utilized wind turbines ranging from 1.5 to 3.0 MW in size with hub heights ranging from 80 to 120 metres. The trend over the past decade has seen the increased use of taller wind towers and turbine units with larger capacity ratings, resulting in improved performance as measured by increases in capacity factor. Evolving trends and factors make it difficult to accurately predict which individual wind turbine unit sizes and types may be utilized in the future. In addition, industry forecasts to 2030 anticipate a 45% increase in energy output from wind turbines, assuming that material costs decrease by 10% in real terms from current levels.

Wind speed is the most important factor affecting the production of wind energy. Therefore, it is desirable to locate a wind project where the average annual wind speed is as high as possible. It is assumed that the best wind resource locations would be developed first, proceeding to progressively less windy locations as the number of developments increase over time. For planning purposes, annual energy projections are estimated through statistical wind resource assessments and operating history. An average annual capacity factor of 40% is assumed for all future wind farm developments in southern Manitoba and 85% of the 40% is assumed to be dependable wind energy.

Manitoba Hydro adopted the 85% factor for determining dependable wind generation based on statistical analysis of wind records for extended periods of time in other jurisdictions. The standard that was adopted required that the dependable energy could be achieved in 19 years out of 20. It is estimated that each year there is a 5% chance that actual annual generation will be less than the 85% level. The five percentile probability is the industry standard for determining the dependable energy of wind generation.

Southern Manitoba's wind resource characteristics are well understood and, for the purposes of modeling and evaluating wind farm developments, can be applied to a generic wind farm. Thus, a generic 65 MW wind farm was created for use in future assessments and evaluations without the need for defining the location, the make, the number or the size of individual towers required. A 65 MW capacity development is a reasonably sized wind farm that can benefit from economies of scale and is also approximately equal to the estimated provincial annual load growth for energy. In order to simplify modeling and evaluations at this stage of planning, it was assumed that all additional wind developments would be owned and operated by Manitoba Hydro.

Table 7.5 summarizes the characteristics of the wind resource option used for planning purposes.

Table 7.5 ON-SHORE WIND RESOURCE OPTION CHARACTERISTICS

		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	✓

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

7.2.5 Imports

For planning purposes, 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 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.

Under seasonal diversity agreements, the supplier not only agrees to provide winter capacity but also agrees to provide winter energy and may provide summer energy if it is available during off-peak periods. If an energy agreement is not associated with capacity, energy is not guaranteed for any particular hour because it may be required to serve the supplier’s firm load obligations. To the extent that the supplier has surplus energy, the agreement makes the energy available to the other party. Manitoba Hydro has a 500 MW import agreement with

Northern States Power which provides access to energy from the MISO market throughout the year on firm transmission service.

Although Manitoba Hydro has access to large quantities of energy under contract, there are limitations to the amount of imports that can be relied upon for planning purposes. As described in more detail in ***Appendix 4.1 – Manitoba Hydro Generation Planning Criteria***, 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. Manitoba Hydro's Preferred Development Plan includes a new interconnection with additional import capability of 750 MW.

Generation from the MISO market, on average across all generation types, results in significant amounts of CO_2 and other hazardous air emissions on a per unit (MWh) basis. As explained in ***Chapter 3 – Trends and Factors Influencing North American Electricity Supply***, 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. Department of Energy's Energy Information Administration (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.

As discussed in ***Chapter 5 – The Manitoba Hydro System, Interconnections and Export Markets***, Manitoba Hydro's imports (and exports) have implications on the dispatch of resources in the MISO region. Based on MISO Independent Market Monitor's 2011 annual report, coal was on the margin 93% of all hours in the year. Natural gas was the only other significant marginal fuel, on the margin 23% of the time. (Due to transmission constraints it is possible for more than one fuel to be on the margin in any particular hour).

Coal generation GHG emissions are typically on the order of 0.9 to 1.1 tonnes CO_2 /MWh while natural gas can range from about 0.3 to 0.8 tonnes CO_2/MWh depending on the specific technology and its efficiency. Manitoba Hydro currently assumes that its exports displace and its imports result in 0.75 tonnes CO_2/MWh.

This reflects a marginal generation mix of various fossil-fuels and technologies. Given that the current marginal generation remains primarily coal (at an emission rate of about 1 tonne CO_2/MWh) the 0.75 tonnes $CO_{2/}$MWh factor used by Manitoba Hydro is considered to underestimate both the emissions displaced by exports and the emissions caused by imports. Since Manitoba Hydro is typically a large net exporter, this assumption is considered conservative in that it underestimates the emission displacement benefit. While Manitoba Hydro does not forecast the annual marginal export displacements, it expects that as coal units retire and more natural gas generation is built, the marginal emission factor should decrease over 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.

As mentioned previously, for planning purposes, imports have to date represented in the order of 10% of Manitoba Hydro’s total supply under low flow or dependable flow conditions. The approximate proportion of imports associated with Manitoba Hydro’s Preferred Development Plan is expected to remain generally the same.

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.

7.3 Summary of Selected Resource Options

Table 7.6 presents an overview of the key technical, environmental, socio-economic/provincial and economic characteristics of the resource options selected in Section 7.2. These resource options are incorporated into the development plans which are presented in ***Chapter 8 – Determination and Description of Development Plans***.

