Integrated Resource Plan

Appendix 3C

Technical Planning Assumptions: Intermittent Resources Effective Load Carrying Capability & Firm Energy Load Carrying Capability

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1 Introduction

Intermittent resources, such as run-of-river hydro and wind, have varying output due to natural changes in stream flows and wind speeds. The intermittency of the outputs and the seasonal profile of these resources results in varying levels of energy and capacity contribution to the system's firm energy and dependable capacity requirements.

BC Hydro uses Firm Energy Load Carrying Capability (**FELCC**) and Effective Load Carrying Capability (**ELCC**) to estimate intermittent resource contributions to firm energy and dependable capacity, respectively. The FELCC and ELCC are defined as follows:

- The FELCC is the maximum amount of annual energy that a hydroelectricity system can produce under critical water conditions. The FELCC contribution from intermittent resources can be limited due to their large freshet inflows and significant annual variability.
- The ELCC is the maximum peak load that a generating unit or system of units can reliably supply such that the Loss of Load Expectation will be no greater than one day in ten years. The ELCC contribution from intermittent resources can be impacted by fuel supply, planned outages, and forced outages due to mechanical failures.

The FELCC and ELCC contributions of intermittent resources rely on being aggregated with the system as a whole, and are used in developing the energy and capacity Load/Resource Balances (**LRB**s) to determine future system needs. This appendix updates the FELCC and ELCC contributions for small hydro and wind resources from the 2008 LTAP.

2 Firm Energy Load Carrying Capability – Small Hydro

2.1 Summary Of Previous FELCC Analysis

BC Hydro previously undertook FELCC analyses on small hydro resources during the 2007 Standing Offer Program (**SOP**) application and the 2008 Long-Term Acquisition Plan (**LTAP**). The following bullets summarize the results of these analyses and how they were applied:

- The SOP FELCC analysis determined that about 85 per cent of the 500 GWh/year average annual small hydro SOP energy[1] would be available during the critical period and about 45 per cent of the average annual small hydro SOP energy would be generated during the three month (May to July) freshet period
- The FELCC of pre-existing small hydro was also set at 85 per cent of aggregate average annual energy, given their pre-existence to SOP projects, and their similarities in locations and energy production profiles
- For the 2008 LTAP, a formula-based simplified methodology was developed, which resulted in a small hydro FELCC for future resource additions of approximately 70 per cent of the average annual energy. It has since been determined that this is likely overly conservative when compared to modelling small hydro resources as aggregate blocks.

2.2 FELCC For Existing/Committed Small Hydro

As part of the Integrated Resource Plan (**IRP**), and with anticipated major changes to the BC Hydro system - such as the updated Non-Treaty Storage Agreement (**NTSA**) and the addition of Revelstoke Unit 5, and Mica Unit 5 and 6 - the FELCC contributions for existing and future small hydro projects were updated separately.

[1] 500 GWh/year average annual SOP energy is approximately the mid-point of the estimated amount of SOP energy to be delivered during the two year review period.

To reflect the enhanced system benefits of Resource Smart additions, such as Revelstoke Unit 5, Mica Unit 5 and 6, and potentially Site C, the FELCC for all existing small hydro projects was recalculated, resulting in an FELCC contribution of 85 per cent of average annual energy. The two main resource characteristics that affect this FELCC valuation are:

- The proration of the current block of independent power producer (**IPP**) small hydro average energy by 85 per cent to estimate firm energy is considered reasonable, based on the expectation that average runoffs for a diverse group of IPP projects in the province would generally be about 15 per cent lower than average during a recurrence of the BC Hydro system critical period. This reflects the fact that, on a province-wide basis, regional inflows would be expected to be about 10 to 15 per cent lower during a period of extended multi-year drought as occurred in the early 1940s. This was confirmed in the response to the 2006 Integrated Electricity Plan (**IEP**) British Columbia Utilities Commission information request 1.23.1, whereby a 59-year tabulation of simulated BC Hydro system energy was generated from inflows (i.e., assuming run-of-river operation), which showed a ratio of critical period average to 59-year average inflow energy of approximately 86 per cent.
- The aggregation of existing and committed small hydro electricity purchase agreements (**EPAs**) – including the pre-2006 Call projects, 2006 Call projects, Clean Power Call (**CPC**) projects, and SOP projects – resulted in a total firm energy contribution of about 5,700 GWh/year, with roughly 39 per cent of firm energy occurring in the freshet period. The aggregated monthly average energy and FELCC profiles as well as the associated freshet ratios of all existing and committed small hydro EPAs are shown in Table 1. On an aggregated basis, the freshet energy ratio of 43 per cent is comparable to the ratio in the SOP study.

