McCullough Research

Robert F. McCullough, Jr.
Principal

Date: September 13, 2017

To: British Columbia Utilities Commission

Copy: Peace Valley Landowners Association and
Peace Valley Environment Association

From: Robert McCullough

Subject: What We Have Learned About Site C

I. Executive Summary

Key Findings:

1. Terminating Site C and building a renewable portfolio of wind, solar and geothermal would save British Columbia $.7 to $ 1.6 Billion. Greater savings could be achieved by including upgrades to existing hydro facilities. The savings would be even greater if Site C is not on time and on budget ($1.5 to $5.9 Billion) or if demand for electricity is less than BC Hydro's overstated load forecast requiring more power to be exported at a loss.

2. Site C is not needed to act as a back-up battery for times when intermittent resources such as wind and solar are unavailable. The Williston reservoir already plays this role.

3. If Site C were completed, BC Hydro will almost certainly lose money on any exports of surplus electricity to the United States.

4. The findings of Deloitte LLP on Site C delays, cost overruns, and electricity demand and energy generation alternatives are consistent with our findings and the findings of other acknowledged energy experts.

The effort to develop Site C on the Peace River has been underway for almost thirty years. Curiously, the project failed to pass elementary economic tests in the 1980s and continues to fail them today. Stripped of the complexity of British Columbia Hydro's (BCH) documentation, the project is largely a run of river project downstream from the largest single reservoir in British Columbia and the Pacific Northwest– the Williston.[1]

The cost of Site C is high – approximately C$8.8 billion *even if it's on budget*. Approximately 20% of the project is completed, so the actual "go ahead" value is only C$7.0 billion. Given a nameplate capacity of 1,100 MW, Site-C's cost per kilowatt is approximately C$6,340; far more expensive than an equivalent capacity wind farm.

On Friday, September 8, 2017, Deloitte issued two complex technical reviews of British Columbia Hydro's Site C project. The first reviews the construction plans, contracts, and progress at the project. The second report opines on the load forecast, resource alternatives, and overall modeling.

The two reports largely agree with the thousands of pages of submissions submitted by opposing third parties to the British Columbia Utilities Commission on or before August 30, 2017, although a number of Deloitte's estimates are more favorable to Site C than official estimates from elsewhere in the U.S. and Canada.[2]

The basic questions asked by the BCUC have been answered by Deloitte's second report – it is possible to build a renewable based portfolio that meets the province's standards. Interestingly, even if Deloitte's corrections to BCH's load forecast are not used, the best marginal resource is wind – an almost inexhaustible resource in the Pacific Northwest. Deloitte also tags hydroelectric upgrades, geothermal and solar as viable alternatives to more hydroelectric projects.

The only relevant question is whether the renewable resources in the Deloitte portfolio are less expensive than Site C. This is a relatively easy question to answer.

---

[1] "The Project reservoir, with a normal operating range of 1.8 m and an active storage volume of 0.4 per cent of the active storage volume of Williston Reservoir, does not have sufficient storage volumes to provide seasonal shaping of generation. The upstream regulation at Williston Reservoir allows the Project to generate electricity to match the timing of BC Hydro customer demand without the need to establish another large multi-year storage reservoir similar to Williston Reservoir. As a result, the Project is able to produce approximately 35 per cent of the energy produced by the G.M. Shrum generating station with 5 per cent of the reservoir area."
BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, pages T-2 and T-3.

[2] Wind is a good example. Although expansion of wind resources is proceeding rapidly elsewhere in North America, British Columbia Hydro has determined these options are not feasible in British Columbia. Neighboring (and similar) jurisdictions like the U.S. states of Oregon and Washington have developed ten times the level of existing wind capacity as British Columbia at considerably less than British Columbia Hydro's assumed costs.

The chart below shows the comparable costs of renewables and Site C from the Deloitte research which gave estimates in a range. Appendix A in this report provides the detailed calculations. The chart describes the average of the high and low scenarios.

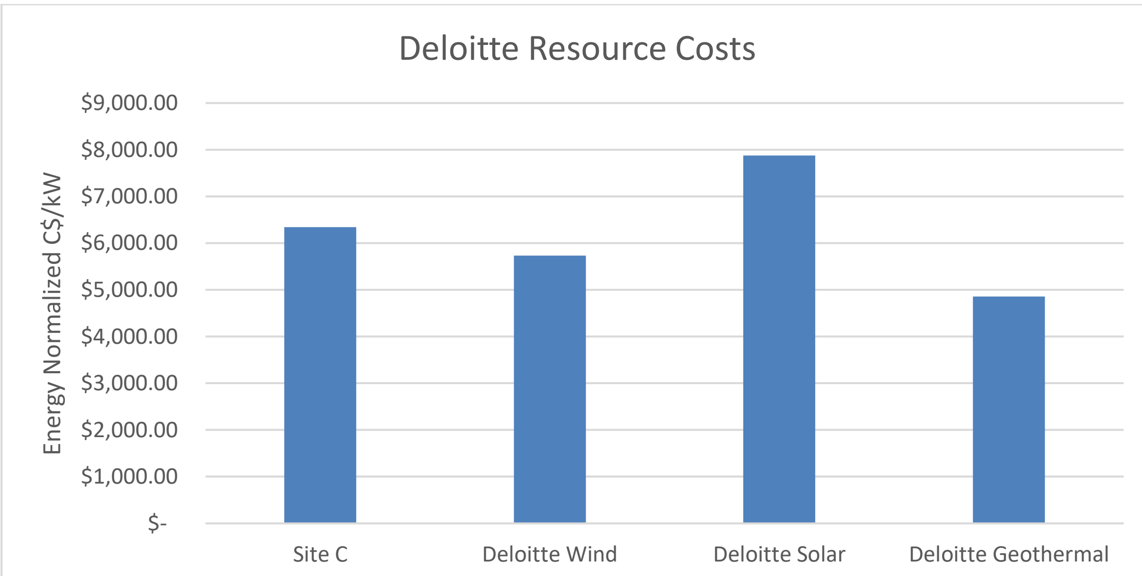


Figure 1: Deloitte Resource Costs

The basic premise of this chart is to compare the output of four different resources – Site C with an average availability of 53%, on-shore wind with an availability of 30%, utility scale solar with an availability of 20%, and geothermal with an availability of 92%.[3] Similarly, the high and low costs for capacity from these resources are taken from Deloitte's second report.[4]

Site C termination costs are a necessary burden for abandoning Site C and having the opportunity to purchase alternative less expensive resources, so these have been added to the costs of on-shore wind, solar, and geothermal.

Since each resource can provide a different amount of energy for each kilowatt of capacity, the cost of capacity has been adjusted to reflect the same annual level of energy output as Site C.

[3] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, pages 18, 22, 23, and 39.
[4] Ibid., pages 18, 22, 23, and 39.

The question of how accurate the Deloitte analysis is can easily be addressed by comparing it to other authoritative sources. Similar estimates from the U.S. Energy Information Administration generate similar results.[5]

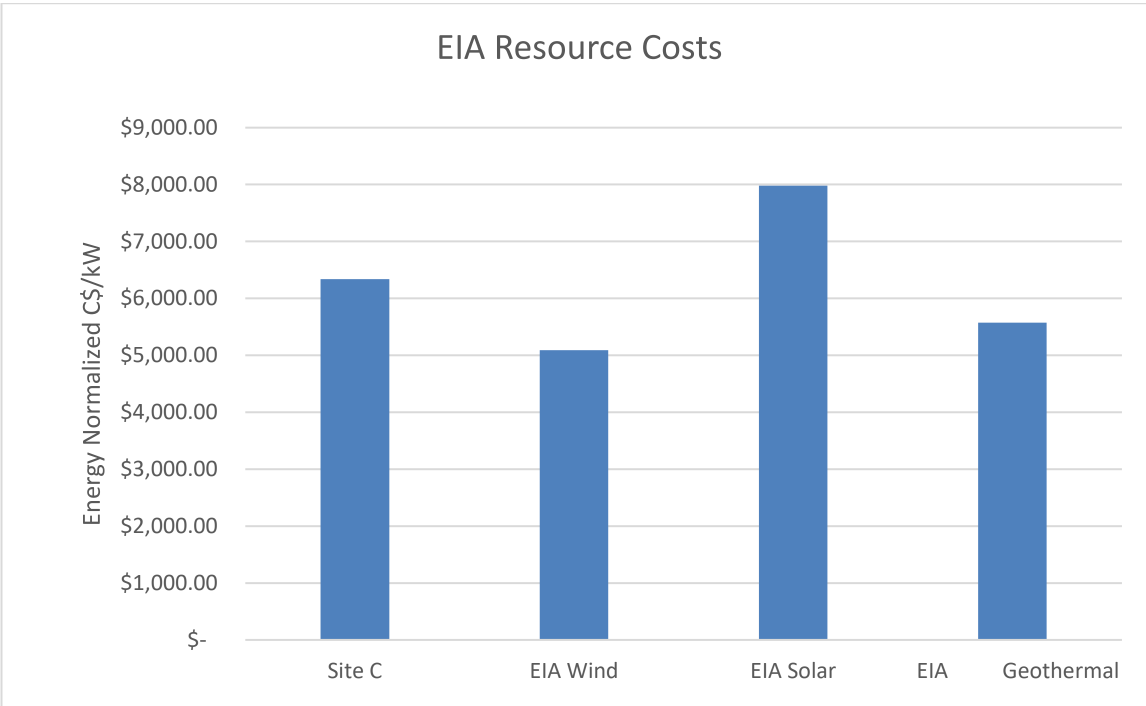


Figure 2: EIA Resource Costs

These two charts show that two authoritative sources indicate we have renewable resource alternatives providing the same amount of energy at lower costs for wind and geothermal.[6]

The bottom line is that Deloitte's alternative portfolio is feasible and it includes less expensive resources than Site C. The cost differentials are not small – if Site C was replaced primarily by geothermal, the savings would be on the order of C$1.6 billion.

