Executive Summary

Background

In June 2011 the Lieutenant-Governor in Council of Newfoundland and Labrador referred to the Board of Commissioners of Public Utilities (the Board) a Reference Question requesting the Board review and report to Government on whether Nalcor Energy's (Nalcor) proposed Muskrat Falls Generating Station and Labrador-Island Link HVdc projects are the least cost option for the supply of power and energy to the Island of Newfoundland as compared to the Isolated Island Option.

The Reference Question stated:

> *"The Board shall review and report to Government on whether the Projects represent the least-cost option for the supply of power to Island Interconnected Customers over the period of 2011-2067, as compared to the Isolated Island Option, this being the 'Reference Question'.*

In answering the Reference Question, the Board:

- *shall consider and evaluate factors it considers relevant including NLH's and Nalcor's forecasts and assumptions for the Island load, system planning assumptions, and the processes for developing and comparing the estimated costs for the supply of power to Island Interconnected Customers; and*

- *shall assume that any power from the Projects which is in excess of the needs of the Province is not monetized or utilized, and therefore the Board shall not include consideration of the options and decisions respecting the monetization of the excess power from the Muskrat Falls generation facility, including the Maritime Link Project."*

The Reference Question identifies the two options to be compared:

1. the Infeed Option which is the Muskrat Falls Generating Station and Labrador-Island Link HVdc project; and
2. the Isolated Island Option.

It should be noted that the investigation of alternative fuel types, other island supply options, consideration of the export market via the Maritime Link, the technical feasibility of the Maritime Link, electricity requirements in Labrador as well as potential impacts on island rates were not included in the review by the Terms of Reference.

Generation Expansion Options

Nalcor's planning load forecast for 2010 projected energy requirements for that year at 7,585 GWh increasing to approximately 12,000 GWh by 2067. Year 2067 was chosen as the end of forecast period as this matches the estimated life of the Labrador-Island Link electrical infrastructure and is a suitable timeframe to depreciate that asset. This forecast, as well as Nalcor's generation planning criteria, indicates island capacity deficits (inability to meet peak demand) starting in 2015 with energy deficits (inability to meet annual load requirements) occurring post-2019. Nalcor's generation expansion

analysis led to the identification of the two alternatives under review to address these capacity and energy deficits.

The Infeed Option is largely a hydroelectric generation plan (900 MW from the Muskrat Falls Generating Station and Labrador-Island Link HVdc system, and 23 MW from Portland Creek Generating Station), with the addition of 520 MW of thermal generation using combustion turbines. Power from Muskrat Falls Generating Station on the Lower Churchill River in Labrador is planned to be supplied to Newfoundland over the Labrador-Island Link HVdc transmission line that would cross the Strait of Belle Isle. The annual average energy from Muskrat Falls Generating Station is estimated at 4,900 GWh with first power available in 2016. When all Muskrat Falls Generating Station power is required to satisfy load requirements on the island, or reliability criteria are about to be violated, additional hydro and thermal resources are required to ensure an adequate supply of capacity and energy to meet demand. The cumulative present worth of the Infeed Option in 2010 was estimated by Nalcor at $6,651 million.

The Isolated Island Option is largely a thermal generation plan (1,640 MW), with the addition of 77 MW of small hydroelectric generating stations and 79 MW of wind power. The net 465.5 MW Holyrood Thermal Generating Station, which consumes up to 18,000 barrels of oil a day, plays a major role in this option. The generation plan includes:

- Installation of environmental emissions controls at Holyrood (electrostatic precipitators, scrubbers and NOx burners) as per Newfoundland and Labrador Government's policy directives
- Life extension projects at Holyrood with eventual replacement of the units in 2033 and 2036
- 25 MW wind farm
- 2 X 27 MW wind farm replacements
- 36 MW Island Pond Generating Station
- 23 MW Portland Creek Generating Station
- 18 MW Round Pond Generating Station
- 1,640 MW of 50 MW Combustion Turbines and 170 MW Combined Cycle Combustion Turbines. This includes 510 MW for replacement of the Holyrood units.

The cumulative present worth of the Isolated Island Option in 2010 was estimated by Nalcor at $8,810 million.

