RESPONSE TO WORKING GROUP AND PUBLIC COMMENTS ON THE SITE C CLEAN ENERGY PROJECT ENVIRONMENTAL IMPACT STATEMENT

Technical Memo

ALTERNATIVES TO THE PROJECT

MAY 8, 2013

Subject: Alternatives to the Project

Purpose

The purpose of this technical memo is to provide an overview of how BC Hydro reviews potential electricity resources to meet customer demand, and to address questions raised during the comment period on the EIS regarding BC Hydro's analysis of alternatives that has identified the Project as the preferred option to meet the need for firm energy and dependable capacity in BC Hydro's service area.

Overview

Consistent with Section 4.2 of the EIS-G[1] and good utility practice (as reflected in the BCUC's Resource Planning Guidelines among other things), BC Hydro identified and undertook a multi-layered review of electricity resources which could be alternatives to the Project:

- EIS, Section 5.4.1 - BC Hydro used the 2010 Resource Options Report (ROR) as the starting point for identification of resources. BC Hydro updated the 2010 ROR with respect to forecasted wind prices and made other adjustments to facilitate comparisons described in the EIS and in further detail below.
- EIS, Section 5.4.2 - As mandated by Section 4.2 of the EIS-G, BC Hydro screened resources to determine if the resources are economically and technically feasible. BC Hydro clearly identified and set out its conclusions with regard to these screened resources.
- EIS, Section 5.5 – BC Hydro developed criteria "*to identify the major environmental, economic and technical costs and benefits of"* available resources, which are resources that are viable and which in various combinations could be alternatives to the Project:
    - In Section 5.5.1 BC Hydro set out the attributes it used to measure "*the relative consideration of the environmental, economic and technical costs and benefits*" of the available resources and the Project
    - In Section 5.5.2, BC Hydro applied the four types of attributes (financial, technical, environmental and economic development) to individual available resources through: the Unit Energy Cost (UEC) or the Unit Capacity Cost (UCC); describing whether a resource was intermittent or dispatchable, and whether a resource provides dependable capacity; and presenting an overview of the environmental effects and benefits of different available resources. BC Hydro also highlighted where Provincial legislation such as the *Clean Energy Act* set out limits to or otherwise impacted individual available resources.
    - In Sections 5.5.3 and 5.5.4, and consistent with the BCUC's Resource Planning Guidelines, BC Hydro developed three plausible resource portfolios which could meet the identified need – (1) Site C portfolio; (2) Clean Generation Portfolio; and (3) Clean +Thermal Generation Portfolio, with natural gas as a component within the *Clean Energy Act's* 93% clean or renewable target. These three portfolios were compared using the four types of attributes.

As a result of this analysis, BC Hydro reached the conclusion that the Project provides the best combination of financial, technical, environmental, and economic development attributes and is therefore a preferred option to meet the need for energy and capacity within BC Hydro's planning horizon.

[1] The EIS Guidelines are quoted in italics throughout this Technical Memo.

Identifying Alternatives

The EIS-G in Section 4.2 provides that BC Hydro must identify the alternatives to the Project that were considered; this was done in Section 5.4 and summarized in Table 5.17 of the EIS. The information on the alternatives as shown in the EIS is based upon, but in certain aspects supersedes, the 2010 ROR. The 2010 ROR is a database of resource option attributes and costs reflecting: (1) input from stakeholders with technical expertise, including information from members of the independent power producer (IPP) community, as well as First Nations and public stakeholders; (2) consultant studies; and (3) BC Hydro's own project experience. Please see Appendix 1 to this Technical Memo for a list of the resource technologies considered in the EIS.

There are five main changes from the values presented in the 2010 ROR to the values presented in the EIS:

1. BC Hydro updated the wind energy volumes and UECs based on observed changes in turbine efficiencies and wind turbine prices that have occurred over the past three years as described in Section 5.4.1.2
2. BC Hydro updated the UECs and UCCs of all resources to constant dollars as of January 1, 2013 ($F2013) using a 2% inflation factor where necessary as described in Section 5.5.1.1
3. BC Hydro used an 8% real cost of capital for determining the UECs and UCCs for IPP resource options and a 6% real cost of capital for determining the UECs and UCCs for BC Hydro resource options as described in Section 5.5.3.4
4. For natural gas resource options, UECs and UCCs include associated fuel and greenhouse gas (GHG) costs
5. For pumped storage resource options, UCCs include associated costs for 30% energy losses with an 18% capacity factor

BC Hydro describes the limitations of the 2010 ROR on page 5-29 of the EIS. The 2010 ROR contains sufficient information on physical, financial, environmental and economic development characteristics for analysis at a planning level; however, the values:

- Do not reflect site-specific information, permitting constraints and other development risks
- May not accurately predict future prices or projects set through BC Hydro's power acquisition processes. Historically, the resource options with the lowest unadjusted UEC values are not always bid into BC Hydro's power acquisition processes.

Screened Resources

The EIS-G in Section 4.2 provides that alternatives must be "*technically and economically feasible*". In Section 5.4.2 of the EIS, BC Hydro described the process of screening resources on the basis that they are not viable; all other resources were deemed available for creating portfolios. The screened resources fall into three categories:

- Supply-side (generation) resources that are legally barred. Section 4.1.2 of the EIS-G provides that "*the purpose of the Project will be established from the perspective of the Proponent, and will provide context for the consideration of alternatives to the Project*". A potential resource that is legally barred is not available to BC Hydro and thus not an alternative to the Project. Refer to Section 5.4.2.1 of the EIS, where four groups of supply side options were screened – Burrard Thermal Generating Station, large hydroelectric projects prohibited by the *Clean Energy Act*,

nuclear, and external market resources prohibited by the self-sufficiency provisions of the *Clean Energy Act*.

- Supply-side resources that are not economically or technically feasible. Refer to Section 5.4.2.2 of the EIS, where coal-fired generation with carbon capture and storage, wave, tidal and solar resources were screened.
- Demand Side Management (DSM) options that are not economically or technically feasible – refer to Section 5.4.2.3 of the EIS for the screening analysis regarding two broad DSM categories, and within these two categories, additional DSM options. Please also see the Technical Memo on Demand-Side Management for further discussion on these DSM options.

In addition, supply-side generation resources that appeared to be economically or technically feasible based on the 2010 ROR results were screened for use in the portfolio analysis. BC Hydro used the results of its acquisition processes to date as the basis for this step. This resulted in the screening of two additional resources: geothermal and biogas/landfill gas. For example, while geothermal is a mature technology, there are significant risks in developing green-field geothermal sites and no projects have ever been bid into BC Hydro acquisition processes. However, the attributes of both geothermal and biogas/landfill gas are reviewed in Section 5.5.2 of the EIS.

Resources Available for Portfolio Analysis

As shown in EIS Table 5.38 on page 5-60 there is over 140,000 GWh of available clean or renewable resources were identified that could be used as alternatives to the Project's 5,100 GWh of energy supply. For additional clean or renewable resource options to impact the EIS, the additional resources would need to be identified in volumes comparable to the Project and at costs that are below the most cost-effective shown in this table and selected in the portfolios as shown in Section 5.5.4 of the EIS. Appendix 5 shows supply curves for the resources available for portfolio analysis.

Resource Option Attributes

Section 4.2 of the EIS-G requires BC Hydro to "*[d]evelop criteria to identify the major environmental, economic and technical costs and benefits of the alternatives".* In Section 5.5.1 of the EIS BC Hydro describes the financial, technical, environmental and economic development attributes that were used to compare the resource alternatives. The comparison of alternatives consists of 1) an overview of the attributes of each individual resource option, provided in Section 5.5.2, and 2) portfolio analysis, the results of which are set out in Section 5.5.4.

The purpose of the resource option attributes is not to essentially undertake a formal environmental assessment of the alternatives to the Project; this is both untenable and outside the scope of the environmental assessment, and indeed has never been required in past harmonized environmental assessment/Joint Review Panel processes for hydroelectric projects:

- The scope of the assessment of the alternatives to the Project described in Section 5 meets both Section 4.2 of the EIS-G and the Canadian Environmental Assessment Agency's Operational Policy Statement for alternatives analysis
- Attributes were developed for resource options as a way of characterizing and comparing, at a high level, different portfolios. These high-level attributes are used for comparison of resource options across provincial-scale portfolios, and act as proxies for more detailed economic, technical, environmental, social, and heritage effects of potential projects. Since detailed site-specific information is unknown for the majority of the potential sites in the 2010 ROR database, these

attributes are not appropriate, or intended to be used, for individual site-specific evaluations and comparisons of the impacts of potential resource options.

- The attributes for the Project are unique compared to the alternatives as a result of the advanced level of project definition for the Project, which allows a higher level of accuracy in determining the Project costs and footprint. The portfolios without the Project are populated with forecast "typical" projects with estimated costs and footprints. As a result, the differences in attributes between portfolios compare a defined attribute for the Project to a representative estimate for IPPs.

Financial and Technical Attributes

BC Hydro showed the UECs of generation resources in two ways:

- UEC at Point of Interconnection to the BC Hydro integrated system (POI), as described in Section 5.5.1.1, shown in Section 5.5.2. and summarized in Table 5.38 of the EIS. These are calculated based on the total energy provided by the resource options.
- UEC adjusted to the Lower Mainland ("Adjusted UEC"), as summarized in the comparable block analysis in Section 5.5.4.3 and Table 5.42. These are calculated based on the firm energy provided by the resource options. These adjustments reflect delivery costs to the lower mainland, wind integration costs (where applicable), capacity costs, soft costs, and adjustments to reflect the time of delivery of the energy (the freshet firm energy adjustment and the time of delivery price adjustment).

The Adjusted UEC is the appropriate measure to use when comparing resource options as it adjusts the generation resources to be a common firm energy product delivered to BC Hydro's major load centre, the Lower Mainland. To make these comparisons more obvious, Table 5.38 of the EIS has been modified in Table 1 below to include Adjusted UECs upon which Table 5.42 of the EIS was created.