[5] Capital Cost Estimates for Utility Scale Electricity Generating Plants, U.S. Energy Information Administration, November 2016, pages 7, 9, and 11.

[6] The second Deloitte report has an extensive discussion of various resource options. Their analysis shows that geothermal is commercially viable and an effective choice for British Columbia. See for example Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 23.

	Savings to British Columbia	
Continue Site C	$	-
All Geothermal	$	1,633,447,939.79
All Wind	$	666,158,156.91
Half Geothermal/Half Wind	$	1,149,803,048.35

It should be noted that all four potential resources possess a degree of intermittency. Site C, as a primarily run of river project, faces annual and seasonal run off risk. Wind and solar have daily availability risk. Geothermal is less intermittent than the others, but has also faced varying output levels.

Contents

Figures:

II. British Columbia Hydro's August 30, 2017 Submission

British Columbia Hydro's 886 page submission is basically a recapitulation of previous materials. Little attention has been given to the dramatic changes in the industry ranging from changes in resource prices and power markets.

The fundamental economic argument is presented on page 62:

Cost Factor	Unit Energy Cost $/MWh
Site C Cost To Ratepayers in 2013 Integrated Resource Plan (November 2013) at Point of Interconnection in F2013$	**$83**
Change to project capital and operating costs	+1
Debt Finance as per OIC No.590-2016 Net Income Frozen	-26
Site C Cost To Ratepayers at Final Investment Decision (December 2014) at Point of Interconnection in F2013$	**$58**
Updated financing rates and conversion to F2018$	-10
Adjustment for Delivery to Lower Mainland and annual shape adjustment	+10
Site C Cost To Ratepayers Today Delivered to Lower Mainland in F2018$	**$58**
Adjustment For Sunk Costs	-15
Site C Cost To Ratepayers Today Less Sunk Costs	**$43**

Cost Factor	Unit Energy Cost $/MWh
Delivered to Lower Mainland in F2018$	
Credit for avoiding termination and site remediation costs	-9
Site C Cost To Ratepayers Today Less Sunk Costs and Credit for Termination / Remediation Costs Delivered to Lower Mainland in F2018$	**$34**

Figure 3: Site C UEC

British Columbia Hydro has never publicly documented the values in this chart – either in the current submission or previous submissions. The $83/MWh does not match more commonly accepted Levelized Cost of Energy (LCOE) calculations used elsewhere in the industry. The most important adjustment is highlighted above – a $26/MWh reduction due to 100% debt financing.

There is a strong sense of sleight of hand in this calculation. British Columbia Hydro is a branch of the government of British Columbia, and so lenders will simply require coverage of the debt payments out of the provincial budget. Somebody has to pay that $26/MWh, and all evidence points to the fact that British Columbia ratepayers will have to foot the bill. In the end, regardless of the descriptions, the bill for Site C must be borne by British Columbia.

British Columbia Hydro uses an idiosyncratic approach to calculating levelized resource costs called the "UEC" or "Unit Energy Cost." The industry uses a similar measure called the Levelized Cost of Energy. As far as can be determined, British Columbia Hydro has never published the calculations behind Site C's UEC estimates which had reached a high of $88/MWh in 2013 dollars but has since fallen to $83/MWh in 2016 dollars.[7,8]

An alternative approach is to use the industry standard measure, the Levelized Cost of Energy with data from the U.S. Energy Information Administration. Estimates of the LCOE can be calculated at C$100/MWh to $C105/MWh.[9]

On Page 64 of British Columbia Hydro's submission there a chart showing Site C's UEC compared to forecasted Mid-Columbia market prices. The chart purports to indicate that Site C may be marketable into the spot market at a profit.[10]

However, British Columbia Hydro's submission compares market prices with rate payer's costs – not total costs – and assumes, without justification a continuing growth in Mid-Columbia prices.

[7] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, page 62.
[8] Integrated Resource Plan Appendix 3A-34 2013 Resource Options Report Update Appendix 12, British Columbia Hydro, 2013, November page 9.
[9] Costs of Continuing Site C and the Alternatives, Robert McCullough, August 30, 2017. page 7.
[10] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, page 64.

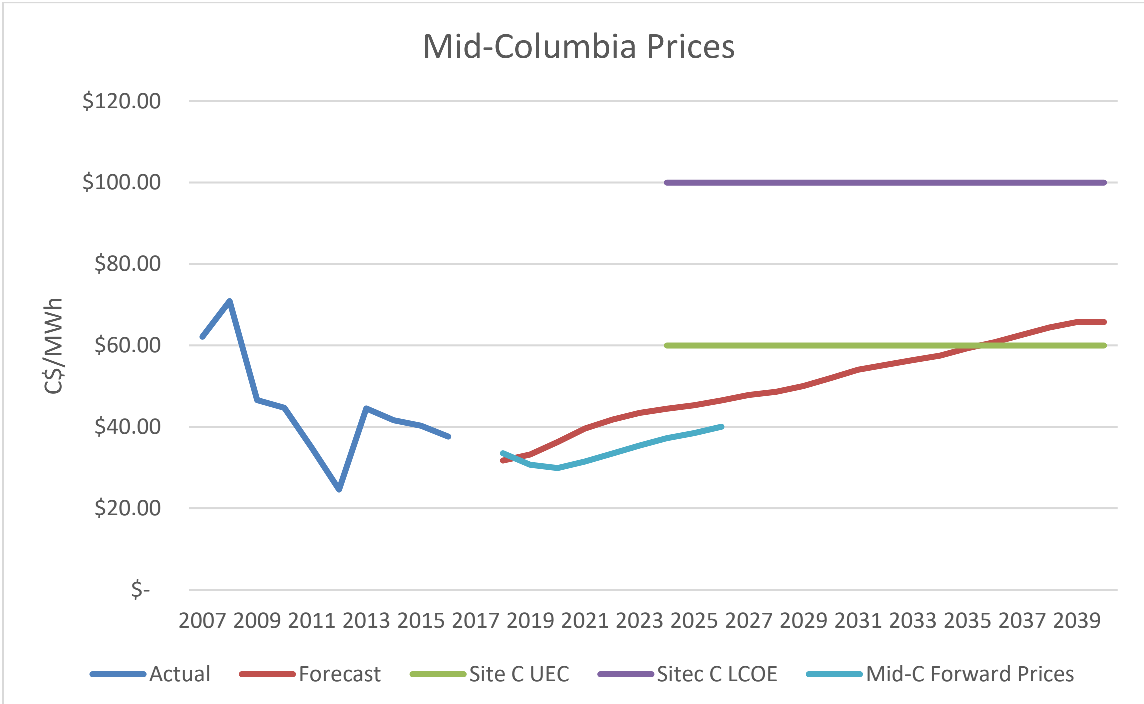


Figure 4: Mid-Columbia Prices

Actual on-peak prices (shown in blue) from the InterContinental Exchange (in Canadian dollars) are considerably below British Columbia Hydro's forecasts.[11]

The UEC of Site C is above British Columbia Hydro's forecast of Mid-Columbia prices until 2035. Using the Levelized Cost of Energy (LCOE) for Site C, the prices at Mid-Columbia would never be high enough to market the project.

British Columbia Hydro's analysis of alternative resource costs continues to be idiosyncratic. While B.C. Hydro asserts that wind is not economic in its submission, this is at odds with industry experience elsewhere in North America.

[11] https://www.theice.com/marketdata/reports/12

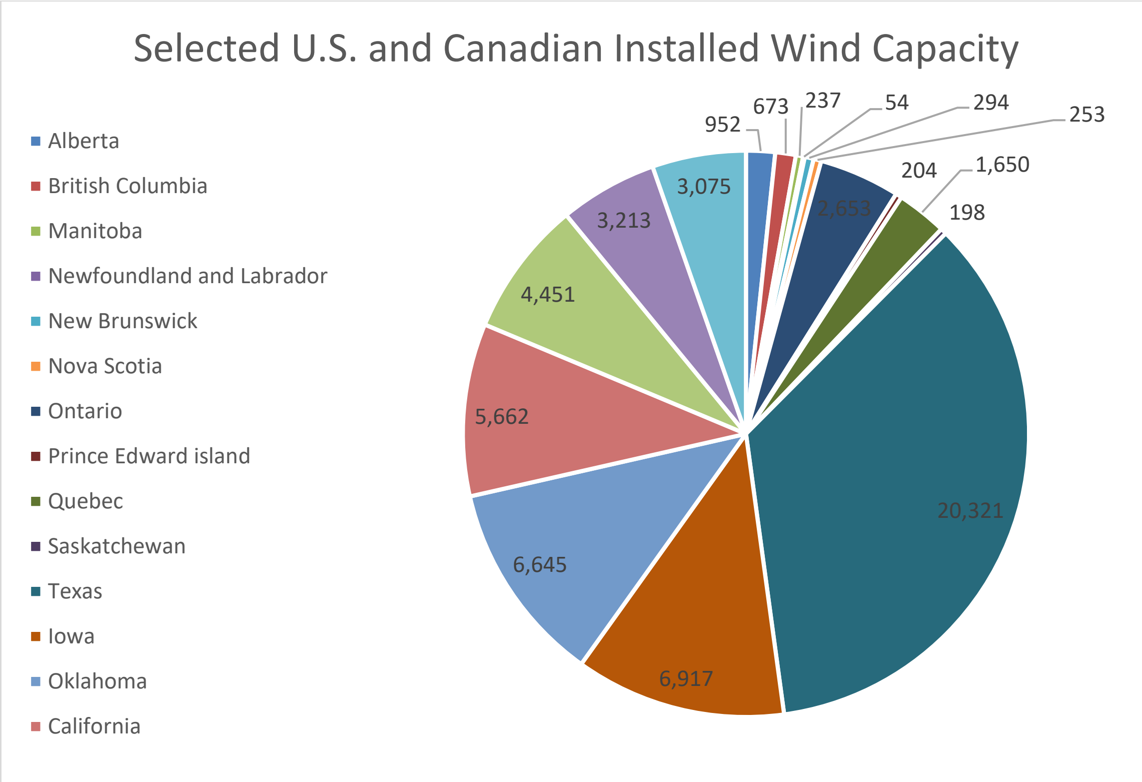


Figure 5:Selected U.S. and Canadian Installed Wind Capacity

III. Deloitte Reports

On Friday, September 8, 2017, financial consultant Deloitte LLP issued two complex technical reviews of British Columbia Hydro's Site C project. The first reviews the construction plans, contracts, and progress at the project. The second report opines on the load forecast, resource alternatives, and overall modeling.

