


2015 Thermal Generation Options Assessment

AMEC Report 179019
Revision 1: June 13, 2015

June 13, 2015

BC Hydro
6911 Southpoint Drive, 13th Floor
Burnaby BC, Canada
V3N 4X8

Attn: David Fox, Sanjaya De Zoysa

Ref: 2015 Thermal Generation Options Assessment (BC Hydro Agreement #: RFSQ 1140, BCO/Release#: BCO 73769/ Release 11)

Re: AMEC Foster Wheeler Report 179019 Revision 1

As per our Agreement and recent discussions, we have revised the Revision 0 report to incorporate some additional comments and have now completed the 2015 Thermal Generation Options Assessment.

Thank you for the opportunity to work on this very interesting project.

Yours truly,

Blair Seckington

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2015 Thermal Generation Options Assessment

AMEC Foster Wheeler Report 179019 Revision 1
June 13, 2015

Blair Seckington ______ 13 June 2015
Prepared by: Date

Ian Leach ______ 13 June 2015
Checked by: Date

Blair Seckington ______ 13 June 2015
Approved by: Date

Rev.	Description	Prepared By:	Checked:	Approved	Date
A	Draft Report	B Seckington		B. Seckington	24 April 2015
0	Final Report	B. Seckington	I. Leach	B. Seckington	28 April 2015
1	Final Report	B. Seckington	I. Leach	B. Seckington	13 Jun 2015

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EXECUTIVE SUMMARY

2015 Thermal Generation Options Assessment

Background

As part of its ongoing planning assessment of the reliability of electricity service within BC, BC Hydro requires updated information on various generating options, including medium to larger size simple cycle gas turbine (SCGT) and combined cycle gas turbine (CCGT) generating units.

BC Hydro requested Amec Foster Wheeler to provide it with estimates for the capital costs of several greenfield generation options:

1. Single unit simple cycle LM6000PH unit (Gross MW: 45-49)
2. Single unit simple cycle LMS100 unit (Gross MW: 100)
3. Single unit simple cycle 7FA.04 unit (gross MW: 190)
4. Single unit combined cycle facility with one LM6000 gas turbine and steam turbine (gross MW: 56)
5. Single unit combined cycle facility with one 6FA gas turbine and steam turbine (gross MW: ~ 120)
6. Single unit combined cycle facility with one 7FA gas turbine and steam turbine (Gross MW ~ 280)

Results

Task						
Option #	1	2	3	4	5	6
New Greenfield Option	1 x SCGT	1 x SCGT	1 x SCGT	1x1 CCGT	1x1 CCGT	1x1 CCGT
Technology	LM6000PH	LMS100	7FA.04	LM6000	6FA GT	7FA GT
Gross MW	(Gross MW: 45-49)	(Gross MW: 100)	(Gross MW: 190)	(Gross MW: 56)	(Gross MW: ~120)	(Gross MW: ~ 280)
Gross MW @32oF (Natgas; Oil 2.5% less)	48.6	104.3	194.7	69.2	122.4	287.3
Net MW @32oF (Natgas; Oil 2.5% less)	47.6	100.4	192.4	67.1	119	279.2
Heat Rate - MCR BTU (LHV)/kWh @32oF	8150	8154	8999	6394	6500	6211
Heat Rate Average BTU (LHV)/kWh @32oF	8721	8725	9629	6842	6955	6646
Nox	No SCR, 25ppm	No SCR, 25ppm	No SCR, 25ppm	No SCR, 25ppm	No SCR, 25ppm	(5ppm)
COSTS - 2015 Cdn $				Cooling Twr	Cooling Twr	Cooling Twr
I Specialized Equipment	37,225,063	82,489,500	79,278,250	63,459,438	94,723,000	146,323,250
II Other Equipment	3,297,315	7,771,877	9,314,078	17,613,632	24,361,168	42,150,951
III Civil	7,278,766	14,288,923	16,988,724	14,790,860	21,649,914	38,500,363
IV Mechanical	3,752,008	8,268,942	9,476,296	12,252,833	19,145,014	34,538,152
V Electrical Assembly & Wiring	1,523,540	3,061,606	3,229,917	4,849,802	7,250,874	13,379,483
VI Buildings & Structures	1,953,127	2,668,585	3,241,413	8,152,434	10,810,243	17,263,398
VII Engineering & Plant Startup	2,315,558	3,736,030	5,020,943	7,482,813	10,129,478	15,903,210
Subtotal - Contractor's Internal Cost	**57,345,376**	**122,285,463**	**126,549,620**	**128,601,810**	**188,069,690**	**308,058,807**
VIII Contractor's Soft & Miscellaneous Costs	21,881,203	43,016,427	65,436,539	65,789,218	107,968,829	224,158,298
Contractor's Price	**79,226,579**	**165,301,890**	**191,986,159**	**194,391,028**	**296,038,520**	**532,217,105**
IX Owner's Soft & Miscellaneous Costs	6,327,283	12,240,932	14,032,228	14,264,123	20,907,003	34,438,262
Total - Owner's Cost	**85,553,862**	**177,542,821**	**206,018,387**	**208,655,151**	**316,945,522**	**566,655,367**
Net Plant Output (MW)	**47.6**	**100.4**	**192.4**	**67.0**	**119.0**	**279.2**
Price per kW - Contractor's	**1,665**	**1,647**	**998**	**2,901**	**2,488**	**1,906**
Cost per kW - Owner's	**1,798**	**1,769**	**1,071**	**3,114**	**2,664**	**2,030**