Different resources have different technical attributes. For example, intermittent clean or renewable resources like wind and run-of-river are not always available and cannot be economically dispatched, that is, cannot be used to take advantage of market conditions (shut down when market electricity prices are low, ramped up when electricity markets prices are high). In contrast, dispatchable resources such as the Project and natural gas-fired generation are reliable and can be economically dispatched. BC Hydro analyzed the available resource option technical attributes in two steps:

- In Section 5.5.2 and in Table 1 below, BC Hydro used the following to begin the technical attributes analysis: FELCC (which stands for Firm Energy Load Carrying Capability); ELCC (which stands for Effective Load Carrying Capability, which as explained in Sections 5.2.1.2 and 5.5.1.2 of the EIS is applied to intermittent resources that provide little if any dependable capacity); and DGC (which stands for Dependable Generating Capacity which, as described in Section 5.5.1.2 of the EIS, is used for non-intermittent resources such as the Project and natural gas-fired generation).
- These measures do not capture the ability to economically dispatch, which provides value to BC Hydro's ratepayers and is a point of differentiation between intermittent resources and resources with dispatchable capacity. The portfolio analysis captures most of the economic dispatch value; refer also to the Hydro-Electric Storage and Dispatchable Capacity Technical Memo.

Table 1 Selected Financial and Technical Attributes of Available Energy Resource Supply Options

Energy Resource	Total FELCC Energy (GWh/year)	Total DGC or ELCC Capacity (MW)	UEC at POI ($F2013/MWh)	Adjusted UEC ($F2013/MWh) Capacity Cost Adder based on Pumped Storage[2]	Adjusted UEC ($F2013/MWh) Capacity Cost Adder based on Pumped Storage and SCGTs[3]
Biomass – Wood Based	11,946	1,499	125 – 985	158 - 1135	151 – 1128
Biomass – Biogas	134	16	60 – 159	91 - 194	84 – 187
Biomass – Municipal Solid Waste	499	58	117 – 259	152 - 324	144 – 316
Wind – Onshore	46,165	3,942	96 – 332	178 - 447	161 - 431
Wind – Offshore	50,261	3,681	190 – 734	263 - 881	246 – 864
Geothermal	5,992	780	88 – 581	119 - 631	112 – 626
Run-of-River	33,619	1,018	82 – 600	164 - 1508	151 – 1496
Site C Clean Energy Project	4,700	1,100	94	110	110
Combined cycle gas turbine (CCGT) and Cogeneration	7,623	964	75 – 166	95 - 173	86 - 164

Notes:

1. Adjusted UEC values include transmission-related costs to the Lower Mainland, wind integration costs, a freshet firm energy cost adjustment, time of delivery costs, soft costs (refer to EIS, page 5-64) and capacity adjustments to provide the same relative contribution of dependable capacity as the Project.
2. The UEC for the Project does not include sunk costs.
3. The variation in UEC values shown in Table 1 is largely determined by the quality of the underlying resource, the distance to POI, and the transmission costs of delivering the electricity to the Lower Mainland.
4. Appendix 2 provides detail on the calculation of the Project UEC.

The life-cycle costs of the capacity provided by resource options are provided as Unit Capacity Costs (UCCs). As stated in Section 5.5.1.1 of the EIS:

- The UCC "reflects the real levelized cost of a unit of capacity from a resource option (typically in $F2013/kW-year). UCCs are calculated by taking the levelized annual cost of a capacity resource divided by the resource's dependable capacity."
- POI-level UCCs for resource options are provided in Section 5.5.2 of the EIS and reproduced from table 5.37 in Table 2 below.

Table 2 UCCs of Available Capacity Resource Supply Options

Resource Type	Dependable Capacity (MW)	Unit Capacity Costs at POI ($F2013/kW-year)
Simple Cycle Gas Turbine (SCGT)	98	89 – 121
Pumped Storage	1,000	216 – 440

[2] Capacity Credit Valued at $232/kW-year (based on pumped storage only).

[3] Capacity Credit Valued at $154/kW-year (based on pumped storage and SCGTs).

Resource Smart	About 390	28 – 370

Environmental Attributes

Section 5.5.1.3 of the EIS explains that BC Hydro retained a number of consultants to provide a high level indication of the environmental attributes of the resource options. The environmental attributes were tabulated for four key categories: land, atmosphere, freshwater and marine, and are further broken down into indicators as described in table 5.24 of the EIS. Please refer to Section 5.5.2 of the EIS for a description of the environmental attributes of the available alternative resource options.

In some cases, measures were further classified to allow more detailed comparisons. As the rightmost column in Table 5.24 of the EIS displays, these classes subdivide each measure into 3 – 5 subcategories in order to facilitate some of the comparisons shown in Section 5.5.4. The assessment of the potential effects of the Project is provided in Volumes 2, 3, and 4 of the EIS.

Economic Development Attributes

As described in Section 5.5.1.4 of the EIS, BC Hydro uses economic development attributes to describe the contributions of resource options to the provincial economy. The British Columbia Input-Output model was used to determine the economic development attributes. There are three categories of attributes as follows:

1. Provincial Gross Domestic Product (GDP)
2. Employment; and
3. Provincial government revenue.

These categories are further broken down into sub-categories in table 5.25 of the EIS.

Creating Portfolios

As described in Section 5.5. of the EIS, the comparison of alternatives is largely done through portfolio modelling and further analysis on the underlying resources. Portfolios are created by the linear optimization model (System Optimizer) that selects the optimal combinations of available resource options under different assumptions and constraints that will meet the energy and capacity needs of BC Hydro's customers as defined in Section 5.2. Portfolio modeling runs economic dispatches of the potential portfolio in a way that looking at resource UEC comparisons cannot. The portfolio modeling provides:

- Timing of resources, including modelling their operation;
- Capital expenditures based on the timing of resource additions;
- Expected operating costs from the manner in which the resources will be operated;
- Electricity market trade benefits depending on the flexibility of the portfolio; and
- Permits the calculation and comparison of a portfolio present value (PVs) to allow 30 year planning timeframe cost comparisons.

BC Hydro built three categories of portfolios as follows:

- **Site C Portfolios:** include the Project;
- **Clean Generation Portfolios:** exclude the Project and use clean or renewable alternatives; and

- **Clean + Thermal Generation Portfolios:** exclude the Project and use a combination of clean or renewable resources with capacity provided by thermal generation (in the form of SCGTs) up to the 93% *Clean Energy Act* clean or renewable target, and pumped storage.

System Optimizer was used to select the resource mix to make up the portfolios. BC Hydro created sets of portfolios for Project in-service dates of F2022 and F2024. For additional information on the System Optimizer model and the portfolio construction, please refer to Appendix 4.

To facilitate a useful comparison to the Project the resource options selected in the portfolio analysis were used to create a comparable block of energy **and capacity** to the Project's 5,100 GWh/year of energy and 1,100 MW of dependable capacity for the three portfolio categories. These blocks were used to calculate the values for 1) the Adjusted UEC comparison shown in table 5.42 of the EIS; 2) the environmental attribute comparison in table 5.43 of the EIS; and 3) the economic development attribute comparison in table 5.44 of the EIS.

Compared to the 30-year portfolio PV calculation, the adjusted UEC value is a proxy for a comparison of the costs of the Project and alternatives over their project lives and demonstrates the long-term value of the Project. This analysis excludes the consideration of resource timing and of some operational considerations.

To account for the energy losses associated with pumped storage and still supply 5,100 GWh of clean energy, the clean generation portfolio and clean + thermal generation portfolio were made up of approximately 5,800 GWh and 5,400 GWh of resources, respectively. Tables are included in Appendix 3 to this memo that show the resources selected for the comparable blocks and the construction of the UEC.

Portfolio Evaluation and Decision Process

To identify the preferred portfolio, BC Hydro undertook an analysis of the quantitative financial, technical, environmental and economic development attributes of the three categories of portolios. The attributes are described in Section 5.5.1 of the EIS which includes the details of the indicators, units of measures, and classifications provided in Table 5.24 and Table 5.25. For each portfolio, attribute values were calculated for each measure by summing up the attribute values of the selected resource options. For the environmental attributes BC Hydro brought forward footprint-level indicators to facilitate portfolio comparisons as a further level of detail did not provide any additional useful information.

For convenience, portfolio attributes and results described in Section 5.5.4 are reproduced in Table 3.

Table 3 Portfolio Analysis Consequence Table

Attribute	Units	Clean Generation		Clean + Thermal Generation		Site C Portfolio	
Financial Attributes (EIS Section 5.5.4.3)							
PV Differential	$F2013 million	F2022	F2024	F2022	F2024	N/A	
		450	660	(150)	180		
Adjusted UEC	$F2013/MWh	181		156		110	
Environmental Attributes (EIS Section 5.5.4.4)							
Land footprint	Hectares	2,230		2,430		5,660	
Affected stream length	Kilometres	15		15		125	
Reservoir created	Hectares	0		0		9,300	
GHG emissions	Tonnes/year, thousands	200		650		0	
Local Air Emissions	Tonnes/year, thousands	NOx	CO	NOx	CO	NOx	CO
		0.5	0.4	0.6	1.3	0	0
Economic Development Attributes (EIS Section 5.5.4.5)							
Construction jobs	Total Jobs	33,200		28,500		44,200	
Construction GDP	$F2013, million	2,600		2,200		3,500	
Operations jobs	Jobs per Year	1,175		1,025		75	

Notes:

1. Portfolios are created to have similar technical attributes – i.e., the amounts of energy and dependable capacity are roughly similar
2. All values are rounded, with the exception of the adjusted UEC costs

In both cases, compared to both the Clean portfolio and the Clean + Thermal portfolio, the Site C portfolio had sufficiently superior characteristics that no quantitative weighting of attributes was conducted.

