

Geothermal Technical Supplement

October 2016

Summary

GeoscienceBC and BC Hydro jointly sponsored a consultant's report, "An Assessment of the Economic Viability of Selected Geothermal Resources in British Columbia" released July 2015. The report summarizes the publicly available research and data for 18 prospective sites, and provides an estimate of generation potential and project costs for the 11 most favourable. A [revision of the report](#) was issued March 31, 2016, to correct an error in the way levelized costs of energy (LCOE¹) were calculated, with the revised report's range of costs increasing to \$117–\$398/MWh from \$71–\$230/MWh in the original report. Although the lifecycle costs of energy are significantly increased, there was no change in project capital costs, operating and maintenance (OMA) costs or energy production values in the revised report. Feedback on the original report from geothermal industry stakeholders suggested that a sensitivity analysis of the project costs was warranted due to the uncertainty of some of the underlying cost assumptions. In response, a sensitivity analysis was undertaken to generate a range of unit energy costs for each of the 11 favourable sites. Based on the sensitivity analysis, the updated range of geothermal costs is \$77–\$398/MWh.

Conclusions of the Revised Consultant's Report

- The initial July 2015 report contained an error in the depreciation schedule, which is an input into the calculation of LCOE. The revised report contains the correct depreciation schedule as well as the resulting LCOE, which are materially different from the original report.
- Based on an economic analysis of each site using the Geothermal Electricity Technology Evaluation Model (GETEM), the LCOE range from 117 CAD\$/MWh at Pebble Creek to 398 CAD\$/MWh at Jedney
- Assumptions about the cost of drilling have a significant impact on LCOE. The costs for Pebble Creek (with a base cost of 117 CAD\$/MWh) are 78 and 152 CAD\$/MWh when drilling costs are tested at 50% and 150% of base case, respectively.

Stakeholder Feedback from Original Consultant's Report

The BC Hydro Technical Engagement Summary describes the engagement process and the feedback received. One stakeholder provided a detailed review of the economic assumptions made in the consultant's report, with illustrations of how different economic assumptions result

¹ Levelized Cost of Energy (LCOE) and Unit Cost of Energy (UEC) are two largely interchangeable terms to describe the cost of energy over the lifetime of a project. The LCOEs in the consultant's report are calculated using a post-tax discounted cash-flow analysis. Within the Resource Options Report, BC Hydro uses a comparably simple analytical model to calculate UECs.

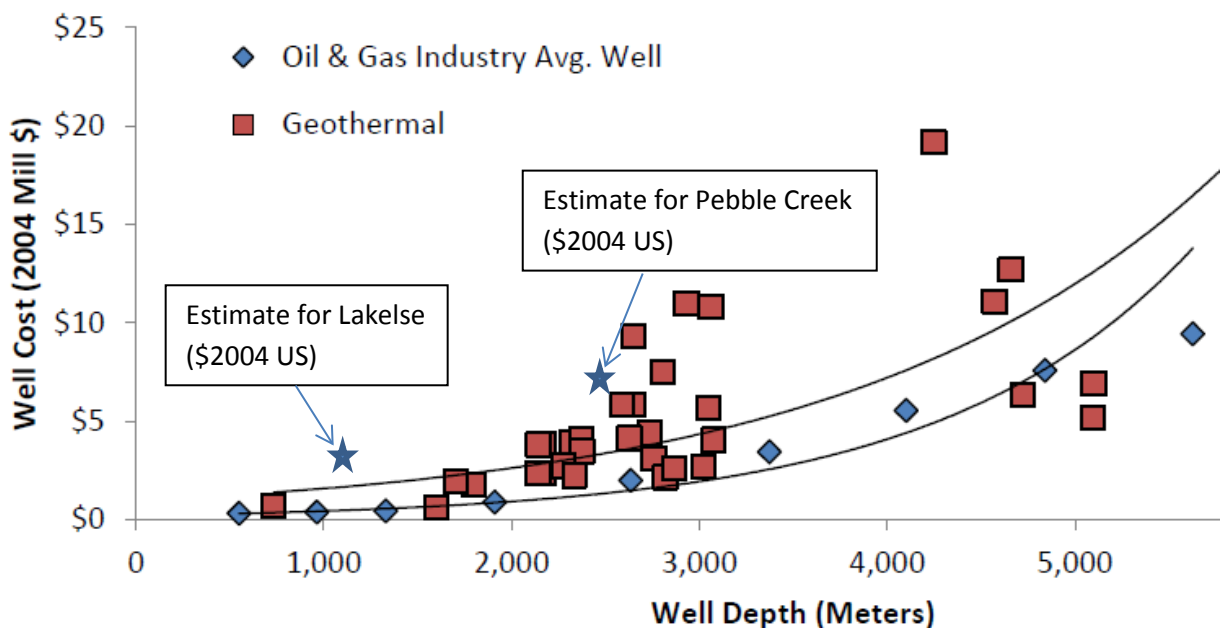
in very different energy costs. BC Hydro has considered this feedback, and recognizing the high-degree of uncertainty in the cost of geothermal development in B.C., a high-level sensitivity analysis of the energy costs was conducted to generate a range of potential energy costs for each of the 11 sites.