It should be noted that the performance values above (capacity and heat rates) and costs are for "new" units at near sea level, at 0°C for general average geotechnical conditions at a rural/remote BC site. Several factors such as site elevation, geotechnical conditions, and water availability are key site specific issues that could impact the performance / cost parameters – also weather.

For capacity, actual new values are likely slightly higher, guaranteed new OEM values likely about this or slightly lower, and new EPC guaranteed values generally another 1-2% lower than OEM guarantee values. Similarly actual new heat rate values are likely slightly lower, guaranteed new OEM values likely about this or slightly higher, and new EPC guaranteed values generally another 1-2% higher than OEM guarantee values.

There is also an average degradation over the lifetime of the units in both capacity and in the average heat rate. Some/most degradation is temporary and can be recovered during overhauls. The use of an average heat rate and capacity degradation over the life of the facility would be a reasonable consideration in an overall lifetime assessment. A 2% average allowance is reasonable (Note that means capacity drops by 1-2% and heat rate in GJ/MWh or BTU/kWh would increase by 2%)

Site elevation and ambient temperature play a significant role and performance impacts will vary depending on whether the unit is a simple cycle gas turbine or a combined cycle unit, as well as with the type of gas turbine involved (i.e. aeroderivative gas turbine such as LM6000; heavy frame gas turbine such as GE 6FA/7FA; LMS100). The potential impacts are illustrated in the table below.

Configuration	Impact 100 m Elevation vs Base **Capacity**	Impact 100 m Elevation vs Base **Heat Rate**	Impact 15°C Ambient Temp vs Base **Capacity**	Impact 15°C Ambient Temp vs Base **Heat Rate**
Aeroderivative LM6000 SCGT	-1.2%	+5.6%	-9.1%	+7.8%
Aeroderivative LM6000 CCGT	-1.2%	+5.6%	-8.4%	+1.4%
Heavy Frame 6FA/7FA SCGT	-1.1%	+5.5%	-5.4%	+6.8%
Heavy Frame 6FA/7FA CCGT	-1.1%	+5.5%	-5.7%	+0.4%
LMS100 SCGT	+0.8%	+5.2%	+1.7%	+6.0%

Summary – Key Issues

a) Site specific issues, particularly labour costs and availability but including gas and electrical transmission infrastructure costs which are not addressed herein, can have significant capital cost impacts.

b) Site specific generation reliability issues could impact the choice of a larger single unit or smaller multiple units, depending on specific system considerations. Capital cost will generally favour larger units, but reliability particularly for peaking applications will tend to favour unit redundancy where reliability is critical.