Compared to the Clean portfolio, the Site C portfolio had the following results:

- Superior financial attributes, with a lower PV and portfolio UEC than alternatives
- Mixed economic development attributes, with a larger number of construction jobs created and higher construction GDP but lower operations jobs
- Mixed environment attributes, with a larger land and stream footprint but slightly lower GHG and local air emissions (CO, NOx).

The Site C portfolio was preferred under financial and most economic development attributes, as well as based on a comparison of GHG and local air emissions. The land and stream footprint was higher with the Site C portfolio, although the majority of the Site C portfolio footprint represents a conversion of habitat from terrestrial and river environments to a reservoir environment rather than a facility footprint.

As the Site C portfolio was preferred in nearly all attributes there was no requirement to undertake a quantitative weighting exercise. The superior financial, economic development and air emission attributes would have to be effectively ignored compared to the land and stream footprint for the Clean portfolio to be preferred.

Compared to the Clean + Thermal portfolio, the Site C portfolio had the following results:

- Mixed financial attributes, with a Site C PV either higher or lower than the Clean + Thermal portfolio depending on the Project in-service date, and the Site C portfolio having a lower UEC than the Clean + Thermal portfolio
- Mixed economic development attributes, with a larger number of construction jobs created and higher construction GDP but lower operations jobs
- Mixed environment attributes, with a larger land and stream footprint but lower GHG and local air emissions. Similar to the Clean portfolio, the Project footprint represents a conversion of habitat from terrestrial and river environments to a reservoir environment rather than a facility footprint.

Given the Province's legislated GHG emission targets, and given the financial and technical benefits of including the Project, the Project was determined to be a preferred resource option compared to the Clean + Thermal portfolio.

Based on the consideration of alternatives and the portfolio analysis of the Clean and Clean+Thermal portfolios, BC Hydro believes that the Project provides the best combination of financial, technical, environmental, and economic development attributes and is therefore a preferred option to meet the need for energy and capacity within BC Hydro's planning horizon.

Appendix 1 – Resource Technologies

Technology	Screened/Available Resource	EIS Section Reference
DSM Options		
DSM Option 1	Available Resource	Section 5.2.3
DSM Option 3	Available Resource	Section 5.2.3
DSM Options 4 and 5	Screened Resource	Section 5.4.2.3
DSM capacity-only initiatives	Screened Resource	Section 5.4.2.4
Clean or Renewable Resources		
Wave	Screened Resource	Section 5.4.2.2
	Screened Resource	Section 5.4.2.2
Solar	Screened Resource	Section 5.4.2.2
Wind (on-shore and off-shore)	Available Resource	Section 5.5.2.2 and Section 5.5.2.3
Run-of-river hydro	Available Resource	Section 5.5.2.1
Geothermal	Available Resource	Section 5.5.2.7
Biomass	Available Resource	Section 5.5.2.4, Section 5.5.2.5, and Section 5.5.2.6
Large hydroelectric (other than the Project)	Screened Resource	Section 5.4.2.1
External Markets	Screened Resource	Section 5.4.2.1
Nuclear	Screened Resource	Section 5.4.2.1
Pumped storage (dependable capacity only)	Available Resource	Section 5.5.2.10
BC Hydro Resource Smart	Available Resource	Section 5.5.2.9
Fossil Fuel Resources		
Coal-fired generation with carbon capture and storage	Screened Resource	Section 5.4.2.2
Burrard Thermal Generating Station	Screened Resource	Section 5.4.2.1
Natural gas-fired generation SCGTs (dependable capacity) CCGTs (firm energy)	Available Resource within the 93% *Clean Energy Act* clean or renewable target	Section 5.5.2.8

Appendix 2 – Unit Energy Costs and Calculation of Project UEC

There have been a number of references to the Project UEC in the EIS and this Technical Memo:

- The UEC at POI in $F2011 is $95/MWh as provided in Volume 1 Appendix F Part 1 (Project Cost Estimate) on page 5. After removing the sunk costs of the Project, described on page 5-64 of the EIS, and adjusting to $F2013 the value becomes $94/MWh.
- The Adjusted UEC is $110/MWh as provided in Section 5.4.4.3 (Financial Attributes) Table 5.42 on page 5-68. As noted in footnote (2) to Table 3 in Volume 1 Appendix F Part 1, the difference between the $110/MWh UEC and the $95/MWh UEC is the inclusion of adjustments to reflect delivery costs to the lower mainland, escalation to F$2013 and the exclusion of sunk costs.

All UEC figures provided for the Project in the EIS are consistent and based on the same project cost estimate as provided in Volume Appendix F Part 1 (Project Cost Estimate).

Please see the table below for details on the development of Project UEC values.

Unit Energy Cost Calculation at 6% Discount Rate

		$/MWh
POI-level UEC	**UEC at POI including sunk costs (F2011 dollars)**	**95**[a]
	Less sunk costs	-5
	Escalation to F2013 dollars	+4
	UEC at POI excluding sunk costs (F2013 dollars)	**94**
	Adjustments to reflect delivery costs to the lower mainland	+16
LM-level UEC	**UEC adjusted to Lower Mainland, excluding sunk costs (F2013 dollars)**	**110**

Note: All analysis in the EIS has been performed at a 6.0% discount rate. At the time of preparation of the EIS BC Hydro's planning discount rate was 5.5%. Using a 5.5% discount rate, the UEC at POI including sunk costs (F2011 dollars) was $87/MWh.

Appendix 3 – Comparable Block Resource Composition

Clean Generation Block Details and UEC Calculation

Project Name	Dependable Capacity (MW)	Annual Firm Energy (GWh)	Adjusted Unit Energy Cost ($F2013/MWh)	Total Cost ($F2013 million)
Energy Costs				
Wind_PC28	-	591	128	76
MSW2_LM	33	285	129	37
Wind_PC21	-	371	129	48
Wind_PC19	-	441	130	57
Wind_PC13	-	541	130	70
Wind_PC16	-	377	133	50
Wind_PC14	-	527	134	71
ROR_T1R1_60-80_LM	-	238	135	32
Wind_PC10	-	1,023	136	139
Wind_PC15	-	382	136	52
WBBio_VI	80	641	137	88
Wind_VI12	-	151	138	21
Wind_VI14	-	113	140	16
Wind_PC41	-	155	140	22
Pumped Storage Variable Cost (see notes)	n/a	(736)	13	10
Sub-total	114	5,100	155	788
Capacity Costs	**Dependable Capacity (MW)**	**Annual Firm Energy (GWh)**	**Unit Capacity Cost ($F2013/kW-year)**	**Total Cost ($F2013 million)**
Pumped Storage Fixed Cost (see notes)	1,000	n/a	133	133
Sub-total	1,000	n/a	133	133
Clean Generation Block	**Dependable Capacity (MW)**	**Annual Firm Energy (GWh)**	**Adjusted Unit Energy Cost ($F2013/MWh)**	**Total Cost ($F2013 million)**
Total	1,114	5,100	181	921

Notes:

1. Project names refer to project identifiers from the 2010 Resource Options Report
2. UECs include a regional transmission cost adder of $6/MWh, a soft cost adder of 5%, a freshet firm energy cost adjustment, a time of delivery cost adjustment, and the cost of delivery to the Lower Mainland.
3. Pumped Storage variable costs include variable OMA and water rentals. The cost of energy losses is included in the total cost of the clean resources that would be used to serve those losses. The yearly variable cost of the pumped storage was calculated using a capacity factor of about 20% for the peak usage. BC Hydro used a slightly higher capacity factor than the 18% used in the portfolio analysis to make the comparable blocks exactly 5,100 GWh per year.

Clean + Thermal Generation Portfolio Details and UEC Calculation

Project Name	Dependable Capacity (MW)	Annual Firm/Effective Energy (GWh)	Adjusted Unit Energy Cost ($F2013/MWh)	Total Cost ($F2013M)
Energy Costs				
Wind_PC28	-	591	128	76
MSW2_LM	33	285	129	37
Wind_PC21	-	371	129	48
Wind_PC19	-	441	130	57
Wind_PC13	-	541	130	70
Wind_PC16	-	377	133	50
Wind_PC14	-	527	134	71
ROR_T1R1_60-80_LM	-	238	135	32
Wind_PC10	-	1,023	136	139
Wind_VI12	-	151	138	21
Pumped Storage Variable Cost (see notes)	n/a	(369)	13	5
SCGT Variable Cost (see notes)	n/a	924	72	67
Sub-total	33	5,100	132	672
Capacity Costs	**Dependable Capacity (MW)**	**Annual Firm Energy (GWh)**	**Unit Capacity Cost ($F2013/kW-year)**	**Total Cost ($F2013 million)**
Pumped Storage Fixed Cost	500	n/a	133	66
SCGT Fixed Cost	588	n/a	88	52
Sub-total	1,088	n/a	109	118
Clean + Thermal Generation Comparable Block	Dependable Capacity (MW)	Annual Firm Energy (GWh)	Adjusted Unit Energy Cost ($F2013/MWh)	Total Cost ($F2013 million)
Total	1,121	5,100	155	791

Notes:

1. Project names refer to project identifiers from the 2010 Resource Options Report
2. UECs includes a regional transmission cost adder of $6/MWh, a soft cost adder of 5%, a freshet firm energy cost adjustment, a time of delivery cost adjustment, and the cost of delivery to the lower mainland.
3. Pumped Storage variable cost include variable OMA and water rentals. The cost of energy losses is included in the total cost of the clean resources that would be used to serve those losses. The yearly variable cost of the pumped storage was calculated using a capacity factor of about 20% for the peak usage. BC Hydro used a slightly higher capacity factor than the 18% used in the portfolio analysis to make the comparable blocks exactly 5,100 GWh per year.
4. SCGT variable cost includes variable OMA, fuel cost and GHG cost

Appendix 4 – System Optimizer and Portfolio Construction

BC Hydro built a number of portfolios to compare the Project to available resources. As described in section 5.5.3 of the EIS, the System Optimizer model was used in creating the portfolios.

