Review of BC Hydro's Alternatives Assessment Methodology

Prepared for BC Hydro

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AUTHORS

Rachel Wilson
Bruce Biewald
David White

Synapse Energy Economics, Inc.

485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139

617.661.3248 | www.synapse-energy.com

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1. EXECUTIVE SUMMARY

Synapse Energy Economics, Inc. (Synapse) was retained by BC Hydro to conduct a review of its 2013 Integrated Resource Plan (IRP) and to prepare a report detailing whether specific input assumptions and the methodology for analyzing resource alternatives align with good utility resource planning practices. Before preparing this report, we reviewed the relevant sections of BC Hydro's IRP, the various filings made as part of the 2013/2014 Site C environmental assessment process, and various other utility planning documents.

Specifically, Synapse was asked to comment on the following: 1) the differential between the weighted average cost of capital (WACC) for BC Hydro and for Independent Power Producers (IPPs); 2) the use of sensitivity analyses as a means to evaluate the direction and magnitude of risk; 3) the use of analytical methods, including the appropriateness of BC Hydro's Unit Cost Comparison, as well as the System Optimizer model; and 4) the calculation of annualized costs with respect to resource end-of-life. This report does not include validation of the remaining input assumptions or the recommended actions contained in BC Hydro's 2013 IRP. Our review is largely of the methods used for analysis in this IRP. With the exception of the WACC, Synapse was not asked to review or evaluate any of BC Hydro's input assumptions and has no comment on those assumptions at this time.

With respect to the WACC, BC Hydro has selected reasonable values and has given proper consideration and quantification of resource cost uncertainty through sensitivities. The Company's alternatives analysis methodology and tools are consistent with good utility practice and includes valuable elements. There may be areas in which BC Hydro might improve in future resource plans as changes occur in the natural world and in the resource planning environment, but those need not be considered at this time.

2. INTRODUCTION

In 2013, BC Hydro completed its most recent IRP. This plan looks out over a period of 30 years, forecasting energy and capacity needs of British Columbia and making a determination of the best portfolio of supply- and demand-side resources to meet those needs at the lowest cost to consumers.

Integrated resource planning is an extremely valuable exercise, but is nonetheless difficult and time-consuming. BC Hydro faces some additional challenges in its resource planning that are unique to the Province, which narrow the pool of resources from which it can choose. First, the British Columbia *Clean Energy Act* (CEA) mandates that BC Hydro become self-sufficient – holding the rights to enough electricity generated in the province to meet the utility's supply obligations – by the year 2016, and each year thereafter.[1] The CEA also states that at least 93% of the electricity generated in British Columbia must be from clean or renewable resources. Finally, Policy Action No. 13 of the BC Government's 2002 Energy Plan restricts BC Hydro's capacity to add new generating resources to Site C and improvements at existing plants. Other new electricity generation must be developed by the private sector. This is important, as, unlike many other utilities, BC Hydro has to go to IPPs for new capacity and energy. Financing costs and BC Hydro's WACC becomes especially important in this context, and is the only one of the BC Hydro input assumptions that Synapse was asked to review.

Given the constraints described above, and others, BC Hydro made a number of additional input assumptions (which Synapse did not review) and engaged in various types of cost and modeling analysis in order to generate various resource portfolios. These portfolios provide for the capacity and energy necessary to meet demand over a 30 year planning period at a specific cost to consumers. BC Hydro completed a levelized cost analysis that examined the unit energy and unit capacity costs of various types of resources. Those supply- and demand-side resources with the greatest potential for meeting energy and capacity needs at the lowest cost were then included in the System Optimizer model. This model generated several resource portfolios, calculating the present value of revenue requirements (PVRR), which were compared by BC Hydro. Risks and uncertainties of each of these portfolios were evaluated using a variety of sensitivity analyses. These methods of analysis that Synapse was asked to evaluate in the 2013 IRP are largely consistent with good utility practice. There may be areas in which BC Hydro might improve in the future, but there is uncertainty as to whether or not these suggestions will improve the resource planning process.

