La Capra Associates

NEEDS FOR AND ALTERNATIVES TO (NFAT) REVIEW OF MANITOBA HYDRO'S PROPOSAL FOR THE KEEYASK AND CONAWAPA GENERATING STATIONS

Technical Appendix 2

Generation Alternatives

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This report contains information that has been deemed Commercially Sensitive Information and is, therefore, subject to a protective order.

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Technical Appendix 2: Generation Alternatives

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Acronyms

Technical Appendix 2

CCGT	Combined Cycle Gas Turbine
DSM	Demand Side Management
EIA	US Energy Information Administration
GS	Generating Station
IGCC	Integrated Gasification Combined Cycle
IR	Information Request
KP	Knight Piésold Consulting
KIP	Keeyask Infrastructure Project
LCA SOW	La Capra Associates Scope of Work
LCA	La Capra Associates
LCOE	Levelized Cost of Energy
MH	Manitoba Hydro
NFAT	Needs for and Alternatives to
NREL	National Renewable Energy Lab
O&M	Operations and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaic
SCGT	Heavy Duty Simple Cycle Gas Turbine
US	United States

I. Introduction

Manitoba Hydro (MH) has developed a set of assumptions on generation technologies including costs, performance, resource life, and environmental impact, among others. These assumptions impact multiple aspects of the NFAT analysis, particularly the screening of resource technology options and the comparative economic analysis of the alternative development plans.

This Appendix will evaluate the reasonableness MH's assumptions and discuss the levelized cost of energy (LCOE) analysis conducted by MH.

A. Scope

La Capra Associates (LCA) has prepared this Technical Appendix to address two elements of our Needs For and Alternatives To (NFAT) Scope of Work (LCA SOW) and support other elements of our work that rely on the materials in this report. The two specific LCA SOW elements addressed here are:

Power Resource Planning and Economic Evaluation

12. *Address the relative generation and integration costs of hydro, wind, natural gas turbines (single-cycle and combined-cycle) and Demand-Side Management.; and*

Business Case and Risk Assessment

4. *Address estimate uncertainties involving large complex hydro projects.*

The material contained in this Technical Appendix also relies on the information prepared by Knight Piésold Consulting (KP) in its work regarding the cost estimates for the Keeyask and Conawapa Generating Stations (GS) and generic wind and gas generation.

B. La Capra Associates' Approach to Reviewing Manitoba Hydro's Analysis of Generation Technologies

Our approach to evaluating MH's generation technology assumptions included the following:

1) La Capra Associates reviewed materials relevant to this assessment, including:
   - The information contained in the NFAT submission pertaining to generation technologies considered by MH; and
   - MH's responses to Information Requests (IRs) and information provided to LCA in lieu of responses to IRs.
2) LCA held discussions with MH personnel regarding their assessment of generation technologies for this NFAT application.
3) LCA conferred with KP regarding their review of the cost estimates for the Keeyask and Conawapa GS and generic wind and gas generation and Enernex with respect to their review of wind energy technologies.
4) LCA conducted independent research regarding recent published information on technology cost and performance characteristics.

II. Evaluation of MH Technology Assumptions

A. Large Hydro

KP filed its report with the PUB on January 13, 2014. This report included a review of MH's cost estimates and construction management strategies for Keeyask and Conawapa. KP's findings are below.

Both Keeyask and Conawapa

- **Approach to Capital and Operations and Maintenance (O&M) Cost Estimates.** KP found that MH's approach and methodologies to estimate Capital and O&M costs are consistent with industry best practices.
- **Total Project Costs.** Knight Piésold noted that capital investments in large hydropower range from $2,000-10,000 per KW. The proposed Keeyask and Conawapa facilities are estimated at $9,000 and $7,000 per KW respectively, putting these projects at the top end of the range. This is because the two sites are not particularly favorable for hydropower development given their location on large flat rivers.[1]
- **Contingency in Capital Cost Estimate.** KP has concerns about the amount of contingency included in the Base Cost estimate. MH has developed a contingency curve whereby the capital cost estimate was expressed in terms of probability of cost over or under run. MH has used the P50 value from this curve in for its Base Cost estimate of both Keeyask and Conawapa. KP cites an article from Cost Engineering magazine which notes that the P80 or P90 estimate would be more appropriate for large projects. These estimates would have a 10 to 20 percent probability of overrun. Using the P90 estimate for Keeyask would increase the contingency by $423 Million and increase the overall project costs by about seven percent.[2]
- **Construction Indirect Costs for Conawapa and Keeyask GS.** KP found that the indirect costs for the Conawapa and Keeyask GS are thought to be high, but are

[1] Knight Piesold Independant Expert Consultant Report, p. 7.

