

Appendix 17.4-G

Energy Trade-Off Study

AJAX PROJECT

**Environmental Assessment Certificate Application / Environmental Impact Statement
for a Comprehensive Study**



KGHM Ajax Mining Inc.

Energy Trade Off Study

Final Report for Scoping Study

H348101-0000-90-124-0001

Rev. A

April 30, 2015

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Disclaimer

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List of Abbreviations

AAC – Allowable Annual Cut
BC – British Columbia
BC Hydro – BC Hydro and Power Authority
BCUC – British Columbia Utilities Commission
CBL – Customer Baseline Load
CCGT – Combined cycle gas turbine
CEA – Clean Energy Act
CO – Corporate overhead
CPI – Consumer price index
CSP – Concentrating solar power
EPA – Electricity purchase agreement
GHG – Greenhouse gas
Hatch – Hatch Ltd.
IDC – Interest during construction
IRP – Integrated Resource Plan
KGHM Ajax – KGHM Ajax Mining Inc.
LNG – Liquefied natural gas
NWGA – Northwest Gas Association
O&M – Operation and maintenance
ODT – Oven dry tonne
POI – Point of interconnection
PV – Photovoltaic
PW – Present worth
RFP – Request for Proposal
RoR – Run-of-river
SCGT – Simple cycle gas turbine
TPD – Tonne per day
TSF – Tailing storage facility



1. Executive Summary

KGHM Ajax Mining Inc. (KGHM Ajax) is working towards the development of the Ajax Mine Project, located south of the City of Kamloops, British Columbia (BC). The project consists of an open-pit mine to be located on the historic Ajax-Afton mine site and a new mill. To assist it with project planning, KGHM Ajax retained Hatch Ltd. (Hatch) to undertake this Energy Trade Off Study.

The main objective of the study is to carry out a scoping level assessment of viable alternative energy sources for the Ajax Mine Project followed by a pre-feasibility study of one or more options that are shown to be of further interest. This information is desired to:

- 1) Identify any cost saving opportunities
- 2) Identify any cost effective opportunities to reduce the project's environmental footprint

Based on discussions with KGHM Ajax, it is understood that two cases are being considered that could have a significant impact on the total electrical demand of the facility. In one case, mine haul trucks would be diesel/electric hybrids and in this case the connected electrical load for the facility would be approximately 165 MW. In the second case the mine haul trucks would operate only on diesel fuel and in this case the connected load of the site is projected to be in the 110 MW range.

Due to the location of the Ajax Mine Project, the base case for electricity supply is considered to be purchases from the BC Hydro grid. As an alternative to this source for its electricity requirements, the Ajax Mine Project could generate electricity for its own use with the installation of generation facilities at the mine or in the mine's vicinity. These facilities could be owned by KGHM or by a third party Independent Power Provider. The options for this generation that are assessed in this study include natural gas combined cycle, geothermal, wind, solar, biomass and small hydro. This study analyzes the capital and operational costs of these options and compares the total costs with the projected cost of purchases from BC Hydro.

In the BC Hydro supply case, all electricity required by the Ajax Mine Project would be supplied by BC Hydro through its 230 kV transmission line running through Kamloops vicinity. Due to its meshed transmission network and generation resources, it is expected that BC Hydro would meet the mine's electricity requirements with a very high reliability level. A new transmission interconnection line would be required to connect the substation at the mine site to the existing 230 kV BC Hydro transmission line. Based on the published information on future increases to BC Hydro's large industrial tariff, the levelized cost of power purchases from BC Hydro over the life of the Ajax Miner Project was estimated at \$86/MWh in 2014\$.

BC Hydro's 2013 Integrated Resource Plan provides information on the costs of various electricity supply options in British Columbia. This information was used as a screening level assessment of the options to compare with the Ajax Mine Project's costs of purchases from



BC Hydro. Based on the assumptions described in the BC Hydro report, the levelized costs of energy of the alternatives compare as follows.

- 1) Natural gas based combined cycle – \$62/MWh to \$92/MWh (\$2013)
- 2) Geothermal – \$141/MWh (\$2013)
- 3) Wind – \$122/MWh to \$164/MWh (\$2013)
- 4) Solar – \$290/MWh (\$2013)
- 5) Biomass – \$141/MWh (\$2013)
- 6) Small Hydro – \$142/MWh to \$162/MWh (\$2013)

Based on the above information, natural gas based combined cycle generation was selected as the preferred option for the self generation case. The costs of this option were estimated based on Hatch internal data on capital and operating costs of this technology and available projections of natural gas prices. The estimated annual costs were discounted to 2014 to arrive at the cumulative present worth over the mine life for each case. These estimates are as follows:

- 1) BC Hydro Supply – \$717 million
- 2) Self Generation (natural-gas based combined cycle generation) – \$960 million
- 3) Independent Power Provider – Higher than or approximately equal to the Self Generation cost
- 4) Supplemental Power Supply to the BC Hydro Supply – Higher than the BC Hydro Supply cost

Sensitivity analysis was also carried out for the BC Hydro Supply and Self Generation cases by varying key parameters.

Based on the results of the Scoping Study, KGHM Ajax requested Hatch to prepare a Phase 2 Study of the Self Generation case using natural gas based combined cycle generation.

2. Introduction

2.1 Background

KGHM Ajax Mining Inc. (KGHM Ajax) retained Hatch Ltd. (Hatch) to undertake the Energy Trade off Study. KGHM Ajax is working towards the development of the Ajax Mine Project, located south of the City of Kamloops, British Columbia (BC). The project consists of an open-pit mine to be located on the historic Ajax-Afton mine site (which has seen a range of exploration and extraction from small-scale mine operation to the development of an open-pit operation under Teck Resources Ltd. and the Afton Operating Corporation between 1989 and 1997) and a new mill.



The proposed complex will have a 60,000 tonnes per day (TPD) processing capability in a conventional milling plant and target annual production of 109 million pounds of copper concentrate and 99,000 ounces of gold. The copper and gold concentrates will be transported to the Port of Vancouver for shipment to offshore smelters.

The proposed Ajax Mine Project would employ state-of-art mining and environmental monitoring technologies.

It is expected that the Ajax Mine Project operation will require approximately 500 full-time persons with positions ranging from technical, to mining services, health and safety, and administrative.

2.2 Objective of the Study

The main objective of the study is to carry out a scoping level assessment of viable alternative energy sources for the Ajax Mine Project and a subsequent pre-feasibility study of one or more options that may have potential to reduce project costs. This information is desired to:

- 1) Identify any cost saving opportunities
- 2) Identify any cost effective opportunities to reduce the project's environmental footprint

The energy alternatives to be assessed in this study include natural gas combined cycle generation, geothermal, wind, solar, biomass and small hydro against the base case of BC Hydro grid power supply. This study is to analyze capital and operational costs and provide insight into technical feasibility, timelines and work required to design and assess options as well as identify potential social benefits or implications.

In addition to the base case of BC Hydro grid supply, the study includes three analysis streams, (1) full replacement of the base case to meet Ajax Mine Project power requirements, (2) independent power provider case, and (3) supplemental power to BC Hydro base case.

2.3 Scope of Work

The request for proposals (RFP) of this study describes in detail the analysis required to be carried out, which includes the following main components:

- 1) Project review – review of the current Ajax Mine Project conceptual plans for energy demand and supply, determination of site specific information for properly assessing the energy options identified and completion of a sensitivity analysis to the base energy case to assess the range of costs
- 2) Scoping study – assessment of the viability of each energy supply alternative identified, estimate of the capital and operating costs of each energy supply alternative, and recommendation of the alternative(s) having merit in moving ahead with a pre-feasibility study, if any
- 3) Pre-feasibility study on the selected option – after approval from KGHM Ajax, completion of a prefeasibility level study on the selected option



- 4) Final report

2.4 Outline of This Report

. This report is arranged as follows:

- Section 1 Executive Summary
- Section 2 Introduction
- Section 3 Key Assumptions
- Section 4 Overview of Energy Demand Estimate
- Section 5 Electricity Supply Options and Costs
- Section 6 Electricity Supply Cases and Their Costs

3. Key Assumptions

This section describes the key assumptions used in this study, including site location, current status of site development and general and financial parameters.

3.1 Site Location

The Ajax Mine Project is located in the south-central interior of BC, south of the junction of the Trans-Canada Highway (Highway 1) and the Coquihalla Highway (Highway 5). The coordinates for the centre of Ajax Mine Project are approximately 50°37' north latitude and 120°24' west longitude. Ajax Mine Project is situated south of downtown Kamloops, BC as shown in Figure 1.

The City of Kamloops is located at the confluence of the two branches of the Thompson River near Kamloops Lake. It is the largest community in the Thompson-Nicola Regional District and the location of the regional district's offices. The surrounding region is more commonly referred to as the Thompson Country. It is ranked 37th on the list of the 100 largest metropolitan areas in Canada and represents the 44th largest census agglomeration nationwide, with 85,678 residents in 2011.

Industries in the Kamloops area include primary resource processing such as Domtar Kamloops Pulp Mill, Tolko-Heffley Creek Plywood and Veneer, Lafarge Cement, Highland Valley Copper Mine (in Logan Lake), and others.

Figure 2 shows the currently planned layout of the proposed Ajax Mine Project, which includes the following main areas/facilities:

- 1) Open-pit mine
- 2) Tailing storage facility (TSF)
- 3) T&F mine rock storage facility
- 4) East mine rock storage facility
- 5) South mine rock storage facility
- 6) Ore stockpile



7) Processing plant



Figure 1: Ajax Mine Location Map

The open-pit mine will be located on the historic Ajax - Afton mine site which has seen a range of exploration and extraction from small scale mine operations to the development of an open-pit operation under Teck Resources Ltd. and the Afton Operating Corporation between 1989 and 1997. The project is located on traditional Secwepemc territory and sits entirely within the Thompson Nicola Regional District. Upon completion, the project would have an annual production of 109 million pounds of copper concentrate and 99,000 ounces of gold, and 60,000 tonne-per-day (TPD) processing capacity. It is expected that the project will have a mine life of 20 years and will employ approximately 500 full-time positions ranging from technical, to mining services, health and safety, and administrative.