Table 7.6 SELECTED RESOURCE OPTIONS CHARACTERISTICS

Resource			DSM	Keeyask	Conawapa	Wind	GE 7FA Heavy Duty CCGT	GE 7FA Heavy Duty SCGT	GE LM 6000PH Aeroderivative SCGT	Imports
Technical		Fuel Type	-	Water	Water	Air	Natural Gas	Natural Gas	Natural Gas	Predominantly Thermal
		Renewable	Yes	Yes	Yes	Yes	No	No	No	No
		Dispatchability	No	Yes	Yes	No	Yes	Yes	Yes	Yes
		Mode of Operation	Must Take	Baseload & Peaking	Modified Run-of-River	Must Take	Intermediate & Peaking (70-35% capacity factor)	Peaking (20-5% capacity factor)	Peaking (20-5% capacity factor)	Flexible
		Asset Life	Variable	67 years	67 years	20 years	30 years	30 years	30 years	Not Applicable
		Resource Lead Time	Variable	7 years	13 years	3 years	3 - 5 years	3 - 5 years	3 years	Not Applicable
		Transmission Length	-	38 Km	7 Km	Avg. 29 Km	0 Km (First Plant)	0 Km (First Plant)	0 Km (First Plant)	0 Km
	Capacity at Plant	Nominal	-	695 MW	1485 MW	65 MW	308 MW	209 MW	47 MW	Up to Transmission Interconnection Limits
		Net Winter Peak	-	630 MW	1300 MW	0 MW	325 MW	223 MW	50 MW	Up to Transmission Interconnection Limits
Environmental	Air Impacts	GHG Emission Intensity Plant Operations	None	Negligible	Negligible	Negligible	342 t CO2e/GW.h	506 t CO2e/GW.h	506 t CO2e/GW.h	≈ 750 t CO2e/GW.h
		Regional GHG Disp. Intensity Potential	≈ 750 t CO2e/GW.h	≈ 750 t CO2e/GW.h	≈ 750 t CO2e/GW.h	≈ 750 t CO2e/GW.h	≈ 408 t CO2e/GW.h	≈ 244 t CO2e/GW.h	≈ 244 t CO2e/GW.h	-
		NOx Emissions Intensity	-	-	-	-	100 kg NOx/GW.h	150 kg NOx/GW.h	230 kg NOx/GW.h	Not Determined
	Land Impacts	GS Footprint	0 ha	214 ha	164 ha	≈ 10 - 20 ha	≈ 3 ha	≈ 2 ha	≈ 1 ha	0 ha
		Flooded Area	0 ha	4,463 ha	507 ha	0 ha	0 ha	0 ha	0 ha	0 ha
		Additional Impacted Area	0 ha	9,302 ha	1,381 ha	≈ 990 - 2,980 ha	0 ha	0 ha	0 ha	0 ha
		Total Impacted Area	0 ha	13,979 ha	2,052 ha	≈ 1,000 - 3,000 ha	≈ 3 ha	≈ 2 ha	≈ 1 ha	0 ha
	Water Impacts	Water Consumption	-	Domestic Needs Only	Domestic Needs Only	Domestic Needs Only	≈ 900 m^3/GW.h	Domestic Needs Only	Domestic Needs Only	-
		Water Quality	-	Erosion & Mercury	Negligible	None	Negligible	None	None	-
		Water Regime	-	Regulated Operating Range	Regulated Operating Range	None	Negligible	None	None	-
	Wildlife Species of Interest	Aquatic	-	Lake Sturgeon Habitat	Lake Sturgeon Habitat	None	Negligible	None	None	-
		Terrestrial	-	Caribou Habitat	Caribou Habitat	Negligible	Negligible	Negligible	Negligible	
		Avian	-	Nesting Habitat	Negligible	Bird & Bat Collisions	Negligible	Negligible	Negligible	
Socio-Economic/Provincial	Generic Tech. Rating	Health Concerns	-	Very Low	Very Low	Low	Low	Low	Low	-
		Safety Concerns	-	Medium	Medium	Very Low	High	High	High	-
	MB Business Opportunities (% of capital spent in MB)		100%	53%	46%	18%	30%	17%	17%	-
	Employment	Direct Construction	Program Dependent	4480 Person-Years	6650 Person-Years	35 to 80 Person-Years	329 Person-Years	116 Person-Years	65 Person-Years	-
		At Northern Work Sites	Program Dependent	94%	94%	0%	0%	0%	0%	-
		Permanent O&M	Minimal	58 FTE	61 FTE	4 to 8 FTE	94 FTE (for 1 to 2 plants at site)	52 FTE (for 1 to 4 plants at site)	52 FTE (for 1 to 4 plants at site)	-
		At Northern Work Sites	0%	100%	100%	0%	0%	0%	0%	-
	Royalties / Taxes (2014$)	Water Rentals	-	$9.0 M/year	$12.8 M/year	-	-	-	-	-
		Capital Taxes	Program Dependent	$17.3 M/year	$28.6 M/year	$0.8 M/year	$2.0 M/year	$0.8 M/year	$0.4 M/year	-
		Guarantee Fees	Program Dependent	$27.7 M/year	$45.8 M/year	Potential for $1.3 M/year	$3.2 M/year	$1.3 M/year	$0.6 M/year	-
		Other	-	-	Grants-in-lieu of taxes	Land Rentals, Grants-in-lieu of taxes	Grants-in-lieu of taxes	Grants-in-lieu of taxes	Grants-in-lieu of taxes	-
	Nearby Population Centers		-	Fox Lake CN, Gillam, Tataskweyak CN, Thompson, War Lake FN, York Factory FN	Fox Lake CN, Gillam, Shamattawa FN, Tataskweyak CN, War Lake FN, York Factory FN	Southwest & South-central Manitoba	Brandon, Southern centre near pipeline	Brandon, Southern centre near pipeline	Brandon, Southern centre near pipeline	-
Economic	Levelized Cost (2014$)		Program Dependent	$60/MW.h	$67/MW.h	$86/MW.h	$75 - 97/MW.h	$125 - 266/MW.h	$163 - 430/MW.h	Projected Market Prices