c) Dual fuel capability has several impacts: limited selection - not all units are available as dual fuel capable; higher equipment and infrastructure costs; higher NOx emissions for oil fuelled generation generally requiring additional facilities for water or steam injection where an emergency operation exemption is not achieved. Oil also requires additional site infrastructure for fuel delivery/storage and fire suppression.

d) NOx emissions are assumed to be satisfied at 25 ppm on natural gas, although some units can achieve 9 to 15 ppm. For CCGT options (particularly if operated at moderate to higher capacity factors), a lower NOx emission value may be necessary requiring an SCR (selective catalytic reduction) back end emission control system using aqueous ammonia. The SCR would reduce emissions by about 80-90%. SCR on SCGT units is complicated and would require significant additional equipment to lower exhaust temperatures to levels similar to those of CCGT units at which SCR is effective.

e) Existing BC Hydro sites with facilities and space for additional facilities could have potential savings on the order of 6% to 10% of a comparable new greenfield installations.

f) Typical project time is 2 years for a SCGT unit and 3 years for a CCGT, but shorter periods can be achieved for smaller aeroderivative gas turbines where previously sold units are available or under some market conditions. Newfoundland and Labrador Hydro in 2014/15 had a 120 MW SCGT project completed from initiation to available for generation in about 9-10 months using a previously purchased, stored GT.

g) Fuel costs form the largest part of the electricity cost of any SCGT or CCGT, except for highly peaking units, and are a key element of option optimization. .

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2015 Thermal Generation Options Assessment

1 INTRODUCTION

1.1 Background

As part of its ongoing planning assessment of the reliability of electricity service within BC, BC Hydro requires updated information on various generating options, including medium to larger size simple cycle gas turbine (SCGT) and combined cycle gas turbine (CCGT) generating units.

2 AMEC FOSTER WHEELER SCOPE OF WORK

BC Hydro requested Amec Foster Wheeler to provide it with estimates for the capital costs in 2015 Canadian $ of several greenfield generation options:

1. Single unit simple cycle LM6000PH unit (Gross MW: 45-49)
2. Single unit simple cycle LMS100 unit (Gross MW: 100)
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5. Single unit combined cycle facility with one 6FA gas turbine and steam turbine (Gross MW: ~ 120)
6. Single unit combined cycle facility with one 7FA gas turbine and steam turbine (Gross MW ~ 280)

This information is intended to be used in resource planning analysis as representative information for a greenfield gas plant anywhere within BC. It won't reflect any site specific advantages of locating at any existing sites, but it is assumed as requested by BC Hydro that all required services are available at the property line. It will assume NOx control requirement is 25 ppm and that dual fuel capability is required with two weeks of oil fuelled generation at a 70% average plant loading, but with the cost of backup fuel storage facilities and diesel NOx control not included in the cost estimate. The design operating life is 30 year life starting in 2020.

3 TASK 3-2 NEW GREENFIELD GENERATION OPTIONS

3.1 Description of New Greenfield Options Analysis

The new generation configurations are all based on a dual fuel facility on a generic BC Hydro site. It does not include any allowance for electrical transmission facilities, assuming that the plant costs are up to and including a power transformer and high voltage disconnect on the plant site. It also does not include any allowance for fuel delivery infrastructure, assuming a gas pipeline to site up to and including a metering station (supplying gas at about 350 psia) which may require additional on-site gas compression for some units. Oil deliveries include an oil receiving and storage facility. It does not include generally any special facilities for NOx control, assuming 25 ppm on natural gas is acceptable. No incremental special measures for NOx control for dual fuel use of oil are assumed and thus no water treatment facility is included, as per client.

The costs are based on Thermoflow GT Pro/Peace models. Key adjustments made to base Thermoflow parameters for Canadian/BC conditions generally and labour/exchange costs.

- Canadian exchange = 1.25 Cdn$/US$

- Canadian equipment supply surcharge = 1.25 x generic southern US (Thermoflow default)
- BC labour cost modifier = to result in a $100 to 115$/hr average wage (including allowances for OT, remote bonus, travel, camps, etc.)

Some technical details of the options are available in the Thermoflow report for each of the options in Appendix 2.

