Energy Alternatives to the Site C Dam in a Climate-Challenged World

By Guy Dauncey

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When I began crunching the numbers on how much power BC would need if we were seriously committed to tackling the climate crisis, I began to think that perhaps the Site C Dam was needed after all, in spite of all the downsides.

So I had to ask this question: with a steadily growing population, and the climate crisis calling for the rapid electrification of transportation and heat, how much electricity will British Columbia really need over the next thirty years or so?

How much energy could wind, solar and geothermal generate, and what would they cost compared to Site C?

How much energy could be saved if BC Hydro made a big investment in conservation and efficiency?

And how do the alternatives compare when it comes to producing dispatchable power?

They seem like straightforward questions - but believe me, they are not. But once I understood and crunched the numbers, I changed my mind. This chapter lays it all out. If you want to skip the numbers and get straight to the answer, here it is:

The numbers show that even with the rapid electrification of transportation and heat, we do not need to flood precious farmland in the Peace River valley to generate hydropower. We can get all the energy we need in an affordable manner from a portfolio of demand-side management, wind, solar and geothermal, and we can handle the need for dispatchability.

So now you can skip straight to the next chapter, or dig in and enjoy the numbers. *Bon appetit*!

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Power utility managers assume a shared understanding of concepts such as gigawatt-hours, capacity factor, firm power, dispatchability, demand-side management, integrated resource planning, present value, total resource cost, unit energy cost, the levelized cost of power, and the weighted average cost of capital. My challenge is to communicate the important understandings without turning you, the reader, into a mental pretzel. As to numbers, however, there's no avoiding them.

So let's start with how much electricity we use. In 2016, BC Hydro supplied its many customers with 51,700 gigawatt-hours (GWh) of electricity to meet their needs, a level that has not changed much for ten years even while our population has grown by half a million. To do so, they use 79,000 kilometres of transmission line - enough to circle the planet twice at the equator, all of which needs maintenance.

Of this, 34% went to residential customers, 36% to light industrial and commercial customers, 27% to heavy industry, and 3% to irrigation, street lighting, and other utilities including FortisBC and New Westminster, which has its own electrical utility. The average household uses just under 10,000 kWh a year, a level that has fallen by 10% since 2012.[1] You'll use more if you heat with electricity, less if you heat with gas.

By the way, a kilowatt (kW) is a measure of capacity, while a kilowatt-hour (kWh) is a measure of delivered power. On average 4 kW of solar panels in BC generate 4,400 kWh of electricity per year. A thousand kilowatt-hours is a megawatt-hour (MWh). A thousand megawatt-hours is a gigawatt-hour (GWh).

Since 1971 our population has grown from just over two million to 4.8 million, and it's estimated to increase to six million by 2040.[2] It takes time to plan and deliver new power, so BC Hydro needs to forecast our future power needs and plan ahead.

To provide the electricity we need BC Hydro generates it from large hydro dams. It also signs electricity purchase agreements with independent power producers, mostly for wind and run-of-river power, and it saves power through demand-side management initiatives.

There are two prices that utility planners keep in mind. The first is the competitive price of cost-effective new power, which is between 8 and 12 cents/kWh regardless of whether it is produced by a public or a private utility. Some people think that buying power from independent producers has caused BC Hydro to rack up a huge unnecessary debt, when we could be buying it at the spot price on the market, ignoring the fact that BC Hydro is required by law to meet the demand from within BC. The so-call 'debt' is actually a long-term purchase, which will be financed by future purchases of electricity.

The second is the spot price at the Mid-Columbia regional electricity hub, where surplus energy is bought and sold. This fluctuates from day to day and year to year. Right now it is cheap, averaging 2.5 cents/kWh, but in future it may be expensive.

Depending on the market would make us vulnerable to the market, trading short-term gain for long-term misery. It would make us depend on the US, and it would remove our ability to control our greenhouse gas emissions, which are such a huge danger both now and far into the future.

A utility like BC Hydro also has to meet people's need for reliable power, which means balancing intermittent power from wind, solar and run-of-river with dispatchable power from the hydro dams. Here in BC nature gave us mountains, enabling us to store large quantities of dispatchable power behind dams. Utilities that depend on coal-fired and gas-fired plants to deliver firm power face a harder challenge in making the transition to 100% renewable energy.