BC Hydro Sensitivity Analysis

The consultant provided to BC Hydro the complete GETEM worksheets for each economic assessment. GETEM requires the user to enter the assumed characteristics of the geothermal resource and project development process, and then calculates the LCOE based on a post-tax discounted cash flow model. The GETEM worksheets allow the user to investigate the impact on capital costs, OMA costs and LCOE from changes in the assumptions.

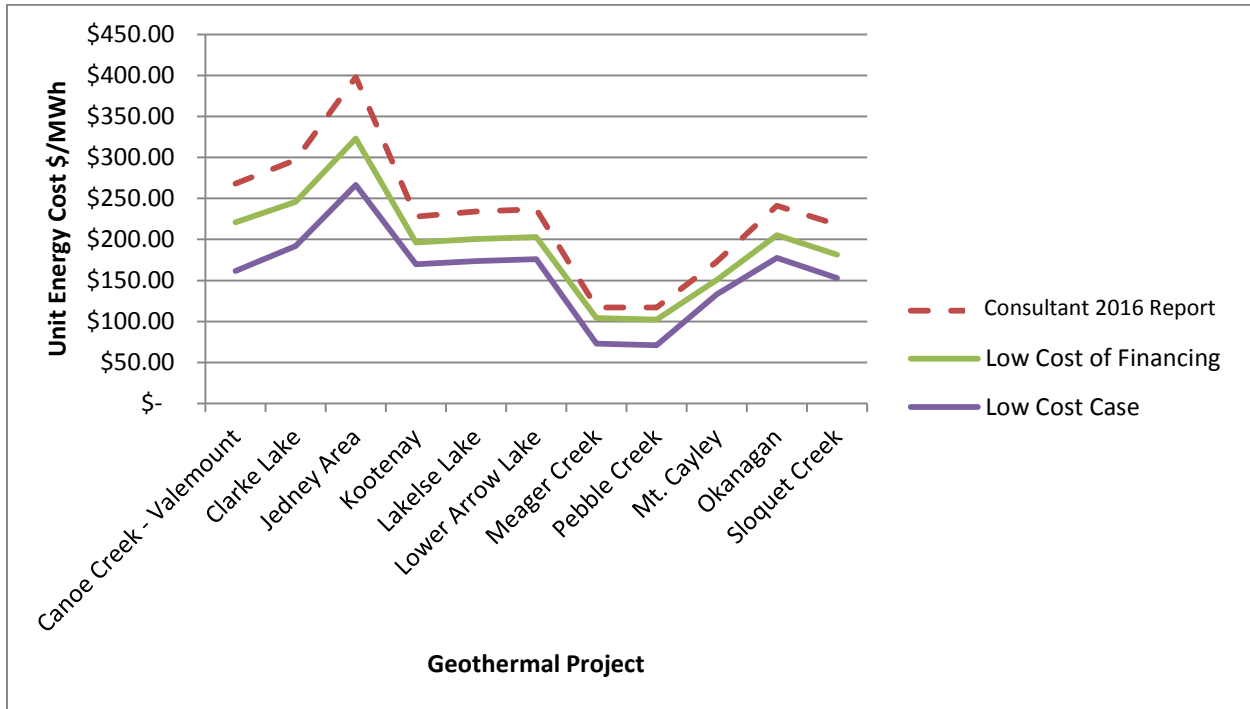
BC Hydro investigated the impacts on project costs from changes to the economic assumptions highlighted in stakeholder feedback. The findings indicate that the energy cost is highly sensitive to the uncertainty of drilling costs, drilling success and financing costs, and not as sensitive to uncertainty of permitting or equipment costs.

A historical review of the costs of geothermal drilling show a wide variability in the costs of drilling – especially pronounced for wells deeper than 2500m. The figure below shows the costs in \$2004 of 34 geothermal wells drilled to various depths between 1972 and 2004². Plotted on the same figure are the estimates produced by the consultant of drilling costs for select B.C. projects in \$2004 US. The consultant estimates of drilling costs appear at the high end of the historical range, supporting a sensitivity analysis around lower drilling cost assumptions.



² Goldstein and Braccio, "The 2013 Geothermal Technologies Market Trends Report", 2014

BC Hydro has calculated the UEC for each of the 11 favourable sites under different assumptions. The figure below plots the consultant report's LCOE alongside the BC Hydro calculated UEC for two sensitivity cases. The cost of energy for geothermal projects range from \$77–\$398/MWh.



Assumptions	Drilling Cost	Financing Cost	Drilling Success Rate
Consultant 2016 Report	“High” costs of drilling as per GETEM	30% for early stages of development, declining to 7% at plant start up	60% for confirmation stage; 80% for well field development
Low Cost of Financing Case	Same as Consultant 2016 Report	5% flat financing rate	Same as Consultant 2016 Report
Low Cost Case	“Low” costs of drilling as per GETEM	5% flat financing rate	90% for confirmation stage; 90% for well field development