3.2 Capital Cost Summary

The following table summarizes the greenfield generation option capital costs in 2015 Canadian $. The table also identifies the power output (net and gross) and heat rate (efficiency) at 0ºC (32ºF) ambient conditions. The outputs and efficiencies could change by about +/- 5-10% at hotter or cooler ambients.

Cost details for components of the options are available in the Thermoflow reports for each of the options in Appendix 2. Operating and cash flow elements of the report should not be utilized as these were not a part of the study and not adjusted for the work.

The costs were compared for the larger combined cycle gas turbine options with recent larger Western Canada facilities and studies and are in line with these. A significant factor in the costs can be the manner in which a project is bid (i.e. lump sum fixed price EPC, time and materials EPC, risk/reward EPC, EPCM, etc.). The manner in which the risk is carried and by whom, can be significant factor in the cost, particularly as it pertains to labour costs or site conditions

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Contractor's Price	**79,226,579**	**165,301,890**	**191,986,159**	**194,391,028**	**296,038,520**	**532,217,105**
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Cost per kW - Owner's	**1,798**	**1,769**	**1,071**	**3,114**	**2,664**	**2,030**

The model is based on the following labour hours (excluding buildings subcontracts) and rates of:

Task							
Option #	1	2	3	4	5	6	
New Greenfield Option	1 x SCGT	1 x SCGT	1 x SCGT	1x1 CCGT	1x1 CCGT	1x1 CCGT	
Technology	LM6000PH	LMS100	7FA.04	LM6000	6FA GT	7FA GT	
Gross MW	(Gross MW: 45-49)	(Gross MW: 100)	(Gross MW: 190)	(Gross MW: 56)	(Gross MW: ~120)	(Gross MW: ~ 280)	
Civil labour	43,597	84,566	103,673	87,906	130,573	236,824	$99.00
Mech labour	22,067	50,266	53,264	75,699	116,705	201,557	$121.77
Elect labour	9,933	19,699	21,324	31,347	46,588	83,340	$115.50

As context, those costs that often can vary significantly between projects are i) the Engineering and Start-Up costs, and ii) the Contractor and Owner's Soft Costs. For the Greenfield costs these are shown below.

Task						
Option #	1	2	3	4	5	6
New Greenfield Option	1 x SCGT	1 x SCGT	1 x SCGT	1x1 CCGT	1x1 CCGT	1x1 CCGT
Technology	LM6000PH	LMS100	7FA.04	LM6000	6FA GT	7FA GT
Gross MW	(Gross MW: 45-49)	(Gross MW: 100)	(Gross MW: 190)	(Gross MW: 56)	(Gross MW: ~120)	(Gross MW: ~ 280)
VII Engineering & Startup (CDN$)	**2,315,558**	**3,736,030**	**5,020,943**	**7,482,813**	**10,129,478**	**15,903,210**
1. Engineering	1,917,000	3,006,000	3,966,000	6,457,000	8,700,000	13,272,000
2. Start-Up	398,558	730,030	1,054,943	1,025,813	1,429,478	2,631,210
3. User-defined	0	0	0	0	0	0
start up labour Hrs	2330	4270	6170	6000	8360	15390