The proposed Ajax Mine Project would employ state-of-the-art mining and environmental protection and monitoring technologies.



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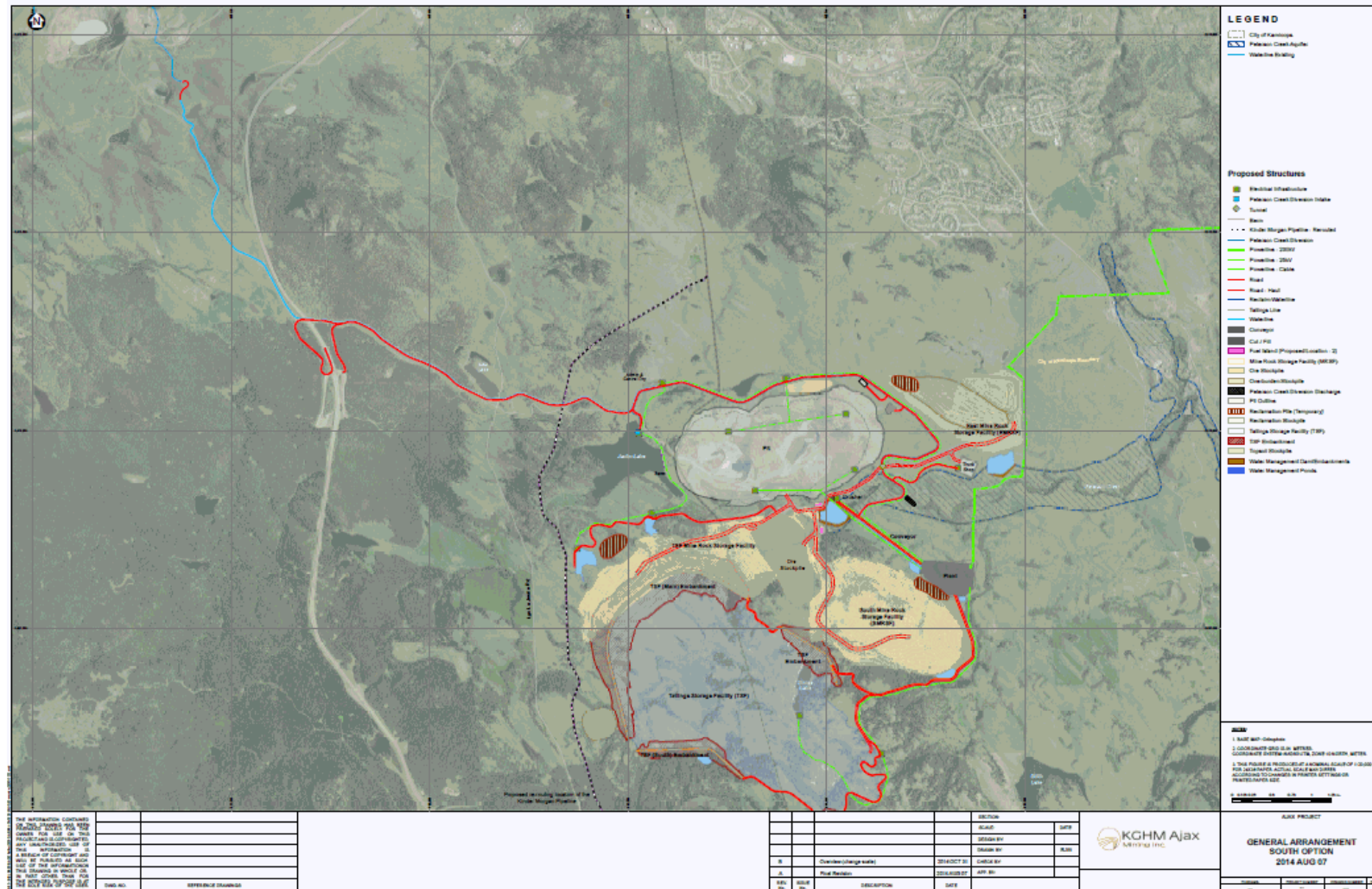


Figure 2: Ajax Mine Layout



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3.2 Current Status of Site Development

It is understood that KGHM is currently working with a consultant to prepare an updated feasibility study and basic engineering for the project. This study is based on a new location for the mill further away from the City of Kamloops and to the South of the city boundary. At the same time, KGHM is developing the baseline and environmental assessment needed as input for the permitting process.

3.3 General and Financial Parameters

A set of general and financial parameters was established based on the information provided by KGHM Ajax, through internet search and analysis of Hatch's in-house data and they were applied in the electricity cost analysis. These parameters are summarized as follows:

- 1) The first full operation year of the mine – 2019
- 2) The total operation period of the mine – 20 years (from 2019 to 2038 inclusive)
- 3) The economic life of proposed generation and transmission facilities – 20 years
- 4) All costs are expressed in Canadian Dollars (\$)
- 5) All costs used in Hatch calculations were estimated in 2014 price levels and then escalated to the year of expenditure
- 6) Annual escalation rate of capital cost is 2%, which would be applied from 2014 to the first full operation year
- 7) Annual escalation rate of power demand and electricity charges by BC Hydro – 2.5%, except for the early years of the time period as noted in Section 5.1.2
- 8) Annual escalation rate of fixed O&M costs – 2%
- 9) Annual escalation rate of biomass fuel – 2%
- 10) Annual escalation rate of natural gas (NG) – 2%
- 11) Present worth base year – 2014
- 12) Discount rate to convert the current values to present worth (PW) – 8%
- 13) Air pollutant emissions are not quantified and assessment of environmental constraints are not included in this study
- 14) Socio-economic impacts are not quantitatively taken into account in comparison of electricity costs

4. Overview of Energy Demand Estimate

4.1 Main Energy Consumption Facilities

The main energy consumption facilities of the Ajax Mine Project will be typical of those for similar projects. Mine haul trucks will be the largest users of diesel fuel and the processing facilities in the mill will be the largest users of electric power.



4.2 Electricity Demand

Based on the discussions with KGHM Ajax, it is understood that two cases are being considered in the feasibility study that could have a significant impact on the total electrical demand of the facility. In one case, mine haul trucks would be diesel/electric hybrids and in this case the current projection of the connected electrical load for the facility is 164 MW. If the mine haul trucks operate on diesel fuel alone the connected load is projected to be in the 110 MW range. For this scoping study, the first case is used in estimating the total electricity supply cost.

KGHM advised that energy design review activities are underway and that a PowerSmart incentive offered by BC Hydro may be used for this analysis.

The Ajax Mine Project would typically operate 24 hours a day, 7 days a week. At this stage of the project development KGHM was not able to provide information on the expected maximum demand (coincident loads) of the facility. For purposes of the analysis of this scoping study an annual load factor of 80% based on the estimated connected load is assumed.

5. Electricity Supply Options and Costs

This section briefly describes the existing electricity supply in the Kamloops area and potential new generation resources and technologies as well as their current tariffs and/or estimated energy costs.

5.1 BC Hydro System

BC Hydro and Power Authority (BC Hydro) is a provincial Crown corporation with a mandate to generate, purchase, transmit, distribute and sell electricity. It delivers electricity to most areas in the province, including the City of Kamloops. BC Hydro reports to the BC Ministry of Energy and Mines and is regulated by the British Columbia Utilities Commission (BCUC).

BC Hydro operates 31 hydroelectric facilities and three natural gas-fuelled thermal power plants as well as the provincial transmission grid and most distribution networks in BC. As of 2014, 95 per cent of the province's electricity was produced by hydroelectric generating stations, which consist mostly of large hydroelectric dams on the Columbia and Peace Rivers.

5.1.1 Supply Capability

BC Hydro divides its electric system into the following 10 Transmission Regions, as shown in Figure 3:

- 1) Central Interior
- 2) East Kootenay
- 3) Kelly Lake Nicola**
- 4) Lower Mainland
- 5) Mica



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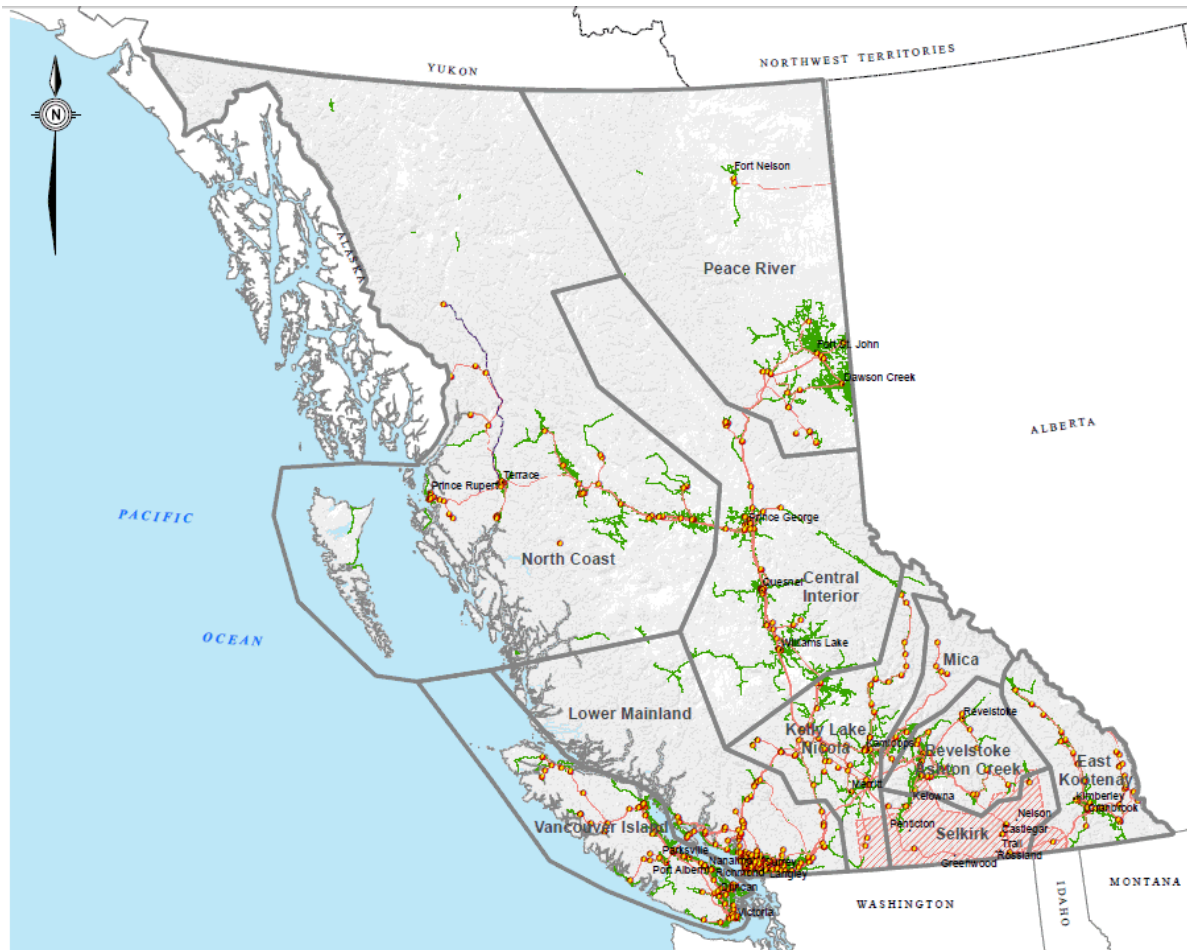


