True Cost of Electricity from the Site C Dam

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What is the Levelized Cost of Electricity for the Site C Dam?

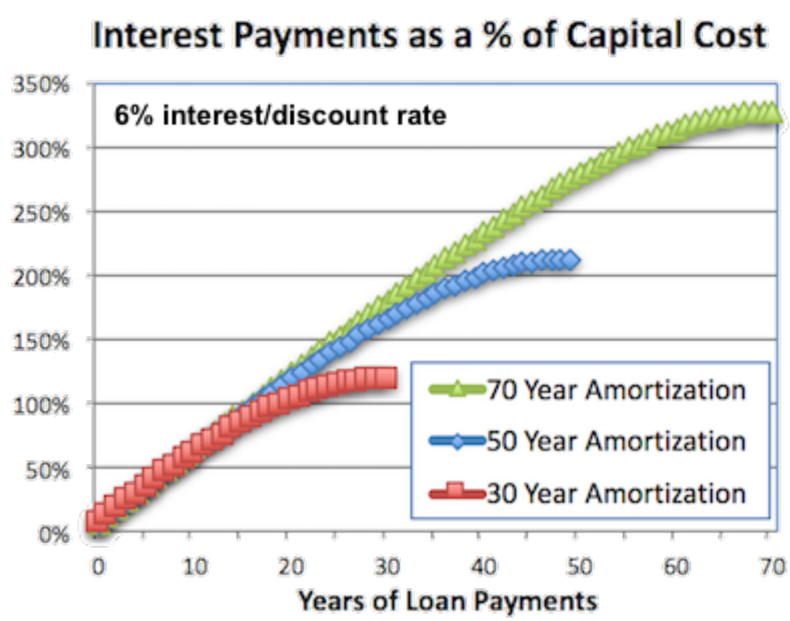
There have been a number of different figures published for electricity from the Site C dam. The BC Sustainable Energy Association has published a figure of $88/MW-Hour. Harry Swain, in an opinion piece in the Vancouver Sun in June, 2016 quoted a figure of $95/MW-Hour. It is quite difficult to find any BC Hydro estimate of Levelized Cost of Electricity for the Site C dam – none is provided in the project FAQ.

As a mental exercise let us suppose that the Site C dam could be magically completed overnight and paid for through a cash grant from the Province for the entire forecast $8.3 Billion.

Site C is designed to produce a maximum of 1.1 GW of electricity and the capacity factor (percentage of maximum capacity that will actually be generated over the course of a year) is estimated by BC Hydro to be 55%. Therefore the dam is estimated to produce about 5.3 Million MW-Hours of electricity per year.

The operating costs of the dam are insignificant relative to the capital cost. If we assume that the dam would produce electricity for 50 years then the distributed capital cost of electricity generated over that time would be $8.3 Billion/(50 * 5.3 Million MW-Hours) = $31/MW-Hour. If we assume that generation can be counted on for 100 years then the distributed cost of capital is $15.50/MW-Hour.

So how to we get numbers like $95/MW-Hour? Because of the interest paid on the amount borrowed to pay for the dam. And that amount can vary widely based upon the assumed interest rate and amortization period. The figure below illustrates the relative amount of interest vs. principal for loans at different amortization rates.



Only by using a very long amortization period and 6% interest can you arrive at a figure of $95/MW-Hour for Site C electricity. If a more realistic amortization period of 30 years is used the LCOE during that 30 year period would be around $125/MW-Hour. But that number does not reflect the true cost of electricity that will be produced from this dam.

In order to understand the true long-term LCOE it is necessary to consider the period of time after the capital cost for the dam has been paid off (end of the amortization period) until the end of life for the dam.

How long will the Site C dam be in operation? There are many hydro dams in the world that are more than 100 years old and operating just as efficiently as when they were constructed. The Cornalvo earth gravity dam built by the Romans is over 1,800 years old!.

If a 70 year amortization period is used then the only costs for the dam over the last 30 years are operating and maintenance expenses which are very small compared to the capital cost. Although it is again highly speculative to try and forecast O&M expenses 70 years from now reasonable guesses result in LCOE values of $5-10/MW-Hour. Combining the costs during and after the amortization period for the Site C dam results in LCOE values of around $75-90/MW-Hour.