Forecasting the Future

In 2016-17, BC Hydro sold 51,700 GWh to its customers. Its total sales, however, were 57,300 GWh. So how does that work? In high water years, when there has been lots of rain and snow, BC Hydro sells the surplus power for a low price on the market rather than see water spill over the dams and be wasted.

BC Hydro also consumes some of the power it produces. Operating the system requires 5,500 GWh a year, and 9% of the power gets lost in transmission. Altogether the actual energy generated in 2016/17 was 63,000 GWh.[3] (Most numbers in this chapter are rounded up or down.)

To plan for our future BC Hydro makes regular load forecasts, taking many factors into account. In 2016 they forecast that demand would grow from 58,000 to 81,000 GWh a year by 2036, including 2,848 GWh a year to power assumed future LNG facilities from 2024 onwards.[4] Including the expected success of conservation and efficiency measures, the forecast falls to 73,600 GWh a year.[5] BC Hydro's load forecasts do not include the possibility of an economic recession every eight years, or a major financial crash.

As one of several initiatives to provide our future power BC Hydro is building the Site C dam, which if completed will contribute 5,100 GWh a year to our needs. Because of the climate danger, BC Hydro is required to generate new power without turning to natural gas even if it is cheaper, a decision that is supported by everyone who understands the nature of the threat.

The three questions that this chapter addresses are first, do we need the power? If yes, could our needs be met in an affordable manner by a portfolio of wind, solar and other means without the Site C Dam? And finally, would the new portfolio allow for dispatchability?

Do We Need the Power?

Over the years, BC Hydro forecasts have often overestimated future demand, leading some to suggest that they may have deliberately inflated future demand to justify the need for Site C. This is politically interesting, but what matters here is the future, not the past.

In reality, power consumption in BC is much the same as it was ten years ago. Residential energy use has fallen by 10% over the past five years due to a mixture of factors, including warmer temperatures, energy efficiency improvements, and what's known as the price elasticity of demand. Low elasticity means people don't change their behaviour much when prices rise; high elasticity means they freak out when they get a huge hydro bill and scramble to find ways to use less power - which is what has been happening, and will continue to happen as the price of electricity rises further. In the US, total and per capita residential energy use have both fallen.[6]

The biggest reason why BC Hydro has been over-estimating its recent load forecasts is that the industrial load has fallen by 9.7% over the last seven years due to the closure of pulp and paper mills and sawmills in response to the growing shortage of trees to cut, reflecting decades of poor forest management. The assumed new investments in mining have also not been forthcoming.

Forecasters face many hazards when attempting to gauge the future, and they invest thousands of hours trying to make an accurate forecast. In general, they look at economic growth and at housing and market trends, and they assume that the future will be more or less an extension of the present, with life continuing as normal.

The climate crisis is anything but normal, however. On current trends, even if the world's nations meet their Paris commitments, our world is heading for a 3-4°C temperature rise and a 2-3 metre sea-level rise by the end of the century. 41% of climate scientists use the word 'catastrophic' to describe the likely effect of global warming over the next 50-100 years.[7]

And that's just the beginning. The last time the world was 3°C warmer the sea level was 25 metres higher. In Greater Vancouver, this would put most of Richmond, Surrey, Delta and Tsawassen under water, with flooding all the way up the Fraser to Hope, creating more than a million climate refugees. The I-5 to Seattle, the airport, and the entire shipping infrastructure would be lost to the ocean, destroying the means by which BC trades with the world.

This would not happen for two or three hundred years, but as the melting of Greenland and Antarctica accelerates it will take on a horrible inevitability. Unprecedented flooding of the scale seen in Texas will become the norm. BC's forest fire season will grow more intense each summer, displacing tens of thousands of people from their homes. Elsewhere on the planet, long-term sea-level rise will wipe out large areas of Florida, China and Bangladesh. Extended drought in the sub-tropical regions of Africa and the Middle East will cause an increasing flow of climate refugees, exacerbating civil conflict, exactly as happened in Syria.[8] Holland will cease to exist, with 95% of its land being claimed by the rising ocean.

Two truths follow. The first is that we must immediately abandon all plans for new fossil fuel extraction, and no longer assume a future for oil extraction, natural gas fracking or LNG. This will cause the demand for electricity associated with these industries to fall. Coal-mining is more complex, since BC's coal is metallurgical and is used to make steel, and until the technology advances it will be needed to make wind turbines and other essentials.

The second truth is that we must move as rapidly as possible to electrify all transportation and heat, using renewable energy. This will cause the demand for electricity to rise.