[2] *Id.*, p. 24.

not inconsistent with other Crown Corporations. The indirect costs were not documented with the same diligence as the direct costs discussed above.

- **Construction Management, Schedule, and Contracting Plans for Conawapa and Keeyask GS.** KP determined that the overall approach to construction management, schedule, and contracting for Conawapa and Keeyask GS follows well-documented internal standards developed by MH's New Generation Construction Division. In order to save costs, MH has assumed project delivery risk rather than requiring contractors to assume that risk for a fee. This leaves MH with the task of managing the construction integration.
- **Escalation Reserve.** KP does not believe that there is enough escalation reserve for either Keeyask or Conawapa. MH received an estimate of the construction escalation rate from IHS Global Insight, but averaged this with Canadian CPI, which has resulted in a lower escalation reserve than required.[3]

<u>Keeyask Only</u>

- **December 2013 Civil Contract Bids.** KP notes that the December 2013 Civil Contract Bids should be considered as part of the NFAT process. The bids should provide better information on the cost estimates and project execution strategy including the construction management, schedule and contracting plans. These bids are for the generation project only; the transmission interconnection project is still in the study phase and has not yet gone out to bid.
- **Keeyask Infrastructure Project (KIP).** The estimates for the KIP are thought to be a higher class of estimate than the Keeyask or Conawapa GS given the advanced stage of this project. This means there is less uncertainty around the cost estimates for the KIP.

MH assumes the uncertainty range for Keeyask given in Appendix 7.2 is minus 10 percent to plus 15 percent around the P50 value and the uncertainty range for Conawapa is minus 15 to plus 20 percent around the P50 value.[4]

It its report, POWER Engineering looks at the MH's cost estimates for the Keeyask and Conawapa Transmission projects. Its findings are summarized below.

[3] *Id.*, pp. 27-28.

[4] NFAT Submission, Appendix 7.2, p. 45.

- **Keeyask Transmission Project**. Initially POWER Engineering felt that the cost estimate for the Keeyask Transmission Project was too high, but POWER Engineering was satisfied with MH justification for the high costs. MH's reasons were: project is very short and efficiencies of long lines cannot be obtained; project required two mobilizations since it is constructed in two separate years; and the river crossing is difficult and expensive.[5]
- **Conawapa Transmission Project.** POWER Engineering stated that MH's estimate for the Conawapa Transmission Project was at the low end of their range they would expect.[6]

B. Natural Gas

MH evaluated three configurations of natural gas generation - a heavy duty combined cycle gas turbine (CCGT), heavy duty simple cycle gas turbine (SCGT) and an aeroderivative simple cycle gas turbine. MH's assumptions, provided in NFAT Appendix 7.2, are summarized below.

Cost Component	CCGT	SCGT	Aeroderivative
Overnight Costs (2012$/kW)	$1,240	$740	$1,450
Fixed O&M (2012$/kW/year)	$20.00	$16.00	$25.00
Variable O&M (2012$/MWh)	$3.50	$4	$4.50
Heat Rate (btu/kWh)	6,652	9,906	9,475
LCOE (2012$/MWh)			
--Without transmission	$72-$93	$120-$256	$157-$412
--Brownfield with transmission	$73-$94	$121-$261	$158-$418
--Greenfield with transmission	$73-$95	$124-$272	$161-$429

Figure 2-1: NFAT Natural Gas Generation Assumptions

MH assumed a range of uncertainty of -30% to +50% for the capital costs for all gas generation.[7] MH also notes that while substantial decreases in the capital costs of combustion turbines are not expected, there will likely be increases in efficiency, which will reduce costs per unit of energy.[8]

[5] POWER Engineering. *Manitoba Hydro NFAT IEC Transmission Line Construction and Management Report - Confidential Version.* January 13, 2014, p. 3.

[6] *Id.*, p. 5.

[7] NFAT Submission, Appendix 7.2.

[8] NFAT Submission, Chapter 7, p. 28.

KP has filed a report ("KP Report") with the PUB reviewing these and other capital cost assumptions made by MH.[9] The KP Report notes that MH developed its assumptions based on a study conducted by Gryphon International Engineering Services, Inc. (Gryphon). In general, the KP Report agreed that MH's assumptions were in line with industry estimates, subject to certain critiques. First, the KP Report recommended a tighter accuracy range of -15% to +20% due to the advanced status of natural gas generation technology. The KP Report also noted that MH's O&M costs fall within the range of industry estimates, but given the wide range MH should perform a sensitivity analysis to see if higher or lower O&M costs will change the results of the economic evaluation of development plans.