But what if a more realistic amortization period of 30 years is used? BC Hydro could easily borrow that amount on capital markets or issue bonds with that type of maturity. In that case the LCOE during the first 30 years (assuming 6% interest/discount rate) would be $125 but the LCOE taken over a full 100 years would be about $41/MW-hour.

The LCOE values quoted so far have been based not only upon 6% interest rate but also using a capacity factor of 55%. That is to say that the dam would only produce 55% of the electricity that it is capable of producing. The capacity factor will depend upon demand and water conditions.

Within the next 100 years all automobiles will almost certainly be electric drive which will significantly increase electricity demand in the province. But we also need to stop burning natural gas to heat our homes and businesses. The renewable alternative is heat pump/geoexchange technology which requires considerably more electricity than traditional heating systems. Burning huge quantities of diesel fuel in our railway locomotives also doesn't make a lot of sense if we are trying to e-carbonize our economy. Electrification of the railway system will add another significant new load on the electrical system.

Finally, if Alberta follows through on its commitment to eliminate burning coal to generate electricity then there will also be additional demand on BC hydro power as a balancing resource for wind farms. Taking all these new system loads into account and barring a drought it is conceivable that the capacity factor for the site C dam could increase to as much as 75%.

What is a realistic interest rate to use for the debt required to pay for Site C? BC Hydro would be able to obtain capital at the most attractive rates possible for a loan of the size required for Site C. For example, BC Hydro could issue a Site C 30 year bond at a rate of 4.5% which would be competitive with other high quality debt instruments.

Using an interest/discount rate of 4.5%, an amortization period of 30 years and a capacity factor of 60% would yield LCOE of about $32/MW-hour over 100 years. In my opinion that is the most realistic and likely multi-generational LCOE for the Site C dam.

The tables below provide other values which indicate the sensitivity to amortization period, interest/discount rate, and capacity factor.

Pessimistic case: 6% discount rate, 55% capacity factor

Amortization (Years)	LCOE*	LCOE^{100}
20	$ 150	$ 34
30	$ 125	$ 41
50	$ 109	$ 58
70	$ 105	$ 75

Realistic case: 4.5% discount rate, 60% capacity factor

Amortization (Years)	LCOE*	LCOE^{100}
20	$ 93	$ 28
30	$ 73	$ 32
50	$ 59	$ 43
70	$ 54	$ 54

LCOE* during amortization period ($/MW-Hour)