System Optimizer (SO) is a linear optimization model that selects the optimal combinations of available resource options and timing under different assumptions and constraints that will meet the energy and capacity needs of BC Hydro's customers as defined in Section 5.2. In constructing the portfolios, SO takes a planning perspective ensuring that the portfolio meets reliability constraints, as well as an operating perspective evaluating the operating performance of the portfolio. The planning perspective requires that the firm energy and dependable capacity of the selected resource portfolio be sufficient to meet system energy and capacity demands respectively, including an allowance for a capacity reserve margin. The operation of the portfolio is simulated taking into account average energy output of the resources and includes sales of portfolio surpluses into export markets.

The model assesses the interaction of future generation and transmission resource options with the existing system and evaluates the manner in which the portfolio can be operated to maximize market revenue while meeting domestic load. It also takes into account system constraints such as minimum generation requirements and transmission constraints both within B.C. and on interties with US and Alberta.

The annual cost of operating the portfolio is a combination of market revenue, transmission costs, and the fixed and variable costs of generation and transmission resources. Fixed costs include capital charges and fixed operating and maintenance costs while variable costs include cost of renewable IPP energy, fuel costs, GHG offset costs, and transmission wheeling costs. The model seeks to minimize the present value of these costs over the planning time period in selecting an optimal resource portfolio.

BC Hydro created a total eight of portfolios in comparing the Project to available resources:

(A) A portfolio with the Project in-service in F2022, with other available clean resources being used to meet any residual needs;

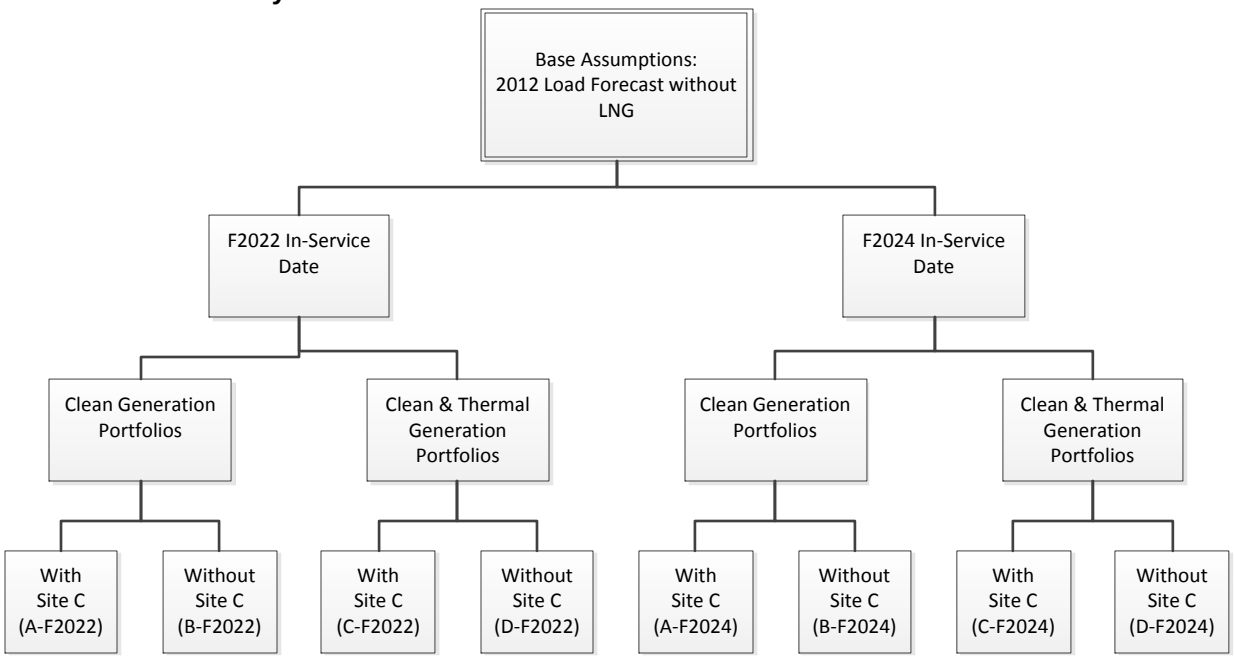
(B) A portfolio where only other available clean resources are used to meet energy and capacity needs;

(C) A portfolio with the Project in-service in F2022, with other available clean and thermal resources (in the form of SCGTs and up to the 93% clean or renewable target) being used to meet any residual needs;

(D) A portfolio where only other available clean and thermal resources (in the form of SCGTs and up to the 93% clean or renewable target) are used to meet energy and capacity needs.

Four more portfolios were created in a similar manner assuming an in-service date of F2024 for the Project; please refer to the figure below showing the eight portfolio runs. The present value of the portfolio cost in $F2013 is also shown in the following table.

Portfolio Analysis Runs



Portfolio Analysis PV Results

Portfolio Name	Portfolio Description	Portfolio PV ($F2013M)	Portfolio PV Difference to Equivalent Portfolio with Site C
A-F2022	Site C in F2022 + Other clean resources	8,898	9,361 – 8,898 = 463
B-F2022	Other Clean Resources	9,361	
C-F2022	Site C in F2022 + Other clean and thermal resources	8,621	8,469 – 8,621 = -152
D-F2022	Other clean and thermal resources	8,469	
A-F2024	Site C in F2024 + Other clean resources	8,533	9,192 – 8,533 = 659
B-F2024	Other Clean Resources	9,192	
C-F2024	Site C in F2024 + Other clean and thermal resources	8,254	8,436 – 8,254 = 182
D-F2024	Other clean and thermal resources	8,436	

The details of the portfolios are presented below with three tables shown for each portfolio.

- The first table shows the energy resources selected. The Resource Name, Type, In-service date as determined by the System Optimizer model, Installed capacity, Average annual energy, and the Unit Energy Cost (UEC) are shown. The UEC shown is the cost of the resource at the point of interconnection and does not include integration costs, transmission costs, capacity costs, freshet firm energy costs, time of delivery costs, and costs associated with disposal of non-firm energy. These costs are reflected in the Present Value (PV) of the portfolios shown above.
- The second table shows the capacity resources selected. The capacity costs shown reflect only the fixed costs of the resource. The cost of operating these resources to meet peak demand is reflected in the portfolio PV, as is the cost of acquiring additional energy resources to meet the energy losses in the case of Pumped Storage facilities.
- The third table shows the transmission upgrades that are required on the bulk transmission system to accommodate the generation resources. The cost of these upgrades is reflected in the portfolio PV.

Portfolio A - F2022: Site C + Other clean resources					
Resource Name	**Type**	**In-Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**UEC ($/MWh)**
Site C	Large Hydro	2022	1100	5100	94
Wind_PC19	Wind	2034	117	441	98
Wind_PC21	Wind	2034	99	371	97
MSW2_LM	Municipal Solid Waste	2034	34	285	117
Wind_PC10	Wind	2035	297	1023	103
Wind_PC28	Wind	2035	153	591	96
ROR_T1R1_60-80_LM	Run of River	2035	73	301	88
Wind_PC13	Wind	2036	135	541	98
Wind_PC16	Wind	2036	99	377	101
Wind_PC14	Wind	2037	144	527	102
Wind_PC09	Wind	2038	207	713	106
Wind_PC15	Wind	2038	108	382	103
Wind_PC41	Wind	2039	45	155	106
ROR_T1R1_80-90_VI	Run of River	2039	98	435	105
Wind_VI12	Wind	2040	48	151	120
Wind_VI14	Wind	2040	35	113	121
WBBio_VI	Biomass	2040	80	641	125
WBBio_PG	Biomass	2041	45	362	143
WBBio_EK	Biomass	2041	37	298	141
Wind_VI08	Wind	2041	41	113	136
Wind_VI13	Wind	2041	35	105	125

Capacity Resources Required for Portfolio A – (F2022)					
Resource Name	**Type**	**In-Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2030	1000	-683	133
1000 MW PS_LM	Pumped Storage	2035	1000	-683	133

Transmission Required for Portfolio A - F022		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2022	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2034	Series compensation upgrade at Kennedy from 50% to 65% on GMS to Williston 500 kV lines 5L1, 5L2, 5L3 and 5L7 with thermal upgrades to 3000A rating.	60

Portfolio B - F2022: Other clean resources only					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**UEC ($/MWh)**
Wind_PC19	Wind	2026	117	441	98
Wind_PC21	Wind	2027	99	371	97
Wind_PC28	Wind	2028	153	591	96
Wind_PC16	Wind	2029	99	377	101
MSW2_LM	Municipal Solid Waste	2029	34	285	117
Wind_PC10	Wind	2030	297	1023	103
WBBio_VI	Biomass	2030	80	641	125
Wind_PC13	Wind	2031	135	541	98
Wind_PC14	Wind	2031	144	527	102
ROR_T1R1_60-80_LM	Run of River	2031	73	301	88
Wind_PC11	Wind	2032	126	473	107
Wind_PC15	Wind	2032	108	382	103
Wind_PC20	Wind	2033	159	609	104
Wind_PC09	Wind	2034	207	713	106
Wind_PC41	Wind	2034	45	155	106
ROR_T1R1_80-90_VI	Run of River	2034	98	435	105
Wind_PC18	Wind	2035	138	486	108
Wind_PC42	Wind	2035	63	219	107
Wind_VI12	Wind	2035	48	151	120
Wind_VI14	Wind	2035	35	113	121
Wind_PC26	Wind	2036	126	416	112
Wind_PC48	Wind	2036	152	505	113
Wind_PC06	Wind	2037	243	761	116
WBBio_KM	Biomass	2037	51	408	144
WBBio_WK	Biomass	2037	39	312	137
WBBio_EK	Biomass	2037	37	298	141
Wind_VI13	Wind	2037	35	105	125
Wind_VI15	Wind	2037	41	126	128
ROR_T1R1_90-110_VI	Run of River	2037	124	488	120
ROR_T1R1_80-90_LM	Run of River	2039	135	545	104
Wind_PC27	Wind	2040	110	333	121
ROR_T1R1_70-80_KN	Run of River	2040	154	588	99
ROR_T1R1_90-100_LM	Run of River	2041	116	482	117