Scope of Work and Report Structure

Manitoba Hydro International (MHI) was engaged as the Board's independent expert consultant to assist the Board in their review.

MHI has reviewed the technical feasibility and cumulative present worth analysis for the two power supply options identified in the Reference Question to serve the Island of Newfoundland with electricity until 2067.

Nalcor is using a staged or phased decision gate process to determine if, and how, the Infeed Option should proceed[1]. Phase 1 of the Infeed Option passed through a decision point, described by Nalcor as Decision Gate 2 (DG2), in November, 2010. DG2 is considered to be approval of a development scenario and allows for commencement of detailed design. Following DG2, engineering will progress to a level required to support project sanction or approval, which is Decision Gate 3 (DG3).

Capital cost estimates evolve with improving accuracy as the level of engineering progresses. Nalcor has adopted estimating practices of the Association for the Advancement of Cost Engineering (AACE) International for the Infeed Option. Nalcor considers the DG2 capital cost estimate to be commensurate with an AACE Class 4 estimate which is a feasibility estimate and has a range of accuracy of +50% to -30%.[2] The DG3 or project sanction capital cost estimate is considered by Nalcor to be a Class 3 estimate with a range of accuracy of +30% to -20%.[3]

MHI reviewed Nalcor's documentation submitted to the Board, prepared Requests for Information (RFI) and reviewed responses from Nalcor, and met with Nalcor staff and their consultants. MHI's report is based on this information and responses to RFIs received up to January 16, 2012. The information provided by Nalcor and reviewed by MHI was generally current as of the fall of 2010 and was used by Nalcor in making its DG2 decision. Nalcor did not generally provide information on the detailed engineering or financial work completed after DG2. Thus the findings in this Report relate to project components and costs as of DG2.

The investigation was approached from two perspectives: a technical review of available studies and related information from Nalcor to determine if the degree of skill, care, and diligence required to meet utility best practices and procedures were followed for the work done to date, and a financial review of the cumulative present worth analysis used to select the least cost alternative. MHI has documented the results of these reviews in the two volumes of this report.

To perform the review MHI assembled a team of specialists with expertise in load forecasting, risk analysis, project management, utility resource planning, hydroelectric and thermal generation, HVdc engineering, hydrology, submarine cable crossings, wind power, and financial analysis.

MHI's report is comprised of two Volumes. Volume 1 contains the Executive Summary, key findings, review methodology and high level summaries of the various technical and financial reviews. Volume 2 contains the detailed reports of the reviews and an overview of the MHI team.

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[1] "Nalcor's Submission to the Board of Commissioners of Public Utilities with respect to the Reference from the Lieutenant-Governor in Council on the Muskrat Falls Project", Volume 2, p. 32
[2] "Nalcor's Submission to the Board of Commissioners of Public Utilities with respect to the Reference from the Lieutenant-Governor in Council on the Muskrat Falls Project", Volume 2, p. 72
[3] CE-51 Rev. 1 (Public), Nalcor, "Technical Note: Muskrat Falls Generation Facility and Labrador – Island Transmission Link Overview of Decision Gate 2 Capital Cost and Schedule Estimates", August 2011, p. 11

Key Findings

MHI found that Nalcor's work and that of the consultants they engaged is well-founded and generally in accordance with industry practices as of DG2 with certain significant exceptions noted in these key findings. The key findings of MHI's review are summarized below.

Load Forecast Findings

1. ***Forecast Preparation*** – A detailed analysis of Nalcor's load forecasting practices and methodologies confirms that the load forecast has been performed with due diligence and care using generally accepted practices, except as noted in key finding #2.

2. ***Load Forecast Accuracy*** – The domestic forecast methodology is acceptable, but consistently under-predicts future energy needs at a rate of 1% per future year. The domestic forecast is entirely prepared using econometric modeling techniques. Although these techniques are acceptable, they are not the best utility forecast practices for this sector. Best utility practices would incorporate end-use modeling techniques into the forecasting process so that electricity growth can be quantified for all major domestic end-uses.

   The general service forecast methodology used by Nalcor is based on a combination of regression modeling and linear extrapolation techniques that have performed extremely well in the past. The general service forecast has produced accuracy levels within 1-2%, as far as 8-9 years into the future.