Figure 3: Transmission Regions

- 6) North Coast
- 7) Peace River
- 8) Revelstoke Ashton Creek
- 9) Selkirk
- 10) Vancouver Island

The Ajax Mine Project is located within the boundaries of the Kelly Lake Nicola transmission region. Based on the information presented in the existing Feasibility Study Technical Report¹, the electric power required by the mine could be supplied by BC Hydro from its existing 230 kV transmission line 2L265 which is some 11 km away from the proposed site. A 230 kV wooden pole overhead line would connect the BC Hydro grid to the proposed 230 kV

¹ Feasibility Study Technical Report for Ajax Copper/Gold Project – Kamloops, British Columbia, WARDROP, January 6, 2012



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step down substation at the mine site. Figure 4 shows the existing transmission network² in the Kamloops area, in which the red, green and blue lines represent 500 kV, 230 kV and 138 kV transmission lines respectively and Figure 5 indicates the route of the proposed 230 kV transmission line. The project would be responsible for the costs of this connection and it is estimated that this would amount to some US\$17.9 million including a deposit of \$3.6 million (equivalent to CAN \$19.69 million). This connection cost would apply to the case with the 110 MW connected load. Under BC Hydro policies, customers with a load in excess of 150 MW are responsible for applicable system impact costs. As the applicable system impact cost for the 164 MW load case is not available, a total of \$50 million was assumed for the interconnection requirement.

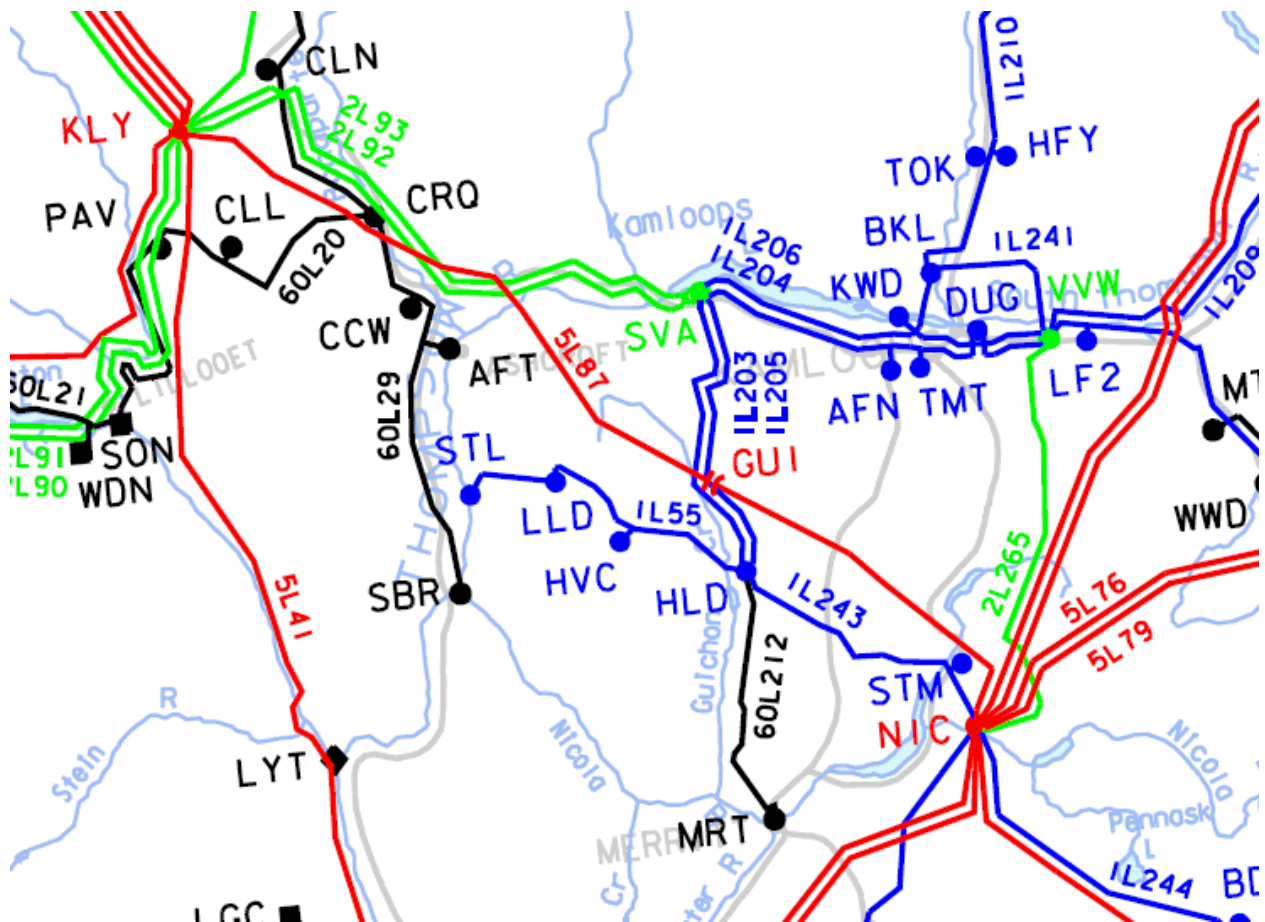


Figure 4: Local Transmission Network

² Excerpted from 2008/2009 BC Transmission System map



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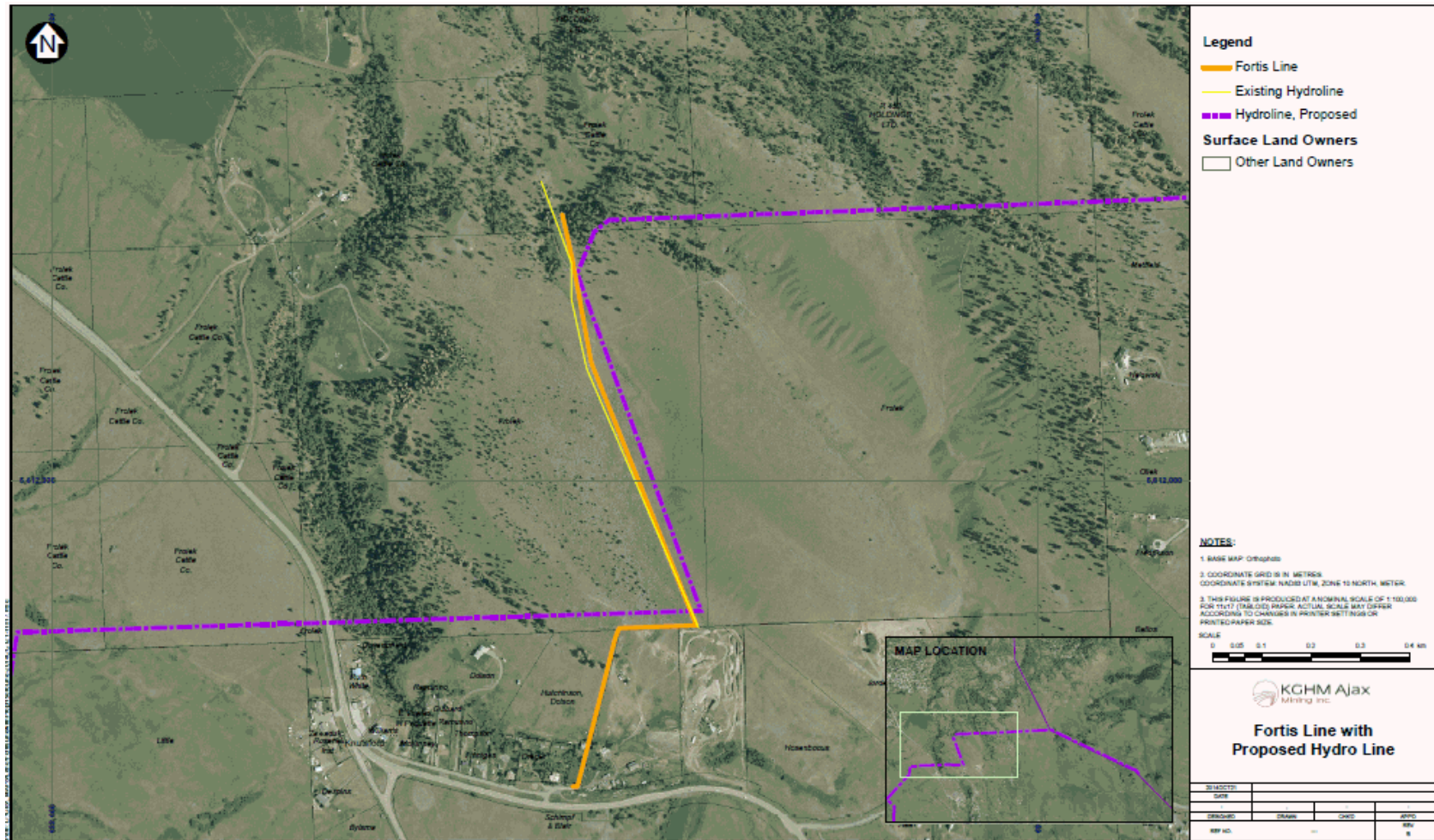