So how much new electricity will BC need to tackle the climate crisis with the urgency and rapidity that is called for? This becomes the critical question.

How Much New Electricity will BC Need for Transportation?

By the end of 2015 BC had just 3,200 electric cars on the road, out of three million.[9] Among 222,000 new car sales,[10] only 1% were full electric. BC Hydro's EV forecast assumes market-driven growth rising from 6,000 EVs in 2017 to 164,000 in 2027 and 580,000 in 2036.

If we are to be serious in tackling the climate crisis we need to look at Norway, which has set 2025 as its target for all new cars to be electric. Germany has chosen 2030 for the same target, France 2040 and Britain 2040. India has set its mind on 2030, and based on current trends 60% of China's vehicle fleet will be electric by 2030. [11]

Battery range is growing and costs are falling every year. By 2025 new electric cars with a range of 400 km will cost the same as conventional cars, so assuming sufficient charging stations, there's no reason why the change need be disruptive. Tesla fans in Italy recently drove the new Model-S a thousand kilometres on a single charge. What is starting as a trickle will turn into a rush as consumers discover how amazing electric vehicles are to drive.[12] Volvo has announced that it will only make electric cars from 2019 onwards.[13] GM is selling a small electric car in China for US $5,300.[14]

In Norway, EV drivers benefit from free municipal parking, free charging, free ferries, free use of bus lanes and zero taxes, compared to taxes at 100% of the price for a conventional vehicle. Perhaps not surprisingly, by July 2017 electric cars were 42% of Norway's new car sales.[15] Bloomberg New Energy Finance has forecast that by 2040 the global EV market share will reach 54%, 72% in France and 79% in the UK. For the past few years most EV forecasts have underestimated the speed at which change is happening.

In North America, by 2020 there will be more than 80 EV and hybrid EV models on the market.[16] By 2025, EVs will achieve cost parity without subsidies, and there could be seven million EVs on the road in America.[17] The equivalent number for BC would be 100,000 EVs, needing 300 GWh of electricity a year. If the government followed Norway's example and aimed for 100% of new cars being electric by 2025, the total would be 350,000, needing 1,000 GWh.

The average life of a car is twelve years, so within twelve years of a ban close to 100% of the cars on the road would be electric. At the same time, buses, light trucks, motorbikes and some longer-distance heavy-duty trucks will be going electric. In July 2017 Daimler announced a 26-tonne electric truck with 200 km range. Tesla has an electric semi-truck on its drawing board.[18]

This has huge implications for our future electricity needs.

We need to address the question head-on. If BC's government has the courage to do what's needed to tackle the looming climate catastrophe, and announce a target for all vehicles of all sizes to be electric by 2040, how much power will we need?

An electric cars uses between 15 and 20 kWh per 100km. The Hyundai Ioniq uses 14, the VW e-Golf 16.6, the Nissan Leaf 17, the Tesla 20.[19] The Renault Zoe, which is completely dominating the market in Europe, uses between 15 and 20, and has a range of 400 kilometres.

To be conservative, I'll go with 20 kwh/100 km. BC has three million vehicles, and the average driver does 20,000 km a year, but many families have two vehicles, so 15,000 km may be more realistic for each car. Driving 15,000 km a year uses 3 MWh (3,000 kWh) of electricity. At the Tier 2 price of 13 cents/kWh the annual fuel cost of driving an EV is $400, compared to up to $3,000 for a conventional car.

BC's population is estimated to grow by 20% to six million by 2040, although it's possible that the housing crisis on Vancouver Island and the Lower Mainland will cause growth to slow if would-be new arrivals can't afford to live here. By 2040, 3,750,000 electric cars each using 3 MWh a year will need 11,250 GWh of power. If *all* vehicles in BC are electric, assuming increasing range and falling prices for battery technology, they will need 26,000 GWh, the equivalent of five Site C dams.

BC Hydro assumed 580,000 EVs by 2036 in its load forecast, needing 1,740 GWh, so we can reduce the additional need for power by that much.