   The industrial forecast is prepared on an individual, case-by-case basis, with direct customer contact concerning future operational plans. This methodology is reasonable considering the small industrial customer base on the island, but, in hindsight, the assumption of continued operation of two pulp and paper mills was too optimistic and has adversely affected the industrial forecast accuracy. The assumption of continued operation of the one remaining pulp and paper mill throughout the forecast horizon is optimistic and the assumption of no new industrial load additions after 2015 is pessimistic. The amount of variability due to potential load changes is high and could materially impact the results of the cumulative present worth analysis.

Generation Resource Planning Process Findings

3. ***Options for Review*** – Nalcor has an exhaustive process for reviewing generation options that is in keeping with leading North American utilities. The *Strategist* software used by Nalcor to evaluate and select a preferred generation development scheme is appropriate. It should be noted that the addition of a large industrial load on the island or in Labrador could result in a different generation expansion plan.

Hydrology Findings

4. ***Hydrology Studies*** – The Muskrat Falls studies were conducted in accordance with utility best practices, comprehensively, and with no apparent demonstrated weaknesses. Also, the energy and capacity estimates for Muskrat Falls and the three small hydroelectric facilities on the island, which were prepared by various consultants using industry accepted practices, were reviewed and confirmed to be reasonable for DG2.

Power System Reliability Findings

5. ***Forced Outage Rates*** – The forced outage rates (FOR) assumed for various types of generating units are based on reliable sources and considered to be reasonable. The information documenting the derivation of the Labrador-Island Link HVdc system FOR of 0.89% on a per pole basis was not available for MHI's review. MHI has compared the Labrador-Island Link HVdc system pole FOR of 0.89% with published information and that of Manitoba Hydro's HVdc system and finds it within the normally accepted range. However, this FOR should be replaced by a more advanced and comprehensive reliability model incorporating all components of the Labrador-Island Link HVdc system.

6. ***System Reliability Studies*** – Probabilistic adequacy studies, including considerations related to transmission for comparison of the reliability of the two options, have not been completed by Nalcor. This is a gap in Nalcor's practices as various Canadian utilities including Manitoba Hydro, BC Hydro, Hydro Quebec, and Hydro One in Ontario have adopted these probabilistic methods for reliability studies for major projects. Probabilistic reliability methods utilize standard terms and indices such as Loss of Load Expectation, or Expected Unserved Energy, and make the risk analysis results plainly understandable in terms of dollars and/or loss of load.

   Deterministic assessments, such as those performed by Nalcor in Exhibit 106, cannot quantify the true risks associated with a power system and are unable to provide some of the important inputs for making sound engineering decisions such as risk and associated costs, including the potential large societal costs related to outages. Probabilistic assessment is a valuable means to assess system risk, reliability and associated costs/benefits for various system improvement options, particularly for major projects proposed by Nalcor. MHI has determined that choosing between the two options under review without such an assessment is a gap in Nalcor's work to date. Typically, these studies are completed at DG2. MHI recommends that these probabilistic reliability assessment studies be completed as soon as possible. Such studies should become part of Nalcor's processes that would allow for a comparison of the relative reliability for future facilities.

AC Integration Study Findings

7. ***AC Integration Studies*** – System integration studies completed as part of the project alternatives screening process, and provided to MHI by Nalcor were for a Gull Island development with a 1600 MW three terminal HVdc system to Newfoundland and New Brunswick. Significant changes were made to the overall project definition with the proposed Muskrat Falls development, and the deletion of the New Brunswick link. Integration studies that would support the changes have not been completed and Nalcor now advises that the studies will not be available until March 2012[4]. As the full requirements for integration of the Labrador-Island Link HVdc system are not known, there may be additional risk factors that may impact the cumulative present worth of the Infeed Option. For example, installation of backup supplies to cover operational limitations in the Labrador-Island Link HVdc system may be required, and additional transmission lines may be needed to maintain acceptable system performance. Spare equipment requirements also need to be taken into consideration. Good utility practice requires that these integration studies be completed as part of the project screening process (DG2). MHI considers this a major gap in Nalcor's work to date. These integrations studies must be completed prior to project sanction (DG3).