Figure 5: Proposed Transmission Line



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5.1.2 **Electricity Tariff Schedule of BC Hydro**

Most customers supplied at 60 kV or higher in BC are charged based on BC Hydro Rate Schedule 1823 – Transmission Service, effective from April 1, 2014. For a new customer (such as the Ajax Mine Project) or a customer without a CBL (Customer Baseline Load) by Order of the BCUC, its monthly (or Billing Period) electricity bill will include the following three components:

- 1) Demand charge at \$6.925 per KVA of Billing Demand per Billing Period
- 2) Energy Charge at 4.059¢ per kWh for all energy per Billing Period
- 3) Rate Rider at 5% of all charges, including demand charge and energy charge but excluding taxes

It is noted that the funds received from the rate rider are used to recover additional and unpredictable costs. For example, low water inflows and higher than-forecast market prices.

The current electricity rates are 9% higher than the previous ones. On November 26, 2013, the BC Government announced a 10 year plan that will keep electricity rates as low as possible while BC Hydro makes investment in aging assets and new infrastructure to support BC's growing population and economy.

The ten-year plan is stated to be as follows:

- 1) The Government will set rate increases for the initial two years of the 10 year plan at 9% and 6%
- 2) The BCUC will set increases for the following three years within caps of 4%, 3.5% and 3%
- 3) In the final five years of the plan, rates will be set by the BCUC and actions by government and BC Hydro will ensure that increases remain low and predictable (for this period the calculations assume a 3% annual increase)

These planned increases are generally consistent with information provided to KGHM by BC Hydro indicating an average all-in tariff for supply to the Ajax Mine Project of 6.7 cents per kWh in 2018.

5.2 **New Power Generation Facilities**

The scope of work for this study requires analysis of alternative power supply sources such as natural gas combined cycle generation, geothermal, wind, solar, biomass and small hydro. In preparation of this analysis, our primary reference was BC Hydro's 2013 Integrated Resource Plan (IRP), which is a flexible long-term strategic plan to meet BC's growth in electricity demand over the next 20 years. The IRP focuses on making prudent investments in conservation and clean energy, and on keeping future electricity supply options available. On November 15, 2013, BC Hydro submitted the plan to government and it was accepted on November 25.



The IRP includes all generation resource options that KGHM has selected for analysis and provides estimates of the unit energy cost for each option. The following sections summarize the information.

5.2.1 **Natural Gas**

Natural gas-fired power plants produce electricity using the heat released by combustion of natural gas. Simple cycle gas turbine (SCGT) and combined cycle gas turbine (CCGT) are the most commonly employed technologies. Conversion efficiencies are typically from 35 to 40 per cent for SCGT generators, and from 50 to 60 per cent for CCGT generators.

Co-generation of both heat and electricity using natural gas as a fuel is another form of natural gas-fired generation. Cogeneration involves electricity production using reciprocating engines or turbines and a steam/thermal host to use the excess heat produced by the generation process. Resource potential is limited by the availability of steam/thermal hosts such as greenhouses, hospitals, universities and industrial facilities that use steam or heat. By using waste heat in a process that requires heating, the overall efficiency of cogeneration plants can be even higher than that of CCGT plants.

Development of any gas-fired generation in BC would need to be within the allowance made for non-clean resources in the BC CEA (Clean Energy Act), except for those built to serve Liquefied Natural Gas (LNG) facilities. The CEA states that no more than 7 per cent of total electricity generation in the province can come from non-clean sources.

FortisBC is an energy utility delivering natural gas to homes and businesses in the Kamloops area. Figure 6 shows the service areas covered by FortisBC, including supplying natural gas, electricity and propane.

Although a natural gas distribution pipeline passes a few km from the project site, it may not have adequate capacity to fuel the new generation facility that would be required by the project. However, the cost for construction of a new distribution pipeline or reinforcement of the existing pipeline could be at a reasonable level as a Spectra Energy natural gas transmission pipeline runs through 30 km to 40 km west of Kamloops (the dashed yellow line shown in Figure 6 and the thick blue line shown in Figure 7), which should have sufficient capacity to transport natural gas from wells and other pipelines to the vicinity of Kamloops.

BC Hydro's 2013 IRP presents three representative CCGT plants/units located in the Kelly Lake Nicola area – a 50 MW unit, a 250 MW unit and a 500 MW unit. The basic technical and financial information of the three representative units is presented in Table 1 and is taken from the 2013 Resource Options Report Update³. This data shows that on a unit basis a smaller size plant would be more costly than a larger size plant due to the requirements for basic infrastructure.

³ Appendix 3, Resource Options Database (RODAT) Summary Sheets, 2013 Resource Options Report Update

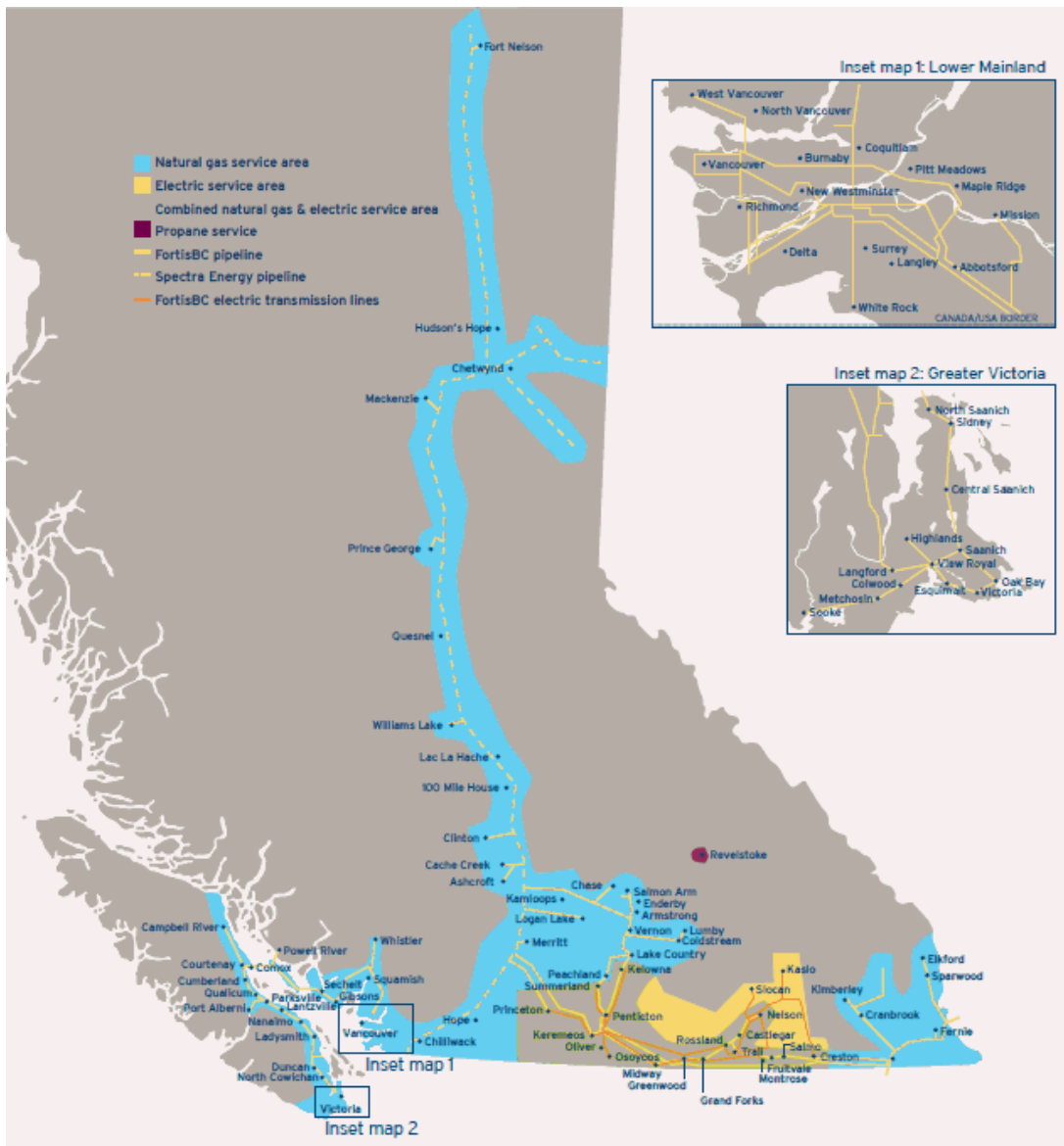


Figure 6: Fortis BC Service Area

One could also see from Table 1 that the estimated capital cost of all three plant sizes is relatively high compared to the industry norms. As the detailed breakdown of the capital cost estimates is not available, it is understood that the capital cost estimate includes allowance for infrastructure connection such as natural gas, transmission and water. This allowance could be in the range of \$50 to \$80 million.



