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Decision Gate 3: Review of the Muskrat Falls and Labrador Island HVdc Link and the Isolated Island Options

Department of Natural Resources
Government of Newfoundland and Labrador
October 22, 2012

Outline

- Introduction
- Options Reviewed
- Review Methodology
- Decision Gates and Estimating
- Load Forecast
- AC Integration studies
- HVDC Converters
- Transmission Lines
- SOBI
- Muskrat Falls GS
- Isolated Island Option
- CPW Analysis
- Conclusions

MHI Engagement

- MHI is a wholly owned subsidiary of Manitoba Hydro
- MHI has provided consulting services to over 70 countries worldwide
- Contract for this engagement
  - With the Department of Natural Resources
  - Contract signed May 22, 2012

The MHI Team

- MHI assembled a team of specialists in:
  - Load Forecasting
  - Project Management
  - Hydroelectric Generation
  - Thermal Generation
  - HVdc Engineering
  - AC Integration and Planning Studies
  - Submarine Cables and Marine Crossings
  - Financial Analysis
  - Additional subject matter experts as needed from the parent company

Terms of Reference

Objective

The Department of Natural Resources retained MHI to review work completed by Nalcor Energy since Decision Gate 2 in preparation for Decision Gate 3. The review shall include an assessment of the Cumulative Present Worth Analysis of the various components for each of the two Options, including a reasonableness assessment of all inputs into that analysis

Terms of Reference

Technical Assessment included

- Load Forecast
- AC Integration Studies
- Muskrat Falls Generating Station
- HVdc Converter Stations, Electrodes, and AC switch yards
- HVdc Transmission Line and collector system
- Strait of Belle Isle Marine Crossing
- Isolated Island components including Holyrood

Terms of Reference

Items excluded

- Load in Labrador
- Reliability Assessment of the two Options
- Hydrology Assessment of Muskrat Falls GS
- Alternative fuel types except wind (other report)
- Other island supply options
- Consideration of export market via Maritime Link
- Technical feasibility of Maritime Link
- Electricity requirements in Labrador
- Rates Impact of the two Options

Terms of Reference

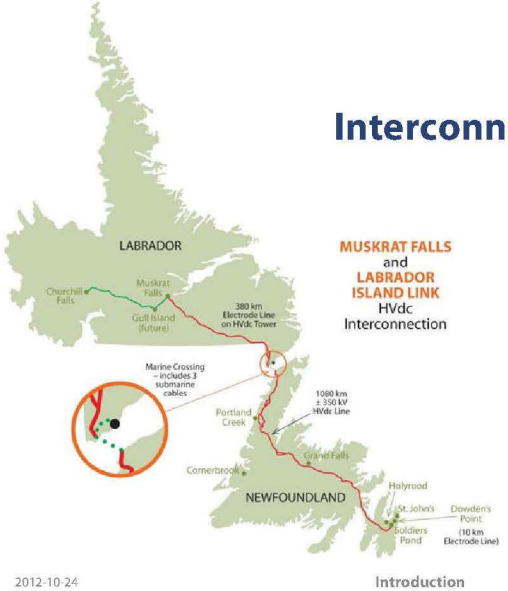
Background

- Only examined work done by Nalcor in preparation for Decision Gate 3 (DG3)
- Provide no comment on the Board of Commissioners of Newfoundland and Labrador Report and prior work on Decision Gate 2 (DG2)