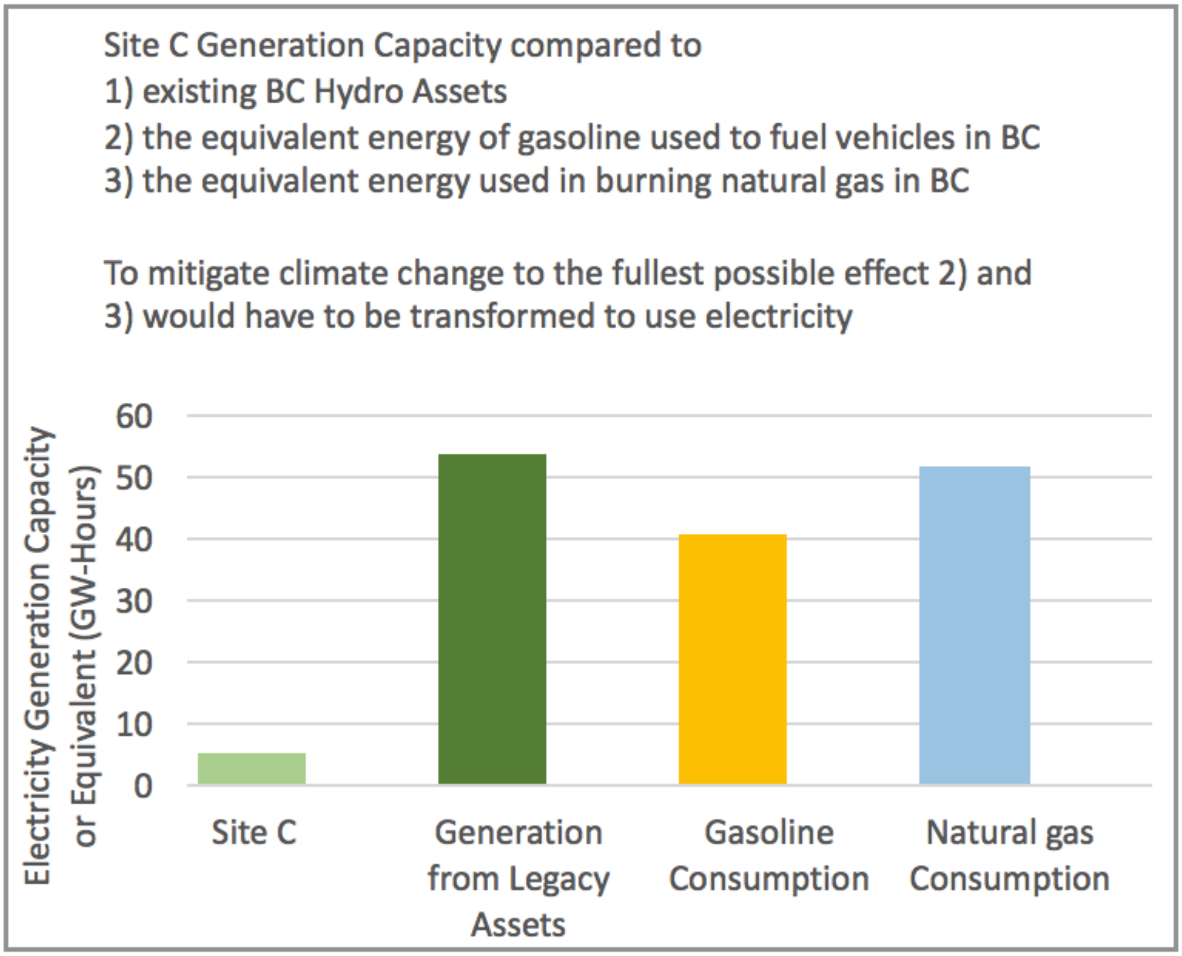
LCOE^{100} over 100 years ($/MW-Hour)

It it clear that hydro, amortized over a reasonable period, is by far the least expensive renewable resource available. More importantly, hydro power is available when it is needed each and every day because of its ability to follow system load. The only other renewable technology that can do that is geothermal and there is certainly not enough economically developable potential for geothermal in BC to match the generation from Site C.

For solar PV and wind it would only be reasonable to add a significant additional cost for energy storage or some other reliable generation source to provide power on calm nights. Those critical additional costs are conveniently ignored when comparing LCOE values for solar, wind, and hydro.

Key Figures for Site C vs. Renewable Alternatives

The figures below provide some comparative costs for electricity from Site C vs. from solar and wind and these figures do not include the cost of storage. Without storage no reliable and renewable alternative to site C exists.



$32/MW-Hour

This is the most likely multi-generational cost of electricity from Site C. That should be compared to the [$68/MW-Hour]() paid for Private Power Purchases that BC Hydro was forced to negotiate with for-profit companies.

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54 TW-Hours

This is the total annual electrical generation from existing legacy Hydro assets in BC. Site C will add 5.3 TW-Hours.

4.6 Billion liters

Amount of gasoline consumed in BC each year

=41 TW-Hours

additional generation which will be needed when all cars and trucks are electric (a certainty over the next 50 years)

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5 Billion Cubic Meters

Annual domestic consumption of natural gas in BC

=52 TW-Hours

additional generation which will be needed when we stop burning fossil fuels to heat homes and businesses

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21 Million

Number of solar panels that would have to be installed in BC to generate the same amount of power as Site C

$19 Billion

The cost to install those solar panels – and we still would have no power at night and very little during the day in winter.

700

Number of wind turbines that would have to be installed in BC to generate the same amount of power as Site C

$5 Billion

The cost to install those turbines which would have to be located on pristine mountain-tops causing significant habitat destruction – and we still would have no power on the frequent days when winds are calm across BC. Note also that the best wind resources in the province are on the north section of Vancouver Island and Haida Gwaii. Installation of a larger number of wind turbines in these areas would likely encounter significant protests from environmental groups.

In Conclusion

If we think we're going to need additional electricity capacity in the future why wouldn't we build Site C now when interest rates are low? Do we think construction costs are going to decrease in the future?