Capacity Resources Required for Portfolio B – (F2022)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2023	1000	-683	133
1000 MW PS_LM	Pumped Storage	2031	1000	-683	133
1000 MW PS_LM	Pumped Storage	2038	1000	-683	133

Transmission Required for Portfolio B - F2022		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2036	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2040	Series compensation upgrade at Kennedy from 50% to 65% on GMS to Williston 500 kV lines 5L1, 5L2, 5L3 and 5L7 with thermal upgrades to 3000A rating.	60

Portfolio C - (F022: Site C + Other clean and thermal resources					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**UEC ($/MWh)**
Site C	Largo Hydro	2022	1100	5100	94
Wind_PC28	Wind	2034	153	591	96
ROR_T1R1_60-80_LM	Run of River	2034	73	301	88
Wind_PC21	Wind	2035	99	371	97
MSW2_LM	Municipal Solid Waste	2035	34	285	117
Wind_PC13	Wind	2036	135	541	98
Wind_PC16	Wind	2038	99	377	101
Wind_PC19	Wind	2038	117	441	98
WBBio_VI	Biomass	2039	80	641	125
WBBio_KM	Biomass	2040	51	408	144
WBBio_WK	Biomass	2040	39	312	137
WBBio_PG	Biomass	2041	45	362	143
Wind_SI15	Wind	2041	304	814	133
WBBio_EK	Biomass	2041	37	298	141
Wind_VI08	Wind	2041	41	113	136
Wind_VI12	Wind	2041	48	151	120

Capacity Resources Required for Portfolio C - (F2022)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2030	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2034	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2035	300	450	88
100 MW SCGT KN	Simple cycle Gas Turbine	2036	200	300	88
100 MW SCGT KN	Simple cycle Gas Turbine	2037	300	450	88
100 MW SCGT KN	Simple cycle Gas Turbine	2038	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2039	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2040	100	150	88

Transmission Required for Portfolio C - F2022		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2022	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2034	Series compensation upgrade at Kennedy from 50% to 65% on GMS to Williston 500 kV lines 5L1, 5L2, 5L3 and 5L7 with thermal upgrades to 3000A rating.	60
2037	New 500 kV, 50% series compensated transmission circuit 5L46 between Kelly Lake and Cheekye	657

Portfolio D - F2022: Other clean and thermal resources only					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**UEC ($/MWh)**
WBBio_VI	Biomass	2027	80	641	125
MSW2_LM	Municipal Solid Waste	2027	34	285	117
Wind_PC13	Wind	2030	135	541	98
Wind_PC28	Wind	2030	153	591	96
Wind_PC19	Wind	2031	117	441	98
ROR_T1R1_60-80_LM	Run of River	2031	73	301	88
Wind_PC14	Wind	2032	144	527	102
Wind_PC21	Wind	2032	99	371	97
Wind_PC16	Wind	2033	99	377	101
Wind_PC41	Wind	2033	45	155	106
Wind_PC10	Wind	2034	297	1023	103
Wind_PC42	Wind	2034	63	219	107
Wind_PC09	Wind	2035	207	713	106
Wind_PC11	Wind	2035	126	473	107
Wind_PC15	Wind	2035	108	382	103
Wind_PC20	Wind	2036	159	609	104
ROR_T1R1_80-90_VI	Run of River	2036	98	435	105
ROR_T1R1_80-90_LM	Run of River	2037	135	545	104
Wind_PC18	Wind	2038	138	486	108
Wind_PC26	Wind	2038	126	416	112
ROR_T1R1_70-80_KN	Run of River	2039	154	588	99
Wind_PC48	Wind	2040	152	505	113
Wind_VI14	Wind	2040	35	113	121
ROR_T1R1_90-110_VI	Run of River	2041	124	488	120

Capacity Resources Required for Portfolio D – (F2022)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
100 MW SCGT KN	Simple cycle Gas Turbine	2023	200	300	88
100 MW SCGT KN	Simple cycle Gas Turbine	2024	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2025	200	300	88
100 MW SCGT KN	Simple cycle Gas Turbine	2026	100	150	88
1000 MW PS_LM	Pumped Storage	2028	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2029	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2031	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2033	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2035	100	150	88
1000 MW PS_LM	Pumped Storage	2036	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2039	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2040	100	150	88

Transmission Required for Portfolio D - F2022		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2038	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65

Portfolio A - F2024: Site C + Other clean resources					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Energy Cost ($/MWh)**
Site C	Large Hydro	2024	131	390	94
Wind_PC19	Wind	2034	117	441	98
Wind_PC21	Wind	2034	99	371	97
MSW2_LM	Municipal Solid Waste	2034	34	285	117
Wind_PC10	Wind	2035	297	1023	103
Wind_PC28	Wind	2035	153	591	96
ROR_T1R1_60-80_LM	Run of River	2035	73	301	88
Wind_PC13	Wind	2036	135	541	98
Wind_PC16	Wind	2036	99	377	101
Wind_PC14	Wind	2037	144	527	102
Wind_PC09	Wind	2038	207	713	106
Wind_PC15	Wind	2038	108	382	103
WBBio_VI	Biomass	2039	80	641	125
Wind_PC11	Wind	2040	126	473	107
Wind_PC41	Wind	2040	45	155	106
Wind_VI12	Wind	2040	48	151	120
Wind_VI13	Wind	2040	35	105	125
WBBio_WK	Biomass	2041	39	312	137
WBBio_EK	Biomass	2041	37	298	141
Wind_VI08	Wind	2041	41	113	136
Wind_VI15	Wind	2041	41	126	128

Capacity Resources Required for Portfolio A – (F2024)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2030	1000	-683	133
1000 MW PS_LM	Pumped Storage	2035	1000	-683	133

Transmission Required for Portfolio A - F2024		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2024	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2034	Series compensation upgrade at Kennedy from 50% to 65% on GMS to Williston 500 kV lines 5L1, 5L2, 5L3 and 5L7 with thermal upgrades to 3000A rating.	60

Portfolio B - F2024: Other clean resources only					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**UEC ($/MWh)**
Wind_PC19	Wind	2026	117	441	98
Wind_PC21	Wind	2027	99	371	97
Wind_PC28	Wind	2028	153	591	96
Wind_PC16	Wind	2029	99	377	101
MSW2_LM	Municipal Solid Waste	2029	34	285	117
Wind_PC10	Wind	2030	297	1023	103
WBBio_VI	Biomass	2030	80	641	125
Wind_PC13	Wind	2031	135	541	98
Wind_PC14	Wind	2031	144	527	102
ROR_T1R1_60-80_LM	Run of River	2031	73	301	88
Wind_PC11	Wind	2032	126	473	107
Wind_PC15	Wind	2032	108	382	103
Wind_PC20	Wind	2033	159	609	104
Wind_PC09	Wind	2034	207	713	106
ROR_T1R1_80-90_VI	Run of River	2034	98	435	105
Wind_PC18	Wind	2035	138	486	108
Wind_PC41	Wind	2035	45	155	106
Wind_PC42	Wind	2035	63	219	107
Wind_VI12	Wind	2035	48	151	120
Wind_VI14	Wind	2035	35	113	121
Wind_PC26	Wind	2036	126	416	112
Wind_PC48	Wind	2036	152	505	113
Wind_PC06	Wind	2037	243	761	116
Wind_PC27	Wind	2037	110	333	121
WBBio_WK	Biomass	2037	39	312	137
WBBio_EK	Biomass	2037	37	298	141
Wind_VI08	Wind	2037	41	113	136
Wind_VI13	Wind	2037	35	105	125
ROR_T1R1_90-110_VI	Run of River	2037	124	488	120
ROR_T1R1_80-90_LM	Run of River	2039	135	545	104
ROR_T1R1_70-100_NC	Run of River	2040	40	153	110
ROR_T1R1_70-80_KN	Run of River	2040	154	588	99
Wind_VI15	Wind	2040	41	126	128
ROR_T1R1_90-100_LM	Run of River	2041	116	482	117

Capacity Resources Required for Portfolio B – (F2024)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2025	1000	-683	133
1000 MW PS_LM	Pumped Storage	2031	1000	-683	133
1000 MW PS_LM	Pumped Storage	2038	1000	-683	133

Transmission Required for Portfolio B - F2024		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2035	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2037	Series compensation upgrade at McLeese from 50% to 65% on Williston to Kelly 500 kV lines 5L11, 5L12 and 5L13 with thermal upgrades to 3000A rating.	57

Portfolio C - F2024: Site C + Other clean and thermal resources					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Energy Cost ($/MWh)**
Site C	Large Hydro	2024	1100	5100	94
Wind_PC28	Wind	2034	153	591	96
ROR_T1R1_60-80_LM	Run of River	2034	73	301	88
Wind_PC21	Wind	2035	99	371	97
Wind_VI12	Wind	2035	48	151	120
MSW2_LM	Municipal Solid Waste	2035	34	285	117
Wind_PC13	Wind	2036	135	541	98
Wind_PC19	Wind	2038	117	441	98
Wind_PC41	Wind	2039	45	155	106
WBBio_VI	Biomass	2039	80	641	125
Wind_PC15	Wind	2040	108	382	103
WBBio_WK	Biomass	2040	39	312	137
Wind_PC10	Wind	2041	297	1023	103
WBBio_PG	Biomass	2041	45	362	143
WBBio_KM	Biomass	2041	51	408	144
WBBio_EK	Biomass	2041	37	298	141

Capacity Resources Required for Portfolio C – (F2024)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
1000 MW PS_LM	Pumped Storage	2030	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2034	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2035	200	300	88
100 MW SCGT KN	Simple cycle Gas Turbine	2036	200	300	88
100 MW SCGT KN	Simple cycle Gas Turbine	2037	300	450	88
100 MW SCGT KN	Simple cycle Gas Turbine	2038	300	450	88
100 MW SCGT KN	Simple cycle Gas Turbine	2040	100	150	88