Unit	Fixed O&M		Variable O&M	
	MH	Industry	MH	Industry
CCGT	$20.00	$6.30 - $22.00	$3.50	$3.27-$4.90
SCGT	$16.00	$5.26 - $14.00	$4.00	$5.00

Figure 2-2: Comparison of MH assumptions to industry estimates - gas generation O&M[10]

Overall, MH's assumptions regarding gas generation capital costs are generally reasonable for the purposes of the NFAT analysis, albeit at the higher end of the industry range of values. As previously noted, MH anticipates future improvements in combustion turbine efficiency—an assumption which was not incorporated into their analysis.

[9] Knight Piésold Independent Expert Consultant Report, pp. 51-55.

[10] *Id.*, p. 54.

C. Wind

MH has provided its assumptions related the components of wind costs in Appendix 7.2 and these are shown in the table below.

Cost Component	Value
Overnight Costs (2012$/kW)	$2,400
Fixed O&M (2012$/kW/year)	$39.55
Variable O&M (2012$/MWh)	$0.00
Capacity Factor	40%
LCOE (2012$/MWh)	
--Without transmission	$78
--With transmission	$83

Figure 2-3: NFAT Wind Assumptions

MH has identified the source of these assumptions in the information that it provided to La Capra Associates and other IECs as discussed in detail below.

Capital Costs

MH cites a report from the Electric Power Research Institute entitled, *Engineering and Economic Evaluation of Utility-Scale Wind Energy* and dated December 2012. This report gives capital costs for a variety of locations in the United States and Brazil and Australia. MH considers Michigan the most analogous to the development environment in Manitoba and has selected EPRI's estimate for Michigan as the basis for its capital costs. EPRI's estimate for Michigan was [redacted], which is coincidentally the average estimate for all of the locations.

In addition to the EPRI Report, MH also provided a report by Garrad Hassan, entitled *CAPEX & OPEX Estimate for a Generic Wind Farm in the Province of Manitoba* dated September 2011. This report provides an estimate of the costs of generic 150 MW wind farm in Manitoba. It estimates the base case capital costs to be $2,098/kW.[11]

MH's estimate in Appendix 7.2 of the NFAT of $2,400/kW is higher than the sources provided and discussed above. Additionally, MH uses $2,300/kW for wind in the

[11] Garrad Hassan, *CAPEX & OPEX Estimate for a Generic Wind Farm in the Province of Manitoba*. September 2011.

economic analysis in the NFAT. LCA's understanding is that MH had revised its costs downward and used the $2,300 in the economic analysis.[12]

MH's estimate of onshore wind capital costs is higher than LCA expected based on its research of publicly available sources and LCA's experience reviewing capital costs of onshore wind projects. These project costs have been falling in recent years, largely because of declines in turbine prices. MH's response to the PUB IR I-277a provides some evidence of capital cost declines as it provides EIA's historical on-shore wind costs which show capital costs decreased from $2,614 in 2009 to $2,093 in 2011.[13]

The US Department of Energy's *2012 Wind Technologies Market Report* is a survey of wind power development activity and costs in the United States and includes aggregated project cost information on a national and regional level. This report also notes the decline in on-shore wind installed costs in recent years. It notes a steady decline in turbine costs since late 2008 as shown in the figure below. Beyond the price reductions of 20-35% percent reflected in the figure below, the report cites improvements in turbine technology and improvements in turbine contract terms in recent years as factors that have exerted downward pressure on total project costs.

[12] MH's January 20 email in response to LCA's December 16 email.

[13] PUB/MH I-277a, p. 2.