Table 1 Monthly Energy Profile for Aggregated Existing and Committed Small Hydro Projects

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Freshet %
Aggregate Average	300	200	300	400	900	1000	1000	700	600	600	400	300	6700	43
Aggregate Firm	300	200	300	300	700	800	700	700	500	500	400	300	5700	39

The fact that the freshet energy contribution of 39 per cent is somewhat higher than the system load requirement of approximately 23 per cent during freshet months means that system storage will be required to reshape the small hydro generation in order to meet system load outside of the freshet months, subject to the limited storage capability.

The greater the disparity between the freshet energy contribution percentage and the freshet system load percentage, the more stress is placed on the storage system until such time as a "pinch point" is reached. Once the pinch point is reached, the firm energy contribution from additional freshet-rich resources to the system will decline; i.e., the contribution will be less than 85 per cent of average energy assuming all other factors being equal. This energy will then need to be sold into the markets or the resource output will need to be curtailed.

2.3 FELCC For Future Small Hydro

As part of the 2013 Resource Options Report Update, Kerr Wood Leidal updated the analysis of the small hydro resource potential in B.C., assuming the monthly energy profiles as shown in Table 2. The FELCC was determined to be 78 per cent of average energy for up to 7,500 GWh of average energy. The two driving factors for the lower FELCC are: 1) a higher freshet energy ratio of 46 per cent; and 2) the additional small hydro resources added to the portfolio, which exacerbate the existing freshet limitations. The FELCC would be further reduced for the energy additions in excess of 7,500 GWh, due to limited system capability to absorb additional freshet energy.

Table 2 Monthly Energy Profile for Aggregated Future Small Hydro Projects

	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %	Freshet %
Aggregate	4	3	4	9	16	17	13	9	6	7	7	5	46

2.4 FELCC Versus Contractually Firm

BC Hydro used contractually firm energy as a proxy for physically firm energy in the 2006 Call Large Project stream and for hydro projects in the 2010 CPC. However, as explained in the 2005 Resource Expenditure and Acquisition Plan (**REAP**) and the 2006 IEP/LTAP, portions of contractually non-firm energy product may be considered from a planning perspective as physically firm energy. The BCUC, in its 2006 IEP/LTAP Decision, accepted the rationale and directed BC Hydro to continue to carry out studies that may inform BC Hydro's estimates of the physically firm portion of energy tendered for an intermittent resource. The approach is also consistent with the Alcan 2007 EPA, where an FELCC contribution was included from the contractually non-firm energy.

The difference between assuming that only the contractually firm or physically firm energy contributes to FELCC can be substantial. For example, the contractually firm energy for the 2010 CPC hydro projects is 1,400 GWh/year, whereas the physically firm energy amounts to 1,800 GWh/year, a 400 GWh/year increase (or about a 200 GWh/year increase after attrition).

It should be noted that BC Hydro will continue to base its call evaluation upon contractually firm energy, which is evaluated on a stand-alone project-by-project basis. Physically firm energy will only be considered from a planning perspective, whereby the FELCC assessment reflects the aggregated benefits provided by the entire system, particularly from the Heritage assets.

3 Firm Energy Load Carrying Capability – Wind

Additional analysis of FELCC for wind was undertaken for the IRP. Five wind profiles were tested, with one representing the aggregated wind project EPAs and four representing the wind penetration scenarios as used in the wind integration studies. The FELCC analysis utilized 10 years of monthly wind power production data for 95 potential wind generation plants across B.C., as provided in the 2009 BC Hydro Wind Data Study by DNV Global Energy Concepts Inc.

The analysis showed an FELCC factor of 100 per cent of average annual energy when aggregated in bundles. This figure was relatively stable over a variety of assumptions regarding both aggregate volumes and regional mix of resources. The FELCC was applied to existing, committed and future wind IPPs.

4 Effective Load Carrying Capability – Existing And New Small Hydro Resources

4.1 Hourly Metered Data From Existing IPPs

BC Hydro has limited hourly data available for establishing the capacity contribution of small hydro resources. Therefore, a method of comparing the regional monthly shapes of sites with data to sites with limited data is required.