Brief overview of the two Options

OPTIONS REVIEWED

Interconnected Option

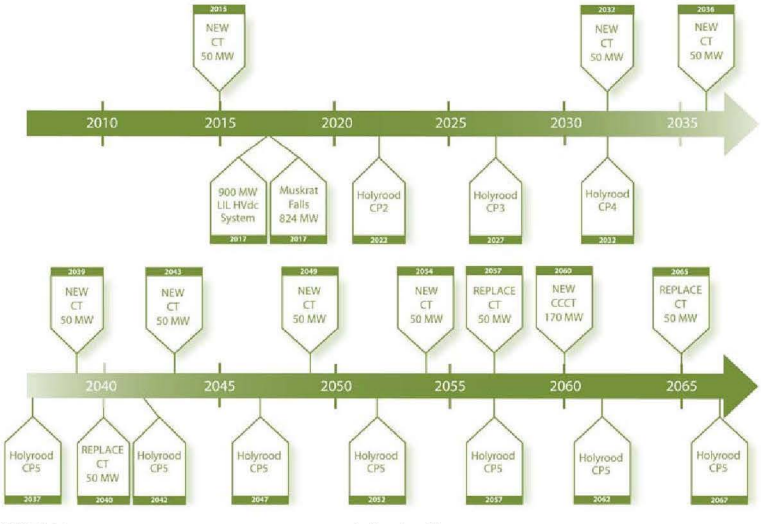


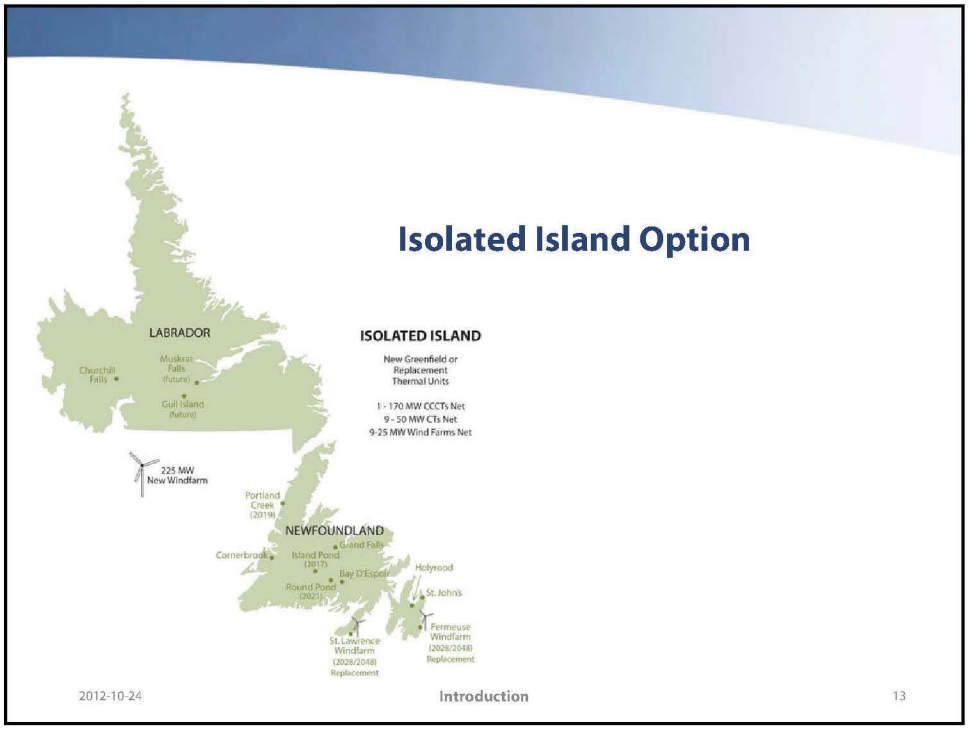
Interconnected Option

- Muskrat Falls Generating Station – 824 MW with average energy of 4.9 TWh/year. (8 TWh on the Island now).
- 900 MW Labrador-Island HVdc Transmission Link (LIL)
  - HVdc Converter Stations
  - 380 km electrode line in Labrador
  - 1080 km Transmission Line
  - Strait of Belle Isle (SOBI) Marine Cable Crossing
- Addition of:
  - One 170 MW Combined Cycle Combustion Turbine (CCCT) net
  - Ten 50 MW Combustion Turbines (CT) net
  - Three high-inertia synchronous Condensers