Transmission Required for Portfolio C - F2024		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2024	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2034	Series compensation upgrade at Kennedy from 50% to 65% on GMS to Williston 500 kV lines 5L1, 5L2, 5L3 and 5L7 with thermal upgrades to 3000A rating.	60
2037	New 500 kV, 50% series compensated transmission circuit 5L46 between Kelly Lake and Cheekye	657

Portfolio D - F2024: Other clean and thermal resources only					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Energy Cost ($/MWh)**
WBBio_VI	Biomass	2027	80	641	125
MSW2_LM	Municipal Solid Waste	2027	34	285	117
Wind_PC13	Wind	2030	135	541	98
Wind_PC28	Wind	2030	153	591	96
Wind_PC19	Wind	2031	117	441	98
ROR_T1R1_60-80_LM	Run of River	2031	73	301	88
Wind_PC14	Wind	2032	144	527	102
Wind_PC16	Wind	2032	99	377	101
Wind_PC15	Wind	2033	108	382	103
Wind_PC21	Wind	2033	99	371	97
Wind_PC10	Wind	2034	297	1023	103
Wind_PC09	Wind	2035	207	713	106
Wind_PC11	Wind	2035	126	473	107
Wind_PC41	Wind	2035	45	155	106
Wind_PC42	Wind	2035	63	219	107
Wind_PC20	Wind	2036	159	609	104
ROR_T1R1_80-90_VI	Run of River	2036	98	435	105
ROR_T1R1_80-90_LM	Run of River	2037	135	545	104
Wind_PC18	Wind	2038	138	486	108
ROR_T1R1_70-80_KN	Run of River	2038	154	588	99
Wind_PC26	Wind	2039	126	416	112
Wind_PC48	Wind	2040	152	505	113
Wind_VI14	Wind	2040	35	113	121
ROR_T1R1_90-100_LM	Run of River	2041	116	482	117

Capacity Resources Required for Portfolio D – (F2024)					
Name	**Type**	**In Service Date**	**Installed Capacity (MW)**	**Average Annual Energy (GWh)**	**Unit Cost of Capacity ($/kW-year)**
Revelstoke Unit 6	Resource Smart	2019	500	26	56
100 MW SCGT KN	Single Cycle Gas Turbine	2025	500	750	88
100 MW SCGT KN	Single Cycle Gas Turbine	2026	100	150	88
1000 MW PS_LM	Pumped Storage	2028	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2029	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2031	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2034	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2035	100	150	88
1000 MW PS_LM	Pumped Storage	2036	1000	-683	133
100 MW SCGT KN	Simple cycle Gas Turbine	2039	100	150	88
100 MW SCGT KN	Simple cycle Gas Turbine	2040	100	150	88

Transmission Required for Portfolio D - F2024		
Year	**Name**	**Capital Cost ($M)**
2019	50% series compensation of the 500 kV lines 5L91 and 5L98	62
2027	500 kV and 230 kV shunt compensation: At Meridian 230 kV add two 110 MVAr capacitor banks At Nicola 500 kV add one 250 MVAr capacitor bank.	10
2038	500 kV Shunt compensation: At Williston add one 300 MVAr SVC and two 250 MVAr switchable capacitor banks. At Kelly Lake add one 250 MVAr shunt capacitor.	65

Appendix 5 – Adjusted UEC Supply Curves for Available Resources Used in Portfolio Analysis

The following figures show supply curves for individual available resources as well as a consolidated supply curve for all available resources used in the portfolio analysis.

All figures include the following curves:

- **Adj UEC (PS):** Adjusted UEC for the energy resources, including a capacity cost adder priced based on pumped storage
- **Adj UEC (PS+SCGT):** Adjusted UEC for the energy resources, including a capacity cost adder priced based on a blend of pumped storage and simple-cycle gas turbines

The consolidated supply curve also includes the Adjusted UEC of the Project as the curve “Site C” for comparison purposes.

Figure 1 – Consolidated Adjusted UEC Supply Curve for Available Resources Used in Portfolio Analysis