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Figure 7: Natural Gas Pipeline in the Kamloops Vicinity

5.2.2 **Geothermal**

Geothermal power is a form of renewable energy utilizing subsurface hot water or steam created by the heat beneath the earth’s surface. Heat from the earth’s molten core in areas of volcanic activity or at the juncture of the earth’s tectonic plates, flows naturally toward the cooler surface to form hot springs, geysers, steam vents (fumaroles) and boiling mud pots.

Low temperature geothermal sources can be utilized to heat and cool residential and commercial buildings by installing heat pump systems. High temperature (some 170°C and above) sources can be extracted with standard well drilling technology in the form of hot water or steam to power turbines and produce clean, renewable electrical energy. The numerous hot springs found around the province point to the presence of high heat and energy geothermal deposits.

Geothermal projects in BC are subject to the Geothermal Resources Act and Regulations and to a full range of provincial licensing and permitting requirements covering land leases, drilling permits, wildlife protection, public health and safety, environmental monitoring and protection, road construction and use and water use. Projects in excess of 50 megawatts are subject to review under the BC Environmental Assessment Act and Canadian Environmental Assessment Act.



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Table 1: Technical and Financial Information of Natural Gas CCGT Plants

Parameter	Natural Gas CCGT Size (MW)		
	50	250	500
Technical Information			
Installed Capacity (MW)	56	263	530
Dependable Capacity (MW)	49	236	479
Energy production (GWh/Year)	386.3	1860.6	3776.4
Average Heat Rate (GJ/MWh)	7.58	7.35	7.362
Project Life (Year)	30	30	30
Project Lead Time (Year)	5	5	5
Financial Information (\$2013)			
Direct Capital Cost (\$1000) ⁽¹⁾	159,117.0	359,730.0	602,664.0
Fixed O&M Cost (\$1000/Year)	3,590.1	3,607.1	3,815.2
Variable O&M Cost (\$/MWh)	7.1	5.1	4.8
Fixed Taxes (\$1000/Year)	42.0	70.0	70.0
Variable Taxes (\$1000)	0.0	0.0	0.0
Unit Energy Cost at POI (\$/MWh)	92.0	62.0	58.0

Note: (1) Direct Capital Cost excludes interest during construction (IDC) and Corporate overhead (CO)

Since the energy source for geothermal generating plants is either steam or hot water, they produce no combustion emissions (including no CO₂) and virtually no other air emissions. Elements such as nitrous oxide, hydrogen sulphide, sulphur dioxide, carbon dioxide and particulates may be present in the source “fuel” – but in extremely low amounts that can be controlled by an abatement system.

Figure 8 presents a draft geothermal resources map prepared by BC Hydro. In its 2013 IRP⁴, BC Hydro has identified 15 prospective geothermal power plant sites in the province. One of them, the Canoe Creek/Valmont project, is in the Kelly Lake Nicola Transmission Region, within which the Ajax Mine Project is located. The potential annual energy production of these sites is presented in Table 2. This table also shows the estimated unit energy cost at the point of delivery in \$/MWh although the detailed assumptions used in the calculation are not provided in the IRP document.

⁴ Appendix 3A-34, 2013 Resource Options Report Update, Firm Energy Cost Adjustments



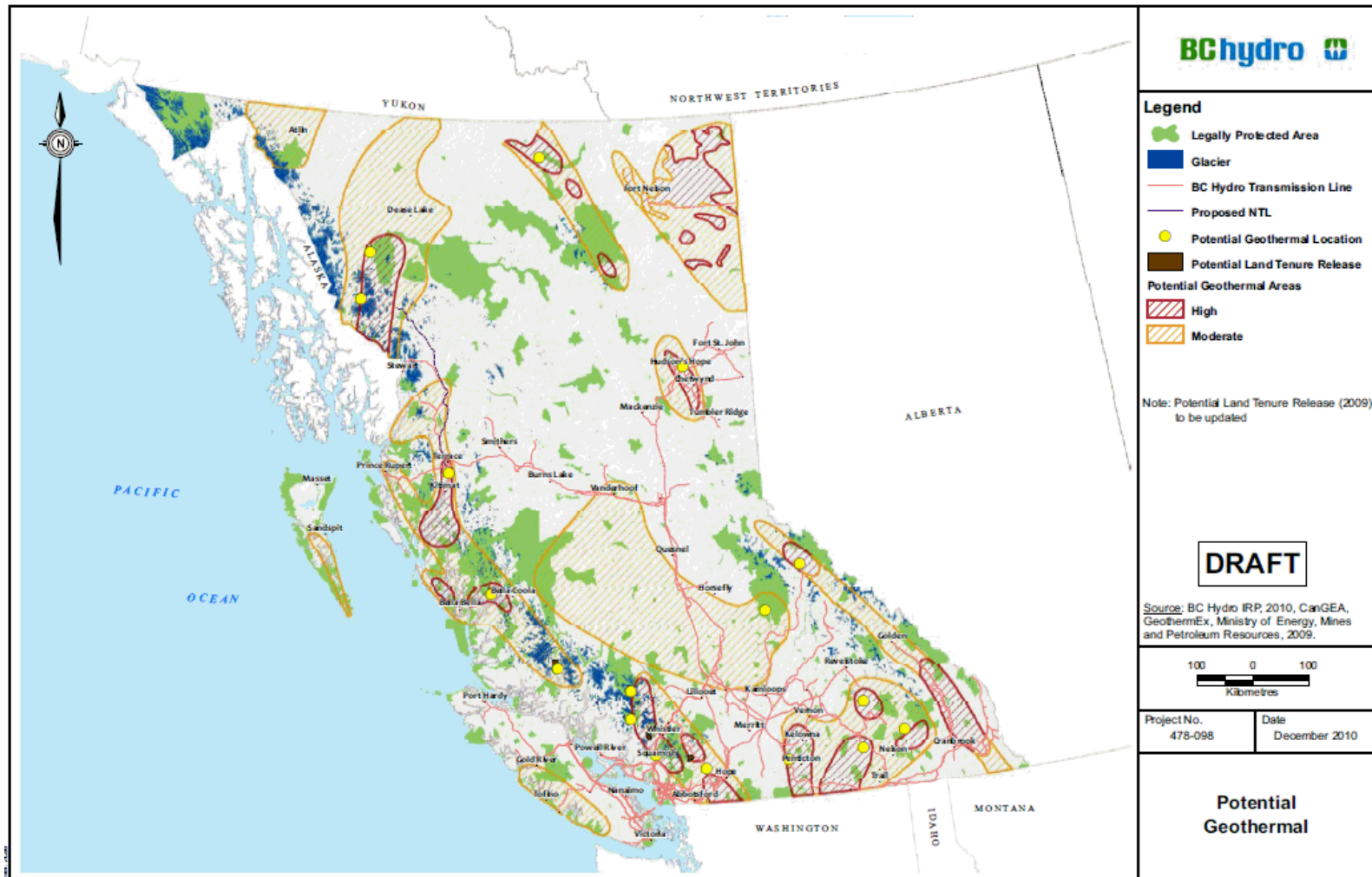


Figure 8: Geothermal Resources Map



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Table 2: Potential Geothermal Power Plant Sites Identified by BC Hydro

No.	Project	Transmission	Expected Annual Energy (GWh)	Estimated Energy Cost (\$/MWh)
	Name	Region		
1	Canoe Creek/Valemont	Kelly Lake Nicola	140	141
2	Harrison Hot Springs	Lower Mainland	140	139
3	Mt. Caribaldi	Lower Mainland	394	91
4	Mt. Cayley	Lower Mainland	394	105
5	Pebble Creek	Lower Mainland	788	99
6	South Meager Creek	Lower Mainland	788	99
7	Hoodoo Mountain	North Coast	394	122
8	Lakelse Lake	North Coast	140	136
9	Mt. Edziza	North Coast	1577	97
10	Hudson's Hope	Peace River	140	134
11	Upper Arrow Lake	Revelstoke Ashton Creek	140	142
12	Kootnay Lake	Selkirk	140	134
13	Lower Arrow Lake	Selkirk	140	155
14	Okanagan Valley	Selkirk	140	179
15	Mt. Silverthorne	Vancouver Island	394	134

The technical and financial information for the potential geothermal plant in the Kelly Lake Nicola Transmission Region is presented in **Error! Not a valid bookmark self-reference..** The unit energy cost of the project would be approximately \$141 per MWh, which is extremely expensive when compared with the BC Hydro electricity rates.

5.2.3 Wind

Wind power is the energy extracted from wind using wind turbines to produce electrical power. British Columbia has abundant, widely distributed wind energy resources in most areas of the province. Modern utility-scale wind turbines are horizontal axis machines with three rotor blades. The blades convert the linear motion of the wind into rotational energy that then is used to drive a generator. The power output of a wind turbine is dependent on wind speed, direction and consistency as well as the overall efficiency of the entire wind turbine generator set.

There are four main factors that affect wind speed. The first is pressure gradient which is generated by differences in atmospheric pressure between two adjacent areas. The second is frictional force which is increased by features on the earth's surface such as trees and mountains. The third factor is the Coriolis Effect which deflects the direction of wind flow on the earth's surface. Finally, elevation plays a major role in wind speed as there are fewer obstacles at higher elevation to block wind creating higher wind speed.



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Table 3: Technical and Financial Information of the Geothermal Power Plant

Parameter	Geothermal
Technical Information	
Installed Capacity (MW)	20
Dependable Capacity (MW)	20
Energy production (GWh/Year)	140.2
Average Heat Rate (GJ/MWh)	
Project Life (Year)	40
Project Lead Time (Year)	6
Financial Information (\$2013)	
Direct Capital Cost (\$1000) ⁽¹⁾	155,142.0
Fixed O&M Cost (\$1000/Year)	104.8
Variable O&M Cost (\$/MWh)	42.8
Fixed Taxes (\$1000/Year)	122.0
Variable Taxes (\$1000)	0.0
Unit Energy Cost at POI (\$/MWh)	141.0

Note: (1) Direct Capital Cost excludes interest during construction (IDC) and Corporate overhead (CO)

As wind speed changes from time to time, wind power is an intermittent power source, with output fluctuating as wind speed varies. Depending on its location, the capacity factor of an onshore wind power plant in BC could be in the range of 21% to 48%⁵.