Timelines

INTERCONNECTED OPTION



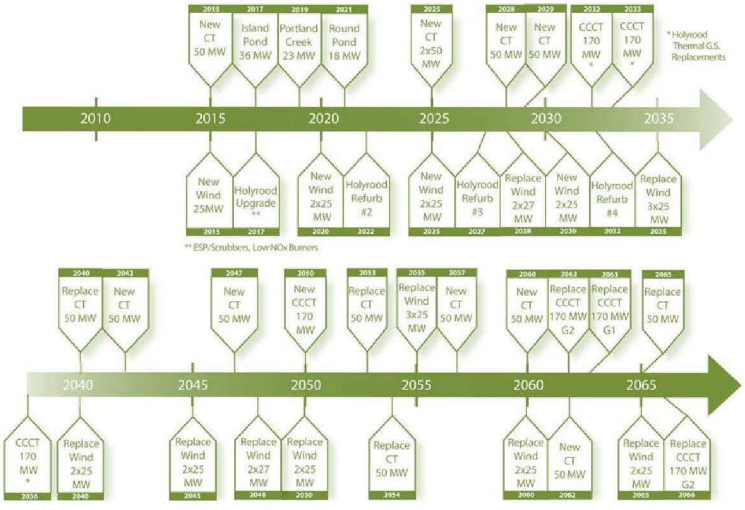


Isolated Island Option

- Holyrood Thermal Generating Station
  - Install pollution control equipment
  - Provide life extensions for generation to 2033 and 2036
  - Plant replaced with three 170 MW CCCTs, two in 2033 and one in 2036
- Three small hydroelectric generating sites are developed
  - Portland Creek (23 MW)
  - Island Pond (36 MW)
  - Round Pond (18 MW)
- Additional thermal units
  - Nine 50 MW combustion turbines (450 MW net)
  - One 170 MW combined-cycle combustion turbine (170 MW net)
- Wind farms
  - 23 – 25 MW, plus four 27 MW of wind farm (279 MW net)

Timelines

ISOLATED ISLAND OPTION



REVIEW METHODOLOGY

Technical Perspective

- Examined the schedule and cost estimates for
  - Generation stations
  - HVdc and AC transmission lines
  - SOBI
  - Converter Stations and associated equipment
  - Thermal and wind plants
- Reviewed Load Forecasts for both options
- Reviewed AC integration studies (previously not available at DG2)
- Reviewed HVdc drawings and specifications (not available at DG2)

Financial Perspective

- Reviewed CPW Analysis
  - Capital and Operating Costs
  - Fuel Price Forecasts
  - Allowance for Funds Used During Construction (AFUDC)
  - Escalation Rates
  - Discount Rates
  - Debt and Equity Components
  - Power Purchase Agreements (PPA)
- Examined the Sensitivity Analyses

Nalcor Participation

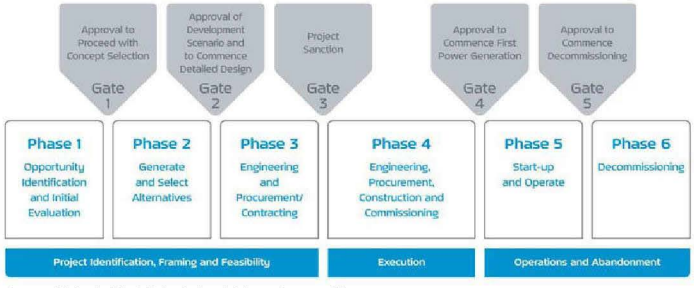
- Nalcor has provided all cost estimate and schedule information requested, along with project progress reports to confirm project definition completion.
- Detailed technical material, reports, and process documents were not provided in order to limit the scope of the examination as per the Terms of Reference except for AC integration, HVDC systems and associated equipment, and transmission lines.
- Nalcor has fully cooperated and made their technical staff available for meetings with MHI when requested.

Nalcor's Decision Gate Process

DECISION GATE AND ESTIMATING PROCESS

Decision Gate Process Overview

- Decision Gate 2: Selection of preferred option
- Decision Gate 3: Final check and confirmation that the investment decision is well founded (project sanction).



Source: Nalcor's Final Submission, Volume 2, page 35

AACE Cost Estimating Classes

- AACE International Recommended Practices No. 17R-97
- Recognized as a leading authority to cost estimating standards, practices, and methods

Class 5: +100% to -50%,	Concept Screening
Class 4: +50% to -30%,	Study or Feasibility (DG2)
Class 3: +30% to -20%,	**Budget Authorization (DG3)**
Class 2: +20% to -15%,	Control or Bid/Tender
Class 1: +15% to -10%,	Check Estimate

Project Definition

- The Lower Churchill Project team has demonstrated in documents provided to MHI by Nalcor that the overall design and engineering for the project was 40% complete at the time of submission (May 23).