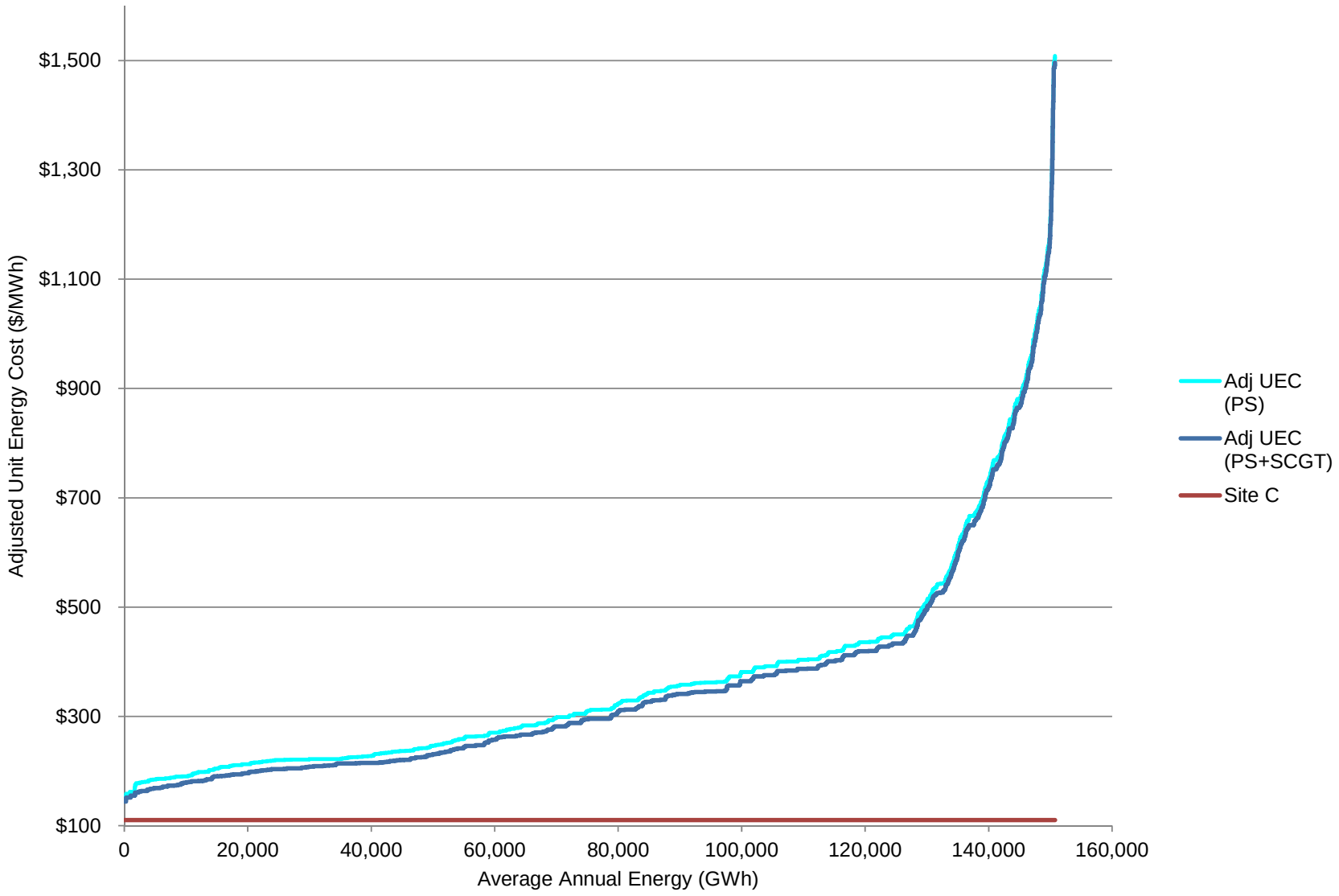


Figure 2 – Adjusted UEC Supply Curve for Onshore Wind

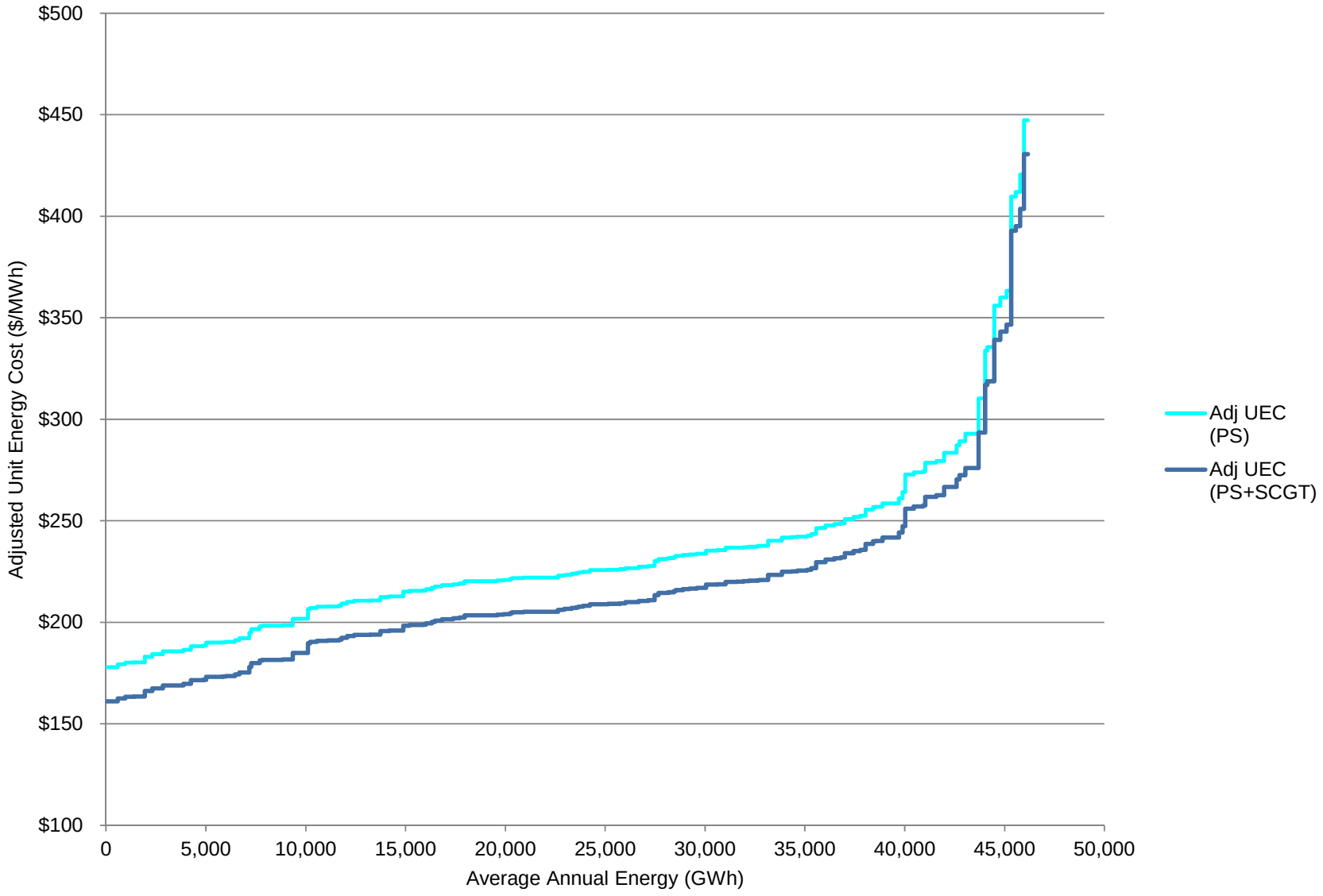


Figure 3 – Adjusted UEC Supply Curve for Offshore Wind

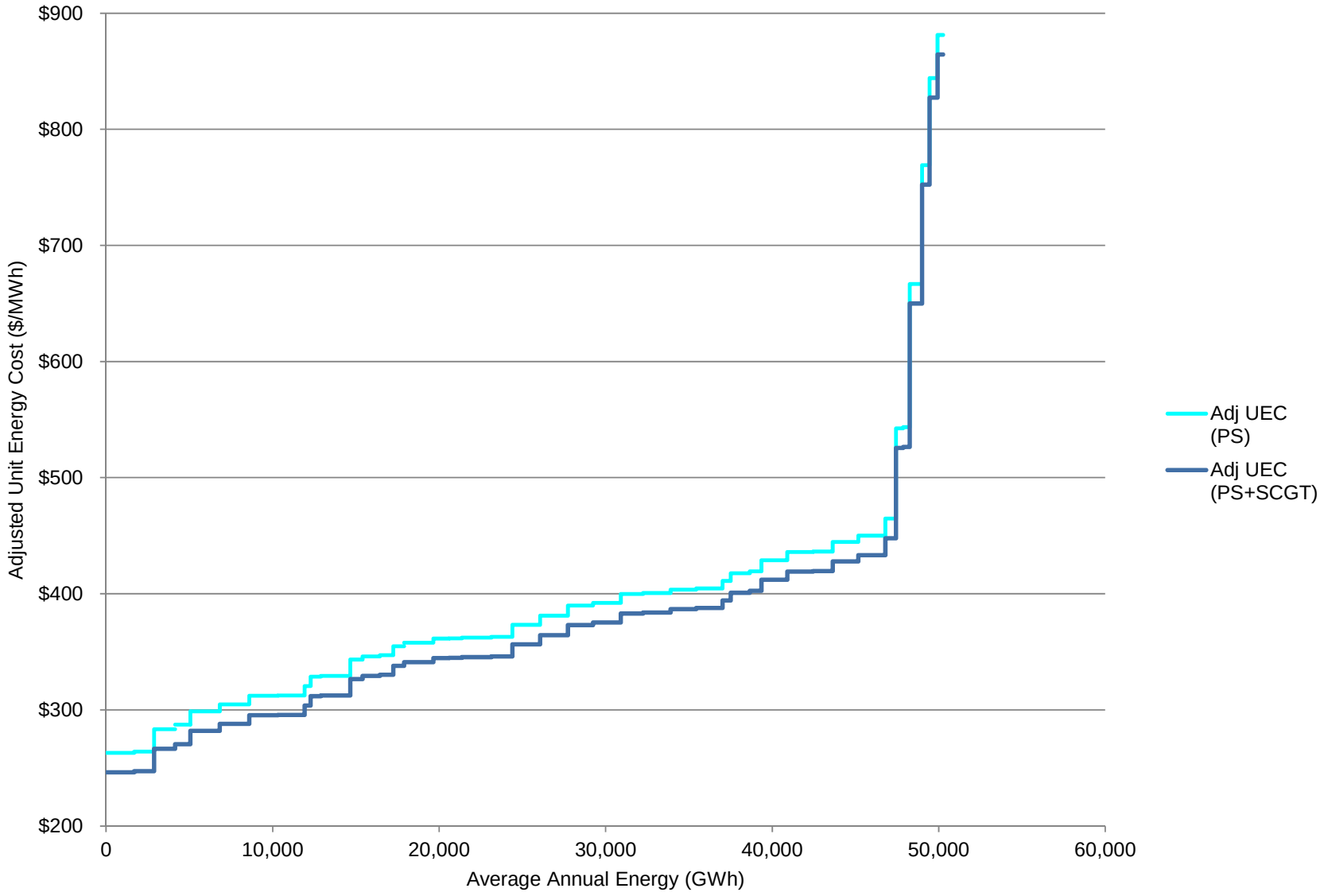


Figure 4 – Adjusted UEC Supply Curve for Run of River

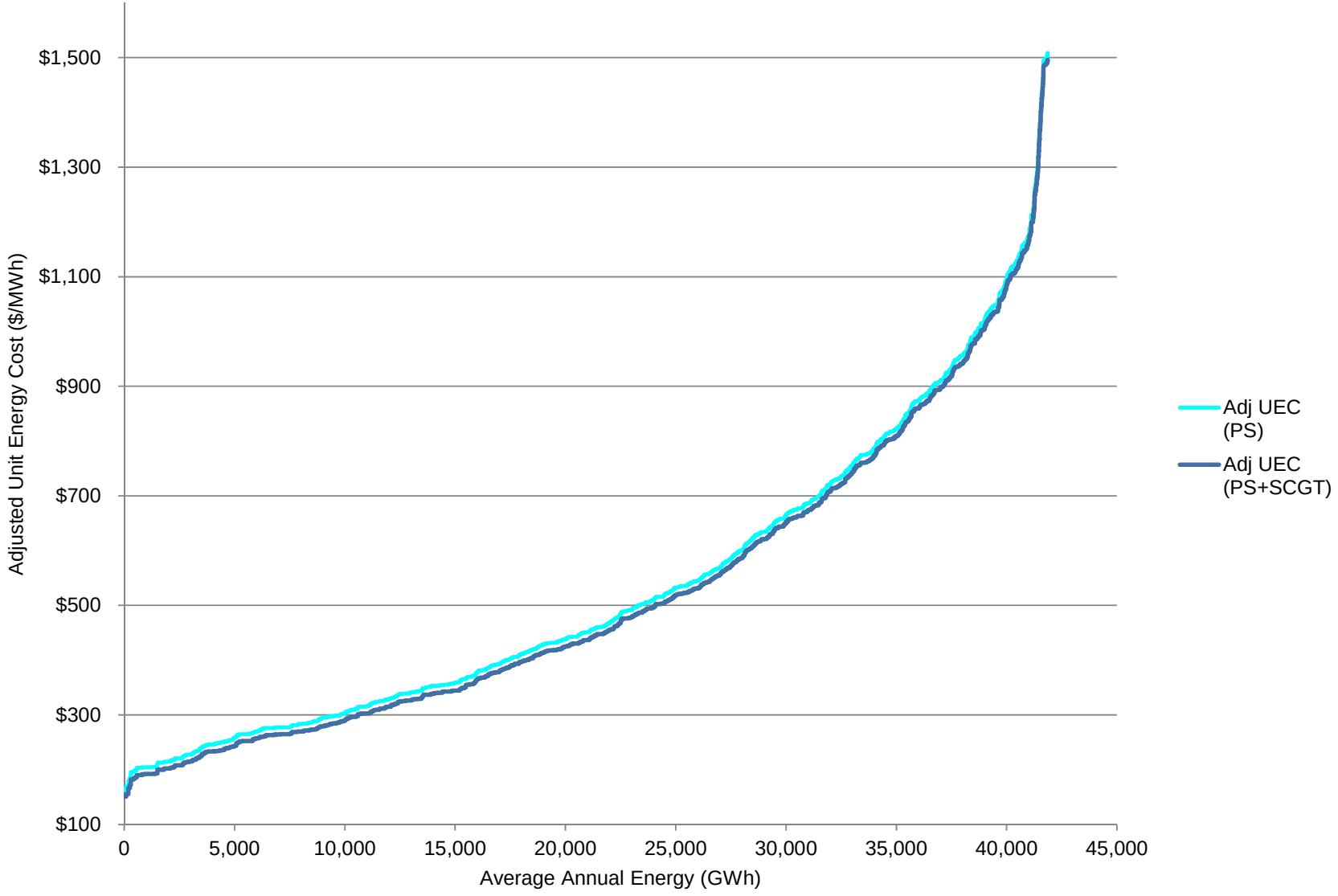


Figure 5 – Adjusted UEC Supply Curve for MSW

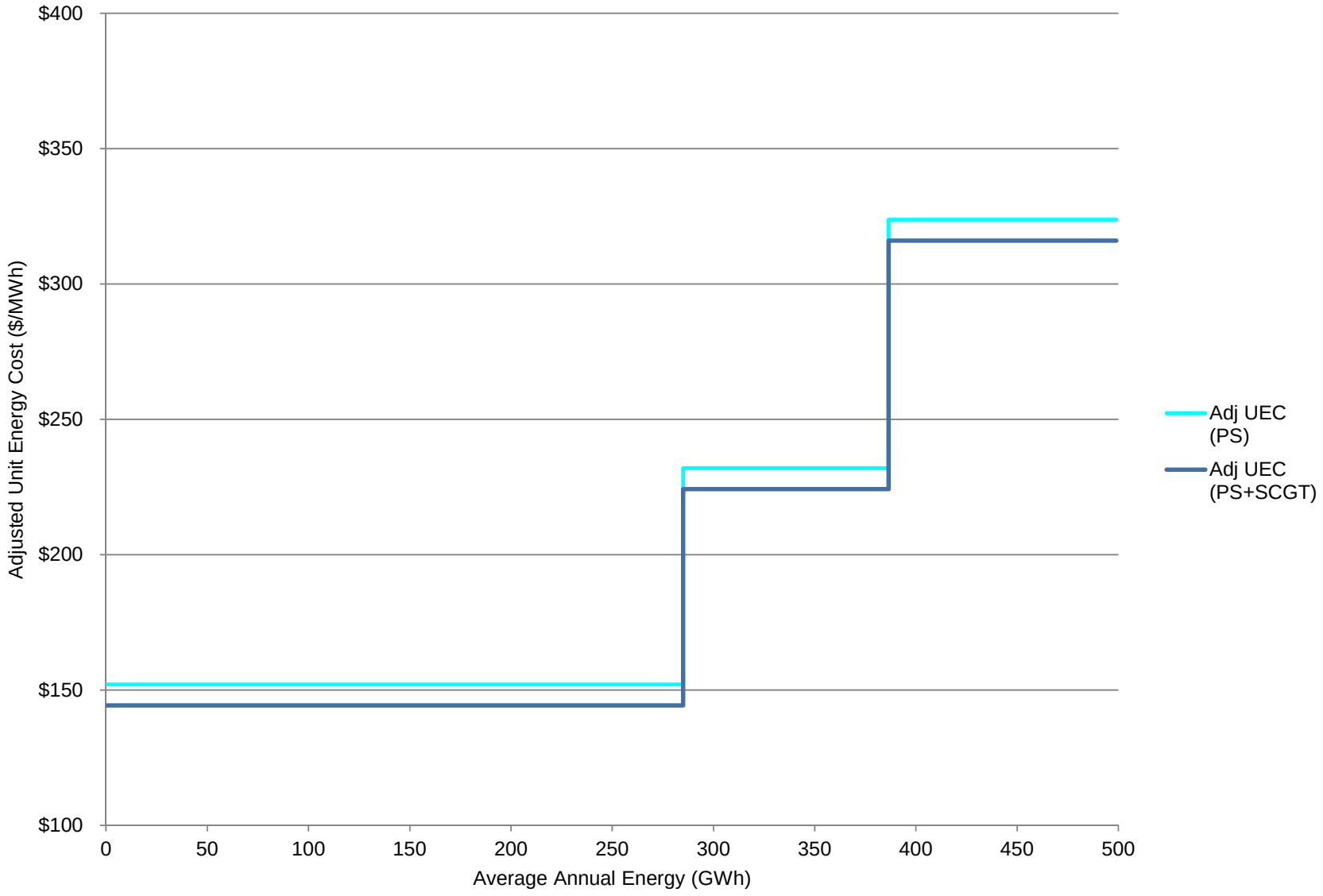
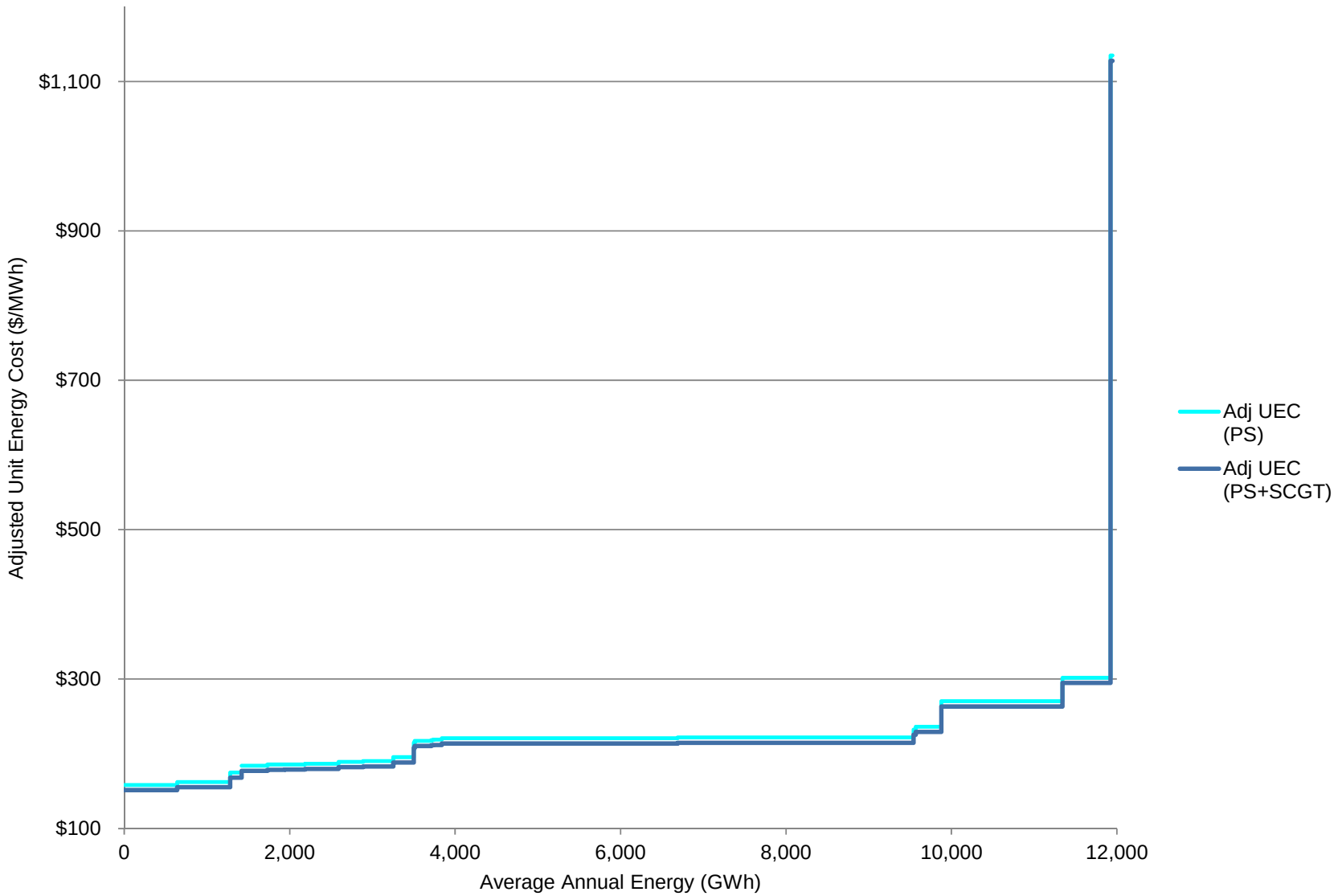


Figure 6 – Adjusted UEC Supply Curve for Biomass Woodwaste



SITE C CLEAN ENERGY PROJECT

Related Comments / Information Requests:

This technical memo provides information related to the following Information Requests:

form_0004-006	gov_0013-006	pub_0001-001	pub_0014-001	pub_0030-001
pub_0048-001	pub_0053-001	pub_0059-001	pub_0064-001	pub_0065-001
pub_0066-001	pub_0185-001	pub_0191-001	pub_0194-001	pub_0202-001
pub_0203-001	pub_0225-001	pub_0227-001	pub_0229-001	pub_0248-001
pub_0252-001	pub_0257-001	pub_0258-001	pub_0291-001	pub_0294-001
pub_0407-001	pub_0428-002	pub_0438-004	pub_0438-021	pub_0457-002
pub_0472-003	pub_0478-001	pub_0478-004	pub_0478-005	pub_0486-001