The two reports largely agree with the thousands of pages of submissions submitted by opposing third parties to the British Columbia Utilities Commission on or before August 30, 2017, although a number of Deloitte's estimates are more favorable to Site C than official estimates from elsewhere in the U.S. and Canada.[12]

[12] Wind is a good example. Although expansion of wind resources is proceeding rapidly elsewhere in North America, British Columbia Hydro has determined these options are not feasible in British Columbia. Neighboring (and similar) jurisdictions like the U.S. states of Oregon and Washington have developed ten times the level of existing wind capacity as British Columbia at considerably less than British Columbia Hydro's assumed costs.

Key Deloitte Findings:

On Delays and Cost Overruns

Deloitte found that the Site-C dam faces a significant risk of missing a 2019 deadline for starting river diversion.[13] Missing this deadline has significant cost implications for BC Hydro, and can add upwards of $0.8 to $4.3 billion to the currently accepted construction cost. [14]

Canadian hydroelectric dams have a history of significant delays and cost overruns. Recent projects in Manitoba and Newfoundland had cost overruns of 55% to 90%.[15]

On Energy Demand

Deloitte studied previous demand forecasts made by BC Hydro and found that they over-estimate demand for electricity by nearly 30.8%.

Deloitte's revised forecast shows that Site C is not needed. Put another way, the amount by which BC Hydro has exaggerated forecast demand for electricity is larger than the capacity and energy provided by Site C – 1,100 MW and 5,100 GWh respectively. Despite this, both Deloitte and BC Hydro forecast higher inputs for the demand for electricity than Bloomberg, Wood Mackenzie, ABB Power and PIRA Energy. That implies that the need for Site-C is even less justified than Deloitte assumes.

On Alternatives to Site C

Deloitte used their revised electricity demand forecast and power generation options to produce an environmentally friendly and less costly power generation portfolio by upgrading hydroelectric facilities and building wind and geothermal power plants. Even taking into account the sunk costs of Site-C, Deloitte's portfolio is significantly less expensive than finishing Site-C construction.

In addition, Deloitte estimated larger capital costs for wind projects than Lazard or the EIA.[16] This implies that, even with conservative estimates of wind costs, that wind investments are a better option than Site-C.

[13] Site C Construction Review, Deloitte, September 8, 2017, page 16.
[14] Site C Construction Review, Deloitte, September 8, 2017, page 16.
[15] Ibid., page 36.
[16] Energy information Administration.
Capital Cost Estimates for Utility Scale Electricity Generating Plants. November 2016. Accessed September 10, 2017

Report 1: Deloitte's Site C Construction Review

Overall, Deloitte reports that Site C is likely to miss the 2019 Start of River Diversion. Deloitte predicts a possible delay costing as much as $.8 to $4.3 billion.[17] Although this possible milestone delay is pivotal, the British Columbia Hydro submission makes passing references to it – none of which specifically addresses the significance or the potential cost.[18]

Suspending the project will cost $1.4 billion.[19] British Columbia Hydro estimates that suspension will cost $1.2 billion.[20]

Deloitte estimates that terminating the project will cost $1.2 billion, which is approximately the same estimate made by BC Hydro.[21,22]

Deloitte found substantial evidence that Canadian hydroelectric dams usually experienced significant delays and cost overruns – summarizing recent projects in Manitoba and Newfoundland with overruns ranging from 55% to 90%.[23] British Columbia Hydro rejected the peer-reviewed research on the issue as being "swayed by outliers" with no mention of recent and current Canadian projects.[24]

Report 2: Deloitte's Site C Alternative Resource Options and Load Forecast Assessment

The second report is even more critical of British Columbia Hydro's analyses, but significantly more complex to read. The primary conclusions are:

Deloitte extensively documents the upward bias of previous British Columbia Hydro forecasts citing overestimates from past forecasts:

- by 4.5% of actual loads over five years,
- 12.2% of actual loads over ten years,

[17] Site C Construction Review, Deloitte, September 8, 2017, page 2.
[18] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, pages 35 and 37.
[19] Site C Construction Review, Deloitte, September 8, 2017, page 3.
[20] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, page 5.
[21] Site C Construction Review, Deloitte, September 8, 2017, page 4.
[22] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, page 62.
[23] Site C Construction Review, Deloitte, September 8, 2017, page 36.
[24] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, Appendix T, page 6.

- 15-year forecasts were overestimated on average by 18.0% of actual loads,
- forecasts were overestimated on average by 30.8% of actual loads over twenty years.[25]

Deloitte's more accurate load forecast indicates that capacity loads will be lower by 1,140 to 1,160 megawatts, and corresponding energy loads are overstated by 6,000 to 6,500 GWh.[26,27] The exaggerated British Columbia Hydro forecasts are actually larger than the capacity and energy provided by Site C – 1,100 MW and 5,100 GWh.[28] However, BC Hydro maintains that their forecasts are dependable despite all of the evidence to the contrary.

Both forecasts – Deloitte and British Columbia Hydro are likely to be higher than actual loads since British Columbia Hydro loads have been flat for the past decade and a return to rapid growth seems doubtful given challenges facing British Columbia's paper and LNG sectors. Alternative load forecast inputs provided by Bloomberg, Wood Mackenzie, ABB Power and PIRA Energy are lower than British Columbia Hydro's.[29]

Deloitte identified a wide variety of resources generally not described in British Columbia Hydro's submissions. The most significant of these are additions to existing hydro projects that can be implemented at much lower costs.[30]

Backed by extensive research, Deloitte questions British Columbia's rejection of wind and geothermal projects.[31] Deloitte maintains a less positive view of the price of wind power than authorities in the United State who estimate that prices have fallen 65% since 2010.[32]

Finally, Deloitte used their load forecast and revised resources to produce an environmentally friendly and potentially less costly resource portfolio that does not include Site C.[33]

---

[25] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 63.
[26] Ibid., page 6.
[27] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 6.
[28] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, Appendix P, page 12.
[29] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 74.
[30] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 40.
[31] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 39.
[32] For example, "Levelized Cost of Energy Analysis – Version 9.0.", Lazard, December 2016, page 3.
[33] Site C – Alternative Resource Options and Load Forecast Assessment, Deloitte, September 8, 2017, page 113.

It should be noted that Deloitte has not provided an apples-to-apples comparison with British Columbia Hydro's portfolio, but the components in their portfolio are less expensive than those chosen by British Columbia Hydro and it is rational to expect that the entire portfolio will be less expensive than Site C.

IV. Alternative Resource Costs

On a cost basis, hydroelectric greenfield generation can no longer compete favorably with renewable energy (or natural gas). While natural gas prices plummeted over the past decade, very importantly the cost of renewables also fell – sharply – as economies of scale in wind and solar dominated the market. Once thought to be too expensive, renewables are becoming a viable option for utilities. The cost effectiveness of renewable resources has traditionally been controversial. However, numerous recent studies indicate that renewables are now competitive with hydro generation. As John Maynard Keynes once quipped, "When my information changes, I alter my conclusions. What do you do, sir?"

Prices for renewables are still higher than spot wholesale market prices, but they have fallen sharply enough that they are now below the operating costs of new hydropower, existing nuclear and new coal. Figure 1, taken from a 2016 report by the Under Secretary of the U.S. Department of Energy (DOE), illustrates the cost reductions in renewable prices since 2008.[34]

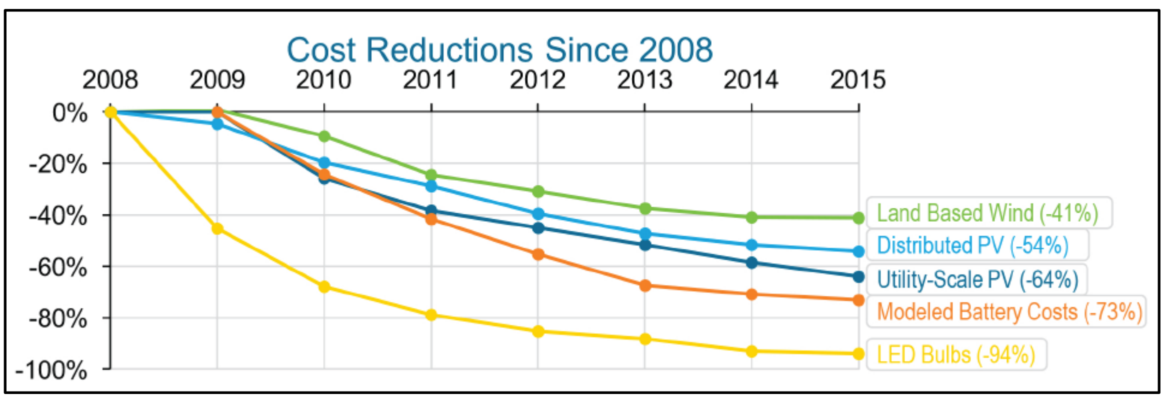


Figure 6: Indexed Cost Reductions Since 2008

In light of the changing landscape for energy, this report explores the cost effectiveness of adding renewable energy to the Pacific Northwest and British Columbian grid.

[34] Donohoo-Vallett, Paul et al. "Revolution… Now – 2016 Update." U.S. Department of Energy. Accessed October 5, 2016. p 1.

