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April 1, 2021

Mr. Patrick Wruck
Commission Secretary and Manager
Regulatory Support
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Mr. Wruck:

RE: Project No. 1598990
British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Fiscal 2020 to Fiscal 2021 Revenue Requirements Application

BC Hydro writes further to the BCUC's October 2, 2020 Decision and Order No. G-246-20 on BC Hydro's Fiscal 2020 to Fiscal 2021 Revenue Requirements Application (**Decision**) to provide its submission in response to Directives 9 and 10 of the Decision.

Directive 9 of the Decision related to the Energy Studies models and directed BC Hydro to file the following with the BCUC within six months:

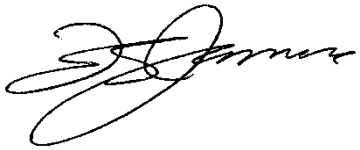
- A summary of the model improvements required;
- A plan to fully update the models in the monthly Energy Studies; and
- A plan to have an independent third party test the Energy Studies Market Model.

Directive 10 of the Decision directed BC Hydro to file its plan to review recommendations and priorities on back testing and benchmarking from the Energy Studies Internal Audit.

BC Hydro welcomes the opportunity to provide additional information on the Energy Studies development plan. We believe that our approach to implementing these updates will further improve operational decision-making ability to optimize the use of BC Hydro's large reservoirs in the best interests of our ratepayers.

For further information, please contact Chris Sandve at 604-974-4641 or by email at bchydroregulatorygroup@bchydro.com.

Yours sincerely,



Fred James
Chief Regulatory Officer

cs/rh

Enclosure

BC Hydro
Power smart

Fiscal 2020 to Fiscal 2021
Revenue Requirements Application

BC Hydro Compliance with BCUC Decision and Order G-246-20, Directives No. 9 and 10

April 1, 2021

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1 Introduction and Background

On October 2, 2020, the BCUC issued Decision and Order No. G-246-20 on BC Hydro's Fiscal 2020 to Fiscal 2021 Revenue Requirements Application (**Decision**). Directive 9 of the Decision related to the Energy Studies models and directed BC Hydro to file the following with the BCUC within six months:

- A summary of the model improvements required;
- A plan to fully update the models in the monthly Energy Studies; and
- A plan to have an independent third party test the Energy Studies Market Model.

A preliminary schedule for model improvements was provided in Table 3-15 of section 3.4.1 of BC Hydro's December 1, 2020 compliance filing to the Fiscal 2020 to Fiscal 2021 Revenue Requirements Application (**Compliance Filing**).

Directive 10 of the Decision directed BC Hydro to file its plan to review recommendations and priorities on back testing and benchmarking from the Energy Studies Internal Audit. A preliminary schedule to address Directive 10 was provided in sections 3.4.1 and 3.4.2 of the Compliance Filing.

This submission supplements the Compliance Filing and provides further details on BC Hydro's plan for model improvements as well as back testing and benchmarking. In summary, the relative priorities for model improvements set out in Table 3-15 of the Compliance Filing remain the same; however, the implementation timing has been revised to balance available subject matter expertise across the multiple deliverables included in BC Hydro's responses to Directive 9 and Directive 10 of the Decision.

BC Hydro welcomes the opportunity to provide additional information on the Energy Studies development plan. We believe that our approach to implementing these

updates will further improve operational decision-making ability to optimize the use of BC Hydro's large reservoirs in the best interests of our ratepayers.

2 BC Hydro Continues to Improve Its Energy Studies Models

BC Hydro is continually improving its modelling and tool capability. The Energy Studies models and operational planning models and tools meet BC Hydro's operational requirements and are validated and updated on an ongoing basis.

The Energy Studies model improvements are broken up into seven model tasks that outline the plan for continuous improvement for fiscal 2022 to fiscal 2027. The completion of each task generally addresses some or all of the following objectives:

- Reduce execution time to run the models;
- Reduce the amount of person resources needed to run the models;
- Improve data transcription and transfer between large databases;
- Increase model accuracy;
- Facilitate the ability to run different and parallel scenarios;
- Improve error handling during the Energy Studies Manager process;
- Improve reporting capabilities; and
- Reduce issues associated with an aging programming environment or legacy code and documentation.