pub_0508-001	pub_0509-001	pub_0510-001	pub_0519-001	pub_0525-001
pub_0535-001	pub_0535-002	pub_0565-001	pub_0579-001	pub_0591-001
pub_0604-001	pub_0605-004	pub_0605-013	pub_0605-014	pub_0605-015
pub_0605-016	pub_0605-031	pub_0605-034	pub_0605-036	pub_0605-037
pub_0606-001	pub_0612-001	pub_0633-004	pub_0641-001	pub_0644-001
pub_0657-001	pub_0696-001	pub_0702-001	pub_0703-001	pub_0705-001
pub_0706-001	pub_0740-001	pub_0855-001	pub_0856-001	pub_0857-001
pub_0858-001	pub_0859-001	pub_0861-001	pub_0862-001	pub_0863-001
pub_0883-001	pub_0886-001	pub_0889-001	pub_0890-001	pub_0892-001
pub_0894-001	pub_0895-001	pub_0901-001	pub_0903-001	pub_0910-001
pub_0923-001	pub_0936-001	pub_0941-001	pub_0965-001	pub_0988-001
pub_0989-002	pub_0999-001	ab_0001-071	ab_0001-076	ab_0001-096
ab_0001-077	ab_0001-080	ab_0001-092	ab_0001-093	ab_0001-103
ab_0001-097	ab_0001-100	ab_0001-101	ab_0001-102	ab_0001-109
ab_0001-104	ab_0001-105	ab_0001-106	ab_0001-108	ab_0001-130
ab_0001-114	ab_0001-115	ab_0001-118	ab_0001-129	ab_0001-138
ab_0001-134	ab_0001-135	ab_0001-136	ab_0001-137	ab_0001-148
ab_0001-144				