Significant expansion of renewable generation, especially for solar photovoltaics (PV) and onshore wind, is both plausible and economically sound. Economies of scale, technological innovation, "learning by doing" effects, and fuel price movements for conventional generation have brought significant reductions in the relative cost of solar PV and wind installations, and have made them economically competitive with conventional fossil fuel generations, even without subsidies.

Because renewable energy is such a rapidly advancing industry, the best possible cost projection should use up-to-date estimates like those derived by Lazard, rather than retrospective LCOE estimates. Lazard's LCOE figures have historically tracked closely with estimates by EIA and the National Renewable Energy Laboratory (NREL), which together are the three most authoritative and frequently updated sources.[35] See Figure 3. Rather than directly comparing reported LCOEs, NREL applies a consistent calculation methodology to each group's assumptions; report writer Wesley Cole notes, "Because of differences in financing assumptions, construction schedules, capacity factors, fuel prices, etc., directly comparing the reported LCOE values is not very meaningful. The calculated ranges shown here are calculated using the same methodology and assumptions in order to avoid differences due to financing, etc."[36] The results show largely similar results between the three groups.

[35] Cole, Wesley et al. "2016 Annual Technology Baseline." NREL. September 2016. Accessed February 3, 2017. <http://www.nrel.gov/docs/fy16osti/66944.pdf>. See page 130.
[36] Ibid. See page 130.

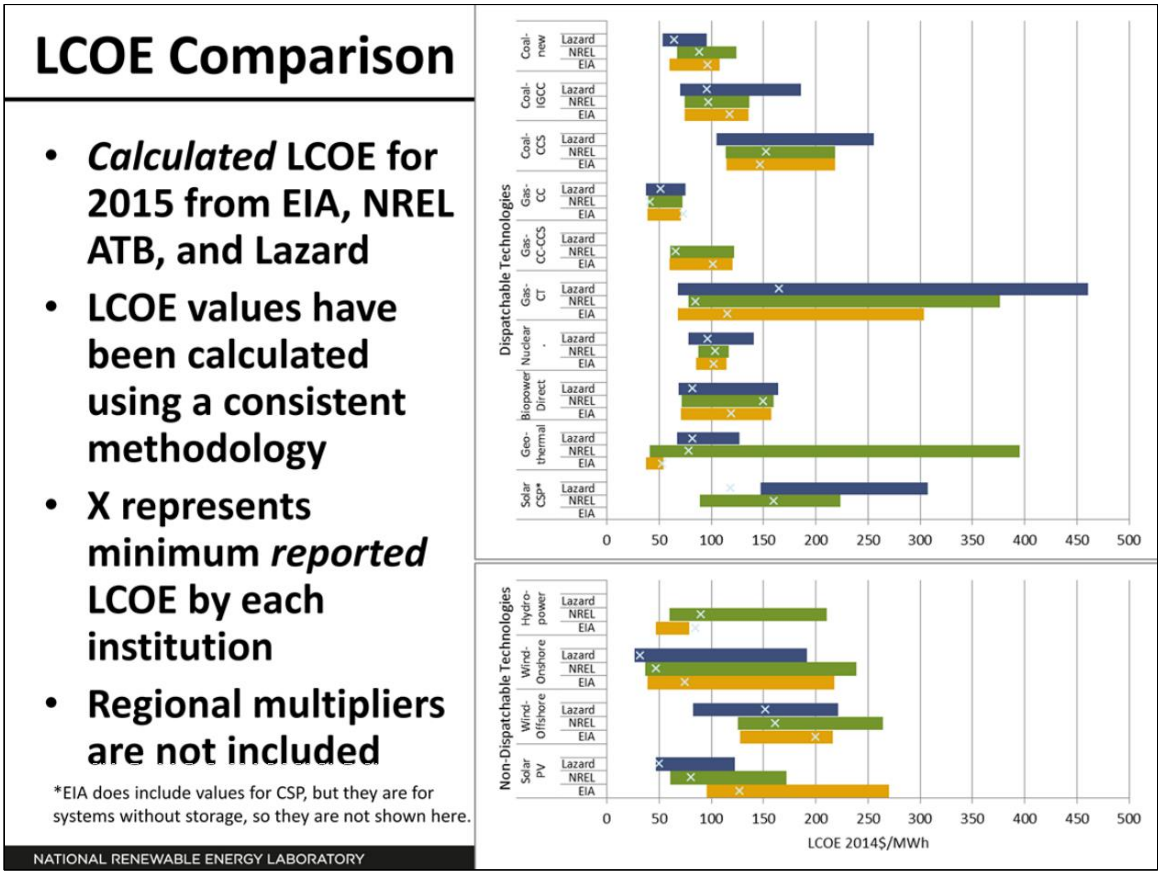


Figure 7: NREL Comparison of LCOE Calculations

The capital costs for solar PV and wind installation are already lower than those for new coal or nuclear generation, and are approaching those of natural gas. Figure 8 presents estimates of the overnight capital cost for installing a number of renewable and conventional generation types, as reported by Lazard.

As alternative sources of electricity come of age, the need for new large hydroelectric projects continuously decreases. In the past, large expenditures on concrete dams were justified by the low price per MWH after initial construction costs had amortized, but wind and solar power can now deliver an even lower price per MWH with less initial construction expenditure. Below is a figure demonstrating that the capital costs of wind and solar projects is substantially cheaper than building hydroelectric dams like Site C.

Capital Costs (2016 $/kW)[37]	Lazard LCOE Analysis (2016)[38]	Lazard LCOE Analysis (2017 estimate)[39]	V. John White and Associates and James Caldwell[40]	EIA American Energy Outlook 2017[41]	NREL RE Futures (2030 Estimate)[42]	NREL RE Futures (2050 Estimate)[43]
Utility-Scale Solar PV (crystalline)	$1,903.71-$2,200.00	$1,713.35	$1,926.31	$3,147.48	$3,238.93	$2,846.33
Utility-Scale Solar PV (thin film)	$1,776.80-$2,030.63	$1,713.35	$1,926.31	$3,147.48	$3,238.93	$2,846.33
Wind	$1,586.43-$2,157.55			$2,086.18	$2,636.00	$2,636.00
Nuclear	$6,853.70-$10,407.00			$7,757.50		
Gas Combined Cycle	$1,269.15-$1,649.89			$1,214.34		
Coal	$3,807.95-$10,660.65			$6,475.63		
Hydroelectric				$3,062.50	$4,911.65-$7,718.31	$4,911.65-$7,718.31

Figure 8: Overnight Capital Cost for Installation of Conventional and Renewable Energy Sources in C$

Despite this, some argue that the Site-C project can still be justified by having a lower variable cost per MWH than wind and solar. Levelized Cost of Energy analysis by the EIA, however, dispels this notion.

[37] All estimates adjusted to 2016 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. Accessed August 30, 2016.
[38] Lazard. "Levelized Cost of Energy Analysis – Version 10.0." December 2016. Accessed August 28, 2017.
[39] Lazard. "Levelized Cost of Energy Analysis – Version 10.0." December 2016. Accessed August 28, 2017. .
[40] V. John White and Associates and Caldwell, James. "A Cost Effective and Reliable Zero Carbon Replacement Strategy for Diablo Canyon Power Plant." Study commissioned by Friends of the Earth. 2016. Accessed August 28, 2016. p 40.
[41] EIA. "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016." June 2016. Accessed August 28, 2017. p 2.
[42] Ibid., page A-11.
[43] Ibid., page A-11.

Dispatchable Technologies	Capacity	Levelized Capital	Fixed	Variable	Transmissio	Total LCOE	Levelized Tax	Total LCOE w/
Coal 30% **with carbon sequestration**								
Coal 90% with carbon sequestration								
Natural Gas-fired								
Conventional **Combined Cyde**	87	16.8	1.7	50.4	1.3	70.3		70.3
Advanced Combined Cycle	87	16.8	1.6	45.0	1.2	64.6		64.6
Advanced CC with CCS								
Conventional Combustion Turbine	30	44.2	7.9	65.2	3.6	120.8		120.8
Advanced Combustion Turbine	30	27.4	3.1	70.6	3.6	104.5		104.5
Advanced Nuclear	90	85.0	15.1	14.0	1.2	115.4		115.4
Geothermal	90	35.0	16.0	00.0	1.8	52.8	-3.5	49.3
Biomass	83	56.6	18.2	41.0	1.4	117.2		117.2
Non-Dispatchable Technologies		00.0	0.0	00.0	0.0	0.0		0.0
Wind-Onshore	41	47.8	15.7	00.0	3.5	67.0	-13.9	53.2
Wind - Offshore								
Solar PV⁴	25	71.8	12.1	00.0	4.6	88.4	-18.7	69.7
Solar Thermal								
Hydroelectric	60	64.9	3.7	06.2	1.8	76.7		76.7

Figure 9: EIA LCOE analysis[44]

Even without tax incentives and subsidies, alternative sources of energy come out to produce cheaper electricity over the lifetime of the project.

The majority of growth in solar PV generation in recent years has been at a utility-scale. Nationally, utility-scale generation grew from only 157 GWh in 2009 to 23,232 GWh in 2015, representing two-thirds of all solar PV generation in 2015.[45]

In Oregon, Washington, Idaho, and Montana, solar PV had a total installed capacity of 18.4 MW in 2009, but grew to 109.2 MW in 2015.[46] The BPA Interconnection Queue is a strong indicator of the market's readiness to transition to renewable electricity. Of the transmission service requests processed since 2011, there are 3,020 MW of solar resources in queue.[47] See Figure 24.

The cost of solar generation fell dramatically in the 2010-2016 period. According to the annual analysis conducted by Lazard, utility-scale solar PV's median LCOE fell from $201 to $53.25/MWh over this period, a 73.6% drop. [48] Lazard estimates the LCOE for utility-scale solar PV in 2016 to be between $45 and $61/MWh based on scheduled tax policy and standard assumptions on financing.[49]

---

44 U.S. Energy Information Administration. "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017". April 2017. Accessed September 11, 2017

45 EIA. "Electric Power Monthly with Data for June 2016." August 24, 2016. Accessed December 20, 2016. <http://www.eia.gov/electricity/monthly/>.