Table 1. The Full Electrification of Transportation in BC

BC Transportation with 100% electric vehicles	**2017 Vehicles**	**2040 Vehicles**	**kWh/ 100km**	**Average Km/year**	**MWh per vehicle pa**	**2040 GWh/year**
Light vehicles	3,000,000	3,750,000	20	15,000	3	11,250
Intermediate 4000-15,000kg	114,000	142,000	70	50,000	35	5,000
Heavy vehicles 15,000 kg+	43,000	53,000	125	160,000	200	10,600
Buses	10,000	12,500	125	50,000	62.5	780
Motorbikes, mopeds	64,000	80,000	7	15,000	1	84
Bicycles	n/a	1,000,000	1.25	7,500	0.094	94
Off road, farm, construction	54,000	67,500	70	2,500	1.75	1,180
Total electricity required	-	-	-	-		28,988
Total less 1,740 GWh in BC Hydro's load forecast	-	-	-	-		27,250

Many factors could change these estimates:

- A big investment in transit and luxury coaches could cause people to abandon their cars for pleasant, relaxed commuting with coffee, orange juice and WiFi.
- A big investment in safe, separated bike lanes could persuade people to switch to cycling as their main mode of travel. In Holland, 32% of all personal trips are by bike, compared to 1-2% in most Canadian cities and 7% in Vancouver.[20] Holland is flat, but electric bikes make cycling

up a hill as easy as cycling down. Electric bikes are so efficient that even a million electric cyclists, each cycling 7,500 km a year, would only require 94 GWh a year.

- Electric heavy-duty trucks could take longer to reach the market.
- The increasing efficiency of electric vehicles could reduce their power need.
- Future BC governments could fail in their climate courage, and drag their heels.
- Automatic driverless cars and carsharing could reduce car ownership, while increasing the driving distance per vehicle.

How Much New Electricity Will BC Need for Heating?

The climate crisis also demands that we cease burning oil and gas to heat our buildings and to provide industrial heat. In keeping with this, Vancouver has declared its intention to seek a 70% reduction in the use of natural gas by 2020 and 100% by 2050, to the outrage of those who don't understand the urgency of the climate crisis. 56% of households in BC use forced air furnaces for heating, burning either oil or natural gas,[21] and the switch to a heat pump increases electrical consumption by around 5,000 kWh a year per home.[22]

Of the 1.8 million households in BC, approximately a million will need to convert to heat pumps, requiring 5,000 GWh a year. With a 20% population increase, we will need an additional 6,000 GWh a year by 2040.

BC also has around 63,000 commercial and institutional buildings.[23] If half need to convert and each is on average seven times the size of a residential home, they will require an additional 1,375 GWh by 2040.

We will also need to convert industrial heat from fossil fuels to some combination of biofuel, biogas, hydrogen and/or electricity. Lacking the data or the ability to provide an informed estimate, I suggest the need for an additional 10,000 GWh a year by 2040 as a guestimate.

Taken together, the electrification of transportation and heat by 2040 will require 45,000 GWh on top of BC Hydro's forecast. You can argue that the transition will take longer, but the case I'm building is based on a combination of what's needed from a climate emergency perspective (100% electrification yesterday), and what is possible given the progress of electric vehicles, the fall in battery prices, and the ability of government policy to drive change.

Table 2: Rapid Electrification Power Needs (GWh)

	2020	2025	2030	2035	2040
Electric vehicles demand	10	7,500	15,000	22,000	27,250
Residential Buildings	500	1,500	3,000	5,000	6,000
Commercial buildings	0	250	500	1,000	1,375
Industry estimate	0	2,000	5,000	7,500	10,000
Total energy demand	510	11,250	23,500	35,500	44,625

We now come to the next critical question: how can the additional electricity be supplied if the Site C dam is not built?

How Much Energy Can BC Save Through Demand-Side Management?

Two things cause us to reduce our demand for power: demand-side management initiatives, and people's decisions to use less power in response to the rising price of electricity.

Demand-side management (DSM) is a family of initiatives that includes new building codes, new standards for lighting and appliances, different rate structures, and programs and incentives to persuade us to switch to more efficient appliances, and to retrofit our homes and buildings.

BC Hydro's investments in DSM have been successful at a cost of 5 cents/kWh, which is cheaper than any known method of developing new power.[24] The savings accumulate year by year, creating a significant reduction in demand.

The other method involves the 'price elasticity of demand', which is a measure of how we respond to the rising price of electricity. When people don't change their behaviour much that's low price elasticity; when we change it a lot that's high price elasticity. BC Hydro assumes very low price elasticity, an assumption that many have criticized.

Since 2008, DSM initiatives combined with high price elasticity have been sufficient to neutralize the growth in demand, a situation that BC Hydro has forecast will continue until 2021. BC Hydro's current goal for new incremental DSM energy savings is 700 GWh a year. In their 2013 Integrated Resources Plan they planned on saving 1,000 GWh a year through DSM, so we know they think this much annual saving to be possible.