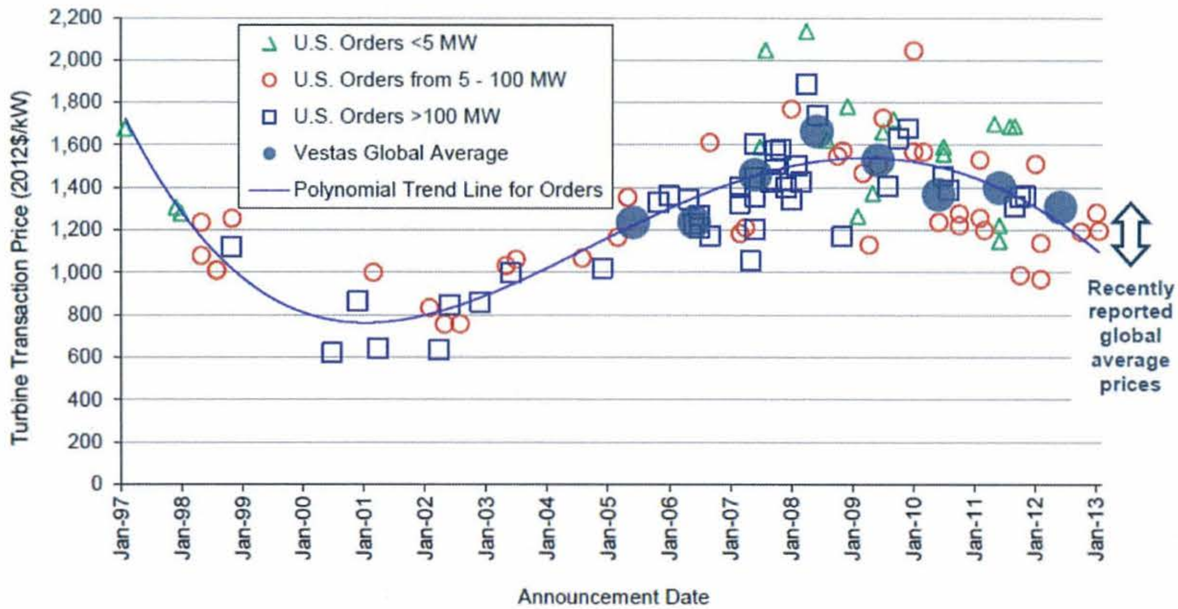

Figure 2-4: Turbine Transaction Prices[14]

In addition to turbine transaction prices, the report also looks at trends in total project costs. This analysis shows that total project costs have declined by about $300/kW from their peak in 2009 and 2010. The national average costs for 2012 were $1,940/kW and early anecdotal indications from 2013 projects showed further declines for 2013.[15] These estimates include transmission interconnection costs.

The US Department of Energy report also looked at regional difference for project costs in the United States. It found that the capacity weighted average installed costs for projects in the interior region, which includes the central portion of the country from Montana, Minnesota, and North Dakota south to Texas and New Mexico, were about $1,750 in 2012 including transmission interconnection costs.

The majority of wind farms are merchant generators, so the cost data in the Department of Energy report reflects the costs experienced by merchant generators. If MH builds its own wind generation, its experience may be different. For example, capital costs for a plant and interconnection could be reduced somewhat since MH could optimize the

[14] US Department of Energy, *2012 Wind Technology Market Report,* August 2013, p. 33. http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf

[15] *Id.*, p. 34.

interconnections rather than have independent developers building to an established grid code.

Operations and Maintenance Costs

MH cites the United States Energy Information Administration (EIA) document, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, dated April 2013[16] as the source for the O&M Costs. It also states that these costs are consistent with the EPRI report cited above.

The variable O&M costs are not documented by MH.

Capacity Factor

The source of MH's 40 percent capacity factor assumption is an EPRI Solution Report entitled, *Manitoba Hydro Wind Integration Sub-Hourly Operational Impacts Assessment.*[17] The 40 percent capacity factor is consistent with the historical production of MH's two existing wind farms.[18]

Recent improvements in wind turbine technology have yielded higher capacity factors for a given wind resource. MH has not provided information about the Province's wind resource, but the North Dakota has one of the best wind resources in the United States. Recently Northern States Power filed for approval of 600 MW of wind projects with an average capacity factor of 42 percent.[19] This is consistent with La Capra Associates' experiences with other wind energy developments in this region.

Change in Cost over Time

MH assumes that wind costs remain constant in real terms over time.

Recent research funded by the International Energy Agency and conducted by the National Renewable Energy Laboratory (NREL) projects substantial decreases in the LCOE of onshore wind power from improvements in wind turbine technology between

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[16] US Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants,* April 12, 2013, http://www.eia.gov/forecasts/capitalcost/.

[17] Attached to GAC/MH I-014.

[18] KP/MH I-007b.

[19] North Dakota Public Service Commission, Docket 13-0706, Northern States Power: Testimony of Steven W. Wishart, p. 17. http://www.psc.nd.gov/database/documents/13-0706/001-040.pdf.

now and 2030. The decreases in LCOE are expected to come from a variety of sources including improvements in:

- Drivetrain technology;
- Manufacturing efficiency;
- O&M strategies;
- Power conversion;
- Real time resource assessment;
- Rotor concepts (more energy capture through better rotor design); and
- Tower concepts.