The seven model improvement tasks are discussed in the following sub-sections below:

- Section 2.1.1 - Increase the Automation of the Energy Studies Manager
- Section 2.1.2 – Replace the Peace System Optimization Model

- Section 2.1.3 - Upgrade the Columbia and Peace Simulation Model (SOPHOS)
- Section 2.1.4 - Update the Load Variability Model
- Section 2.1.5 - Develop a Three Reservoir Stochastic Dynamic Program (SDP)
- Section 2.1.6 - Update the Cloud Computation Interface (Amazon Web Service)
- Section 2.1.7 - Update Ultralight (Short Term Model)

Table 1 below provides a summary of BC Hydro's updated schedule for improvements to the Energy Studies models as well as the review of the Market Model and the review the recommendations and priorities on benchmarking and back testing from the Energy Studies Internal Audit. The schedule estimates are considered suitable for initial planning purposes and will be updated as each model upgrade advances through the project lifecycle.

Table 1 Summary of Improvements to the Energy Studies Models (Update to Table 3-15 in the Compliance Filing)[1]

Ref	Directive	Tasks	Fiscal 2022				Fiscal 2023				Fiscal 2024				Fiscal 2025				Fiscal 2026				Fiscal 2027			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Revenue Requirements																								
2.1.1	#9(2)	ESM Efficiency																								
2.1.1	#9(2)	ESM Data Transfer																								
2.1.2	#9(2)	Peace Optimizer																								
2.1.3	#9(2)	SOPHOS Upgrades																								
2.1.4	#9(2)	Load Variabiltiy Model																								
2.1.5	#9(2)	Three Reservoir SDP																								
2.1.6	#9(2)	Cloud Computing (AWS)																								
2.1.7	#9(2)	Ultralight (Short Term Model)																								
3	#9(3)	Market Model (Review)																								
4	#10	Benchmarking																								
4	#10	Backtesting																								

[1] Pink blocks are used to indicate implementation timing that is less certain. Anticipated Revenue Requirements Application preparation and proceeding times are included as these applications require significant effort from the same group of subject matter experts that are required to support the Energy Studies Model improvement tasks.

Table 2 below provides an estimate of the costs for improvements to the Energy Studies models as well as the review of the Market Model and the review of the recommendations and priorities on benchmarking and back testing from the Energy Studies Internal Audit. The cost estimates total $2.28 million from fiscal 2022 to fiscal 2027 and are considered suitable for initial planning purposes. These estimates will be updated as each model upgrade advances through the project lifecycle.

Table 2 Cost Estimates for Improvements to the Energy Studies Models

Fiscal Year	ESM Efficiency	ESM Data Transfer	Peace Optimization	SOPHOS Upgrades	Load Variability Model	Unit Availability Model	Three Reservoir SDP	Cloud Computing (AWS)	Ultralight Rewrite	Market Model (Review)	Benchmarking	Backtesting	Total
F2022	55	84	2	6	34	-	-	275	69	78	166	-	771
F2023	42	19	71	-	-	-	-	-	19	14	126	-	290
F2024	42	9	24	98	-	-	-	-	-	-	158	116	447
F2025	42	-	-	44	-	-	188	-	-	-	-	99	374
F2024	42	-	-	-	-	-	264	-	-	-	-	-	306
F2025	38	-	-	-	-	-	56	-	-	-	-	-	94
$ thousands	262	113	96	148	34	-	508	275	88	93	450	215	2282

Further information on the planned improvements to the Energy Studies models is provided in the sub-sections below.

2.1.1 Increase the Automation of the Energy Studies Manager

The Energy Studies Manager is a process and data management tool that tracks the progress of individual data integration steps, the completion status of discrete Energy Study models, and reporting status for the Monthly Energy Studies. Within the Energy Studies Manager, there are opportunities to further automate data transfer between process steps, data transformation, data archiving, and the execution of discrete Energy Study models. While this improved automation will not

directly upgrade the core functionality in the Monthly Energy Studies models, it will improve the Energy Studies Manager process, and reduce the overall execution time and person resources needed to run the Monthly Energy Studies.

There are two projects within the Increase the Automation of the Energy Studies Manager task that are expected to result in material improvements for the Energy Studies Manager process and, subsequently, on the entire process for the Monthly Energy Studies:

- **Improved Energy Studies Manager Efficiency:** There are several upgrades to the Energy Studies Manager that would cumulatively reduce the execution time needed to run an Energy Study and reduce the person resources needed to administer the Energy Studies Manager process. These include parallel running of independent Energy Studies Manager steps and executing individual Energy Studies models directly from the Energy Studies Manager interface; and
- **Improved Energy Studies Manager Data Transfer:** An automated data integration platform was developed in 2020. The platform is scalable and BC Hydro plans to expand this platform to support more data sources for the Energy Studies.