Task						
Option #	1	2	3	4	5	6
New Greenfield Option	1 x SCGT	1 x SCGT	1 x SCGT	1x1 CCGT	1x1 CCGT	1x1 CCGT
Technology	LM6000PH	LMS100	7FA.04	LM6000	6FA GT	7FA GT
Gross MW	(Gross MW: 45-49)	(Gross MW: 100)	(Gross MW: 190)	(Gross MW: 56)	(Gross MW: ~120)	(Gross MW: ~ 280)
VIII Soft & Miscellaneous Costs	**28,208,486**	**55,257,359**	**79,468,767**	**80,053,341**	**128,875,832**	**258,596,559**
1. Contractor's Soft Costs	**21,881,203**	**43,016,427**	**65,436,539**	**65,789,218**	**107,968,829**	**224,158,298**
Contingency:	3,655,162	6,493,393	8,473,208	8,855,182	13,190,958	22,802,561
Lump Sum Fixed Price Risk Premium	8,923,430	18,822,138	36,072,513	35,900,770	63,738,491	149,569,751
Profit:	5,288,434	9,873,772	12,032,345	12,031,139	17,874,502	30,221,869
Permits, Licenses, Fees, Miscellaneous	0	0	0	0	0	0
Bonds and Insurance	1,146,908	2,236,321	2,530,992	2,572,036	3,761,394	6,161,176
Spare Parts & Materials	0	0	0	0	0	0
Contractor's Fee	2,867,269	5,590,803	6,327,481	6,430,091	9,403,485	15,402,940
2. Owner's Soft Costs	**6,327,283**	**12,240,932**	**14,032,228**	**14,264,123**	**20,907,003**	**34,438,262**
Permits, Licenses, Fees, Miscellaneous	1,406,063	2,720,207	3,118,273	3,169,805	4,646,001	7,652,947
Land Cost	0	0	0	0	0	0
Utility Connection Cost	0	0	0	0	0	0
Legal & Financial Costs	1,406,063	2,720,207	3,118,273	3,169,805	4,646,001	7,652,947
Escalation and Interest During Construction	2,812,126	5,440,414	6,236,546	6,339,610	9,292,001	15,305,894
Spare Parts & Materials	0	0	0	0	0	0
Project Administration & Developer's Fee	703,031	1,360,104	1,559,136	1,584,903	2,323,000	3,826,474
3. Total of all user-defined costs displayed on	**0**	**0**	**0**	**0**	**0**	**0**

The Engineering and Soft/Miscellaneous Costs are shown below as percentages. As can be seen the percentages can appear to be quite low for some items and BC Hydro may wish to make adjustments to reflect their level of comfort. The one very high element is for “Lump Sum Fixed Price Risk Premium”. This Lump Sum Fixed Price Risk Premium has more typically been included in some recent larger recent CCGT projects in Western Canada where the owner has significantly shifted risk to the EPC contractor in highly uncertain labour markets. It has been reduced for but may still likely not be applicable here for simpler SCGT aero projects. It is a cost element that BC Hydro may wish to eliminate or adjust.

- Engineering: 2.5 to 3%, primarily because the equipment is largely modular and aero engines are a large part of cost. Typically fairly low, but could be twice as high.

- Contingency: 6% to 7%, primarily because largely modular and aero engines. Typically fairly low, but could be twice as high.

- Lump Sum Fixed Price Risk Premium – 15% to 30% for SCGT and 28% to 49% for CCGT. Supports very low contingency, but more typical for the larger recent CCGT project and likely not applicable to SCGT.

Task						
Option #	1	2	3	4	5	6
New Greenfield Option	1 x SCGT	1 x SCGT	1 x SCGT	1x1 CCGT	1x1 CCGT	1x1 CCGT
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Gross MW	(Gross MW: 45-49)	(Gross MW: 100)	(Gross MW: 190)	(Gross MW: 56)	(Gross MW: ~120)	(Gross MW: ~ 280)
Engineering	3.34%	2.46%	3.13%	5.02%	4.63%	4.31%
Contingency:	6.37%	5.31%	6.70%	6.89%	7.01%	7.40%
Lump Sum Fixed Price Risk Premium	15.56%	15.39%	28.50%	27.92%	33.89%	48.55%
Profit:	9.22%	8.07%	9.51%	9.36%	9.50%	9.81%
Permits, Licenses, Fees, Miscellaneous	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bonds and Insurance	2.00%	1.83%	2.00%	2.00%	2.00%	2.00%
Spare Parts & Materials	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Contractor's Fee	5.00%	4.57%	5.00%	5.00%	5.00%	5.00%
OWNERS						
Permits, Licenses, Fees, Miscellaneous	1.77%	1.65%	1.62%	1.63%	1.57%	1.44%
Land Cost	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utility Connection Cost	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Legal & Financial Costs	1.77%	1.65%	1.62%	1.63%	1.57%	1.44%
Escalation and Interest During Construction	3.55%	3.29%	3.25%	3.26%	3.14%	2.88%
Spare Parts & Materials	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Project Administration & Developer's Fee	0.89%	0.82%	0.81%	0.82%	0.78%	0.72%

3.3 Capital Cost Comparisons and Accuracy

The modelling used is particularly good for assessing differences between generating options, so in this case the differential accuracy should be fairly high. The absolute cost values depend a lot on site and regional specific cost differences, particularly for labour, and on assumed exchange rates. By checking \$/kW costs against recent larger combined cycle projects in Western Canada, it appears that the individual capital costs are likely be on the order of +/-25%. Normally the costs would likely be +40/-10%, but the significant lump sum fixed price EPC risk premium and labour modifier have moderated this in our judgment.