The NREL report compiled information from 13 separate studies which projected future wind costs and created the graph below. The studies compiled projected decreases in LCOE ranged from 0 to 40 percent by 2030, with the central 60% of industry projections showing a mean decline of 20 to 30 percent by 2030.[20]

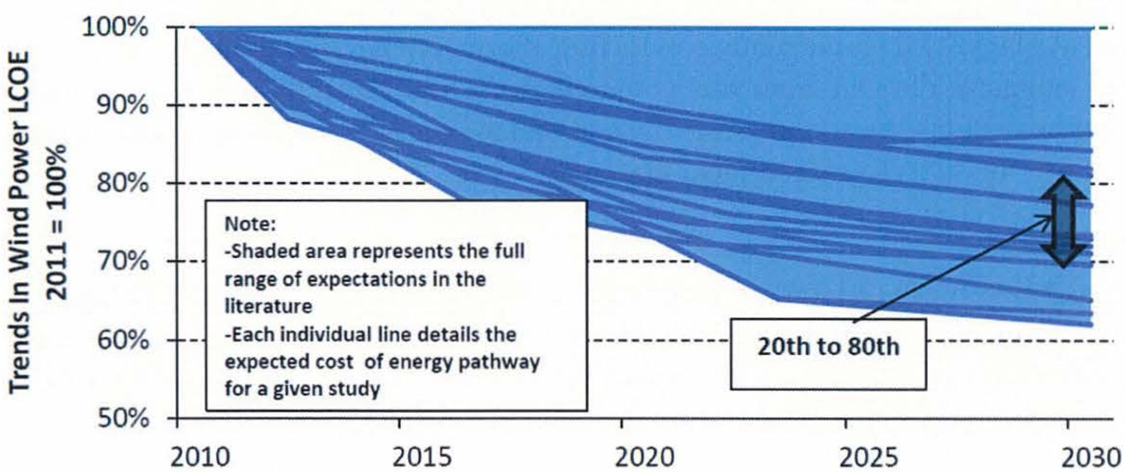

Figure 2- 5: Range of LCOE Projections from 13 Studies[21]

[20] National Renewable Energy Laboratory, *The Past and Future Cost of Wind Energy,* IEA Wind Task 26, NREL/TP--6A20--53510. May 2012, p. 7. http://www.nrel.gov/docs/fy12osti/53510.pdf.

[21] *Id.*, p. vi.

Lifetime

MH assumes a 20-year project life for wind generation. The length of power purchase agreements (PPAs) in the industry is typically between 20 and 25 years. MH has a 25-year PPA with the St. Leon wind project[22] and a 27-year PPA with the St. Joseph wind project.[23] MH's project life assumption is on the low end of the range of typical industry estimates and is lower than the terms of their current agreements.

D. Demand Side Management

MH has identified demand side management (DSM) as a potential resource option which passed the initial resource technology screening process. MH has also recently contracted a third party consultant to perform a DSM potential study, which concluded that there is significant potential for additional DSM programs, beyond the levels currently in the Power Smart program.[24]

Despite this evidence, MH did not develop assumptions and parameters for additional DSM resources, and did not incorporate additional DSM into any of the alternative development plans.[25] MH is currently conducting alternative development case analysis with DSM estimates derived from this potential study and has indicated its intent to complete those studies (economic and financial analysis) in February and introduce those results in this NFAT proceeding at that time.

E. Biomass

MH included two types of biomass generation in its initial screening of technologies, agricultural crop residues and wood based fuel. MH deemed both not suitable for further exploration due to high fuel transportation costs. The cost assumptions for biomass generation from Appendix 7.2 are included in the table below.

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[22] *Harvesting the Wind in St. Leon Manitoba,* http://www.manitoba.ca/iem/energy/wind/files/stleons_wind_brochure.en.pdf.

[23] St. Joseph Wind Farm in Manitoba Begins Producing Power. North American Windpower, 13 Jan 2011, http://www.nawindpower.com/naw/e107_plugins/content/content.php?content.7183

[24] NFAT Submission, Chapter 7, pp. 20-23.

[25] *Id.* See also NFAT Submission, Appendix 7.2, pp. 12-13. See also La Capra Associates' Technical Appendix 3: Alternative Development Plans.