46 Renewable Northwest Project. "Renewable Energy Projects." Accessed December 20, 2016. <http://www.rnp.org/project_map>.

47 BPA. "Interconnection Request Queue." Accessed December 20, 2016. <https://www.bpa.gov/transmission/doing%20business/interconnection/pages/default.aspx>.

48 Lazard. "Levelized Cost of Energy Analysis – Version 10.0." December 15, 2016. Accessed December 20, 2016. <https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf>.

49 Ibid., page 4. Figures stated in 2015 dollars.

Research from the Lawrence Berkeley National Laboratory finds that recently signed Power Purchase Agreements (PPAs) for solar PV at $62.50/MWh are economically sound, even when unsubsidized.[50] In its annual review of solar technology, the group cites a substantial reduction in the price of utility-scale solar installations for power purchase agreements (PPA):

> "PPA Prices: Driven by lower installed project prices and improving capacity factors, levelized PPA prices for utility-scale PV have fallen dramatically over time, by $25-$35/MWh per year on average from 2006 through 2013, with a smaller price decline of ~$13/MWh per year evident in the 2014 and 2015 samples. Most PPAs in the 2015 sample—including many outside of California and the Southwest—are priced at or below $62.50/MWh levelized (in real 2015 dollars), with a few priced as aggressively as ~$37.5/MWh. Even at these low price levels, PV may still find it difficult to compete with existing gas-fired generation, given how low natural gas prices (and gas price expectations) have fallen over the past year. When stacked up against new gas-fired generation (i.e., including the recovery of up-front capital costs), PV looks more attractive—and in either case can also provide a hedge against possible future increases in fossil fuel costs."[51]

The technology for utility-scale solar is based on two major approaches: crystalline silicon ("c-SI") and thin film ("CdTE"). There are numerous reasons why the efficiency and cost effectiveness of solar has improved in recent years. Mark Bolinger and Joachim Seel, the report writers, cite technological improvement, especially the rapid increase in solar tracking technology. They note that 70% of capacity added in 2015 used tracking technology.[52] Solar equipment costs have also declined in price due to improvements in manufacturing costs.[53]

---

50 Bolinger, Mark et al. "Is $50/MWh Solar for Real? Falling Project Prices and Rising Capacity Factors Drive Utility-Scale PV Toward Economic Competitiveness." Ernest Orlando Lawrence Berkeley National Laboratory. May 2015. Accessed December 20, 2016. <https://emp.lbl.gov/sites/all/files/lbnl-183129_0.pdf>.

51 Bolinger, Mark and Seel, Joachim. "Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States." Lawrence Berkeley National Laboratory, U.S. Department of Energy. August 2016. Accessed December 20, 2016. <https://emp.lbl.gov/sites/all/files/lbnl-1006037_report.pdf>. See page ii.

52 Ibid., page 5, page ii.

53 Chung, Donald et al. "U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems." NREL. 2015. Accessed December 20, 2016. <http://www.nrel.gov/docs/fy15osti/64746.pdf>. See pages iv and 2.

There is a continuing efficiency competition between the two major solar technologies. Again, Bolinger and Seel report that the efficiencies of the two approaches are currently comparable.[54]

According to the annual analysis by Lazard, the midpoint of solar's LCOE fell from $201 to $53.25/MWh over the 2010-2016 period, a 74% decline.[55]

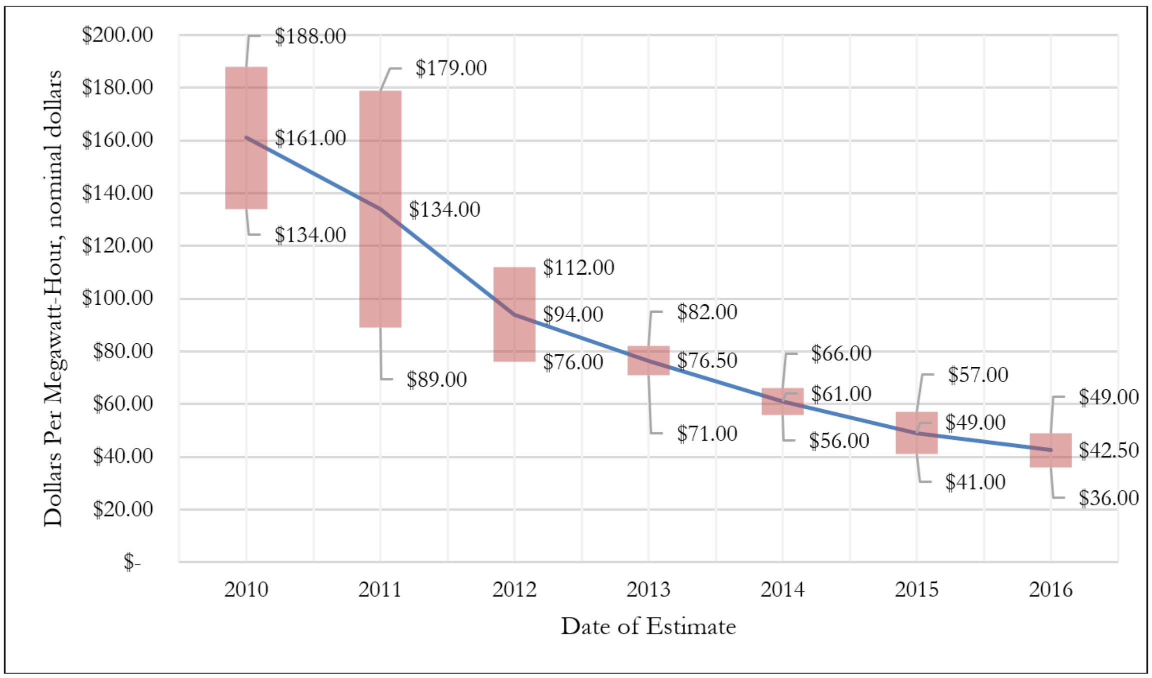


Figure 10: Levelized Cost of Energy for Solar (Lazard Historical Estimates)

Wind generation is a more mature technology compared to solar PV. In 2015, wind generation in the U.S. totaled 190,927 GWh, representing 4.7% of all electricity generation.[56] In recent years the cost of onshore wind generation has also declined steeply, if less dramatically, than that of solar PV generation. According to the annual analysis by Lazard,

[54] Bolinger, Mark and Seel, Joachim. "Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States." Lawrence Berkeley National Laboratory, U.S. Department of Energy. August 2016. Accessed December 20, 2016. <https://emp.lbl.gov/sites/all/files/lbnl-1006037_report.pdf>. See page 5.
[55] Lazard. "Levelized Cost of Energy Analysis – Version 10.0." December 15, 2016. Accessed December 20, 2016. <https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf>.
[56] EIA. "Electric Power Monthly with Data for June 2016." August 24, 2016. Accessed August 28, 2016.

the midpoint of onshore wind's LCOE fell from $109.50 to $38.75/MWh over the 2010-2016 period, a 65% decline.[57]

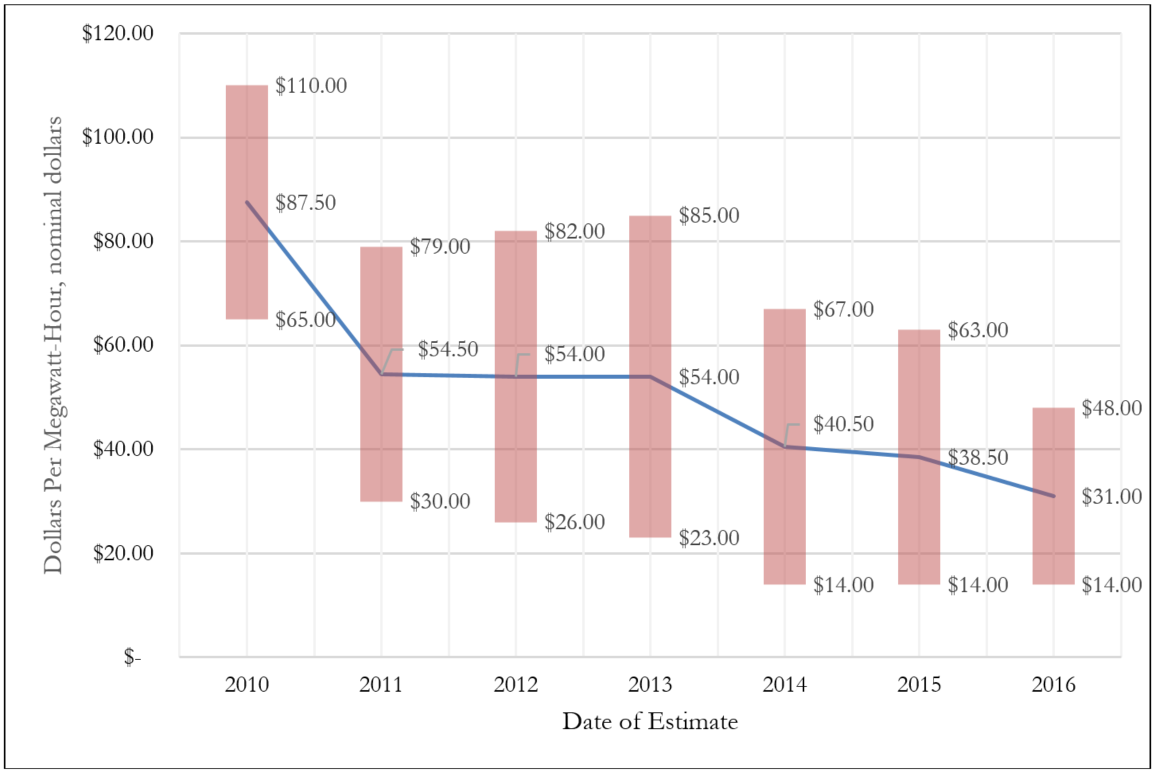


Figure 11: Levelized Cost of Energy for Wind (Lazard Historical Estimates)

BC Hydro has already conducted a study of wind resources in British Columbia, rendering superfluous the argument that BC Hydro will have to invest money into a survey of possible wind farm locations.[58]

[57] Lazard. "Levelized Cost of Energy Analysis – Version 10.0." December 15, 2016. Accessed December 20, 2016. <https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf>.
[58] BC Hydro. "British Columbia Wind Resource Map".