3. Input Assumptions

3.1. Cost of Capital

BC Hydro utilizes two different values for weighted average cost of capital in its Integrated Resource Plan.[2] The Company recommends a 5% real WACC for its own investments and 7% for IPPs and other third party developers; the 2% differential (and a sensitivity that reduces the differential to 1%) is set out in the Site C hydro project environmental assessment documentation and the IRP. The BC Hydro rate of 5% is reasonable, as BC Hydro's borrowing is guaranteed by the government, and the Company may also borrow directly from the Province. The British Columbia Utilities Commission recognizes this, stating that "With respect to the cost of capital, BC Hydro projects will clearly have an advantage as a result

[1] S.B.C. 2010, c.22

[2] BC Hydro. 2013 Integrated Resource Plan. Page 3-8.

of…access to the Province's high credit rating."[3] Utilities similar to BC Hydro appear to be using comparable values for WACC. In its *Needs For and Alternatives To Business Case* submission, for example, Manitoba Hydro conducted its resource analysis using a WACC of 5.05% in its base case.[4]

It can logically be expected that IPP projects will have higher financing costs.[5] BC Hydro did, however, test a sensitivity case that examines a 1% differential in the WACCs . The Site C portfolio did maintain a cost advantage under this sensitivity, though the benefits were slightly reduced when compared to other portfolios.

There are two ways that project specific risks can be analyzed: 1) they can be reflected in the WACC for IPPs; and 2) they can be reflected in sensitivity analyses or project-specific contingences, as discussed in the next section. An adjustment in the WACC for different types of generating projects would depend on many factors. This is, in fact, one of the issues in using the WACC to reflect project risks. Any project may have multiple risk factors, and the use of a single WACC number that reflects all of these does not allow for an evaluation of the direction or magnitude of any individual risk factor. BC Hydro instead performed sensitivity analyses, changing one variable at a time, "to determine which variables are the most influential and which are secondary."[6]

3.2. Project Risks and Sensitivity Analyses

The set of sensitivities analyzed in the IRP include the following:

- Large and small gap conditions in the load and resource balances[7]
- BC Hydro/IPP cost of capital differential (1%)
- Market prices (high and low)
- Site C capital costs (+10%, +15% and +30%)
- Wind integration costs ($5/MWh and $15/MWh)

Fuel cost sensitivities are typically done for integrated resource plans, and BC Hydro's sensitivities around market prices also contain variation around natural gas prices, with the Company examining

[3] British Columbia Utilities Commission. In the Matter of British Columbia Hydro and Power Authority and 2006 Integrated Electricity Plan and 2006 Long Term Acquisition Plan – Decision. May 11, 2007. Page 205.
[4] Manitoba Hydro. Needs For and Alternatives To Business Case Submission. August 16, 2013. Page ES-19. Available at: http://www.hydro.mb.ca/projects/development_plan/bc_documents/nfat_business_case_complete.pdf
[5] California Energy Commission. Comparative Costs of California Central Station Electricity Generation. Draft Staff Report. August 2009. Page 15.
[6] BC Hydro. 2013 Integrated Resource Plan. Page 6-44.
[7] BC Hydro uses the mid-gap in its base case analysis.

High, Mid, and Low gas scenarios.[8] BC Hydro subsequently analyzed compound sensitivities, combining sets of variables that have the largest potential effect on cost-effectiveness: the load/resource gap, market prices, and Site C capital costs.