8. ***NERC Standards*** – Nalcor currently does not comply with North American Electric Reliability Corporation (NERC) standards[5,6]. A majority of utilities in Canada have adopted the definition of "good utility practice" that incorporates adherence to NERC standards. Also, should the Maritime Link proceed, and Nalcor participates in the electricity marketplace, NERC standards will ultimately apply. MHI recommends that Nalcor complete a self-assessment and prepare for compliance to NERC standards with or without the Maritime Link.

Muskrat Falls Generating Station Findings

9. ***Muskrat Falls Technical and Construction Feasibility*** - MHI's review of the Muskrat Falls Generating Station concluded the following:
    - The proposed layout and design of Muskrat Falls Generating Station appears to be well defined and consistent with good utility practices.
    - The general arrangement of the permanent works is a reasonable proposal for the optimum development in terms of cost and construction duration.
    - Based on the information provided, the design and construction of Muskrat Falls Generating Station is consistent with good engineering and construction practices, and should not pose any unusual risks for construction or operation of the facilities.
    - The available studies have identified technical risks and appropriate risk mitigation strategies.

[4] Response to RFI PUB-Nalcor-143
[5] Exhibit 106, Nalcor, "Technical Note Labrador –Island HVdc Link and Island Interconnected System Reliability", pg. 33
[6] Response to RFI PUB-Nalcor-164

10. ***Muskrat Falls Cost Estimate Increase*** – The cost estimate for the Muskrat Falls development has increased by 104% between 1998 and 2010 which can largely be explained by inflation and a change in scope. The change in scope is the addition of the 2 – 345 kV transmission lines from Muskrat Falls Generating Station to Churchill Falls Generating Station, associated switchyards, environmental costs and other items such as insurance. Despite the additional costs, MHI considers the cost estimate at DG2 to be within the accuracy range of an AACE Class 4 estimate (+50%/-30%) which is representative of a feasibility level study.

HVdc Converter Stations Findings

11. ***Application of HVdc to the Island Power System*** – MHI found that the HVdc converter station system design parameters available for review are reasonable for the intended application. The intended application is to transmit 900 MW of firm power over 1100 km of transmission line and inject this power into the island's electrical system at Soldiers Pond with appropriate voltage and frequency control.

12. ***Capital Cost Estimate of the Labrador-Island Link HVdc Converter Station*** – The estimate for the HVdc converter stations and electrodes was reviewed by MHI and found to be within the range of an AACE Class 4 estimate. The cost estimates for the synchronous condensers are low but are still within the range of an AACE Class 4 estimate.

13. ***Choice of HVdc Technology*** – The Labrador-Island Link design progression has specified LCC (line commutated converters) HVdc technology, which is mature and robust for the application[7]. However, the response to RFI MHI-Nalcor-67 has indicated that VSC (voltage sourced converter) options will be considered if there are technical and financial advantages to do so. It is important to note that VSC systems of the size and length of the Labrador-Island Link HVdc system have not yet been built and operated anywhere in the world as of the issue date of this report.

HVdc Transmission Line Findings

14. ***Design Loading Criteria*** – Nalcor has selected a 1:50-year reliability return period (basis for design loading criteria) for the HVdc transmission line, which is inconsistent with the recommended 1:500-year reliability return period outlined in the International Standard CEI/IEC 60826:2003 with Canadian deviations in CSA Standard CAN/CSA-C22.3 No. 60826:06, for this class of transmission line without an alternate supply. In the case where an alternate supply is available, the 1:150-year reliability return period is acceptable. In this latter scenario, Nalcor should also give consideration to an even higher reliability return period in the remote alpine regions[8]. MHI considers this a major issue and strongly recommends that Nalcor adhere

[7] Exhibit 30, Nalcor, "Lower Churchill Project Design Progression", July 2011.
[8] Exhibit 97, Page 8. Alpine regions are defined as Southeastern portion of Labrador, two areas in the Long Range Mountains, and one small section in central Newfoundland.

to these criteria for the HVdc transmission line design. The additional cost to build the line to a 1:150 year return period is approximately $150 million[9].

15. ***HVdc Overhead Transmission Line Capital Cost Estimate*** – The capital cost estimate of the transmission line at DG2 is reasonable, but at the low end of the range for this type of construction utilizing industry benchmark costs as a comparison. A design based on a 150-year return period could be accommodated within the variability of an AACE Class 4 estimate at this stage of development for the entire Labrador-Island Link HVdc project.