The energy cost of a wind power project is dependent on a number of important factors such as capacity factor, economic life, total investment cost (including interconnection costs, financing charges and legal fees), expected return on investment, income tax, allowance on capital cost depreciation, operation and maintenance costs (including land leasing, right of way, property tax and insurance).

In its 2013 IRP, BC Hydro identified 22 potential wind power plant sites in the Kelly Lake Nicola Transmission Region. Table 4 shows the potential annual energy production of these plants and the unit energy costs in \$/MWh estimated by BC Hydro, ranging from \$122/MWh to \$164/MWh. These 22 wind power projects would have a total installed capacity of 3,363 MW and an annual production of 8,437 GWh, which would be an average capacity factor of some 28.6%.

Table 5 shows the technical and financial information for two representative wind power plants in the Kelly Lake Nicola Transmission region.

⁵ Assessment of the Energy Potential and Estimated Costs of Wind Energy in British Columbia, Garrad Hassan, February 22, 2008

Table 4: Potential Wind Power Plant Sites Identified by BC Hydro

No.	Project Name	Expected	Estimated
		Annual	Energy
		Energy	Cost
		(GWh)	(\$/MWh)
1	Wind_BC26	376	151
2	Wind_SI01	553	146
3	Wind_SI02	151	164
4	Wind_SI03	355	145
5	Wind_SI04	253	133
6	Wind_SI05	355	137
7	Wind_SI06	294	152
8	Wind_SI08	256	155
9	Wind_SI09	212	151
10	Wind_SI10	313	130
11	Wind_SI15	814	126
12	Wind_SI16	1632	133
13	Wind_SI18	335	135
14	Wind_SI19	148	133
15	Wind_SI20	122	124
16	Wind_SI22	126	130
17	Wind_SI23	569	122
18	Wind_SI26	263	159
19	Wind_SI28	261	141
20	Wind_SI29	314	150
21	Wind_SI30	396	148
22	Wind_SI31	340	161

5.2.4 Solar

On average, each square metre of land on the earth is exposed to enough sunlight to generate approximately 1,700 kWh of energy every year using currently available technology. The total energy that reaches the earth's surface could meet our existing global energy needs over 10,000 times. Solar power is generated from sunlight and can be achieved directly using photovoltaic cells (crystalline silicon or thin film) or indirectly by using Concentrating Solar Power (CSP) technologies. Both the photovoltaic and CSP technologies are commercially proven.

Table 5: Technical and Financial Information of Wind Power Plants

Parameter	Wind	
Technical Information		
Installed Capacity (MW)	69	193.2
Effective Load Carrying Capability (MW)	17.9	50.2
Energy production (GWh/Year)	151.2	563.9
Average Heat Rate (GJ/MWh)		
Project Life (Year)	20	20
Project Lead Time (Year)	5	5
Financial Information (\$2013)		
Direct Capital Cost (\$1000) ⁽¹⁾	223,820.0	601,639.0
Fixed O&M Cost (\$1000/Year)	2,435.8	8,852.7
Variable O&M Cost (\$/MWh)	0.0	0.0
Fixed Taxes (\$1000/Year)	294.0	566.0
Variable Taxes (\$1000)	0.0	0.0
Unit Energy Cost at POI (\$/MWh)	164.0	122.0

Note: (1) Direct Capital Cost excludes interest during construction (IDC) and Corporate overhead (CO)

It is understood that there are a number of technologies available to convert sunlight into electricity with different overall efficiencies, initial capital investments, land requirements, and operation and maintenance costs. In coastal BC, a 1 kW solar PV panel could generate around 1,100 kWh a year. In sunny Kamloops and Kelowna it could produce approximately 1,200 kWh⁶.

BC Hydro has estimated in its 2013 IRP that a 5 MW solar PV power plant in the Kelly Lake Nicola Transmission Region could produce approximately 6 GWh a year, at a cost of some \$290/MWh. Globally costs for solar technologies have declined dramatically. While this trend is expected to continue, costs are not expected to become competitive with the BC Hydro tariff in the near future in the absence of price support from governments or utilities.

5.2.5 Biomass

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-based materials which are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into thermal, chemical, and biochemical methods.

⁶ [Solar Power – BC Sustainable Energy Association](#)



Wood remains the largest biomass energy source around the world, which includes forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

There is a significant volume of biomass on the landscape in British Columbia that needs to be removed in order to improve ecosystem resilience and sustainability and reduce the threat from wildfires facing rural communities. Although the material we need to remove from the forest has very little economical value to the forest industry, it has certain value as a raw resource in the bioenergy sector where it can be converted into a wood pellet, syngas, bio-char, bio-plastics, etc.

In this report, only wood-based biomass is considered for potential power generation for the Ajax Mine Project. It could consist of standing timber (including beetle-killed wood), roadside wood waste (wood that has already been harvested but has been left in the forest or on road sides, some of which is from pine beetle-killed trees) and sawmill wood waste.

Appendix 6 – Wood Based Biomass Potential Report of BC Hydro’s “2013 Resource Options Report Update” provides detailed analysis on the biomass potential in the province, including the Kamloops/Okanagan Region. The Region has an estimated 210 million cubic metres of pine. By 2013, an estimated 68 million cubic metres of pine had been killed by the Mountain Pine Beetle. This is about 72% of the estimated 94 million cubic meters that is expected to die from the epidemic that peaked in 2007.

The historic Allowable Annual Cut (AAC) for the Region was approximately 9 million cubic metres. It was increased to 13 million cubic metres to support salvage of logs from both fire and beetle mortality, and currently sits at about 10.2 million cubic metres. A future long-term sustainable AAC of about 8 million cubic metres is forecast by 2024.

Eight sawmills, five veneer plants, one independent power plant (Armstrong), three pellet mills and one large pulp mill comprise the existing forest industry in this region. The Ardeu’s sawmill and Tolko’s Kelowna veneer plant shut down in 2012, both citing a lack of sawlog/peeler log supplies. The Domtar pulp mill in Kamloops is the largest regional consumer of wood chips, hog fuel and (until recently) sawdust. In 2012 Domtar announced the closure of the part of the pulp mill that consumed sawdust for the production of “mini” pulp. This closure frees a considerable volume of sawmill residues to a new biomass consumer. It is assumed that Western Bioenergy, who was awarded an EPA (electricity purchase agreement) with BC Hydro for a Merritt bioenergy plant under the Phase 2 Power Call, would eventually consume this surplus volume. Roadside residuals are currently in significant demand. In order to support biomass power production at Howe Sound Pulp and Paper approximately 200,000 ODTs (oven dry tonne) of roadside material is transferred from the Kamloops/Okanagan Region to the coast.



There are multiple users of minor residual sawmill fibre within the Region, resulting in considerable historic demand and competition between companies. It is assumed that a short term surplus of sawdust, shavings and hog fuel exists as a result of the closure of the Domtar sawdust digester. The existing pellet producers or the proposed Western Bioenergy bioenergy power plant would secure this volume in the near term.

It is estimated that the surplus biomass potential in the Region would meet the fuel requirement of a 62 MW power plant producing some 545 GWh of energy a year at a cost of some \$140/MWh over the first 13 years. After AACs are reduced, this potential would fall to 54 MW producing 476 GWh/year at a cost of \$137/MWh. Table 6 shows the technical and financial information of a 60 MW biomass power plant in the Kamloops area.

Table 6: Technical and Financial Information of Wood Based Biomass Power Plant

Parameter	Biomass
Technical Information	
Installed Capacity (MW)	60
Dependable Capacity (MW)	60
Energy production (GWh/Year)	476.5
Average Heat Rate (GJ/MWh)	
Project Life (Year)	15
Project Lead Time (Year)	5
Financial Information (\$2013)	
Direct Capital Cost (\$1000) ⁽¹⁾	283,564.0
Fixed O&M Cost (\$1000/Year)	9,924.8
Variable O&M Cost (\$/MWh)	52.6
Fixed Taxes (\$1000/Year)	0.0
Variable Taxes (\$1000)	0.0
Unit Energy Cost at POI (\$/MWh)	141.0

Note: (1) Direct Capital Cost excludes interest during construction (IDC) and Corporate overhead (CO)

5.2.6 Small Hydro

Hydroelectricity is the term referring to electricity generated by hydropower, production of electrical power through the use of the gravitational force of falling or flowing water. Production potential of a hydropower plant is very site specific. Most of the large hydroelectric power generation projects we see and hear about involve dams and storage reservoirs. They have the advantage of storing energy for release when there is peak demand or during periods of the year when natural water flows are lower. Some of the disadvantages are that the storage reservoirs inundate and alienate large areas of land, affect local climate, and release toxins as organics break down.

Micro and small hydro projects seldom use storage reservoirs and are often referred to as run-of-river (RoR). BC Hydro considers micro hydro developments to have an installed



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capacity of less than 2 MW and small hydro developments have installed capacities between 2 and 50 MW.

A dam (or water reservoir) or weir is a crucial part of a hydroelectric power plant. The site conditions are the determining factors in selection of a hydro power plant. Power potential is a function of head and available flow. Factors affecting selection of a dam site include at least the followings:

- 1) Good topographical location along the path of a river – The best location along the path of the river is a river canyon or at a location where there is a narrowing of the river
- 2) Right geological structure – The rock (or earth) structure on which the dam will be constructed should be strong enough to sustain the weight of dam and water stored in the dam.
- 3) Sufficient water is available – The flow of water where the dam is constructed should be sufficient to fill the reservoir created by the dam

A RoR hydropower station diverts a portion of natural stream flows and uses the natural drop in elevation of a river to generate electricity. A weir (i.e., a structure smaller than a dam used for storage hydro) is required to divert flows into the penstocks that lead to the power generation station. A RoR project either has no storage, or a limited amount of storage, in which case the storage reservoir is referred to as pondage.