Sensitivity testing is a common practice among utilities engaged in resource planning, with most, if not all, utilities completing a sensitivity analysis as part of a resource plan. Best practices dictate that

> At a minimum, important and uncertain input assumptions should be tested with high and low cases to assess the sensitivity of results to changes in input values…Individual utilities must determine those input assumptions that are subject to variability, and model sensitivity cases accordingly to properly account for risks and uncertainties that they face.[9]

It is essential that all important and uncertain assumptions be tested, and the BC Hydro analysis includes many that are significant. The capital cost associated with Site C is one of the most important uncertainties and deserves additional consideration here. BC Hydro evaluated sensitivity cases for Site C that increase capital costs by +10%, +15%, and +30% more than those costs in the base case. As a comparison, Nalcor Energy, in its evaluation of its Muskrat Falls hydro project, evaluated a single capital cost scenario for Muskrat Falls at +25%.[10] This estimate was categorized as Class IV, which is subject to more uncertainty than BC Hydro's Class III estimate. BC Hydro tested a comprehensive set of capital costs sensitivities and output results show that there are still benefits to Site C under some of these scenarios, but that Site C becomes more costly under others.

Water level is a variable that is important for utilities dependent on hydro generation like BC Hydro, and a sensitivity around this variable is one that may appear to be missing from the Company's analysis. In the state of Oregon, which is also largely dependent on generation from hydropower, the Public Utilities Commission *requires* that electric utilities include a consideration of the risks and uncertainties associated with hydroelectric generation in integrated resource plans.[11] Manitoba Hydro is currently pursuing two new large hydro resources: 1) the Keeyask project is 684 MW with an ISD of 2019; and 2) the Conawapa project is 1,485 MW with the earliest ISD of 2026.[12] In Manitoba's planning analysis, generating stations are planned to meet the energy demand under the lowest flow on record (as well as the highest winter peak demand),[13] but the Company also did a low water sensitivity for its proposed projects, intended to simulate severe drought conditions. It also did sensitivities on both increased and decreased river flows due to climate change.

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[8] BC Hydro. 2013 Integrated Resource Plan. Page 5-37.

[9] Wilson, Rachel and Bruce Biewald. Best Practices in Electric Utility Integrated Resource Planning. Synapse Energy Economics. Prepared for the Regulatory Assistance Project. June 2013. Pages 31-32.

[10] Navigant Consulting Ltd. Independent Supply Decision Review Prepared for Nalcor Energy. September 14, 2011. Available at: http://www.nalcorenergy.com/PDF/lcp0923.pdf

[11] Oregon Public Utility Commission. Order No. 07-002. Docket No. UM 1056. January 8, 2007. Appendix A. Page 1.

[12] Manitoba Hydro. Needs For and Alternatives To Business Case Submission. August 16, 2013. Page O-13.

[13] Manitoba Hydro. Needs For and Alternatives To Business Case Submission. August 16, 2013. Page ES-13

BC Hydro meets its energy requirements with firm energy, defined as "the ability to meet load requirements under the *most adverse* sequence of stream flows as experienced by BC Hydro's Heritage hydroelectric assets within the 60-year period between October 1940 and September 2000."[14] There is also a reliance on non-firm hydro energy backed up by market purchases. This non-firm energy is calculated based on the average water conditions experienced by the Heritage assets during the same 60-year time period. As a result, BC Hydro relies upon this non-firm energy of 4,100 GWh. The risk of stream flows that are even lower than the most adverse historic flows, does exist, though it is small. Because of the significant reliance on hydro generation in British Columbia, one might expect to see a similar type of sensitivity in BC Hydro's planning analysis. This type of sensitivity scenario might be something to consider for future IRPs.

BC Hydro did examine the implications of climate change on precipitation in the Province, and the Company's models showed that precipitation would increase under these scenarios.[15] As part of the Environmental Assessment of Site C, Environment Canada agreed with BC Hydro that these effects may be too uncertain and take place too far into the future to be included in this IRP,[16] but should continue to be studied as climate models evolve. The Site C hydro project is a long-lived asset and it is reasonable to expect that a changing climate will have an effect on its operations at some point in the future.