In performing detailed option analysis, one of the most important element other than capital cost is annual fuelling cost differences (hence annual capacity factor and efficiency and hence annual fuel cost). Although not assessed herein, the capacity and heat rate/efficiency values provided for a 0ºC ambient condition provides a good basis for initial BC Hydro analysis (capacity and heat rate versus ambient conditions could be provided for more detailed analysis).

3.4 Generation Capacity and Heat Rate – Degradation and Impacts of Elevation and Ambient temperature

It should be noted that the performance values in the table in Section 3.2 Capital Cost Summary (capacity and heat rates) and costs are for "new" units at near sea level, at 0ºC for general average geotechnical conditions at a rural/remote BC site. Several factors such as site elevation, geotechnical conditions, and water availability are key site specific issues that could impact the performance / cost parameters – also weather.

For capacity, actual new values are likely slightly higher, guaranteed new OEM values likely about this or slightly lower, and new EPC guaranteed values generally another 1-2% lower than OEM guarantee values. Similarly actual new heat rate values are likely slightly lower, guaranteed new OEM values likely about this or slightly higher, and new EPC guaranteed values generally another 1-2% higher than OEM guarantee values.

There is also an average degradation over the lifetime of the units in both capacity and in the average heat rate. Some/most degradation is temporary and can be recovered during overhauls. The use of an average heat rate and capacity degradation over the life of the facility would be a reasonable consideration in an overall lifetime assessment. A 2% average allowance is reasonable (Note that means capacity drops by 1-2% and heat rate in GJ/MWh or BTU/kWh would increase by 2%)

Site elevation and ambient temperature play a significant role and performance impacts will vary depending on whether the unit is a simple cycle gas turbine or a combined cycle unit, as well as with the type of gas turbine involved (i.e. aeroderivative gas turbine such as LM6000; heavy frame gas turbine such as GE 6FA/7FA; LMS100). The potential impacts are illustrated in the table below.

Configuration	Impact 100 m Elevation vs Base **Capacity**	Impact 100 m Elevation vs Base **Heat Rate**	Impact 15ºC Ambient Temp vs Base **Capacity**	Impact 15ºC Ambient Temp vs Base **Heat Rate**
Aeroderivative LM6000 SCGT	-1.2%	+5.6%	-9.1%	+7.8%
Aeroderivative LM6000 CCGT	-1.2%	+5.6%	-8.4%	+1.4%
Heavy Frame 6FA/7FA SCGT	-1.1%	+5.5%	-5.4%	+6.8%
Heavy Frame 6FA/7FA CCGT	-1.1%	+5.5%	-5.7%	+0.4%
LMS100 SCGT	+0.8%	+5.2%	+1.7%	+6.0%

4 SUMMARY – KEY ISSUES

a) Site specific issues, particularly labour costs and availability but including gas and electrical transmission infrastructure costs which are not addressed herein, can have significant capital cost impacts.

b) Site specific generation reliability issues could impact the choice of a larger single unit or smaller multiple units, depending on specific system considerations. Capital cost will generally favour larger units, but reliability particularly for peaking applications will tend to favour unit redundancy where reliability is critical.

c) Dual fuel capability has several impacts: limited selection - not all units are available as dual fuel capable; higher equipment and infrastructure costs; higher NOx emissions for oil fuelled generation generally requiring additional facilities for water or steam injection where an emergency operation exemption is not achieved. Oil also requires additional site infrastructure for fuel delivery/storage and fire suppression.