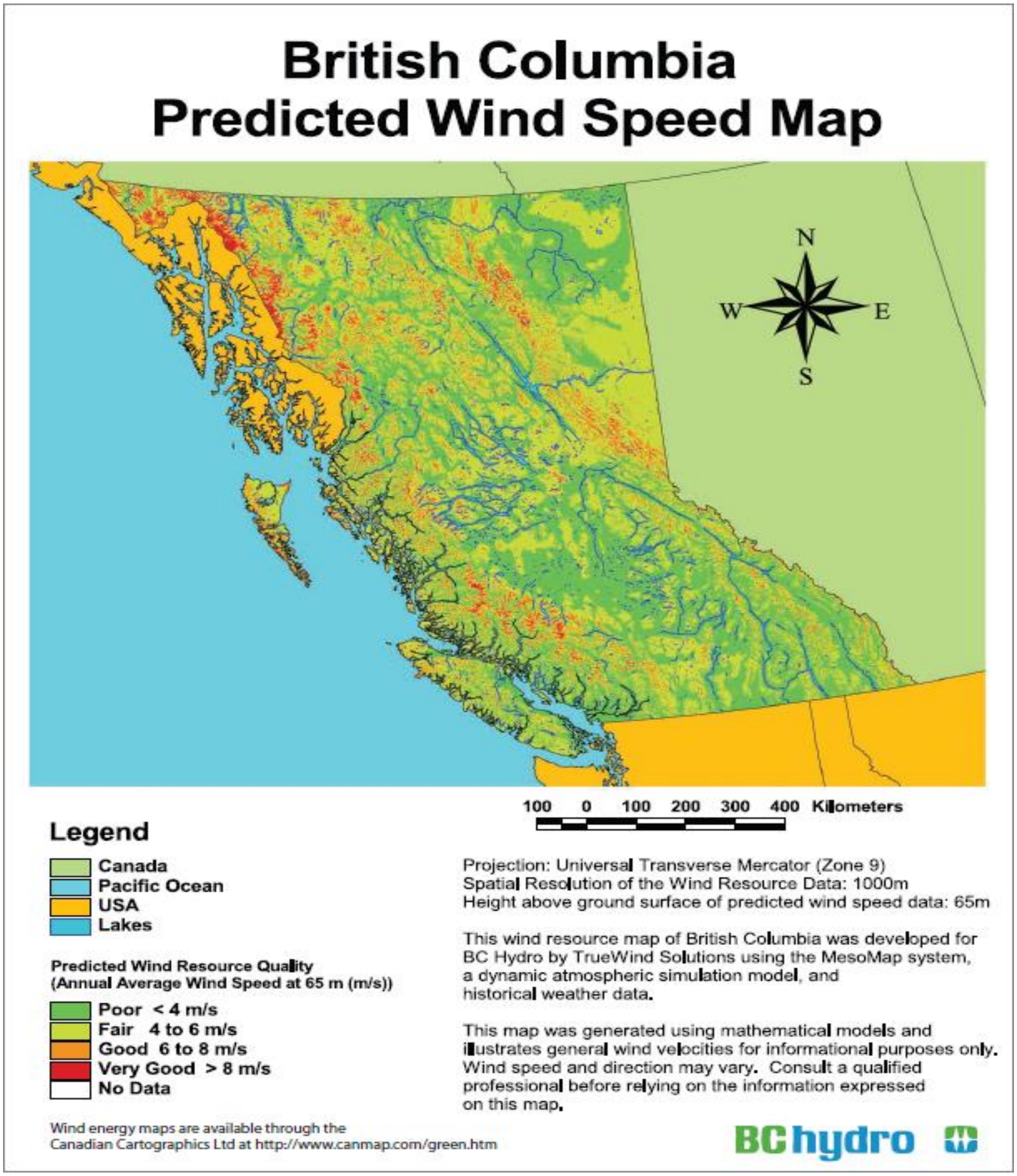


Figure 12: Map of wind resources in British Columbia[59]

[59] Ibid

Moreover, there exist suitable locations for utility-scale wind installations close to urban centers. Deloitte conducted a review of Site-C on behalf of the British Columbia Utility Commission and concluded, "Estimated capital costs for onshore wind range from $1,600 to $3,200/kW, and fixed O&M costs range from $70 to $110/kW-yr."[60.] This is significantly less than the cost of constructing and operating Site-C.

According to Deloitte, not only are the capital costs of alternative energy sources cheaper, but are expected to fall considerably over the next decade.

Source of Energy	Current Capital Costs	Future Costs
Wind	$1,600-$3,200/kw	Expected 10%-12% reduction in 10-20 years
Solar	$2,300-$3,200/kw	Expected 35%-60% reduction in 10 years
Geothermal	$6,000-$8,700/kw	Roughly unchanged
Site-C	$8,800/kw	All costs

Figure 13: Deloitte's prediction of capital costs of alternative energy sources[61]

However, the capacity factor of these energy sources are not in parity. Deloitte estimates that the capacity factor of Site-C, wind, solar, and geothermal is 53%, 30%, 20%, and 92%, respectively[62]. Adjusting for this disparity, the costs of alternative sources are still highly competitive:

Source of Energy	Adjusted Capital Cost (Low Estimate)	Adjusted Capital Cost (High Estimate)
Wind	$8,072/kw	$12,872/kw
Solar	$11,020/kw	$14,920/kw
Geothermal	$7,707/kw	$10,642/kw
Site-C	$12,092/kw	$12,092/kw

Figure 14: Capital costs adjusted for capacity factor

Due to the cost efficiency of alternative sources, termination of the Site-C project and replacement with alternative sources is the best possible outcome for BC's ratepayers.

.[60] Deloitte. BCUC submission. September 8, 2017. Accessed September 11, 2017.
[61] Ibid., pgs. 25-40
[62] Ibid., pg. 43

V. Storage and Dispatchability

The justification for building Site-C to bolster energy storage overlooks some basic facts about British Columbia's energy resources.

British Columbia Hydro characterizes Site C as a project with little actual storage:

> "The Project reservoir, with a normal operating range of 1.8 m and an active storage volume of 0.4 per cent of the active storage volume of Williston Reservoir, does not have sufficient storage volumes to provide seasonal shaping of generation. The upstream regulation at Williston Reservoir allows the Project to generate electricity to match the timing of BC Hydro customer demand without the need to establish another large multi-year storage reservoir similar to Williston Reservoir. As a result, the Project is able to produce approximately 35 per cent of the energy produced by the G.M. Shrum generating station with 5 per cent of the reservoir area."[63]

The argument that Site-C can serve as storage for future alternative sources of energy is highly questionable given its lack of reservoir capacity.

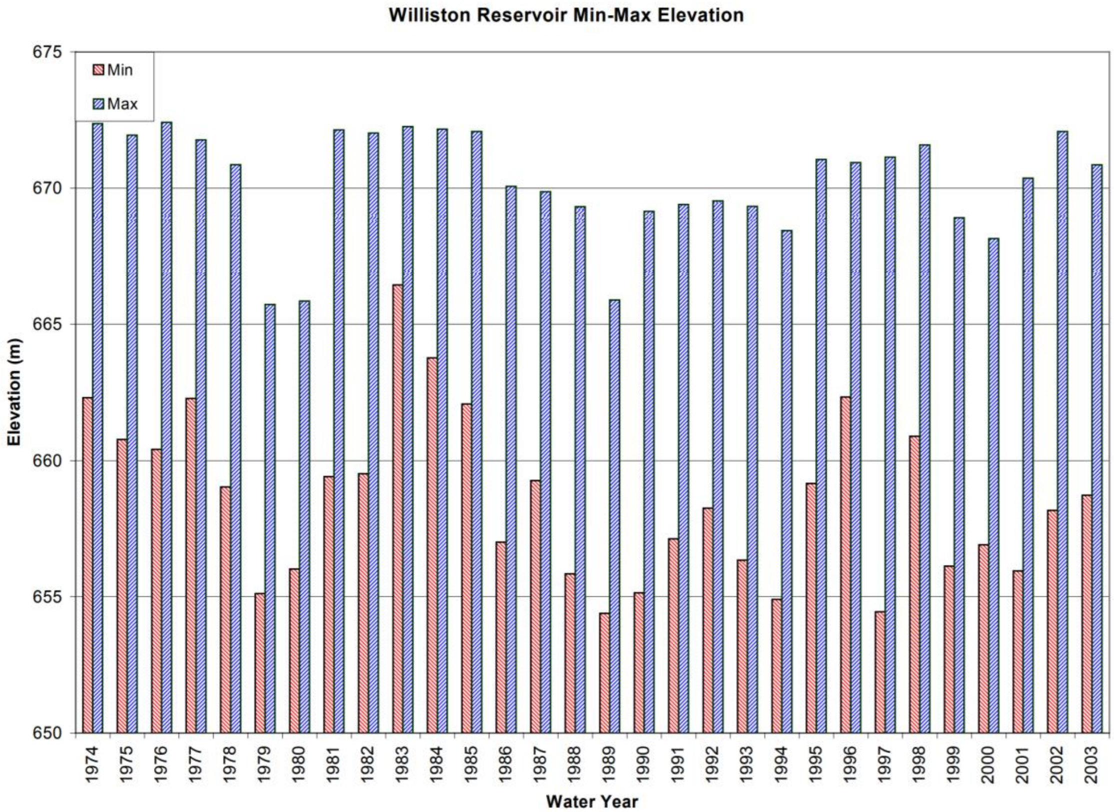
Typical run-of-the-river hydroelectric projects (i.e. those with small associated reservoirs) have limited ability to store water over seasons and years. Site C is no different.