Cost Component	Wood Waste Fired Generation		Agricultural Crop Residue-Fired Generation	
Capacity (MW)	15	30	15	30
Overnight Costs (2012$/kW)	$6,100	$4,100	$6,100	$4,100
Fixed O&M (2012$/kW/year)	$400	$220	$400	$220
Variable O&M (2012$/MWh)	$0.00	$0.00	$0.00	$0.00
Fuel Price (2012$/Oven Dried Tonne)	$73-$100	$73-$100	$74-$96	$74-$96
Capacity Factor	82%	83%	83%	83%
LCOE (2012$/MWh)	$179-$206	$128-156	$180-196	$129-$145

Figure 2-6: NFAT Biomass Cost Assumptions[26]

In the commercially sensitive information provided, MH has provided a study to back up the fuel price assumptions used in the NFAT.[27] MH's response to LCA I-285 includes a table from this report which shows that transportation costs make up about 25 percent of the costs for agricultural residues. The attached report does not contain a similar analysis for forest residues.

F. Solar Photovoltaic

MH deemed solar photovoltaic (PV) not suitable for further evaluation based upon its high costs. The cost components for the three types of solar PV are specified in Appendix 7.2 and are included in the Table below.

[26] NFAT Submission, Appendix 7.2, pp. 205-231.

[27] LCA/MH I-285 Att 1, Agronovita Inc and Golder Associates, *Detailed Information for Stand Alone Biomass Generating Stations in Manitoba,* April 2011.

Cost Component	Fixed Tilt	Single Axis Tracking	Dual Axis Tracking
Overnight Costs (2012$/kW)	$3,750	$4,500	$5,000
Fixed O&M (2012$/kW/year)	$19.70	$21.10	$24.60
Variable O&M (2012$/MWh)	$0.00	$0.00	$0.00
Capacity Factor	20%	26%	28%
LCOE (2012$/MWh)	$203	$187	$193

Figure 2-7: NFAT Solar PV Cost Assumptions

In Appendix 7.2 MH states that solar PV costs are expected to decline significantly during the NFAT study period with Total Plant Costs dropping by over 50 percent by 2020 and by 75 percent by 2030.[28] Using capital costs consistent with these cost declines in MH's LCOE analysis would have the LCOE of a fixed tilt system at $107/MWh and $59/MWh in 2020 and 2030 respectively. While MH notes that the decline in plant costs will make solar PV increasingly competitive in the future, MH screens solar PV out of further analysis based on its costs today. Incorporating these decline estimates, the LCOE of the three solar PV types are included in the table below.

Year	Fixed Tilt	Single Axis Tracking	Dual Axis Tracking
2012	$203	$187	$193
2020	$107	$98	$102
2030	$59	$54	$56

Figure 2-8: Projected Future Solar LCOE (2012$/MWh)

Solar PV costs have declined significantly over the past 15 years. The Lawrence Berkeley National Laboratory report, *Tracking the Sun VI,* states that solar PV installed costs have declined six to seven percent per year with much of that decline occurring since 2009. Additionally early indications show that installed cost declines continued in 2013.[29]

Looking forward, industry sources agree that costs will continue to decline. Navigant Research published a report, *Solar PV Market Forecasts*, in which they state they expect

[28] NFAT Submission, Appendix 7.2, p. 20.

[29] Lawrence Berkeley National Laboratory, *Tracking the Sun VI*, pp. 13-14. http://emp.lbl.gov/sites/all/files/lbnl-6350e.pdf

installed costs to decline at three to eight percent per year through 2020.[30] The US Department of Energy SunShot Initiative is calling for solar PV costs to decline by 75% between 2010 and 2020.[31]

In its screening process for generation technologies, MH split technologies into three categories based on the EIA LCOE analysis. The categories were:

- Less than $100 per MWh;
- $100-130 per MWh; and
- Greater than $130 per MWh.[32]

Assuming the cost declines projected by MH for solar PV installed costs – a decline of 50% by 2020 - the LCOE values of solar PV would be between $98 and $107 per MWh depending on tracking type. This would move solar PV from the greater than $130 per MWh category to the less than $100 per MWh or $100 to $130 categories and solar PV would likely not have been deemed unsuitable for further consideration in the NFAT screening process.

G. Coal

MH deemed coal power generation unsuitable for further exploration due to regulatory concerns. The Province of Manitoba has restricted coal power generation to the support of emergency operations with the January 2010, *Climate Change and Emissions Reductions Act*. MH also cites concerns about permitting new coal facilities in the US.[33]

MH looked at four coal generation types in its analysis: subcritical pulverized coal generation, supercritical coal generation and integrated gasification combined cycle with and without carbon capture and storage. MH's cost assumptions for each are included in the table below.