There is only one potential large hydropower plant identified in BC Hydro's 2013 IRP, which would be located on the Peace River in north-eastern BC. A report⁷ prepared by Kerr Wood Leidal Associates Limited in 2007 indicates that there are more than 8,000 sites in the province with the potential to be developed as RoR power plants. All together, these sites would have a potential installed capacity of more than 12,000 MW and could generate nearly 50,000 GWh of energy per year. The IRP includes 101 RoR hydropower plants in the Kelly Lake Nicola Transmission Region in its options analysis, which have a potential of 783 MW of power and 2277 GWh of energy per year. The estimated energy cost of these RoR plants varies from \$97/MWh to \$494/MWh, a very wide range. Table 7 presents the technical and financial information for two small hydro plants in the Kelly Lake Nikola Transmission region.

5.2.7 Comparison of Unit Energy Costs of New Supply Options

Based on the technical and cost information presented in the previous sections, the most important information (availability and cost) for the selected supply options is summarized in Table 8. The following general conclusions could be obtained from this table:

- 1) Other than the BC Hydro supply option, only natural gas CCGT, wind, solar and small hydro generation could potentially provide the electricity required by the Ajax Mine Project

⁷ Run-of-River Hydroelectric Resource Assessment for British Columbia



Table 7: Technical and Financial Information of Small Hydro Power Plants

Parameter	Small Hydro	
Technical Information		
Installed Capacity (MW)	40.4	41.5
Effective Load Carrying Capability (MW)	2.4	2.6
Energy production (GWh/Year)	117.3	131.4
Average Heat Rate (GJ/MWh)		
Project Life (Year)	40	40
Project Lead Time (Year)	5	5
Financial Information (\$2013)		
Direct Capital Cost (\$1000) ⁽¹⁾	116,194.0	153,923.0
Fixed O&M Cost (\$1000/Year)	2,242.2	2,770.8
Variable O&M Cost (\$/MWh)	0.0	0.0
Fixed Taxes (\$1000/Year)	1,734.0	2,324.0
Variable Taxes (\$1000)	0.0	0.0
Unit Energy Cost at POI (\$/MWh) ⁽²⁾	142.0	162.0

Note:

(1) Direct Capital Cost excludes interest during construction (IDC) and Corporate overhead (CO)

(2) POI -- Point of interconnection

Table 8: Unit Energy Cost of New Supply Options

Technology Name	Potential		Estimated Cost ⁽¹⁾ (\$/MWh)
	Capacity (MW)	Energy (GWh/Year)	
Natural Gas CCGT	56 - 530	386 - 3,776	58 - 92
Geothermal	20	140	141
Wind	3,363	8,437	122 - 164
Solar PV	Sufficient	Sufficient	290
Biomass	60	476	141
Small Hydro	783	2,277	97 - 494

Note: (1)

The cost is from BC Hydro 2013 IRP and its support document. It was calculated at the point of delivery, without consideration of firming requirement.

- 2) The unit energy cost of natural gas CCGT is the lowest while the cost of wind power could be twice as high
- 3) The unit energy cost of solar power could be 3 to 5 times that of natural gas CCGT
- 4) The unit energy cost of small hydro varies significantly, from \$97/MWh to \$494/MWh, which is much more expensive than natural gas CCGT which is in the range of \$58/MWh to \$92/MWh



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- 5) More findings will be discussed in the next section

5.2.8 Findings and Recommendations

5.2.8.1 Findings

Based on the analysis of new supply options described in the previous sections and the summary information presented in Table 8, one could conclude the following points for the six selected supply options, natural gas CCGT, geothermal, wind, solar, biomass and small hydro power:

- 1) Natural gas CCGT – With appropriate designs, this supply option could provide firm and backup power to the Ajax Mine Project. It is also possible that it would only provide firm power and the BC Hydro grid would provide backup power, depending on the expected reliability level and economics. However, this supply option is subject to a few conditions such as (i) the natural gas pipeline capability to transport the required volume from gas wells and other pipelines to the mine site, (ii) the non-clean source limit (7%) established in the BC CEA and (iii) other regulations and policies. In addition, the Ajax Mine Project would increase its atmospheric emissions, particularly CO₂
- 2) Geothermal – Although a geothermal power plant can provide continuous supply to its electricity consumers, the total estimated resources available in the region are very limited (only some 20 MW). If a potential power plant site is relatively far away from the Ajax Mine Project, a transmission or distribution line would also be required, which would further add to the cost
- 3) Wind – There are adequate wind resources and there are likely to be suitable wind power plant sites in the region to provide the peak electricity demand of the Ajax Mine Project. However, due to its intermittent nature, wind power plants alone could not meet the electricity requirements of the mine. It must be backed up by other firm on-site generation, BC Hydro grid, energy storage plant, or a combination of these technologies
- 4) Solar – There are adequate solar resources and there are likely to be suitable solar power plant sites in the region to provide the peak electricity demand of the Ajax Mine Project. As solar power could only be generated during day time and the level of output from a solar power plant is dependent upon the amount of sunlight available, solar PV power plants alone could not meet the electricity requirement of the mine. It must be backed up by other firm on-site generation, BC Hydro grid, energy storage plant, or a combination of these technologies. Solar CSP with storage could provide firm power but its cost is much higher than that of solar PV, depending on storage capacity
- 5) Biomass – A biomass power plant can provide continuous electricity supply to its consumers. Due to the resource limitations, the resources available in the region could only meet the fuel requirement of a power plant with an installed capacity of some 60 MW



- 6) Small hydro – The potential small hydro resources in the region could supply the peak electricity demand of the Ajax Mine Project. As it does not have storage or has only limited storage and its output depends on the water flow, small hydro plants could not meet the continuous supply requirement of the mine if without energy storage plants. Another important consideration is the locations of these small hydro plants. If a small hydro plant is relatively far away from the mine, a transmission or distribution line would be required, which could have an impact on the economics of supply

5.2.8.2 Recommendations

As per the analysis and study results presented in the previous section, Hatch outlines the following recommendations:

- 1) As the natural gas CCGT power plant would have much lower unit energy cost than the geothermal, wind, solar PV, biomass and small hydro options this supply option should be taken into account in all three study streams. However, it is understood that the existing pipeline may need reinforcement in order to transport the volume required by the mine
- 2) Although the region has sufficient resources for wind and small hydro power plants, these two supply options would have higher costs, would produce power intermittently and would possibly be a relatively long distance from the mine. Firming these two supply options using energy storage and/or the BC Hydro grid would add more cost to the already high cost
- 3) Although the area has sufficient resources for solar power plants, this option is too expensive at the current price level and should not be considered further
- 4) The resources available for geothermal and biomass power in the region are very limited. Due to their high costs and resource limitation, they should not be considered in the next step of the study
- 5) Although the five renewable power generation options could not compete in price with natural gas CCGT, KGHM Ajax may wish to install some renewable power to reduce GHG emissions and be seen as “green”

6. Electricity Supply Cases and Their Costs

This section describes the envisaged electricity supply cases and presents their estimated cost in 2014 Present Worth (PW), covering the period from 2014 to the end of the Ajax Mine Project's operation (2038).

6.1 Base Case – BC Hydro Supply

In the BC Hydro Supply case, all electricity required by the Ajax Mine Project would be supplied by BC Hydro through its 230 kV transmission line running through Kamloops vicinity. Due to its meshed transmission network and adequate generation resources, it is expected that BC Hydro would meet the mine's electricity requirements with a very high reliability level.



A new transmission interconnection line would be required to connect the substation at the mine site to the existing 230 kV BC Hydro transmission line.

In addition to the assumptions and parameters listed in Section 3.3 and the BC Hydro tariff schedule described in Section 5.1.2, it was assumed that some \$50 million would be required for interconnection of the Ajax Mine Project to the BC Hydro 230 kV transmission line, including transmission line and substation(s) and a modest allowance for system impact costs. Forty percent of the investment would be required in 2017 and the remainder in 2018.

It was calculated that the total cost for the BC Hydro Supply would be some **\$717** million in 2014 PW, which covers the period from 2014 to the end of the Ajax Mine Project's operation (2038). The cost includes four components, demand charge, energy charge, rate rider and connection costs.

6.2 Alternative 1 – Self Generation

Under the Self Generation case it is assumed that the Ajax Mine Project would generate electricity for its own use, i.e. installation of generation facilities at the mine or in the mine's vicinity. Due to the cost of the different generation options as described in Section 5, this case includes only natural gas CCGT. Taking into account maintenance and forced outages and other factors, it was assumed that Ajax Mine Project would need a minimum of four sets of natural gas fired CCGTs to meet its electricity needs with each rated at 55 MW (total capacity of 220 MW) or one set of CCGT with a total capacity of 165 MW plus one 55 MW GT. However, the specifics on configuration of the plant will be discussed in Phase 2 of the assignment – Prefeasibility Study. Three of the four units would be used for normal operation while the fourth one would be used for reserve. The fourth CCGT would be used when any of other three CCGTs is out of service. It is noted that this arrangement is to minimize the total cost of this supply case although an additional CCGT set may be required for reserve in order to achieve the same reliability level as the BC Hydro Supply case (in case one is on maintenance and one of the three operating units undergoes a forced outage).

6.2.1 Natural Gas Price Forecast

Figure 9 shows the long term natural gas price forecast presented in 2014 Gas Outlook – Natural Gas Supply, Demand, Capacity and Prices in the Pacific Northwest, prepared by the Northwest Gas Association (NWGA) and its members. The price unit 2012\$/Dth means 2012 US\$ per 1000 cubic feet. The heating value of 1000 cubic feet is approximately 1 MMBTU. One could see from this figure that the NWGCC Sumas Forecast indicates the 2014 price would be some 2012 US\$3.75 per MMBTU.