d) NOx emissions are assumed to be satisfied at 25 ppm on natural gas, although some units can achieve 9 to 15 ppm. For CCGT options (particularly if operated at moderate to higher capacity factors), a lower NOx emission value may be necessary requiring an SCR (selective catalytic reduction) back end emission control system using aqueous ammonia. The SCR would reduce emissions by about 80-90%. SCR on SCGT units is complicated and would require significant additional equipment to lower exhaust temperatures to levels similar to those of CCGT units at which SCR is effective.

e) Existing BC Hydro sites with facilities and space for additional facilities could have potential savings on the order of 6% to 10% of a comparable new greenfield installations.

f) Typical project time is 2 years for a SCGT unit and 3 years for a CCGT, but shorter periods can be achieved for smaller aeroderivative gas turbines where previously sold units are available or under some market conditions. Newfoundland and Labrador Hydro in 2014/15 had a 120 MW SCGT project completed from initiation to available for generation in about 9-10 months using a previously purchased, stored GT.

g) Fuel costs form the largest part of the electricity cost of any SCGT or CCGT, except for highly peaking units, and are a key element of option optimization.

Appendices

APPENDIX 1
GLOSSARY OF TERMS

^oF / ^oC	Degrees Fahrenheit / Celsius
$M	Millions of $
ACF	Annual Capacity Factor = actual/maximum MWh possible in one year
BC	British Columbia
BTU	British Thermal Unit
CCGT	Combined Cycle Gas Turbine
EPC	Engineer, Procure, Construct
EPCM	Engineer, Procure, Construction Management
g	Gram
Gen	Generator (Only)
GJ	Gigajoules
GT	Gas Turbine
h / hr	Hours
HHV/LHV	Higher and Lower Heating Value of fuel (typically LHV is about 11% lower than HHV for natural gas and 6% for oil)
k	Thousands
kg	Kilograms
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatthour
m3 or m^3	Cubic meters
mg	Milligrams
Mtce	Maintenance
MW/MWg/MWn	Megawatt /megawatt gross/megawatt net
MWh/MWhg/MWhn	Megawatt hour/ megawatt hour gross/megawatt hour net
NOx or NO_x	Oxides of nitrogen
OMA	Operations, maintenance and administration (at plant)
Psig/a	pounds per square inch gauge/absolute
ppmvd	Parts per million (dry volume basis)
s or sec	Second
SCGT	Simple Cycle Gas Turbine
SCR	Selective catalytic reduction
Yr	Year

APPENDIX 2
NEW GENERATION OPTION THERMOFLOW REPORTS

The following icons represent Thermoflow reports that have been provided separately to BC Hydro for information. They are the basis for the capital costs and capacity/efficiency information summarized and provided in Section 3.2 of the report.

Note that the Operational costs and cashflow sections of the Thermoflow models have not been used and therefore the data in those sections are not accurate or relevant.

1 x GE 6FA CCGT 1 x GE 7FA CCGT 1 x GE 7FA SCGT 1 x LM6000 SCGT 1 x LM6000 CCGT 1 x LMS100 SCGT

APPENDIX 3
ADDITIONAL NEW GREENFIELD THERMAL GENERATION OPTION THERMOFLOW REPORTS

The following icons represent some additional Thermoflow reports for options not requested by BC Hydro but have been provided separately to BC Hydro for information.

<u>Note that the Operational costs and cashflow sections of the Thermoflow models have not been used and therefore the data in those sections are not accurate or relevant</u>.

2 x LM6000PF SCGT   2 x LM6000PH   1 x GE 6FA SCGT

APPENDIX 4
BASIS OF ESTIMATES

Capital costs are in 2015 Canadian $, no inflation and escalation.

No electricity transmission or fuel delivery infrastructure costs included. Infrastructure assumed available at plant site boundary. Units are dual fuel capable, but no incremental NOx control or costs included for oil fuel dual fuelled capability.

Soft Costs, Owner's costs and other contractor soft costs (indirect costs such as project management, construction management, external engineering, corporate overheads, escalation, interest during construction, and BCH contingency) would be expected to be adjusted by BC Hydro engineering based on their own preferences, priorities, and experience in their jurisdiction to establish the total project costs.

The accuracy of the capital estimates is considered to be conceptual. For guidance only it is suggested that they would be approximately +25 / -25%