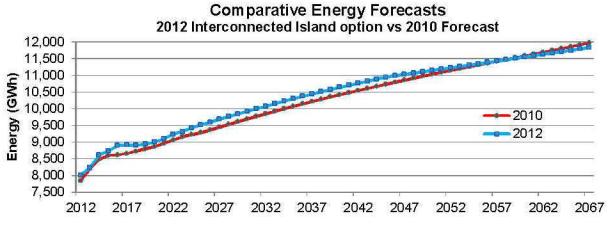
MHI's review of Nalcor's Load Forecast

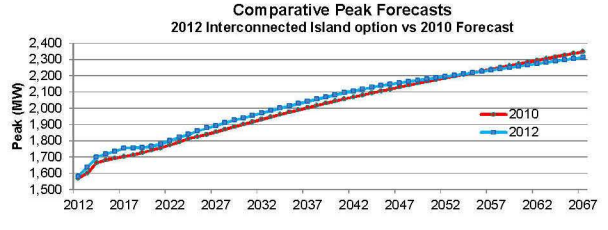
LOAD FORECAST

Load Forecast

- The load forecast is a key input into the generation resource plan where the generation plan is structured to match load growth increments in both capacity and energy.
- Two load forecasts were prepared for DG3
  - Interconnected Option (only this option is presented here)
  - Isolated Island Option

Nalcor's Energy Load Forecast





Load Forecast –Findings

- The 2012 Interconnected Island load forecast showed an increase in the domestic service sector which was expected with the higher econometric data for PDI and Population.
- The 2012 Interconnected Island load forecast showed decrease in the general service sector due to lower levels of growth for commercial business investment which is overly conservative.
- Industrial load does not include any new accounts over the period, which is very likely conservative.

Load Forecast –Findings

- The 2012 Isolated Island load forecast is less than the Interconnected option.
- This is the result of a higher marginal electricity price due to the cost of future generation being more expensive driven by escalating fuel costs.

Load Forecast – Significant Items

- ***MHI finds that the Interconnected Load Forecast is well founded and appropriate as an input into the Decision Gate 3 process.***
- MHI's primary concern is that the total Island energy and peak forecasts over the extrapolation period are too low based on past historical performance.
  - However, this one fact would not negatively impact the CPW analysis.
- MHI notes that the Interconnected option is more resilient to large increases in load as there is surplus energy in the system.

AC integrations studies were not reviewed as part of the DG2 investigations as they were not available.

AC INTEGRATION STUDIES

Integration Studies

- AC integration studies are necessary to assess the impact of new facilities on the existing electrical power system, includes operations, construction, and startup.
- Studies performed for Nalcor by SNC Lavalin include:
  - Construction Power
  - Load Flow and Fault Level
  - Stability
  - HVdc System Modes of Operation
  - Harmonic Impedance
  - Reactive Power
  - Transmission System Analysis – Muskrat Falls to Churchill Falls Transmission Voltage
  - Labrador-Island HVdc Link and Island Interconnected System Reliability

AC Integration Study Results

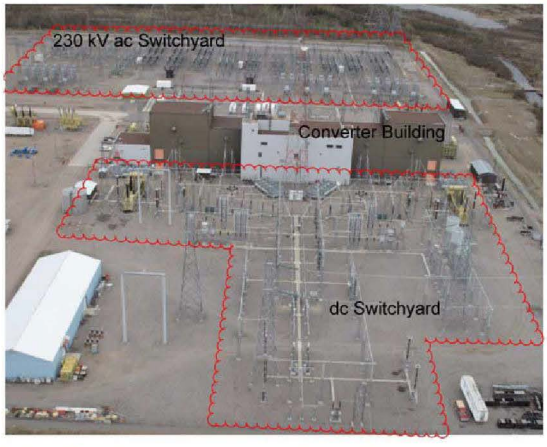
- ***The result of the six studies conducted by SNC Lavalin for ac integration demonstrates that Nalcor is in compliance with good utility practice. There is an opportunity during detailed design to optimize final configurations that may enhance the system reliability.***
- This optimization would not materially impact the CPW analysis.

Valves, Electrodes, AC switchyards & Synchronous Condensers

HVDC CONVERTER STATIONS

HVdc Converter Stations

- The following system single line diagrams were reviewed by MHI
  - HVdc converter stations (dc yard) at both terminals
  - Electrode sites
  - New 315 kV ac switching station at Muskrat Falls
  - AC system extension at Churchill Fall 735 kV / 315 kV switching station
  - New 230 kV ac station at Soldiers Pond.
- The dc and ac yard layouts shown in the single line diagrams follow good utility practice and the identified system upgrades are well supported by the study reports described in the AC Integration Studies.