2.1.2 Replace the Peace System Optimization Model

The existing Peace System Optimization Model optimizes the operation of Williston Reservoir and BC Hydro's GM Shrum and Peace Canyon generation stations. It is written in a legacy language (FORTRAN IV) and in a structure that is challenging to maintain and upgrade.

A new version of the Peace System Optimization Model will be based on the code used in the Columbia optimizer (coded in FORTRAN 2008). It will use the same mathematical framework as the Columbia Optimization Model (**MUREO**). The Peace System Optimization update will improve the accuracy of modelling the Peace system and facilitate easier execution of multiple scenario analysis. This upgrade is

also required to enable the eventual development of the Three Reservoir Stochastic Dynamic Program model, discussed in section 2.1.5 below.

2.1.3 Upgrade the Columbia and Peace Simulation Model (SOPHOS)

The Columbia and Peace system simulator (**SOPHOS**) is one of the core Energy Studies models. The SOPHOS simulator component is run on a monthly[2] basis to generate forecasts of Peace and Columbia reservoir elevations and releases, import/export volumes, and marginal prices. It simulates the operation of the three major storage reservoirs (Kinbasket, Arrow and Williston) based on the results from the MUREO and Peace System Optimization Model. It is coded in Java[3] and contains several pre-processing modules to transform inputs to the MUREO and Peace System Optimization Model.

The upgrades to SOPHOS are expected to improve forecasts of Revelstoke operations, allow more accurate integration of the Site C reservoir operations once commissioned, and improve the forecast of coordination between Columbia and Peace operations. The upgrades will also enable removal of legacy modules and updated documentation, which will improve model resiliency and facilitate future upgrades.

2.1.4 Update the Load Variability Model

The Load Variability Model[4] consists of a regression model running in SAS[5] and a simulation model in Visual Basic enabled Microsoft Excel. The regression model uses historic load data to develop relationships between day of the week, season,

2 SOPHOS is also run on a weekly basis between Energy Studies.

3 Java is a class-based, object-oriented programming language. BC Hydro has developed and maintains a library of Java code that is used in multiple applications to reduce model development effort and enhance reliability.

4 This Load Variability Model is an Energy Studies model that refines the Load Forecast provided by the Load Forecast Department to daily timestep and adds the variability based on weather sequences used in the Energy Studies. It is not the same as the Load Forecast models discussed in Chapter 3 of the Fiscal 2020 to Fiscal 2021 Revenue Requirements Application.

5 The SAS language is a computer programming language used for statistical analysis.

system temperature, and daily precipitation, based on deviations from a 28-day moving average. The simulation model takes the Load Forecast, which provides monthly granularity and downscales it into two daily blocks. It then applies historic weather records to turn this deterministic single trace forecast into a multi-trace weather year ensemble.

Improvements in the planned update include migrating from Microsoft Excel to Java and upgrading from a moving average to a degree day-based regression. These improvements are expected to reduce the number of regression models, improve simulation ability, reduce model run time, and reduce succession risk between subject matter experts.

2.1.5 Develop a Three Reservoir Stochastic Dynamic Program (SDP)

The two river systems, Peace (Williston Reservoir) and Columbia (Kinbasket and Arrow Reservoirs), are currently optimized using an iterative coordination between two separate optimization models.

Once the Peace System Optimization model is replaced, as discussed in section 2.1.2 above, it may enable BC Hydro to take the subsequent step of combining the separate Columbia and Peace optimization models into a single unified optimization model: The Three Reservoir (Williston, Kinbasket, and Arrow) Stochastic Dynamic Program. Benefits of a single unified optimization model include reducing the time to run the Energy Studies and integrating the optimization of storage management for the Columbia and Peace systems.

This task is a longer-term goal and requires prior research and advancements in optimization techniques before it is possible to advance. Accordingly, it is tentatively scheduled to begin no sooner than fiscal 2025 and BC Hydro is planning to evaluate the benefits associated with this task once the other tasks are completed.

2.1.6 Update the Cloud Computation Interface (Amazon Web Service)

BC Hydro uses the Amazon Web Service (**AWS**) for efficient parallel execution of the MUREO. The model requires considerable computer processing resources to perform complex calculations. The existing AWS Cloud Computation Interface transfers data from BC Hydro servers to the Amazon cloud servers. This reduces model execution time from more than four days, if run locally on a stand-alone basis, to hours.