Strait of Belle Isle Marine Crossing Findings

16. ***Cable Technology*** – Mass impregnated cable, as specified by Nalcor, is an appropriate technology for an HVdc marine crossing at ±350 kV. Other technologies, such as cross-linked polyethylene cable (XLPE), have been type tested for this application at ±320 kV, but none have been used at this voltage on a marine HVdc project in the world to date.

17. ***Marine Crossing Cost Estimate*** – Nalcor's total base cost estimate for the marine crossing at DG2 was reviewed by an independent consultant, CESI, retained by MHI and familiar with cable crossings. It was found that this estimate is within the range of an AACE Class 4 cost estimate.

18. ***Marine Crossing Iceberg Risks*** – The iceberg risks are perceived to be significant; however, the application of horizontal directional drilling for shore landings, years of iceberg observations and research performed by C-CORE (a local consulting firm) on the Grand Banks for the various oil projects, and careful route selection across the Strait of Belle Isle have quantified the risks to be less than one iceberg strike in 1000 years. This risk is further mitigated with rock berms, largely for fishing equipment and anchor protection, and a spare cable with separation distance between them of 50 to 150 metres. The research performed by C-CORE found that the risk of a multiple cable contact by icebergs was reduced with greater separation of the cables. Additional research, monitoring of iceberg roll rates, and bathymetric surveys of earlier iceberg scours should be done to provide a level of validation to further tune the iceberg strike risk model.

19. ***Spare Cable*** – The application of a spare cable is a prudent design feature of the Strait of Belle Isle marine crossing considering the difficulties of bringing in repair equipment at certain times of the year.

[9] Response to RFI PUB-Nalcor-15

Small Hydroelectric Plant Findings

20. ***Small Hydroelectric Plants*** – For the three small hydroelectric plants of the Isolated Island Option, a review of the capital cost estimates indicated that the level of engineering and investigations was consistent with a feasibility level study. Considering the age of some of the studies, the review also indicated that the development schedules and cost estimates for the three projects are optimistic due to more stringent current regulatory processes.

    It is expected that resolution of these uncertainties would generally result in increases rather than decreases in the cumulative present worth of the three small plants. However, the magnitude of any changes would not significantly alter the difference in the cumulative present worth between the Isolated Island and Infeed Options.

Thermal Generating Station Findings

21. ***Thermal Options Studies*** – The thermal studies related solely to the Isolated Island Option were screening level studies, while there was a great deal more depth to studies of the Infeed Option. The level of detail of studies on upgrading the Holyrood Thermal Generating Station was found to be adequate, and the related upgrade costs are reasonable and in line with industry standards.

22. ***Holyrood Life Extension Cost Estimates*** – Although the Holyrood Thermal Generating Station life extension costs for the Isolated Island Option are not based on detailed engineering studies, the estimates in the cumulative present worth analysis are conservative and representative of similar plants. This expenditure is needed to extend the life of the plant as a generating facility to 2033 for units 1 and 2, and 2036 for unit 3.

23. ***Holyrood Service Life*** – Even with life extension under the Isolated Island Option, operating Holyrood Thermal Generating Station beyond 50 years, to a maximum of 60 years, with reduced reliability, may not be practical. There may come a point well before 2041 when the plant becomes unreliable to operate.[10] The life extension plan and requirements under the Infeed Option are as follows:

    - 2010 to 2017 Electricity Generation
    - 2017 to 2021 Electricity Generation, as-required primarily on a standby basis
    - 2017 to 2041 Synchronous Condenser Operation – Units 1 and 2 converted to synchronous condenser mode by 2017. Unit 3 is already synchronous condenser capable.

[10] Exhibit 44, AMEC, "Holyrood Thermal Generating Station Condition Assessment & Life Extension Study", January 2011.

24. ***CT and CCCT Technology*** – The technology and base costs assumed for the 50 MW combustion turbine (CT) and the 170 MW combined cycle combustion turbine (CCCT) installations are reasonable. The technology and costs assumed for replacing Holyrood Thermal Generating Station using CCCTs under the Isolated Island Option are reasonable based on present utility plant retirements for plants built in the late 1960's and early 1970's.