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[30] Navigant Research, *Solar PV Market Forecasts,* Q3 2013, p. 2. http://www.navigantresearch.com/wp-assets/uploads/2013/07/MD-SMF-13-Executive-Summary.pdf.

[31] US Department of Energy, *Sun Shot Initiative,* http://www1.eere.energy.gov/solar/sunshot/vision_study.html Accessed January 15, 2014.

[32] NFAT Submission, Chapter 7, p. 10.

[33] NFAT Submission, Appendix 7.2, p. 31.

Cost Component	Subcritical Pulverized Coal	Supercritical Pulverized Coal	Integrated Gasification Combined Cycle (IGCC)	IGCC & Carbon Capture and Storage
Overnight Costs (2012$/kW)	$3,440	$3,440	$3,896	$6,471
Fixed O&M (2012$/kW/year)	$22.83	$22.83	$61.63	$72.10
Variable O&M (2012$/MWh)	$4.20	$4.20	$7.51	$8.37
Fuel Costs ($2011/short ton)	$13.53 (2012) $29.35 (2040)	$13.53 (2012) $29.35 (2040)	$13.53 (2012) $29.35 (2040)	$13.53 (2012) $29.35 (2040)
Capacity Factor	85%	85%	80%	80%
LCOE (2012$/MWh)	$110-$138	$110-$138	$124-$150	$155-$191

Figure 2-9: NFAT Coal Generation Cost Assumptions

H. Nuclear

MH deemed nuclear power generation unsuitable for further exploration due to difficulty integrating nuclear generation into the grid and due to the *Manitoba High-Level Radioactive Waste Act* which prohibits the long-term storage of high level radioactive waste. MH also cites the limited operating flexibility of nuclear generation as a challenge with MH's hydropower based system.[34]

MH's nuclear power cost assumptions are included in the table below.

Cost Component	Nuclear Power Plant
Overnight Costs (2012$/kW)	$6,455
Fixed O&M (2012$/kW/year)	$92.35
Variable O&M (2012$/MWh)	$2.12
Fuel Costs	Not determined
Capacity Factor	90%
LCOE (2012$/MWh)	$130-$144

Figure 2-10: NFAT Nuclear Generation Cost Assumptions

[34] NFAT Submission, Appendix 7.2, p. 35.

I. Geothermal

MH deemed geothermal power unsuitable for further exploration due to the quality of the resource available in Manitoba. MH's cost estimates for geothermal generation are included in the table below.

Cost Component	Enhanced Geothermal System Generation
Overnight Costs (2012$/kW)	$25,000 -$37,000
Fixed O&M (2012$/kW/year)	$66.00
Variable O&M (2012$/MWh)	$0.00
Capacity Factor	90%
LCOE 2012$/MWh	$294-$437

Figure 2-11: NFAT Geothermal Generation Cost Assumptions

J. In-Lake Wind

MH deemed in-lake wind unsuitable for further exploration due to its high costs. Given the availability of on-shore wind at lower cost, this is a reasonable conclusion. MH's cost estimates for in-lake wind are included in the table below.

Cost Component	In-Lake Wind
Overnight Costs (2012$/kW)	$4,000-$7,600
Fixed O&M (2012$/kW/year)	$74.00
Variable O&M (2012$/MWh)	$0
Fuel Costs	Not determined
Capacity Factor	43%
LCOE (2012$/MWh)	
--Without transmission	$132-$225
--With transmission	$140-$233

Figure 2-12: NFAT In-Lake Wind Generation Cost Assumptions

K. Summary of Technology Specific Findings

We found two main issues with MH's technology specific assumptions. The first is with the cost estimates for Keeyask and Conawapa. KP believes that the contingency cost s used by MH are t oo low and should be in line with P90 or P80 on MH's contingency curve. KP also notes the importance of including the December 2013 Civil Contract Bids in the NFAT review process.

The second issue is with the cost declines over time for solar PV and wind. MH is looking at a 78 year planning horizon for the NFAT analysis. By not including any of the expected cost improvement, MH is handicapping technologies with expected improvement. Solar PV was screened out of further considerations in the development plans based on its cost today, while its costs by 2020 would make it competitive with other technologies. Wind makes it through the screening process, but the cost estimates used in the economic analysis make the development plans including wind appear less attractive than they would be.