HVdc Converter Stations

Henday CS is presented as an example.
2000 MW +/- 500 kV dc 230 kV ac

HVDC Schedule

- The HVdc system master scheduling documents provided by Nalcor to MHI outline the schedules for procurement, installation, and commissioning of the HVdc converter stations and related components.
- The project schedules and execution times including engineering, procurement, and constructions are comparable to similar HVdc projects and are reasonable.

HVDC Cost Estimate

- The Lower Churchill Project Short Form Technical Specification dated October 13, 2011 provided by Nalcor was reviewed by MHI.
- This document was provided to three suppliers to obtain cost estimates for the HVdc converter stations: ABB, Siemens and Alstom Grid.
- The Specification forms the basis for the costs estimates received from the suppliers. The typical practice was to discard the lowest estimate and average the two highest for budget preparation which is reasonable.

HVDC Cost Estimate

- The cost estimates for the synchronous condensers appear low when compared to other projects in Canada; however, Nalcor has secured these costs directly from manufacturers. The cost estimates are within the bands of cost estimate variability for an AACE Class 3 estimate.
- The project schedules and execution times including engineering, procurement, and constructions are comparable to similar HVdc projects.

HVdc Converter - Conclusion

- ***The system upgrades identified in the single line diagrams for HVdc converter stations, ac switchyards, and electrodes are well supported by the study reports provided to MHI by Nalcor and are reasonable as inputs to the Decision Gate 3 CPW analysis.***

HVDC and AC transmission line schedule, cost estimate, reliability

TRANSMISSION LINES

Transmission Lines

- The question of design reliability was a major concern at the last review.
- To address this, MHI's review was more involved for transmission lines in DG3 than the prior review as material was now available.

Schedule

- The construction window for all high voltage transmission line construction activities for the project complex has been allocated approximately four years with clearing activities starting in the second quarter of 2013.
- MHI finds the schedule to be reasonable and achievable provided construction work and equipment access is possible during all four construction seasons.

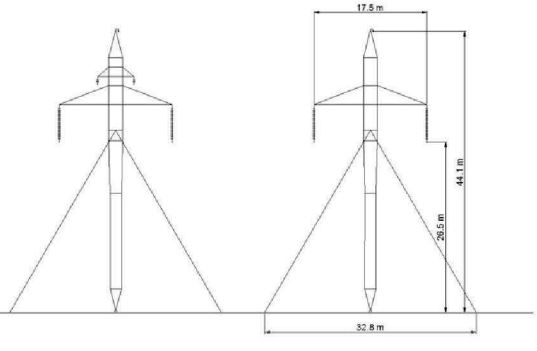
Cost Estimate

- Decision Gate 3 transmission line estimates are based upon the following contributory factors:
  - Costing from suppliers
  - Transmission contractor budgetary feedback
  - Engineering concepts that are virtually complete
  - Labour unit costing assuming a negotiated master labour agreement, equipment and commodity rates are identified
  - Productivity factors for labor, equipment while factoring in seasonal impacts.
- ***The costs for the transmission lines are within an AACE Class 3 estimate accuracy congruent to the requirements of Decision Gate 3.***

Transmission Line Technical Assessment

MHI examined

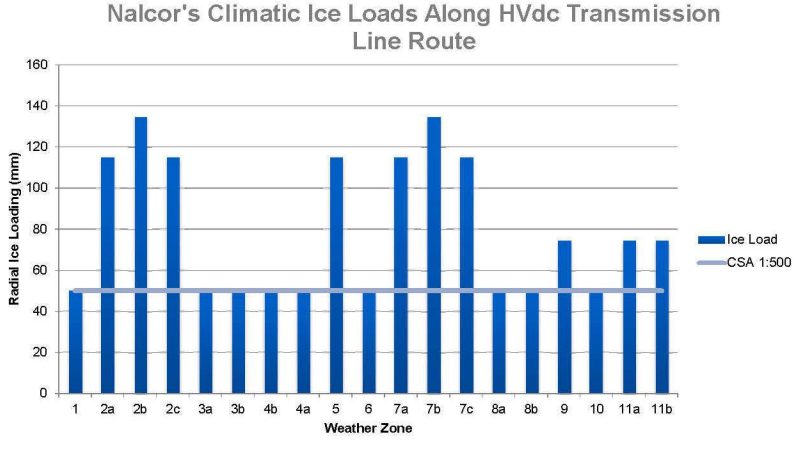
- Line Routes
- Structure Families
- Transmission Line Reliability
- Emergency Response Plan. The ERP will be completed prior to In-service