25. ***Holyrood Decommissioning Costs*** – A detailed site assessment study for decommissioning the Holyrood Thermal Generating Station has not yet been completed by Nalcor. The costs of decommissioning the station are high level estimates, but they are considered reasonable when compared to similar recent projects.

Wind Farms Findings

26. The capacity factor of 40% used by Nalcor is reasonable for a planning study. The estimated capital and operating costs used in the analysis are appropriate. Nalcor's assessment of an 80 MW limit for wind generation under the Isolated Island Option is reasonable. Additional wind power could be installed beginning in the 2025 timeframe as the system capacity grows.

Cumulative Present Worth Analysis Findings

27. ***The Option with the Lowest Cumulative Present Worth*** – Based on the capital and operating costs estimated by Nalcor for each option and a common load forecast, Nalcor has determined that the Infeed Option has a lower cumulative present worth than the Isolated Island Option by approximately $2.2 billion. The detailed analysis performed by MHI determined that Nalcor's cumulative present worth analysis was completed using recognized best practices and the cumulative present worth for each option was correct based on the inputs used by Nalcor. These inputs were reviewed in the technical and financial analyses conducted by MHI and were generally found to be appropriate. There are, however, other considerations related to risks associated with the assumptions used for certain key inputs such as load, fuel prices and cost estimates which may impact the cumulative present worth analysis for the two options. These were tested with the use of several sensitivity analyses and the results of these are summarized as follows:

    - Load Forecast
      A major input to the cumulative present worth analysis is the load forecast, and as a result any large changes in the load would have a significant impact. For example, should the existing pulp and paper mill cease operations, and its generation capacity be available for use on the system, and should the capital costs of both of the Muskrat Falls Generating Station and Labrador-Island Link HVdc projects increase by 10%, the cumulative present worth for the two Options would be approximately equal[11].

    - Capital Cost Estimates
      The current capital estimates are within the accuracy of an AACE Class 4 estimate which has a plus factor variance potential of as much as 50%. Should cost overruns reach that level, the difference between cumulative present worth values for each of the two Options would be less than $200 million in favour of the Infeed Option.

    - Fuel Price
      There remains significant uncertainty in fuel price forecasts. Global disruptions in supply could drive the price of oil well above inflation. However, new sources of supply, such as shale oil or downward trends in natural gas pricing, may have the potential to minimize fuel price increases.

      If fuel prices drop by 44% from those used by Nalcor, there is no difference between the two cumulative present worth results for the two Options. However, if fuel prices rise more than the reference price used in the cumulative present worth analysis, an even greater difference between the cumulative present worth results would occur.

    The risks associated with these inputs are further magnified considering the 50+ year period (2010 – 2067) used in the preparation of the cumulative present worth analysis.

[11] MHI derived from RFI MHI-Nalcor-41 Revision 1

General Findings

28. ***Renewable Sources of Energy*** – The Infeed Option uses more renewable energy sources than the Isolated Island Option. The amount of thermal generation capacity required in 2067 is 35% for the Infeed Option, almost the same proportion that exists in 2010. In contrast, the amount of thermal generation for the Isolated Island Option is projected to reach 62% in 2067, nearly double that of the island mix in 2010 necessitated by greater reliance on thermal energy sources.[12,13]