The AWS interface is necessary to support the continued publishing of the monthly Energy Studies. An update is required as the existing AWS integration software was built in 2014/2015 and is out of date and no longer supported. This has resulted in increasing maintenance and support challenges.

The update will redesign the Cloud Computation Interface software to replace the unsupported integration solution and better incorporate current AWS capabilities to support running MUREO. This task is also expected to include improvements to make it easier to run and maintain the interface.

2.1.7 Update Ultralight (Short Term Model)

Ultralight is a Visual Basic enabled Microsoft Excel optimization model used to provide updates to the marginal prices for the Kinbasket and Williston reservoirs and to facilitate modelling of operational scenarios over a time horizon less than one year. In addition, it provides operational guidance on management of reservoir flow releases required to achieve desired reservoir target levels and spill probabilities based on user defined scenarios. The results from Ultralight are used in between monthly Energy Study runs, to evaluate and update prevailing basin pricing for the Columbia and Peace reservoirs, given changing system conditions (e.g., inflows, loads, outage schedules, and market prices).

Ultralight is intended to provide information on a forecast time horizon between one-month and one-year. Once initialized by optimization data from the current Energy Studies, Ultralight can be run quickly (i.e., in less than a day).

Benefits from the planned upgrade include transferring the Ultralight model from a Visual Basic enabled Microsoft Excel platform to a more robust and formal platform, using Java. This will facilitate easier scenario comparisons, better integrate existing data sources already used for the Energy Studies, reduce the time needed to run the model, and align reporting outputs with formats used for the Energy Studies.

3 Market Model Review

Directive 9 of the Decision also required BC Hydro to submit a plan to have an independent third-party test the Energy Studies Market Model.

The Market Model consists of a set of regression models running in SAS together with a simulation model, called Emprise. The regression model uses historic data on market prices, weather, inflows, generation, seasonality, and energy supply to develop relationships that are considered to influence market prices. The Emprise model takes these relationships, together with forecasts of the driving variables, to develop multi-trace by weather year ensembles of forecast market prices that capture the range of potential outcomes that are driven by unmodelled factors.

BC Hydro expects the review of the Market Model to include:

- Consideration of how well the model covers the range and distribution of potential market price outcomes;
- The selection of driving variables used in the regression models;
- Incorporating outlier events in the model without introducing bias; and
- Evaluating the applicability of gas basis and heat rate models as more renewable energy sources are added to the Pacific Northwest.

Other topics may be added to the scope of the review as it is finalized. BC Hydro plans to engage an independent third-party in fiscal 2023.

Depending on the recommendations coming out of the independent review, BC Hydro may undertake modifications and upgrades to the Market Model.

4 Back Testing and Benchmarking: Updated Schedule

Directive 10 of the Decision required BC Hydro to file a plan to review the recommendations and priorities on benchmarking and back testing from the Energy Studies Internal Audit. A preliminary plan and schedule was provided in sections 3.4.1 and 3.4.2 of the Compliance Filing.

Table 3 below provides an updated schedule for benchmarking and Table 4 below provides an updated schedule for back testing. The schedules have been extended by approximately nine months, relative to the preliminary schedules provided in the Compliance Filing, in order to accommodate higher priority model development work in response to Directive 9.

Table 3 Energy Studies Models: Benchmark Plan (Update to Table 3-16 in the Compliance Filing)

Benchmark Plan	Item	F2022				F2023				F2024				F2025				F2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Model Development	Automation and standardize model inputs																				
	Build comparison tools																				
Data Gathering	Prepare market data for input to the models																				
	Prepare inflow data																				
	Columbia Treaty constraint																				
	Match prices and Terminal Values																				
Model Runs	Run both models for a single trace inflows																				
	Run models with Columbia inflow variation																				
Reporting	Analysis and Reporting																				

Table 4 Energy Studies Models: Back Testing Plan (Update to Table 3-17 in the Compliance Filing)

Back-Testing Plan	Item	F2022				F2023				F2024				F2025				F2026			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data Gathering	Prepare Energy Studies model data																				
Model Runs	Kootenay																				
	Pend d'Oreille																				
	Small hydro generation																				
	Market price variability																				
	Columbia Treaty and Non-Treaty Constraints																				
Reporting	Analysis and Reporting																				