Recent demand has been flat, however, with the consequence that BC Hydro will generate a surplus at least until 2021, selling it on the spot market for a loss. To reduce the loss, BC Hydro has reduced power generation and cut back on its planned DSM investments.

At BC Utilities Commission hearings in 2012 and 2013 the BC Sustainable Energy Association presented expert testimony from John Plunkett, economic policy advisor for Efficiency Vermont, a statewide energy-efficiency utility administered by the Vermont Energy Investment Corporation.[25]

He testified that North American energy efficiency portfolio administrators in Vermont, California and Connecticut have been able to and plan to continue saving 2% of total retail electric sales annually for half the long-run marginal cost of new supply.

He suggested that BC Hydro pursue the integration of electricity and gas in efficiency programs for new construction and retrofits; develop comprehensive retrofit programs for low-income tenants including equipment replacement, air-sealing, duct-sealing and cavity insulation; promote on-bill financing for residential home-owners and small-to-medium commercial and industrial customers; and accelerate the conversion of street lights to LED technology.

In California, all new residential construction is required to be net-zero energy by 2020, and all new commercial construction by 2030. In BC, the equivalent goal for residential construction has been pushed back to 2032 because of foot-dragging by the housing industry.

The easiest way to meet the new standard is with a Passive House, which uses 40% less heating energy than one built to code.[26] In Belgium, Brussels has been requiring that all new buildings large or small meet the Passive House standard since 2015, with no complaints from builders, architects or homebuyers, so this is proof that it can be done. They also require all building retrofits to meet the Passive House retrofit standard.[27]

California has been having success with Property-Assessed Clean Energy (PACE) financing for home retrofits, enabling home-owners to repay an energy-retrofit loan through their municipal taxes, and for subsequent owners to continue the same.[28] BC's experiment with on-bill financing, by contrast, has been miniscule.

In California, all eligible low-income customers will have the opportunity to participate in energy efficiency programs by 2020. In BC, there are very few programs to help low-income people save energy.[29]

The US Department of Energy has projected that LED lighting, as one of many energy-saving technologies, will achieve a market share of 84% of the general illumination market by 2030, reducing lighting energy by 40% for a savings of 261,000 GWh, equivalent to the energy consumed by nearly 24 million homes.[30] The equivalent projection for BC's smaller population would see an energy saving of 3,740 GWh a year, equivalent to 73% of the energy from Site C. Switching all of BC's 360,000 streetlights to LEDs, for instance, would save 105 GWh a year, with financial payback in eight years.[31]

As another example, if the 300,000 homes in BC that still use baseboard electrical heating all switched to air-source heat-pumps their owners or tenants would save 2,500 kWh a year, reducing demand by 750 GWh a year.

John Plunkett provided data showing that if BC Hydro adopted the best practices used by the leading US states, saving 2% or 1,000 GWh a year, between 2013 and 2024 it could reduce its anticipated demand by 11,000 GWh at a levelized cost of 2 cents/kWh - three times cheaper than the estimated cost of power from an on-budget Site C (6.8 cents/kWh).[32]

As investments in DSM are made, the energy savings accumulate (see Table 3). It may be that once the low-hanging fruit has been picked, the ability to sustain a 2% annual saving becomes a challenge. It may also be that the rising price of power combined with new energy-saving technologies will make it quite achievable, which I have assumed here. The 2% formula can't be applied to increased demand for the electrification of transportation and heating.

Table 3. Cumulative Savings from Demand-Side Management (GWh

	2017	2020	2025	2030	2035	2040
2% annual saving from DSM	700	1,000	1,000	1,000	500	400
Cumulative DSM Savings	700	3,600	8,600	13,600	18,600	23,600

How Much Energy Can Be Generated from Wind?

Wind energy has matured in leaps and bounds, with turbines increasing in size from 200 kW in the 1950s to as big as 9 MW today. By the end of 2016 there were 340,000 wind turbines spinning around the world, and the industry was creating over a million jobs.[33]

Meanwhile, the cost of wind energy in America has fallen from 38 cents/kWh in 1980 to 3-6 cents US in 2017.[34] Wind energy in BC costs more because we have mountainous terrain instead of flat Texas and Iowa farmland.