HVdc Transmission Line

Nalcor will only have one line and maybe a moose instead of ponies

Transmission Line Reliability



Transmission Line Reliability

- MHI notes that CAN/CSA C22.3 suggests a greater reliability of design to 1:150-year or 1:500-year return periods for lines of voltages greater than 230 kV which are deemed of critical importance to the electrical system.
- It is MHI's opinion the ±350 kVdc and 315 kV ac lines proposed for the Lower Churchill Project be classified in a critical importance category due to their operating voltage and role in Nalcor's long term strategic plan for its transmission system and be designed to a reliability return period greater than 1:50 years.

Transmission Line Reliability

- Nalcor, from its own analysis of the climatic loading study and information acquired from experience in the region, has specified a transmission line design criteria that exceeds the ice loading requirements experienced in Newfoundland and Labrador over the past 50 years.
- One must note that there is ambiguity in the interpretation on how to apply the 2005 CSA standard. The standard is relatively new and experience in the application to design in Canada is limited.

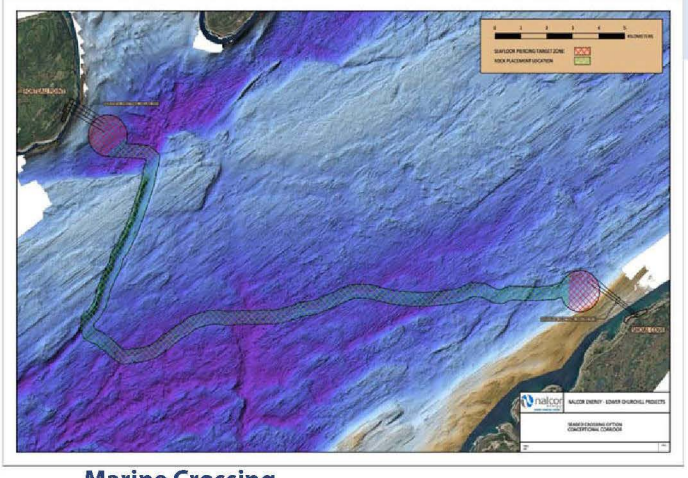
Transmission Line Reliability

- Transmission line reliability return period is not the sole measure in determining how the transmission line will perform.
- Design criteria, operation & maintenance practices, the electrical system, and the effectiveness of any backup and emergency response plans must all be considered together.
- Nalcor's business practices, as any utility following good utility practices, considers all of these factors.

Transmission Line – Conclusions

- ***The transmission line structures and routes selected for all transmission facilities are cost-effective considering the terrain, route, and climatic loading expected.***
- ***From the review of the written documentation provided, design methodology, and information recorded in the Nalcor staff interviews, MHI has found that the Decision Gate 3 estimates for all transmission facilities were prepared in accordance with good utility practice and within an AACE International Class 3 level accuracy range.***

STRAIT OF BELLE ISLE MARINE CROSSING



Marine Crossing

Nalcor's design concept; cables follow the deep trench indicated. Alternate routes may be identified during detail design resulting is additional savings.

Strait of Belle Isle Marine Crossing

Cable landing at a 300 kV DC terminal station
(source: Cabletricity)

SOBI Details

- 3 cables cross the Strait, two are active, one spare
- Design voltage +350 kV MI cable is a mature technology. MI technology has been proven to +/- 500 kV.
- Iceberg risks are mitigated by Horizontal Directional Drilling to reduce shore affects, and placement of cables in deep water across the strait.
- Submarine cable is protected with a rock berm.

SOBI DG3 Review

- Fibre optic cable is now embedded in the marine cable, resulting in net cost savings
- A test bore hole was drilled to confirm drill rates, geology, and process
- Detailed design by the contractor may result in additional savings due to optimized routing

SOBI Conclusion

- MHI considers the project construction schedule to be reasonable but all onshore and HDD work should be completed in advance of receipt of the cable.