4. Electric Generation Resources – Characteristics and Interactions

4.1. Unit Cost Comparison (Block Analysis)

BC Hydro used two different methods to evaluate the costs of new generating resources and resource portfolios. The first of those is a levelized cost analysis, which calculates the cost of a unit of energy ($/MWh) or of capacity ($/kW-year), levelized over the life of the resource. Calculation of these unit energy costs (UECs) and unit capacity costs (UCCs) allows BC Hydro to compare resource options in a way that is economically consistent, and the utility can screen out those resources with costs that are much higher. Levelized cost analysis can enable one to construct a supply stack or curve, that when matched with loads, can provide clues as to the types of resources that might be needed in a future portfolio. The Company applied this methodology to demand-side management (DSM) as well as the following supply-side resources: biogas, biomass, waste heat, municipal solid waste, non-storage hydro, pumped storage, large hydro (Site C), solar, onshore and offshore wind, tidal, wave, geothermal, natural

[14] BC Hydro. 2013 Integrated Resource Plan. Page 1-13.

[15] Site C Environmental Assessment Document – Canadian Environmental Assessment Registry #1640, Response to Joint Review Planel Information Request No. 76.

[16] Site C Environmental Assessment Document – Canadian Environmental Assessment Registry #1843 – Written Submission of Environment Canada, section 3.4.2.

gas (simple cycle gas turbines (SCGT) and combined cycle gas turbines (CCGT)), and coal with carbon capture and storage (CCS).[17,18] If all of these resources were put into an optimization model, the model could never solve within the time allotted for preparation of the IRP. Some resources must be screened out, and the levelized cost analysis is an excellent mechanism by which to do so.

One of the drawbacks of levelized cost analysis is that the resulting values are dependent upon input assumptions about unit operations. Unit capacity factors are selected by resource planners and are fixed within the calculation. In reality, some unit capacity factors can be highly variable depending on load, operating costs, and time of year. When these resources are part of a system portfolio, interactions with other resources may lead them to operate more or less than was assumed in the levelized analysis. From this perspective, levelized cost numbers may over- or underestimate resource costs. Additionally, levelized values cannot capture certain resource attributes like dispatchability or ability to provide ancillary services. These attributes are essential to the function of an integrated electric system, but are not valued from the perspective of levelized cost.

Levelized cost analysis is a valuable tool that provides decision-makers with useful information about unit energy and capacity costs; however, given the limitations of this type of analysis, the primary tool for analyzing resource porfolios should be integrated modeling (discussed in the next section). BC Hydro's analysis methodology is consistent with good resource planning practices, i.e. using levelized cost analysis for "pre-screening" and an integrated model for the optimization and plan simulations.

4.2. System Optimizer

Portfolio analysis is an essential element of integrated resource planning, and electric simulation models are necessary tools that enable utilities to create and evaluate different resource combinations under a variety of scenarios. In portfolio analysis, different individual supply- and demand-side resources are combined into portfolios in a way that meets customer energy needs and system capacity needs over time. There are two types of models that are commonly used in utility planning: optimization, or capacity expansion, models and production cost models. The primary function of optimization models is as described above – to select the best combination of resources over time, meeting the set of input constraints applied to the model while minimizing the PVRR. Optimization models do contain a production cost component; however, the dispatch of resources is often highly simplified. The present value output is thus a combination of the capital and operating costs of the resulting electric system selected by the model.

Production cost models, on the other hand, do not do any optimization and require that any resource additions during the planning period be fixed in place by the modeler. The user must identify any gaps in energy and/or capacity and select the resources necessary to close these gaps, while meeting any

[17] BC Hydro. 2013 Integrated Resource Plan. Chapter 3 – Resource Options.

[18] Note that Synapse did not review and thus had no comment on the reliability of the unit energy and capacity costs resulting from the levelized cost analysis.

renewable energy goals or emissions standards. Production cost models then simulate a detailed dispatch of an electric system or region, calculating system electric generation and operating costs over time. Capital costs of new generating resources are not included in resulting present value outputs. Because the system build-out is user defined in production cost modeling, the use of these types of models without an optimization component may result in a sub-optimal mix of generating resources and transmission over time. In conducting its resource planning study for the Railbelt System in Alaska, Black and Veatch had to use two models: Strategist for the optimization piece and PROMOD for the dispatch piece,[19] which is both time-consuming and costly.