The last call for tenders in Québec in December 2014 resulted in the choice of three projects totaling 446.4 MW on relatively hilly terrain at an average cost 6.3 cents/kWh, adding 1.3 cents for transmission for a total cost of 7.6 cents/kWh.[35]

In 2016 BC Hydro updated its numbers for 124 wind energy sites, and estimated BC's wind energy potential at 16,167 MW, able to generate 49,362 GWh of energy a year.[36] They also classified this as firm energy. Most wind energy comes in the winter whereas most solar comes in the summer, making them a good match for each other, and for the grid. With new wind turbines generating energy 35% of the time, 1 MW of wind generates 3 GWh of electricity a year. 1,000 MW generate 3,000 GWh. Recent experience shows that some of the latest wind turbines are actually generating power up to 47% of the time, so 1,000 MW of wind would generate more than 4,000 GWh a year.[37] This chapter assumes 3,000 GWh a year.

The debate is not about the quantity of wind energy available, but the price of wind at different sites, some being cheaper and some more costly to develop.

In the 2016 update to its 2013 Integrated Resource Plan BC Hydro assumed a wind price of 8 cents/kWh and an adjusted price including grid integration of 10 cents/kWh. They also assumed no future price decline, in contradiction to the historical and predicted trends. [38]

The International Renewable Energy Agency (IRENA), by contrast, has projected that global average onshore wind energy costs will fall by 26% by 2025. The US Department of Energy is projecting a 15%-40% fall by 2030, and Bloomberg New Energy Outlook 2017 is projecting a 47% fall by 2040.[39]

In its 2017 wind energy cost and performance summary, the US National Renewable Energy Lab forecast that the best wind farms will reduce the cost of wind energy from 4 cents US in 2017 to 3 cents in 2030 and 2.6 cents in 2050.[40]

Assuming a 25% fall in price by 2025, by the 2030s BC Hydro could be contracting wind energy providers to produce energy at an adjusted energy cost of 8 cents/kWh.[41] To put this in perspective, if Site C were completed on budget, BC Hydro states that its power would cost 6.8 cents/kWh, though others have questioned this, putting the cost at 8 cents/kwh. If Site C is 33% over budget, its power would cost 9 to 10 cents/kWh.

It takes two to four years to plan, win approval for and build a new wind farm, in contrast to Site C, which will be at least ten years in the making. New wind farms can be contracted as needed, based on load forecasts going just four years out. The data in Table 4 ignores the transmission costs of long-distance wind energy, which reduce its effective yield by 9%,[42] but it also ignores the likelihood that small-scale wind producers with projects up to 15 MW will be knocking at BC Hydro's door much sooner, offering wind energy through the Standing Offer Program.

As well as onshore wind, BC has excellent offshore wind resources along the northern coast. The US National Renewable Energy Laboratory forecast in 2017 that the best offshore wind prices would fall (in US$) from 10.5 cents/kwh in 2017 to 7.5 cents in 2030 and 6.4 cents in 2050.

Table 4. Cumulative New Wind Energy

1 MW produces 3 GWh a year	2016	2020	2025	2030	2035	2040
Price of best wind, cents/kWh (unadjusted for grid integration costs)	10	9	7.5	6.8	6.0	5.3
New wind capacity in MW	0	0	2,000	5,000	8,300	10,000
Cumulative number of 2.5 MW turbines	0	0	800	2,000	3,300	4,000
New wind energy GWh	0	0	6,000	15,500	25,000	30,000

Does Wind Energy Kill Birds?
Yes. In Canada, wind turbines kill an estimated 17,000 birds annually. Potential bird deaths needs to be minimized by careful siting and the involvement of wildlife groups. To put things in perspective, each year cellphone towers kill 220,000 birds, cars kill 14 million, birds flying into tall buildings kills 25 million, and house cats kill 196 million birds.[43] So anyone opposing wind turbines because of birth deaths should also oppose cats, cars, tall buildings and cellphones.

How Much Energy Can Be Generated from Solar?

The price of solar PV has been falling steadily, and it is now being installed on BC's rooftops for $3.25 to $4.00 a watt, or $13,000 for a 4 kW system, plus taxes. Lower prices are being achieved in Alberta. In BC, the average 4 kW rooftop system will generate 4,400 kWh a year (more in Cranbrook, less in Prince Rupert).[44]

BC Hydro's net metering program enables people to sell solar power direct to the grid and not have to bother with batteries. Solar installers have described it as being the best in North America for ease and simplicity, with a simple one-page application form. