

RESOURCE OPTIONS UPDATE

TECHNICAL ENGAGEMENT – GEOTHERMAL

ALEX TU



FOR GENERATIONS

July 17, 2015

BACKGROUND & OBJECTIVES

BC Hydro and Fortis BC are updating their Resource Options Inventory for use in long term planning

Objectives for today:

- Review historical work on Geothermal in BC leading to this study
- Describe the scope and objectives of the update
- Share results of the Economic Assessment study conducted by KWL/GeothermEx
- Allow for clarification questions along the way

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BRIEF HISTORY OF GEOTHERMAL IN BC

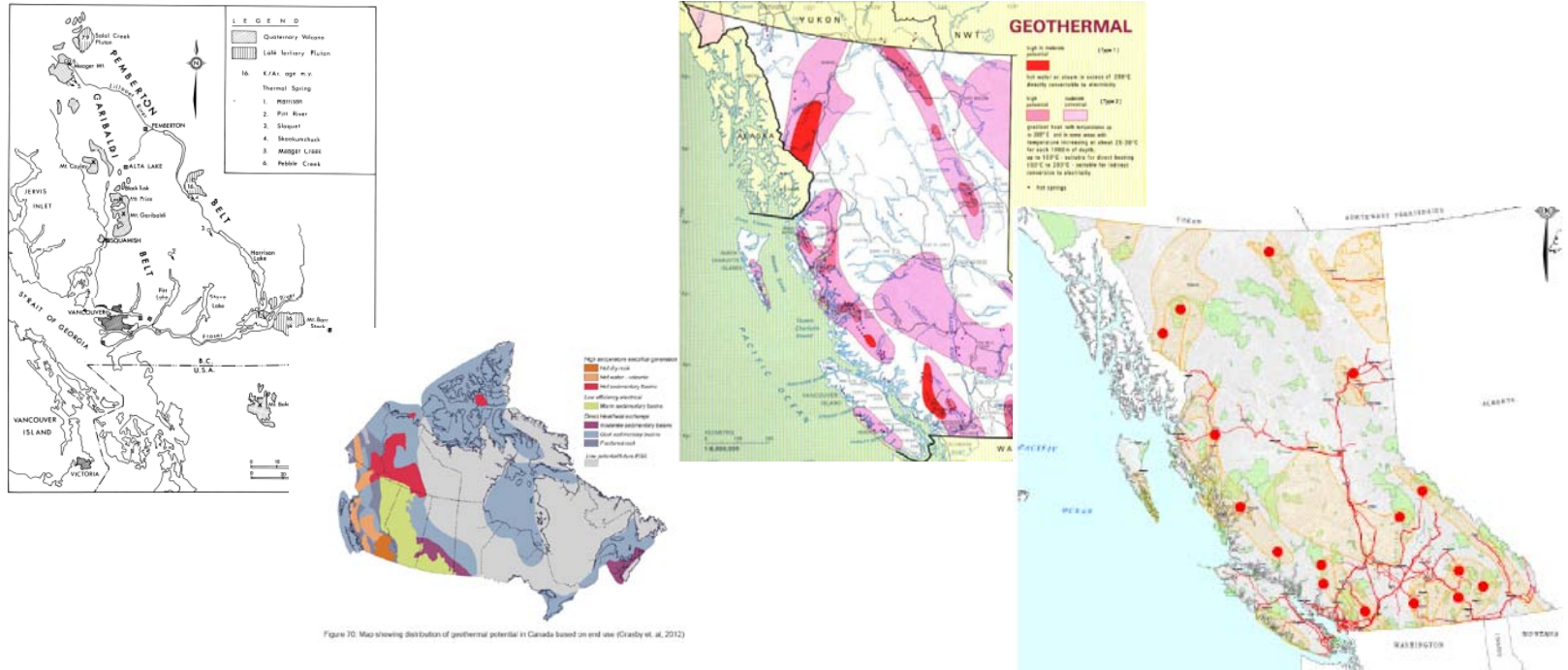


Figure 10. Map showing distribution of geothermal potential in Canada based on end use (Craib et al., 2012)

BC Hydro Geothermal
Exploration Program
(1976 – 1984)

The National
Geothermal Energy
Program (1974 – 1986)

Provincial tenuring
process and private
sector exploration
(1982 – present)

Western Renewable
Energy Zones (WREZ);
BC Hydro Resource
Options Reports;
CanGEA assessment

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KWL/GEOTHERMEX STUDY - OVERVIEW

BC Hydro and GeoscienceBC partnered to issue an RFP to review the previous resource estimate in light of all available public data and provide a transparent analysis of the economic viability of geothermal power projects.

Study Focus:

1. Assess the relative favourability of 18 potential project sites, including two representative sites in the Sedimentary Basin not previously studied
2. Estimate the electricity generation potential of favourable sites using publicly available data
3. Calculate the cost of energy from the favourable sites based on updated cost assumptions and information.

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STEP 1 – FAVORABILITY ASSESSMENT OF CANDIDATE SITES

Table 4-2: Summary of Overall Ratings/Scores³

Geothermal Site	Criteria Rating						Conclusions	
	Reservoir Potential	Exploration Uncertainty (Risk)	Environmental Issues	Transmission Line Infrastructure	Community Issues	Non-electrical Infrastructure (roads and habitation)	Summary Rating / Score	Favourable ✓ / Unfavourable X
Canoe Creek - Valemount (15 MW)	●	●	○	○	●	●	● / +4	✓
Clarke Lake (34 MW)	●	○	○	●	●	●	● / +4	✓
Clearwater Volcanic Field (10 MW)	●	○	○	○	○	●	○ / +0	X
Iskut (10 MW)	●	○	○	○	●	○	○ / +1	X
Jedney Area (15 MW)	●	○	○	○	●	●	○ / +2	X
King Island (20 MW)	●	○	○	⊠	●	○	⊠	X
Kootenay (20 MW)	●	○	●	●	●	●	● / +5	✓
Lakelse Lake (20 MW)	●	●	○	●	●	●	● / +5	✓
Lower Arrow Lake (20 MW)	●	○	●	●	○	●	● / +4	✓
Meager Creek-Pebble Creek (50 - 100 MW each)	●	●	●	●	○	○	● / +4	✓
Mt. Cayley (50 MW)	●	○	○	●	●	●	● / +4	✓
Mt. Garibaldi (50 MW)	●	○	○	●	○	●	○ / +2	X
Mt. Silverthorne - Knight Inlet (50 MW)	●	○	○	⊠	○	○	⊠	X
Nazko Cone (10 MW)	●	○	●	⊠	○	○	⊠	X
Okanagan (20 MW)	●	○	○	●	○	●	● / +3	✓
Sloquet Hot Springs (10 MW)	●	○	○	●	○	●	● / +3	✓
Sphaler Creek (10 MW)	●	○	○	⊠	○	○	⊠	X
Upper Arrow (20 MW)	●	○	○	○	○	○	○ / +1	X

EXPLORATION UNCERTAINTY AND PROJECT RISK AT EACH POTENTIAL SITE

Table 3-3: Geothermal Resource Exploration Uncertainty

Geothermal Site	Development Phase	Project Risk	Cumulative Cost
Canoe Creek – Valemount	Exploration	High	<5%
Clarke Lake	Exploration	High	<5%
Clearwater Volcanic Field	Pre-Survey	High	0%
Iskut	Pre-Survey	High	0%
Jedney Area	Exploration	High	<5%
King Island	Pre-Survey	High	0%
Kootenay	Pre-Survey	High	<5%
Lakelse Lake	Exploration	High	<5%
Lower Arrow Lake	Pre-Survey	High	0%
Meager Creek	Test Drilling	High-Moderate	~15%
Pebble Creek	Test Drilling	High	~10%
Mt. Cayley	Exploration	High	<5%
Mt. Garibaldi	Pre-Survey	High	0%
Mt. Silverthrone – Knight Inlet	Pre-Survey	High	0%
Nazko Cone	Exploration	High	<5%
Okanagan	Exploration	High	<5%
Sloquet Hot Springs	Exploration	High	<5%
Sphaler Creek	Pre-Survey	High	0%
Upper Arrow	Pre-Survey	High	0%

SHORTLIST OF SITES SELECTED AS FAVOURABLE:

- Canoe Creek (CC)
- Clarke Lake (CL)
- Jedney Area (JA)
- Kootenay (K)
- Lakelse Lake (LL)
- Lower Arrow Lake (LA)
- Meager Creek (MC)
- Mt. Cayley (MtC)
- Okanagan (O)
- Sloquet Creek (SC)



ANY QUESTIONS ABOUT SELECTION OF FAVOURABLE SITES?



STEP 2 – VOLUMETRIC ASSESSMENT SAMPLE FOR CANOE CREEK

SUMMARY OF INPUT PARAMETERS

Variable Parameters

	Minimum	Most Likely	Maximum
Reservoir Area (sq. km)	1.04	2.0	3.11
Reservoir Thickness (m)	800	1100	1700
Rock Porosity	0.03		0.07
Reservoir Temperature (°C)	190	210	230
Recovery Factor	0.05		0.20

Fixed Parameters

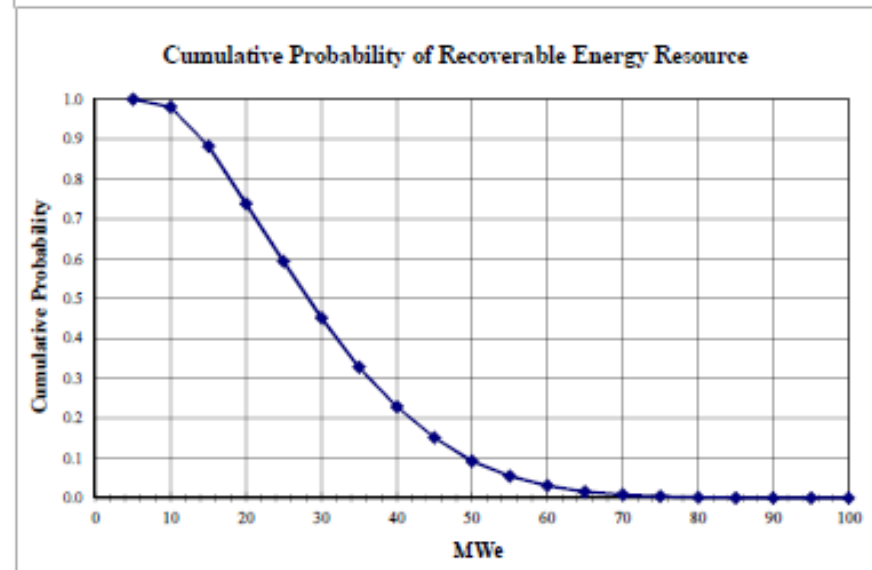
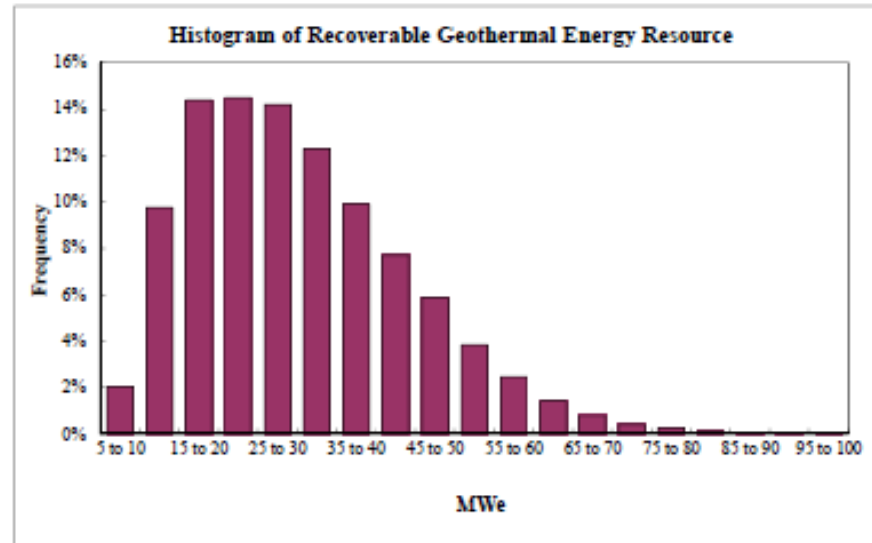
Rock Volumetric Heat Capacity	2613	kJ/cu. m°C
Rejection Temperature	15	°C
Utilization Factor	0.45	
Plant Capacity Factor	0.90	
Power Plant Life	20	years

RESULTS

	Statistics		
	MW	MW/sq. km	Recovery Efficiency
Mean	30.3	14.7	1.33%
Std. Deviation	13.7	5.7	0.46%
Minimum (90% prob.)	14.3	7.4	0.69%
Median (50% prob.)	28.3	14.3	1.32%
Most-likely (Modal)	21.4	12.6	1.59%

Canoe Creek - Valemount

Estimation of Geothermal Energy Resource



STEP 2 – SUMMARY OF VOLUMETRIC ASSESSMENT FOR FAVOURABLE SITES

Geothermal Prospect Site/Area	Plant Type	Initial MW Estimate (GDDM)	MW (gross) at 90% Probability from Volumetric Estimate	MW (net): Parasitic = 10% for Flash, 25% for Binary
Canoe Creek – Valemount	Flash	15	14.3	12.9
Clarke Lake	Binary	34	18.4	13.8
Clarke Lake (5 MW scenario)	Binary	5	-	3.8
Jedney Area	Binary	15	12.2	9.2
Kootenay	Binary	20	19.9	14.9
Lakelse Lake	Binary	20	19.6	14.7
Lower Arrow Lake	Binary	20	19.6	14.7
Meager Creek (Pebble Creek assumed equivalent)*	Flash	100-200 total (50-100 ea)	198.0 combined (99.0 ea)	178.2 combined (89.1 ea)
Mt. Cayley	Binary	50	40.7	30.5
Okanagan	Binary	20	18.3	13.7
Sloquet Creek	Binary	10	10	7.5

ANY QUESTIONS ABOUT VOLUMETRIC ASSESSMENT?



STEP 3 – ECONOMIC ASSESSMENT

Geothermal Prospect Area/Site	Transmission-Line Costs (Incl. Substations) (million CAD\$ 2015)	Road-Building Costs (million CAD\$ 2015)	Permitting & Leasing Costs† (million CAD\$ 2015)	Resource Exploration Costs** (million CAD\$ 2015)	Resource Confirmation Costs†† (million CAD\$ 2015)	Resource Development Costs*** (million CAD\$ 2015)	Power Plant Costs (million CAD\$ 2015)	Total Capital Costs (million CAD\$ 2015)	Total Cost per Gross kW Installed (CAD\$ 2015)
Ganoe Creek - Valemount	\$16.4	-	\$0.5	\$13.0	\$45.2	\$51.2	\$43.8	\$170.1	\$11,900
Clarke Lake	\$14.4	-	\$0.5	\$15.9	\$52.6	\$54.5	\$67.3	\$205.2	\$11,200
Clarke Lake (5 MW scenario)	\$1.5	-	\$0.5	\$5.3	\$16.5	\$20.1	\$19.3	\$63.3	\$12,700
Jedney Area	\$34.5	-	\$0.5	\$10.6	\$36.3	\$42.6	\$45.3	\$169.8	\$14,000
Kootenay	\$10.2	-	\$0.5	\$10.6	\$33.1	\$46.2	\$72.7	\$173.3	\$8,800
Lakelse Lake	\$12.2	-	\$0.5	\$10.6	\$33.1	\$45.0	\$72.1	\$173.5	\$8,900
Lower Arrow Lake	\$13.7	-	\$0.5	\$10.6	\$33.1	\$45.4	\$71.6	\$174.9	\$9,000
Meager Creek (Pebble Creek assumed equivalent)	\$13.2	\$1.0	\$0.5	\$30.0	\$85.9	\$263.4	\$172.5	\$566.5	\$5,800
Mt. Cayley	\$30.6	-	\$0.5	\$10.6	\$33.1	\$80.3	\$110.0	\$265.2	\$6,600
Okanagan	\$12.3	-	\$0.5	\$10.6	\$33.1	\$42.0	\$67.0	\$165.6	\$9,100
Sloquet Creek	\$2.1	-	\$0.5	\$7.0	\$22.9	\$21.5	\$28.6	\$82.6	\$8,300

STEP 3 – LCOE FOR FAVORABLE SITES

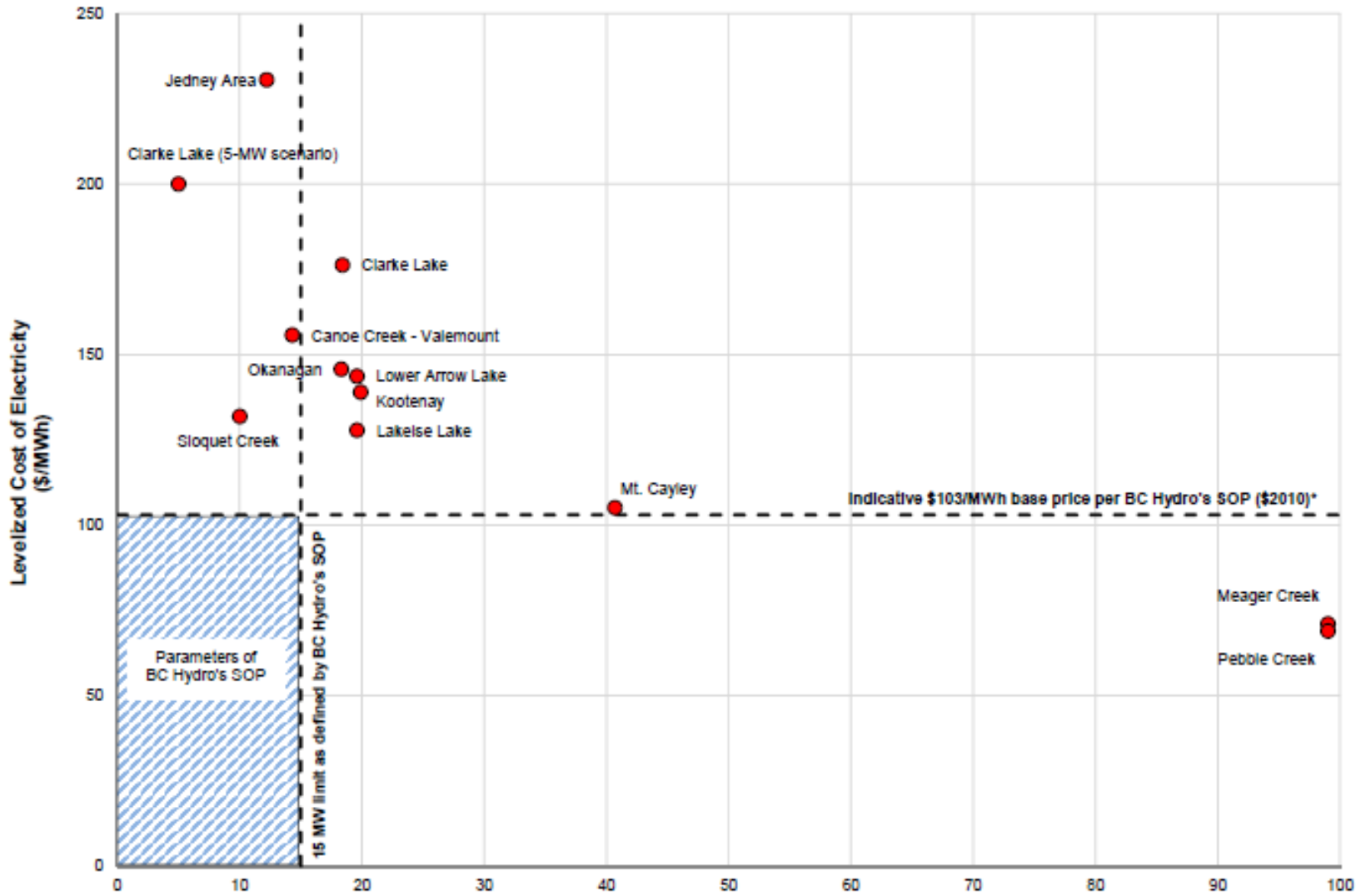


Figure 7-2: Geothermal Resources - LCOE vs Capacity

MW (gross)

* Varies by region of BC, escalation and time of day and month

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NEXT STEPS

- Full report now on the website at www.geosciencebc.com/s/Report2015-11.asp
- Provide written comments to Alex Tu by August 7th
- BC Hydro will consider input and finalize update – September

Contact information

- Alex Tu Alex.tu@bchydro.com
- IRP inbox integrated.resource.planning@bchydro.com

General information

- www.bchydro.com/generationoptions

THANK YOU