III. Levelized Cost of Energy Analysis

A. Manitoba Hydro Levelized Cost of Energy Overview

MH used the technology specific assumptions described above to calculate the LCOE for each technology. In cases where a range of input assumptions was given, a range of LCOEs were calculated.

In the NFAT analysis, the LCOE analysis is used solely as a reference point. The inputs to the LCOE analysis are used in the economic analysis of the development plans, but the LCOEs themselves are not used.

B. Levelized Cost of Energy Methodology

MH conducts its LCOE analysis from the point of view of MH as the owners of the projects. For a given technology, the total project costs are calculated for each year of the project life. Capital costs are spread over several years depending on the construction timeline for each technology. Energy generation is calculated for each year based upon the technology capacity factor. The present value of the project costs is divided by the present value of the energy generation. A discount rate of 5.05% is used in the analysis.

MH's methodology differs from the revenue requirement methodology which involves calculating the revenue requirement from ratepayers each year, taking the present value of the annual revenue requirements and dividing by the present value of the annual generation to get the LCOE in dollars per MWh. The methodology used in the NFAT is from the perspective of MH as project owner, while the revenue requirement methodology would be from the perspective of the rate payer. The two methodologies should yield similar results when looking at the entire life of a generation project, but could have different outcomes when looking at less than a full life. The LCOE analysis is only looking at full project lives, so MH methodology should suffice.

Additionally, MH's LCOE methodology calculates costs based on capacity factors that vary by unit. For example, SCGT units are assumed to have a capacity factor of 5%-20%, while geothermal systems are assumed to have a 90% capacity factor. Generators with low capacity factors will typically have higher LCOE values because they produce less energy to spread out costs. While the capacity factor assumptions used by MH are reasonable based on actual operating characteristics, it is important to acknowledge that different types of units (peaking, base load, etc.) serve different purposes and comparing all technologies on an LCOE basis can be misleading.

C. Use of Levelized Cost of Energy Results

The results of the LCOE analysis are simply provided as a reference point in the NFAT. Instead of using the results of this analysis, MH uses LCOE values developed by the US EIA as their basis for screening technologies on LCOE. The assumptions that go into MH LCOE analysis are used later in the NFAT as part of the economic analysis.

IV. Summary and Conclusions

LCA has reviewed MH's cost assumptions and LCOE analysis. The MH LCOE analysis is developed during the resource screening process, but not actually used for screening purposes. The technology assumptions from the analysis are carried forward into the economic analysis in the NFAT. Several issues were identified with the LCOE analysis and cost assumptions including:

- Some of their cost assumptions are out of date;
- MH does not allow for any changes in technology costs or characteristics over time;
- Their LCOE analysis does not incorporate any uncertainties; and
- The comparison of technologies with different operating profiles, characteristics, etc. on an equivalent LCOE basis can be misleading.

A. Cost Assumption Issues

MH's onshore wind cost assumptions including capital costs, project life and capacity factor combine to make MH's analysis overly conservative with respect to wind costs. Their assumptions significantly overstate the costs in today's market and ignore anticipated improvements over time. These assumptions are carried forward into the economic and financial analyses, which handicaps the development plans containing onshore wind.

Additionally, MH has not presented cost assumptions or a LCOE analysis for DSM.

B. Changes in Technology Costs over Time

Industry sources show that both solar and wind costs are projected to decline over time, and that combustion turbines will experience improvements in efficiency. MH has not included any of these technology changes in the LCOE analysis or the economic analysis. Solar PV was screened out of consideration for inclusion in the development plans based on its current high cost despite projections that installed costs will be a quarter of their current value by 2030.

While wind did make it through the screening process, not including cost declines in the economic analysis makes the development plans which include wind power appear more costly.

C. Uncertainty

In its report, KP noted that given the magnitude of the Keeyask and Conawapa projects, the contingency included in the cost estimate was too low. KP believes that the contingency costs used by MH are too low and should be in line with P90 or P80 on MH's contingency curve.

Manitoba's range of cost uncertainty in Appendix 7.2 is inconsistent across different technologies. The range of uncertainty for Keeyask is minus 10 to plus 15 percent and for Conawapa is minus 15 percent to plus 20 percent, while the range of uncertainty for simple and combined cycle gas turbine is minus 30 percent to plus 50 percent.

D. LCOE Comparison Can Be Misleading

It is important to note operational assumptions can have a big impact on the resulting LCOE and that LCOE may not be the best screening tool for all energy needs. For example, the assumed capacity factor of a peaking unit would have a large impact on the calculated LCOE, but the real value of the peaking unit is the capacity it provides.