Detailed back-up for the numbers:

Generation from Existing Legacy Hydro Assets of 54 GW-Hours

Available form the BC Hydro web site.

Multi-generational cost for Site C electricity of $32/hour

This is an average value over the next 100 years with the first 30 years running at $73/MW-Hour while the capital costs are paid off through a bond bearing 4.5% interest and the next 70 years only with operating costs initially at $10 million/year escalating with a 1.5% rate of inflation.

Gasoline Sales and Required Generation to power Electric Vehicles

Gasoline sales from Statistics Canada. Conversion to TW-Hours: 4.6 Billion liters of gasoline = 4.6 * .264 = 1.214 Billion U.S. gallons. The energy content of this is 33.7 KW-hours/U.S. gallon. Therefore the electrical generation required to replace the burning of gasoline is 1.214 Billion * 33.7 KW-hours = 40.9 TW-Hours. Second source: 34.2 MJ/liter x 4.6 Billion liters = 157 Billion MJ = 43.68 TW-Hours. To be perfectly fair electric vehicles are considerably more efficient than internal combustion engines but I have not included the 1.8 Billion liters of diesel fuel which has a higher energy content than gasoline and I have not accounted for any growth in the number of vehicles in BC in the next 100 years so I believe the 40+ TW-hours of needed electricity generation growth is very conservative.

Natural Gas Consumption and Required Generation to heat homes and businesses with electricity

Consumption of 5 Billion CM from BC Government spreadsheet. Multiplying by .0373 gives .1865 Billion GJ and dividing by 3.6 gives .0518 Billion MW-Hours or 51.8 TW-Hours. Second source: 5 BCM natural gas x 35.7 converts to 178.5 Trillion BTU which is the equivalent of 52.31 TW-Hours.

Equivalent Number of Solar Panels and Cost

Site C is estimated to generate 5.3 TW-Hours of electricity per year. The capacity factor of solar in Germany, the country with the second largest number of solar panels in the world and at roughly the same latitude as BC can be calculated using 40 GW capacity and 37.5 TW-Hours of generation in 2016 to be 10.7%. In the Lower Mainland the OASIS project at BCIT achieved an estimated annual capacity factor of 7% in 2014 (the actual generation amounted to 2% of capacity because of ongoing operational issues). The estimated capacity factor for OASIS varied from 2.8% in December to 14.2% in August).

The estimated net generation capacity at Site C is .582 GW (5,100 GW-Hours/24*265). Using the higher (more optimistic) German capacity factor for solar it would take .582/.11 = 5.29 GW of solar capacity to generate as much electricity as the Site C dam. The most common PV solar panels have a capacity of .25 KW. Therefore it would take more than 21 million solar panels to equal the generation of Site C.

The cost to install PV solar was estimated by the EIA to be $US3.7/watt in 2013. It has been reported that the Canadian average cost is about $3.60/watt. That would make the cost to install enough solar panels to generate the same annual average electricity $3.60 x 5.29 GW = $19.044 Billion.

However, this figure seriously underestimates the cost of the solar panels required. British Columbia's peak electricity demand comes on cold days in December and January when capacity factors for solar would be 2-3%. As a result it would cost at least $60 Billion to install enough solar panels to generate electricity equal to that of Site C in December and January.

Equivalent Number of Wind Turbines and Cost

Modern wind turbines vary in nameplate capacity from 2.5-3 MW. Average capacity factors for wind turbines in Germany, which has 47 GW of wind generation capacity (largest in the world) can be calculated from total generation of electricity of 77.8 TW-Hours to be 19%. The EIA reported a capacity factor of 34% for U.S. wind generation which is concentrated in very good wind resource areas in Texas and the prairies. On balance it would be reasonable to assume that large scale development of onshore wind in BC could achieve a capacity factor of no more than 30%.

Under that assumption the wind capacity required to match Site C would be .582/.3 = 1.94 GW which would require the installation of between 650 and 750 wind turbines. As reported by the EIA the average cost to install wind generation is $US1.9/watt which would translate into a cost of $4.81 Billion using current exchange rates. However, the average cost of installation in BC is likely to be considerably higher than the average cost of installation in the U.S. because of the mountainous terrain and the location of the best wind resources in relatively remote areas.