While Site C may expand British Columbia Hydro's capacity, it will have a minimal impact on the province's storage.[64]

British Columbia Hydro's largest reservoir, Williston, is upstream from Site C. Historically, reservoir elevations have varied between 654 and 672 meters.

[63] BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project, British Columbia Hydro, August 30, 2017, pages T-2 and T-3.

[64] Information Sheet Site C Reservoir, British Columbia Hydro, January 2016, page 1.



[65]

Figure 15: Williston Reservoir Min-Max Elevation

The storage potential of the Site-C dam is remarkably less than even the Williston reservoir upstream:

[65] Independent Power Producers Association of BC Information Request No. 1.80.3 Dated: 2 March 2004, BC Hydro, March 29, 2004, page 3.

Figure 16: Size comparison of the Site-C reservoir and the Williston reservoir[66]

The Williston Reservoir extends across 176,119 hectares compared to 9,330 hectares for the Site-C reservoir.[67]

Thus Williston has approximately ten times the usable elevation and almost twenty times the usable area. Put another way, Site C is not going to meaningfully change the amount of storage in British Columbia beyond what Williston already provides.

If this is not enough surplus dispatchability already employed by the Northwest Power Pool (NWPP). As a participant in the NWPP, British Columbia currently has access to nearly 80,000,000 acre-feet of water available for daily, weekly, monthly, seasonal, and multi-annual storage.

VI. Export market expectations

British Columbia is a net exporter of electricity, with most of that export capacity aimed at the Pacific Northwest of the United States. Energy prices in both British Columbia and the

[66] David Suzuki. "Site C dam proposal puts treaty commitments to the test". September 30, 2014. Accessed September 11, 2017.
[67] BC Hydro. "Backrounder about Site-C". June 2, 2010. Accessed September 11, 2017.

Pacific Northwest are detailed by the Mid-Columbia (Mid-C) spot market. If Mid-C prices were rising, then investment in excess capacity may be warranted.
Unfortunately, Mid-Columbia prices have plummeted since 2008.

Actual transactions on the Intercontinental Exchange (ICE) indicate Mid-Columbia will fall for the next few years, and only rebound to current levels in 2022. The general explanation is that the rapid expansion of renewables has added extensive zero marginal costs to the market.

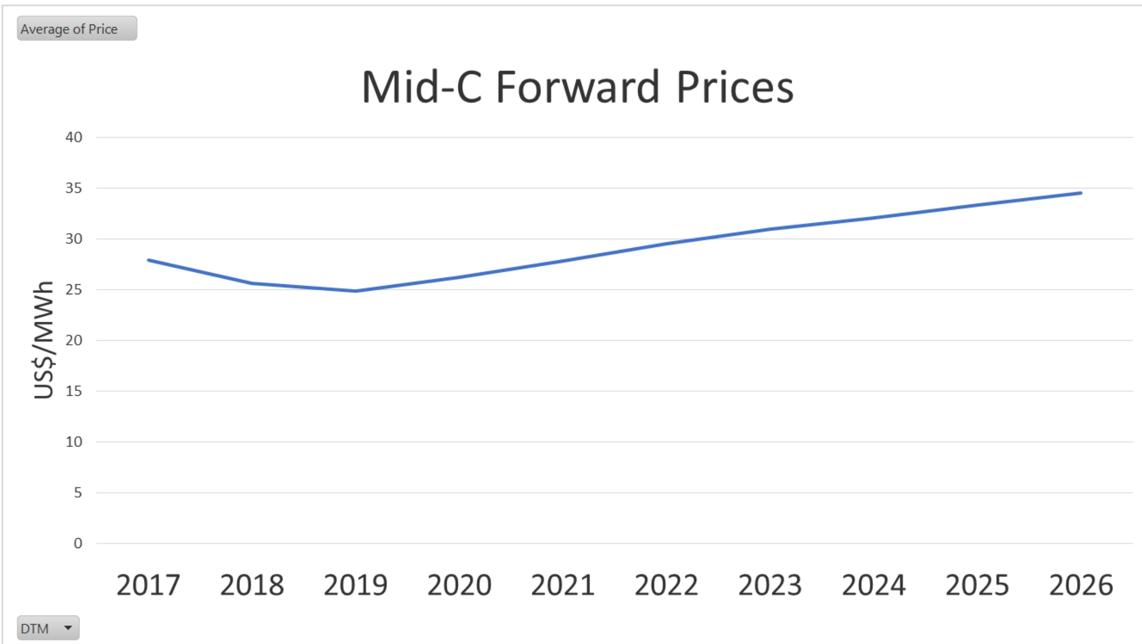


Figure 17: Mid-Columbia Forward Prices

So, we can expect no significant increase in mid-c prices in the next decade.

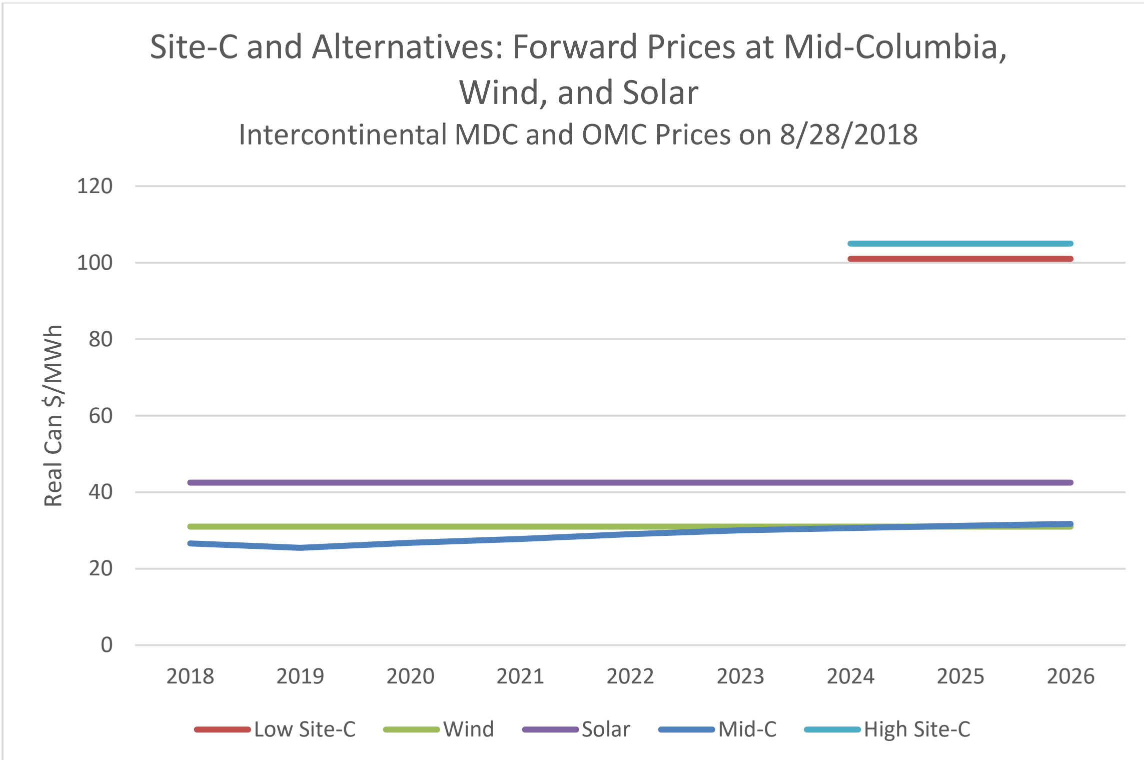


Figure 18: Site C and Alternatives

VII. BC Hydro's demand forecast

The demand forecast of BC Hydro is highly overstated. The historical data is actually flat.[68] BC Hydro then extrapolates from a flat line a sudden hockey-stick style change of direction.[69]

[68] BC Hydro, "BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project," August 30, 2017, page 45.
[69] BC Hydro, "BC Hydro Submission to the British Columbia Utilities Commission Inquiry into the Site C Clean Energy Project," August 30, 2017, page 46.