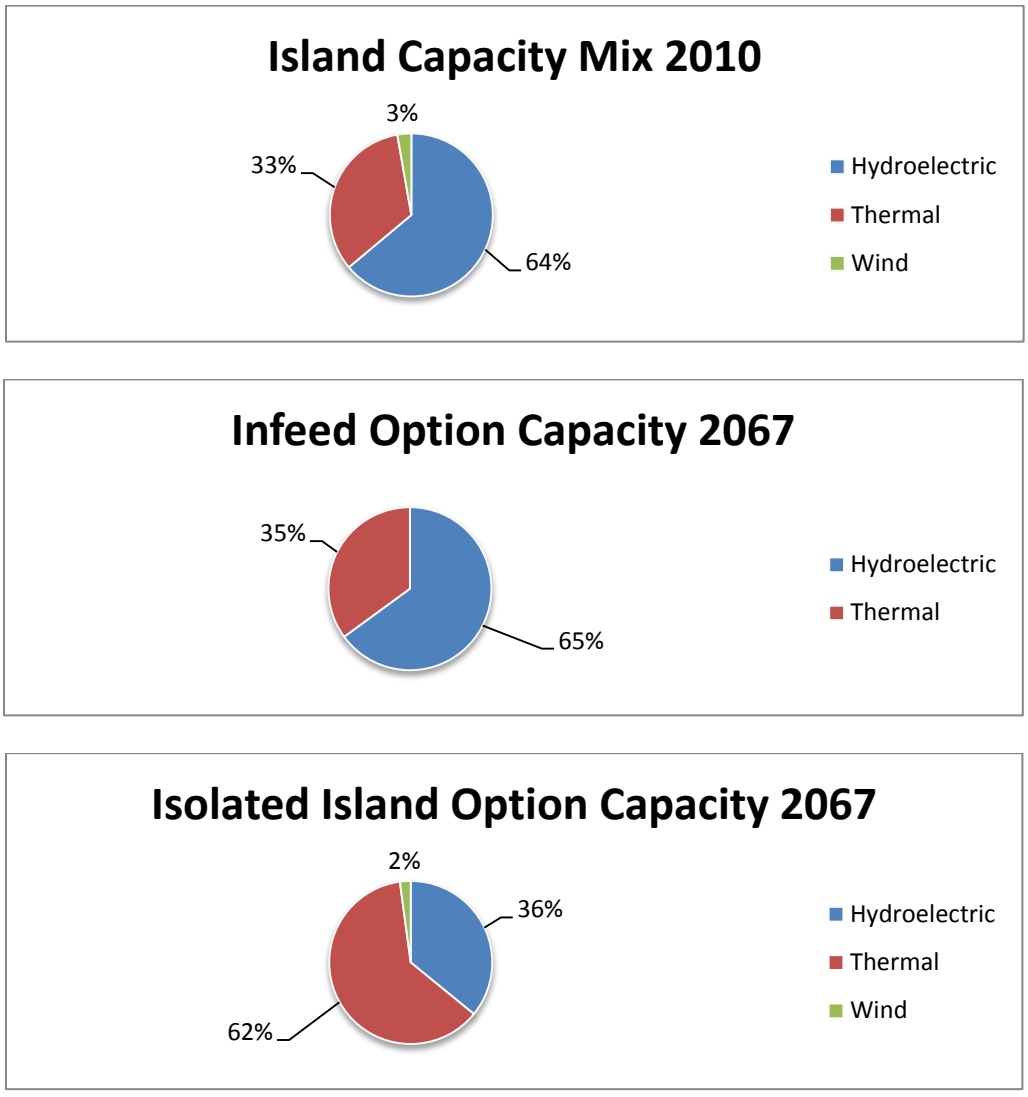

Figure 1: Option Capacity Mix. Use of renewable energy sources between the two options

[12] Exhibit 14 Rev. 1, Nalcor, "2010 PLF Strategist Generation Expansion Plans"
[13] Exhibit 16, Nalcor, "Generation Planning Issues", July 2010

29. ***Carbon Credits*** –Nalcor's Final Submission notes that carbon credits have not been factored into the cost analysis of either option as future carbon emission trading, and its pricing, contains uncertainties regarding timing, scope and design associated with the future regulatory framework. It is possible that future Holyrood Thermal Generating Station operation and redevelopment, and the addition of combustion turbine power plants, may be subject to additional operating costs due to the requirement to purchase carbon credits to offset the greenhouse gases (GHG) these plants emit.

30. ***Environmental Concerns*** – The matter of environmental stewardship is a concern associated with the Isolated Island Option. The Holyrood generating facility has a combined capacity of 465.5 MW and, at peak production, burns approximately 18,000 barrels of oil per day. Even though Nalcor has projected a capital cost of $603 million for an environmental equipment upgrade, this investment will not reduce GHG emissions, which are expected to increase as the load factor of the plant increases. Should the GHG emission standard change through public policy to a lower target, there is the risk that an oil fired facility such as Holyrood may not be able to operate in the long term.