- ***The costs of the Strait of Belle Isle marine crossing have increased marginally but are considered to be reasonable and within the AACE Class 3 estimate range for Decision Gate 3.***

Schedule & Cost Estimate Assessment

MUSKRAT FALLS GENERATING STATION

Muskrat Falls Development

Conceptual Drawing of Muskrat Falls Generating Station

Muskrat Falls – Scope of Review

- Assessed methods used to prepare cost estimates
- Nalcor used a work breakdown structure approach
- Extensive focus on:
  - Construction Labour Rates
  - Construction Materials
  - Construction Equipment
  - Project Management and Engineering
- Provision made for contingencies and cost escalations

Project Concept

- Revisions to project concept are driving budget changes as a result of detail design:
  - Reorientation of the powerhouse in the river by ~30^{0}
  - Spillway configuration changed from a four-radial gate to a five-vertical gate arrangement
  - A significantly more massive powerhouse intake structure
  - The south dam changed from a roller-compacted concrete (RCC) structure to a rock fill dam
  - Addition of a second service bay at the north end of the powerhouse
  - Addition of an RCC cofferdam to the bulk excavation work contract.

Schedule

- The target schedule indicates:
  - Project start fourth quarter 2012
  - Revisions to work package timing and durations as a result of design and engineering changes and refinements
  - First power date is July 2017.
- ***From MHI's perspective, the project scheduling is comprehensive, detailed, and consistent with best industry practice for similar projects.***
- ***The current project schedule is appropriate and reasonable to meet the requirements of DG3.***

Cost Estimate

- For DG3, the Muskrat Falls Generating Station project cost estimate increased by 21% after allowing for a decrease of escalation and contingency funds in 2012.
- The Muskrat Falls Generating Station project contingency in the DG3 estimate is 9.0%, but maybe higher with the application of allowances if required.
- ***Based on the amount of engineering and levels of costs provided, MHI considers the DG3 cost estimate to be an AACE Class 3 estimate and therefore would be considered reasonable for the DG3 project sanction stage.***

Labrador Transmission Assets (LTA)

- LTA includes the 315 kV transmission lines from Muskrat Falls to Churchill Falls, and the switchyards at both Muskrat Falls and Churchill Falls
- LTA schedule (i.e. 315 kV transmission line) has a projected in-service date of May 2016.
- LTA estimate increased significantly with Decision Gate 3 as a result of including the new 735 kV equipment at the Churchill Falls Switchyard
- ***Overall the Labrador Transmission Asset Decision Gate 3 estimate is comprehensive, reasonable and prepared in a manner consistent with best utility industry practice***.

Generation Plan

ISOLATED ISLAND OPTION

Holyrood Thermal Generating Station (HTGS)

- HTGS consists of three heavy fuel oil boilers for a combined net generating capacity of 466 MW.
- HTGS currently supplies approximately one third (up to 2,996 GWh annually) of the island's existing firm energy.
- The plant normally operates all three units during the highest customer demand periods of December through to March.
- End of useful life: 2032 to 2035

Holyrood Thermal Generating Station (HTGS)

- The final regulation for reducing GHG emissions from coal-fired electricity generation were announced by Canada's Environment Minister, the Honourable Peter Kent, on September 5, 2012. Again there was no mention of oil-fired generation but certainly greenhouse gas emissions from oil would certainly mirror those from coal.
- Holyrood could become a target for closure in advance of its end of life.

HTGS Pollution Control Equipment Additions

- Projected capital cost of $680 million in service 2017
  - Electrostatic precipitators
  - Scrubbers
  - Low NOx burners

HTGS Life Extension

- Nalcor has included $463 million in the Isolated Island Option to extend the life of the plant with expenses in 2017, 2022, and 2027.
- Estimates are considered a reasonable value of sustaining capital.
- Nalcor has developed a CPW sensitivity to address carbon pricing if required in the future (2020).

HTGS Replacement

- The Holyrood replacement is anticipated to consist of 3 – 170 MW No. 2 oil-fired combined cycle combustion turbines installed in 2032, 2033 and 2036.
- The technology and the costs for the replacement plant are reasonable.

CTs and CCCTs

- The Isolated Island Thermal Generation Plan includes
  - One CCCT (net)
  - Nine 50 MW CTs (net)
- The technology and base costs assumed for the 50 MW CT and the 170 MW CCCT installations are reasonable.

Small Hydro Plants

- In-Service dates:
  - Island Pond – 2017
  - Portland Creek – 2019
  - Round Pond – 2021
- Cost estimates for Island Pond and Portland Creek were updated to current costs (escalated). Round Pond was re-estimated. The costs are reasonable as AACE Class 4 estimates and are suitable for input into the DG3 analysis.