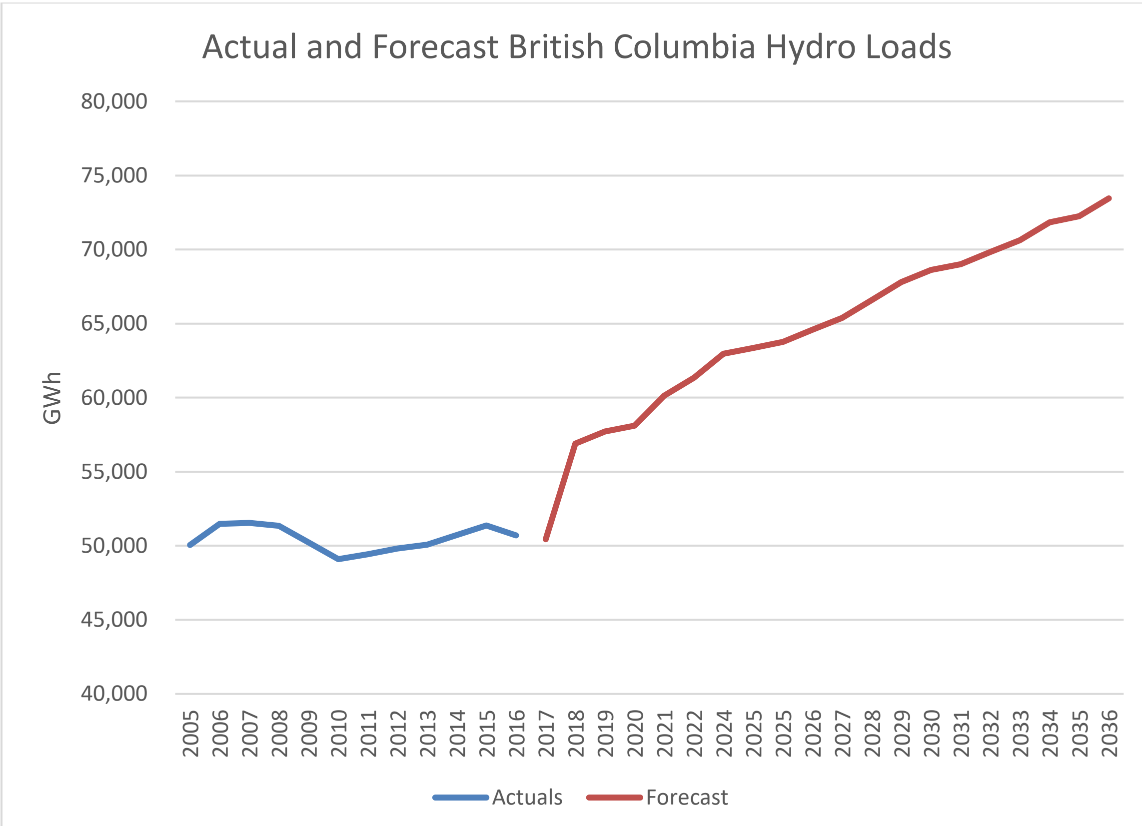


Figure 19:Actual and Forecast British Columbia Hydro Loads

There is no basis for this sudden change in trend in the data or in the province of British Columbia's industrial horizon. The trend has been conservation, not runaway load growth.

BCUC's own contracted research from Deloitte LLC rejects this forecast as well. Deloitte makes it clear that BC Hydro has a history of always over-estimating its forecasts.[70]

[70] Deloitte LLC, "British Columbia Hydro and Power Authority – British Columbia Utilities Commission Inquiry Respecting Site C – Project No. 1598922," September 8, 2017, page 63

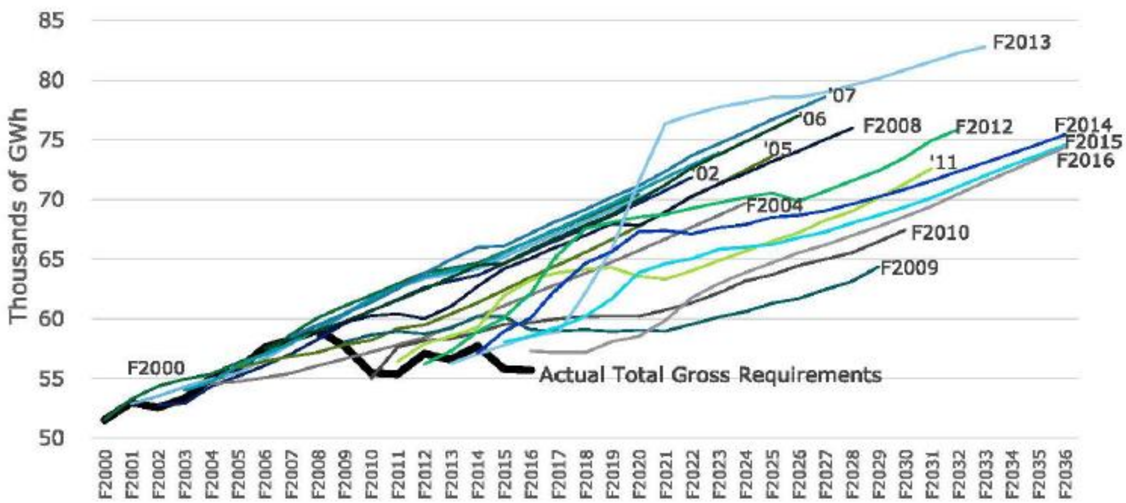


Figure 20: Deloitte Summary of Forecast Errors

Deloitte LLC was particularly interested to find that BC Hydro does not model future recessions into its estimates: "we find it reasonable to assume that there will be at least one recession over the horizon of the 2016 load forecast. However, this assessment does not attempt to model such an adjustment."[71]

While BC Hydro cites the estimates of the Conference Board of Canada as the source of its inputted growth in disposable income, Deloitte reports that BC Hydro's number are "higher than the Conference Board of Canada's, particularly in years six to 10 of the forecast."[72] This is important, because growth in disposable income serves as a key driver of residential load.

Regarding BC Hydro's forecast of industrial load, Deloitte points out that the assumptions used "appear above consensus."[73] Noting that several of the LNG projects BC Hydro relied heavily on in its 2016 forecast have since been cancelled, Deloitte identifies the central error in BC Hydro's forecasts that: "In the high and low forecasts, BC Hydro applies a probability assessment on when, but not if, these projects will come online."[74]

By failing to discount these projects by probability, BC Hydro has overstated future industrial load by using an inappropriate level of certainty in its model. Deloitte thus concludes:

[71] Ibid, page 73.
[72] Ibid, page 73.
[73] Ibid, page 74.
[74] Ibid, page 74.

"We find the assumption that LNG Canada will proceed with certainty to be overly optimistic."[75]

Deloitte finds BC Hydro's price elasticity assumptions to be "simplistic," ignoring the effects of demand side management.[76] Recent research has found evidence that consumers' conservation will be more responsive[77,78]

Deloitte highlights the fact that BC Hydro's model likely underestimates the elasticity of demand from industrial customers when they assume residential and industrial elasticity is the same.[79] Research shows that's not the case.[80]

One of the most remarkable methodological errors that Deloitte discovered is that BC Hydro's model assumes no rate increases from 2025 to 2036.[81] That's truly remarkable given the amount of debt this project entails.

VIII. Conclusion

In conclusion:

- The recent cost reductions of alternative sources of energy make construction of Site-C gratuitous and unnecessary
- British Columbia Hydro and its energy partners in the Northwest United States already have an extraordinarily large amount of energy storage and dispatchability
- BC Hydro's load forecast likely overestimates the need for extra capacity in the near-term
- Even if more capacity is needed, termination of Site-C and replacement with an alternative source minimizes cost to BC ratepayers
- Any excess capacity cannot be sold to the United States with the expectation of a reasonable profit.

[75] Ibid, page 74.
[76] Ibid, page 74.
[77] Espey and Espey, "Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities," Journal of Agricultural and Applied Economics, April 2004 page 65.
[78] Alberini and Filippini, "Response of Residential Electricity Demand to Price: The Effect of Measurement Error," Journal of Energy Economics. 33: 889.
[79] Deloitte LLC, "British Columbia Hydro and Power Authority – British Columbia Utilities Commission Inquiry Respecting Site C – Project No. 1598922," September 8, 2017, page 75.
[80] Griffin and Arent, "A Note on Price Asymmetry as Induced Technical Change," Energy Journal, July 2006.
[81] Deloitte LLC, "British Columbia Hydro and Power Authority – British Columbia Utilities Commission Inquiry Respecting Site C – Project No. 1598922," September 8, 2017, page 75.

Robert McCullough

September 13, 2017

Appendix A

	Site C	Wind		Solar		Geothermal	
		Low Price	High Price	Low Price	High Price	Low Price	High Price
Cost	$ 8,775,000,000.00						
Sunk	$ 1,800,000,000.00						
Net Cost	$ 6,975,000,000.00						
Termination		$ 1,200,000,000.00	$ 1,200,000,000.00	$ 1,200,000,000.00	$ 1,200,000,000.00	$ 1,200,000,000.00	$ 1,200,000,000.00
Net Cost	$ 6,975,000,000.00						
MW	1,100	1,100	1,100	1,100	1,100	1,100	1,100
$/MW	$ 6,340.91	$ 1,090.91	$ 1,090.91	$ 1,090.91	$ 1,090.91	$ 1,090.91	$ 1,090.91
Deloitte							
Resource C$/kW		$ 1,600.00	$ 3,200.00	$ 2,300.00	$ 3,500.00	$ 6,000.00	$ 8,700.00
Price Decrease		10%	10%	35%	35%	0%	0%
Total $/kV	$ 6,340.91	$ 2,530.91	$ 3,970.91	$ 2,585.91	$ 3,365.91	$ 7,090.91	$ 9,790.91
Capacity F	53%	30%	30%	20%	20%	92%	92%
Adjusted !	$ 11,980.59	$ 8,436.36	$ 13,236.36	$ 12,929.55	$ 16,829.55	$ 7,707.51	$ 10,642.29
Site C Cap	53%	53%	53%	53%	53%	53%	53%
Normalize	$ 6,340.91	$ 4,465.07	$ 7,005.55	$ 6,843.16	$ 8,907.29	$ 4,079.32	$ 5,632.60
EIA							
Resource US$/kW		$ 1,970.85	$ 1,970.85	$ 2,508.66	$ 2,508.66	$ 4,600.00	$ 6,600.00
Exchange Rate		1.2	1.2	1.2	1.2	1.2	1.2
Resource C$/kW		$ 2,365.02	$ 2,365.02	$ 3,010.39	$ 3,010.39	$ 5,520.00	$ 7,920.00
Price Decrease		10%	10%	35%	35%	0%	0%
Total $/kW		$ 2,128.52	$ 2,128.52	$ 1,956.75	$ 1,956.75	$ 5,520.00	$ 7,920.00
$/kW		$ 3,219.43	$ 3,455.93	$ 4,101.30	$ 4,101.30	$ 6,610.91	$ 9,010.91
EIA Capaci	53%	35%	35%	27%	27%	74%	74%
Adjusted !	$ 11,980.59	$ 9,277.89	$ 9,959.45	$ 15,078.31	$ 15,078.31	$ 8,909.58	$ 12,144.08
Site C Cap	53%	53%	53%	53%	53%	53%	53%
Normalize	$ 6,340.91	$ 4,910.46	$ 5,271.19	$ 7,980.43	$ 7,980.43	$ 4,715.53	$ 6,427.44