Conclusions and Recommendations

MHI completed a detailed review of the information generally as of DG2 provided by Nalcor on the Infeed and Isolated Island options and has made a number of key findings. While the work and analysis completed by Nalcor generally meets utility best practices, there are several significant exceptions which have been noted above and are summarized as follows:

- Reliability Assessment

  Recent reliability studies completed for, or by, Nalcor are deterministic in nature. The probability assessments done with Strategist are solely resource adequacy studies without consideration for transmission.

  Power system behaviour is, however, stochastic in nature and the uncertainties in power systems have been augmented by various factors such as advancements in technology, the increased complexity of system design and operation, the deregulation of the utility business, the increased utilization of intermittent energy sources and the imposition of more mandatory regulatory requirements.

Therefore, the assessment of such systems exposed to uncertainties should use probabilistic or risk-based techniques. Deterministic assessment cannot quantify the true risks associated with a power system and is unable to provide some of the important inputs for making sound engineering decisions, such as risk and associated costs including the potential large societal costs associated with outages. Probabilistic assessments are a valuable means to assess system risk, reliability and associated costs/benefits for various system improvement options particularly for major projects such as those under review. MHI has determined that making these types of decisions without this information is a gap in Nalcor's work to date and recommends that these studies be completed. Such studies would also enable Nalcor to compare the relative reliability between the two options.

- AC Integration Studies

  The ac integration studies which have been conducted previously were for a Gull Island development with a 1600 MW three terminal HVdc system linking Labrador to Newfoundland and New Brunswick. Significant changes have been made to the overall project definition but the system integration studies that would support the changes have not been completed. As a result, the full requirements for the integration of the revised Labrador-Island HVdc Link with the ac system on the island are not known. There are additional risk factors that may impact the cumulative present worth of the Infeed Option such as a requirement for additional transmission lines or upgrades, standby generation, or other major equipment.

  Good utility practice requires that these integration studies be completed as part of the project screening process (DG2). MHI considers this a significant gap in Nalcor's work to date. These integration studies must be completed prior to project sanction (DG3).

- NERC Standards

  A number of findings discuss the applicability of NERC standards in the definition and application of good utility practices, particularly when evaluating Nalcor's practices in the area of reliability. As a guiding principle, MHI used these standards as a metric for assessing whether best practices were followed.

  MHI has determined that a majority of utilities in Canada have adopted the definition of "good utility practice" that incorporates adherence to NERC standards. Nalcor does not currently comply. With development of the Maritime Link and Nalcor's participation in the electricity market, NERC standards will ultimately apply. MHI recommends that Nalcor complete a self-assessment to prepare for compliance to NERC standards with or without the Maritime Link.

- Transmission Line Design Criteria

  Given the significance of the Labrador-Island Link HVdc transmission line for serving the load on the Island of Newfoundland, Nalcor has gathered significant historical metrological data in accordance with the IEC and CSA Standards. Exhibit 30 indicates that Nalcor has selected a 1:50-year reliability return period which is inconsistent with the recommended 1:500-year reliability return period outlined in the IEC and CSA Standard for this class of transmission line without an alternate supply. In the case where an alternate supply is available, e.g. the Maritime Link or backup generation, then the 1:150-year reliability return period is acceptable. Nalcor has stated that the additional capital cost increase for the 1:150-year return period for the transmission line would be $150 million. In the latter case, Nalcor should also give consideration to an even higher level reliability return period in the remote alpine regions. MHI recommends that Nalcor adhere to these criteria for the HVdc transmission line design.

MHI finds that the Muskrat Falls Generating Station and the Labrador-Island Link HVdc projects represent the least-cost option of the two alternatives, when considered together with the underlying assumptions and inputs provided by Nalcor.

With projects of this magnitude, and considering the length of the analysis period, there are risks and uncertainties associated with the key inputs and assumptions. Changes in these key inputs and assumptions will affect the financial results and must be assessed to determine materiality. These changes in key inputs and assumptions can impact the results of the analysis and shift the preference for what is the least cost option. Fuel costs and construction material costs are variable with world economic conditions. Load forecasts are a major input based on local conditions and must be carefully monitored to ensure that generation development occurs in compliance with future load requirements. Analyses were completed to demonstrate the sensitivity of the cumulative present worth results to material changes to key inputs and these are outlined in this report.