Taking into account a consumer price index (CPI) increase of 2.5% a year, an exchange rate of 1 CAD\$ to 0.9 US\$ and 1 MMBTU to 1.055 GJ, the price of natural gas at Sumas in 2014 would be 2014 CAD \$4.15 per GJ ($3.75 \times 1.025^{2/0.9/1.055}$). This price was adopted and used in the analysis. It could also be calculated that the NWGCC Sumas Forecast has an average increase rate of 2% per year.



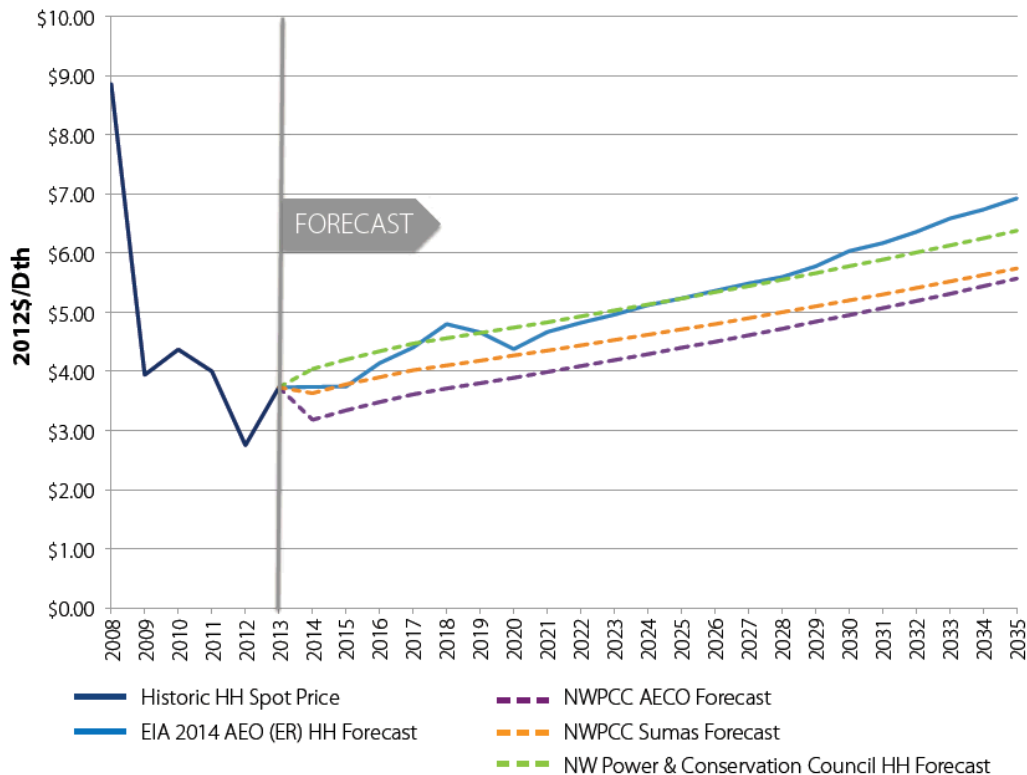


Figure 9: Long Term Natural Gas Price Forecast

6.2.2 Estimated Self Generation Cost

In addition to the assumptions and parameters listed in Section 3.3 and natural gas price discussed in the previous section, the following key assumptions were also used in calculation of the total cost of the Self Generation case:

- 1) Capital Cost
 - i) Overnight cost⁸ – \$1,150/kW plus \$50 million for connection to natural gas pipeline and other supply (low estimate). With a total generation capacity of 220 MW, the total overnight capital cost would be \$303 (\$253+\$50) million
 - ii) Permits and other requirements – 2% of the overnight cost
 - iii) Financing and legal charges – 5% of the overnight cost
 - iv) Decommissioning cost – 2% of the overnight cost

⁸ “Overnight cost” – An estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day, which does not include permits and other requirements, financing, legal, interest during construction, decommissioning, land acquisition, etc.

- v) Disbursement of the total capital cost from 2016 to 2018 would be 25%, 45% and 30% respectively
- 2) Annual Operation and Maintenance (O&M) Costs
 - i) Fixed O&M cost (including insurance and property tax) – 3% of the total capital cost
 - ii) Variable O&M cost – 2.5% of the total capital cost
 - iii) Interim replacement cost – 0.5% of the total capital cost
- 3) Natural Gas Transportation Cost – Based on Rate Schedule 25 of FortisBC Energy Inc., Effective November 1, 2014, the natural gas fired generation plant would need to pay the following transportation costs each month:
 - i) Basic charge per month – \$587
 - ii) Administration charge per month – \$78
 - iii) Demand charge per month per gigajoule of daily demand – \$17.85 (Daily demand is equal to 1.25 times the highest average daily consumption of any month)
 - iv) Delivery charge per gigajoule – \$0.738
 - v) Franchise fee charge – 3.09% of the sum of natural gas commodity and transportation charges, which is only payable if the facilities are located within the municipal boundaries of a municipality or First Nations lands to which FortisBC Energy pays Franchise fees. As per the mine layout shown in Figure 2, the mine is not inside the boundaries of Kamloops. This charge is therefore assumed not applicable to the mine

Based on the above assumptions and parameters it was calculated that the total cost for the Self Generation case would be some **\$960** million in 2014 PW. This figure does not include allowance for any charges that would apply to the greenhouse gas (GHG) emissions by this generation plant.

6.3 Alternative 2 – Independent Power Provider

In this case, all electricity required by the Ajax Mine Project would be provided by an independent power provider (IPP). The IPP would build, own and operate the generation facilities. It is noted that the generation facilities could be located at the mine site or in its vicinity. When generation facilities are located outside of the mine, new transmission or distribution lines would be constructed to transmit power to the mine site. When necessary, BC Hydro's transmission and/or distribution lines may also be used but this may be subject to BC Hydro's Open Access Transmission Tariff or other rate arrangements.

Given the electricity markets in British Columbia and the resources for electricity supply options available in the vicinity of the Ajax Mine Project, it is not considered that the IPP case would have significantly different electricity supply costs than those of the Self Generation case. However, under this option the Ajax Mine Project would not need to make the capital investment in the generation facilities or carry the operating risk. On the other hand, it would lose some control over the supply of electricity.



6.4 Alternative 3 – Supplemental Power Supply to the BC Hydro Supply Case

As per the analysis of supply options and costs presented in Section 5, the unit energy costs of the identified renewable resources are somewhat higher than those of the natural gas CCGT option. Another factor is that most of these renewable resources are intermittent and backup power from BC Hydro is required. For those resources which could provide continuous power supply, backup power may still be required as they will experience maintenance, forced outage and other no-output conditions. It could be concluded that most of the intermittent renewable energy would only reduce the energy payment to BC Hydro and would not reduce the demand payment but the savings on BC Hydro charges would be less than the cost of the intermittent renewable power.

One could therefore conclude that the total electricity cost of the supplemental power supply case would be more than that of the BC Hydro Supply case.

6.5 Sensitivity Analysis

Based on the discussions presented in previous three sections, it was determined that sensitivity analysis would be carried out for the BC Hydro Supply and Self Generation cases only.

6.5.1 BC Hydro Supply

It is recognized that there are two key factors which could impact the BC Hydro supply cost to the Ajax Mine Project, transmission interconnection cost including substation(s) and the future BC Hydro electricity tariff. Table 9 presents sensitivity study results examining the impact of these two key parameters on total electricity cost.

One could observe the following from Table 9:

- 1) The total electricity cost would be increased by some \$41 million (from \$717 million to \$758 million) when the transmission interconnection cost is increased by \$50 million
- 2) The total electricity cost would increase by some \$135 million (from \$717 million to \$852 million) if the electricity tariff rate would be escalated at a rate of 5% per year from 2019 and onwards as opposed to the more modest average annual increase included in the base case
- 3) The additional payment for electricity supply would be some \$175 million if the transmission interconnection cost is increased by \$50 million and the electricity tariff would be escalated by 5% per year, starting from 2019
- 4) The total electricity cost for the BC Hydro Supply case would be \$960 million, equal to the estimate for the Self Generation case if the transmission interconnection cost is increased by \$50 million and the electricity tariff would be increased by 5.96% per year, starting from 2019



Table 9: Sensitivity Study Results – BC Hydro Supply

Parameter	Total Cost
	(M\$, 2014 PW)
Base Case	717
Transmission interconnection cost increases to \$100 million from \$50 million	758
Electricity tariff escalation rate of 5% per year, starting from 2019	852
Transmission interconnection cost increases to \$100 million from \$50 million and electricity tariff escalation rate of 5% per year, starting from 2019	892
Transmission interconnection cost increases to \$100 million from \$50 million and electricity tariff escalation rate of 5.96% per year, starting from 2019	960

6.5.2 Self Generation

In the case of Self Generation, the two most important factors affecting electricity cost would be the capital cost of the generation facilities and the natural gas prices. As an energy utility, Fortis BC's transportation rates for natural gas are regulated by BCUC. In normal conditions, significant increase of these rates would not be expected. Table 10 presents the sensitivity study results for the Self Generation case, which show the impact of the two parameters on total electricity costs.

Table 10: Sensitivity Study Results – Self Generation

Parameter		Total Cost (M\$, 2014 PW)			
		Natural Gas Price Escalation Rate			
		-8.18%	0%	Base Case	4%
Change in Overnight Capital	-50.80%			717	
	-30%		740	816	917
	Base Case	717	884	960	1,060
	30%		1,027	1,103	1,204

The following findings could be obtained from Table 10:

- 1) With a 30% reduction in capital cost and no increase in natural gas price from 2014 to 2038, the total electricity cost would be some \$740 million, which is still \$23 million higher than the BC Hydro Supply case
- 2) The Self Generation case would have the same cost as the BC Hydro Supply case if capital cost could be reduced by 50.8%



- 3) The Self Generation case would be competitive against the BC Hydro Supply case if natural gas price could be reduced by 8.18% per year, from 2015 and onward
- 4) The total cost for the Self Supply case would be some \$1,204 million if the capital cost is increased by 30% and natural gas price grows at 4% per year, starting from 2015



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