BC Hydro states that portfolio analysis was the primary method used in the 2013 IRP to analyze various combinations of resource options.[20] BC Hydro developed its portfolios using System Optimizer, a model using either linear or mixed integer programming, which selects the optimal sequence of generation and transmission resource additions over time for a specific set of input assumptions. System Optimizer determines the optimal resource mix by minimizing the present value of revenue requirements[21] necessary to meet BC Hydro's given load under average water conditions.[22] This PVRR is the primary metric that is analyzed, and minimized, in utility IRPs.[23]

System Optimizer has the ability to add generating units, retire or refurbish existing units, and make changes to resource operations when creating long-term utility portfolios. When adding new resources, the model considers technology type, fuel, size, location, and timing to meet capacity and energy requirements. System Optimizer is not limited to new unit construction, but can also consider demand response programs, energy efficiency or demand side management, and transmission expansion.[24] There is one important drawback to this particular model. While other optimization models often output more than one, sometimes hundreds, of resource plans, System Optimizer outputs only the top plan. Being able to view a series of top plans and their PVRRs can be useful to identify patterns and quantify the magnitude of differences in revenue requirements.[25]

System Optimizer is a very useful tool for use in resource planning. It is particularly well-suited for BC Hydro and the unique policy environment in which it must conduct its resource planning, as "the primary feature of System Optimizer is its ability to analyze renewable portfolio standard and emissions

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[19] Black and Veatch. Alaska Railbelt Regional Integrated Resource Plan (RIRP) Study. February 2010. Available at: http://www.susitna-watanahydro.org/wp-content/uploads/2012/05/Black_Veatch_2010_AlaskaRIRPFinalReport.pdf

[20] BC Hydro. 2013 Integrated Resource Plan. Page 4-59.

[21] Also referred to as Cumulative Present Worth (CPW)

[22] BC Hydro. 2013 Integrated Resource Plan. Page 4-61.

[23] Wilson, Rachel and Bruce Biewald. Best Practices in Electric Utility Integrated Resource Planning. Synapse Energy Economics. Prepared for the Regulatory Assistance Project. June 2013. Page 32.

[24] Ventyx. Product Overview: System Optimizer. Page 1.

[25] Synapse was not asked to review the results of BC Hydro's System Optimizer analysis, but merely the use of the model in resource planning applications.

regulations."[26] The model is widely-accepted within the electric industry, and PacifiCorp, Duke Energy, Tri-State, Colorado Springs Utilities, Basin Electric Power Cooperative, and Tennessee Valley Authority are some of the other utilities using System Optimizer to conduct present value analyses for use in resource planning.

4.3. Annualized Costs and End of Life Issues

When undertaking integrated resource planning, utilities examine a planning period or horizon some number of years into the future, matching annual energy and peak demands with new supply- and demand-side resources. They may evaluate the costs of a resource plan over that planning horizon, but for resources with long operating lives, that metric does not consider costs and revenue requirements after the planning period ends. For example, a utility may use a planning period of 25 years and add a long-lived resource that has high capital costs but low operating costs in one of the last years of that period. The resulting PVRR will capture the high costs of capital but not the benefits of the lower operating costs, which are incurred largely outside the utility's planning period. Annualization of costs provides a way to capture those benefits.