In the 2008 LTAP, two years (F2006 and F2007) of actual hourly data for eight existing small hydro IPP projects were used to test the ELCC of existing resources. From this BC Hydro concluded that the ELCC for existing small hydro IPP projects was 60 per cent of the average of the hourly metered generation rates during December and January.

In this IRP, the metered data record for these calculations was extended to five years (F2006 through F2010) to include the most recent hourly generation output. This resulted in the same ELCC factor of 60 per cent of the average MW for the months of December and January.

4.2 F2006 Call Projects And Clean Power Call Projects

For all non-storage small hydro projects expected to achieve commercial operation under the 2006 Call (both “small” and “large” project streams) and the CPC, the ELCC is assumed to be 60 per cent of the average generation rates during the months of December and January. This differs from the 2008 LTAP where it was assumed that the ELCC for the 2006 Call Large Project stream would equal 100 per cent of the average delivery rate for contractually firm energy during the months of December and January. This prior assumption was found to be overly optimistic given the anticipated physical variations in daily energy production rates, as well as the lack of contractual obligations within the monthly firm and seasonally firm EPAs with respect to maintaining constant daily/hourly capacity delivery rates.

For all storage small hydro projects, that are expected to achieve commercial operation under the 2006 Call and the CPC and have “hourly firm” EPAs, an ELCC of 100 per cent of the average of the contractual delivery rates for firm energy during all heavy load hours is assumed for the months of December and January.

4.3 Generic New Small Hydro Resources

For new non-storage small hydro projects, the ELCC is assumed to be 60 per cent of the forecast average generation rates during the months of December and January. For new small hydro projects with active storage equal to at least 50 per cent of average runoff volumes forecast for December and January, the ELCC is set to 100 per cent of the forecast average generation rate during the months of December and January. These assumptions were also used in the 2008 LTAP.

5 Effective Load Carrying Capability – Existing And New Wind Resources

Additional analysis of wind ELCC factors was undertaken for the IRP. The analysis expanded and refined the work undertaken in the 2006 IEP, which determined ELCC factors of 21 per cent and 29 per cent of installed capacity for onshore wind and offshore wind, respectively. The updated analysis utilized revised wind output-duration tables, based on synthesized chronological hourly wind data for different regions. The data was converted to five-point probability distributions that were input into BC Hydro's loss of load analysis model to compute ELCC contributions, assuming a Loss of Load Probability (**LOLP**) index of one day in 10 years.

The results of the analysis show an ELCC factor of 26 per cent, applicable to both onshore and offshore wind projects when aggregated in bundles. This ELCC factor is relatively stable over a variety of assumptions, involving both aggregate volumes and regional mix of resources.

6 Summary

A summary of the FELCCs and ELCCs for small hydro and wind resources is provided in Table 3.

Table 3 Summary of Firm Energy Load Carrying Capabilities and Effective Load Carrying Capabilities for Small Hydro and Wind Resources

Resource	FELCC	ELCC
Small Hydro Existing Pre-2006 Call for Tender (**CFT**)	85 per cent of Average Annual Energy	60 per cent of the historical average MW in December/January
Small Hydro F2006 CFT Small Project Stream	85 per cent of Average Annual Energy	60 per cent of the forecast average MW in December/January
Small Hydro F2006 CFT Large Project Stream	100 per cent of contractually firm energy levels plus top-up with non-firm to aggregate of 85 per cent of Average Annual Energy	60 per cent of the forecast average MW in December/January
Small Hydro Clean Power Call Seasonal Firm (non-storage hydro)	100 per cent of contractually firm energy levels plus top-up with non-firm to aggregate of 85 per cent of Average Annual Energy	60 per cent of the forecast average MW in December/January
Small Hydro Clean Power Call Hourly Firm (storage hydro)	100 per cent of contractually firm energy levels plus top-up with non-firm to aggregate of 85 per cent of Average Annual Energy	100 per cent of average hourly firm delivery rates during heavy load hours in December/January
Small Hydro New Resources, Non-storage	78 per cent of Average Annual Energy (to aggregate new resource volume of 7,500 GWh)	60 per cent of the forecast average MW in the December/January period
Wind Existing and New Resources, Onshore	100 per cent of Average Annual Energy	26 per cent of Installed Capacity
Wind Existing and New Resources, Offshore	100 per cent of Average Annual Energy	26 per cent of Installed Capacity