Wind Farms

- Wind farms are not added to the system in the Interconnected option due to surplus energy available from Muskrat Falls GS.
- In the Isolated Island Option, nine new 25 MW wind farms are proposed for a total wind power generation capacity of 279 MW which partly offsets fuel costs on the Island.
- Two existing wind farms would be replaced after 20 years of service in 2028 and 2048.
- Capacity factor of 40% is reasonable for DG3.
- The estimated capital cost and operating expenses used in the CPW analysis are appropriate.

Cumulative Present Worth

CPW ANALYSIS

CPW Analysis

- The CPW metric is an acceptable method to measure the present worth of time defined alternative options.
- The CPW focuses on costs only:
  - Capital Expenditures (Fixed Charges)
  - Operating Costs
  - Fuel Costs
  - Power Purchase Costs
- Excludes costs that are common to both Options

CPW Analysis

Comparison of CPW Estimates for the Two Supply Options

Major input category	Interconnected Island option		Isolated Island option		Difference
	CPW ($ 000s)	%	CPW ($ 000s)	%	
Fixed Charges	319,400	3.8	2,555,943	23.7	(2,236,543)
Operating Costs	258,939	3.1	752,448	7.0	(493,509)
Fuel	1,320,530	15.8	6,706,178	62.2	(5,385,648)
Power Purchases	6,467,127	77.3	763,770	7.1	5,703,357
TOTALS	**8,365,997**		**10,778,339**		**(2,412,342)**

Fuel Price Sensitivity

- Fuel Price forecasts are provided by PIRA Energy Group, May 15, 2012.
- PIRA provides: reference, low, high and expected price forecasts for the fuel classes used in DG3.
- Amount of fuel required for the Isolated Island option magnifies fuel price risk.

Barrels ('000)	Isolated Island option	Interconnected Island option
# 2 Fuel	121,632	1,213
# 6 Fuel (Holyrood)	61,509	13,398
TOTAL	183,141	14,611

Summary of Sensitivity Analysis

	CPW (millions)	Interconnected Island option	Isolated Island option	Difference
1	Base Case	8,366	10,778	2,412
2	PIRA Fuel Price – Expected	8,376	11,391	3,015
3	PIRA Fuel Price – Low	8,000	8,584	584
4	PIRA Fuel Price – High	8,836	15,435	6,598
5	Increase Capex 10%	8,882	11,034	2,152
6	Increase Capex 25%	9,654	11,417	1,763
7	Decrease Capex 10%	7,837	10,523	2,686
8	Increase Interest Rate 50 bps	8,604	10,863	2,259
9	Increase Interest Rate 100 bps	8,851	10,947	2,096
10	Decrease Interest Rate 25 bps	8,250	10,736	2,486
11	Carbon Pricing commencing 2020	8,368	11,360	2,992

CPW Analysis – Key Findings

- Nalcor has determined that the CPW differential is favourable to the Interconnected Option by $2.4 billion relative to the Isolated Island Option.
- Based on the inputs provided by Nalcor, determination of the CPW base case results and the related sensitivity analysis presented by Nalcor are considered reasonable.
- Stress testing of the CPW analysis by varying for capital cost increases, or fuel price decreases demonstrate that the Interconnected option is favourable in all cases.

Inclosing

CONCLUSIONS

Areas of Concern

- Prior areas of concern at DG2
  - Reliability Assessment
  - AC Integration Studies
  - NERC Standards
  - Transmission Line Design Criteria
  - Complexity and Risks in the SOBI Marine Crossing

  have all been addressed in DG3.
- There may still be uncertainty with the continued operation of the Corner Brook Mill, although there is other opportunities that may arise in the future that could use this power.

Conclusion

- Overall, Nalcor's inputs (for example, the capital cost estimates, fuel pricing forecasts, and load forecasts) into the CPW were developed in accordance with utility best practices.
- The Interconnected Option was found to be favourable by $2.4 billion over the Isolated Island Option reviewed, based on Nalcor's inputs suitable for Decision Gate 3.

Conclusion

- Overall, HVdc solutions have proven reliable and cost effective in transmitting bulk power long distances.
- Nalcor's proposed system has similar features to Manitoba Nelson River system which has accrued many benefits to the Province.
- MHI believes the Lower Churchill Project to be technically achievable, economic, and the best option for the next large generation resource to meet the load requirements of Newfoundland and Labrador.


Thank you
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2012-10-24
Conclusions
85