BC Hydro used the two different methods described above to analyze the costs of individual resources over their lifetimes, and of portfolios that contain resources with varying book lives. The first of those is the unit cost comparison, that examines the levelized cost of a unit of energy or capacity in dollars per megawatt hour ($/MWh), calculated using an annualized cost method.[27] Annualization, or levelization, is the calculation of the value that, if paid out in equal annual amounts over a specified period and discounted, would be equal to the present value.[28] In this case, annualization results in a stream of cost values that is constant over the book life of a resource, which, when discounted, yields the UECs and UCCs described above. Annualization is a useful tool because different assets have different cost profiles and book lives, and this method provides a consistent way to compare them to each other. A new hydro asset, for example, is one such resource with high upfront capital costs, but very low operating costs over a very long life. Natural gas assets, on the other hand, have much lower upfront capital costs, higher operating costs, and a book life of 25-40 years depending on turbine type. Levelization allows for a consistent comparison between these two very different asset types.

BC Hydro took these annualized values and input them into System Optimizer in order to account for these end of life issues in its analysis of portfolios of resources. In order to be accurate, these annualized values have to be independent of capacity factor in cases where resources are dispatchable, and capital must be levelized on a per kW basis. Thus, the calculation of the annualized values depends on resource type. For resources that are not dispatchable, modelers included a fixed output in the calculation of unit

[26] Ventyx. Product Overview: System Optimizer. Page 1.

[27] BC Hydro. 2013 Integrated Resource Plan. Page 3-6.

[28] US EPA. OAQPS Economic Analysis Resource Document. Section 8.3: Discounting Benefits and Costs. Available at: http://www.epa.gov/ttnecas1/econdata/Rmanual2/8.3.html

costs. For dispatchable resources like gas, costs are annualized absent fuel price inputs (which have monthly values). At a conceptual level, this seems correct.

The longer the planning period, the less important annualization becomes, as costs further out in the future are captured by the PVRR value. In its IRP analysis, BC Hydro used a planning horizon of 30 years. Manitoba Hydro, similarly, looked at a period of 35 years, while in Alaska, a 50 year planning period was used to study the Susitna dam and other hydro projects.[29] Nalcor Energy used a period of 57 years, stating explicitly that it was looking at a longer planning period due to the long-lived nature of the hydro assets it was evaluating.[30] Hydro resources may have a book life of 70 years or more, and these longer planning periods may not need to include an annualization calculation. However, with a 30 year planning horizon and a plan that includes new hydro assets, BC Hydro is correct to include a levelization calculation in its portfolio analysis.

5. Conclusions and Recommendations

Synapse was asked to review and comment on the several elements of the BC Hydro 2013 IRP: 1) the differential between the WACC for BC Hydro and for IPPs; 2) the use of sensitivity analyses as a means to evaluate the direction and magnitude of risk; 3) the use of analytical methods, including the appropriateness of BC Hydro’s Unit Cost Comparison, as well as the System Optimizer model; and 4) the calculation of annualized costs with respect to resource end-of-life. Our review is largely of the methods used for analysis in this IRP, and with the exception of the WACC, Synapse was not asked to review or evaluate any of BC Hydro’s input assumptions. At this time, we cannot determine whether the Company’s projections for these inputs are reasonable or reliable, nor can we comment on the conclusions arrived at by BC Hydro in its 2013 IRP.

With respect to the WACC, BC Hydro has selected reasonable values and has given proper consideration and quantification of resource cost uncertainty. The Company’s alternatives analysis methodology is consistent with good utility practice and includes several valuable elements: a levelized cost analysis, integrated resource modeling using System Optimizer (both of which include annualized costs to take into account end-of-life resource considerations), and a sensitivity analysis that evaluated various risks and uncertainties. Future sensitivity analysis might include variability in water levels and/or impacts of climate change on various generating resources, particularly those long-lived resources that would be expected to operate well into the future.

Integrated resource planning processes and documents must evolve over time as the context for utility operations changes, as different types of resources become technically and economically feasible, and

[29] Black and Veatch. Alaska Railbelt Regional Integrated Resource Plan (RIRP) Study. February 2010.
[30] Navigant Consulting Ltd. Independent Supply Decision Review Prepared for Nalcor Energy. September 14, 2011.

as new types of risks and uncertainty affect the electric system. BC Hydro’s methodologies will help the Company to manage these challenges as they arise.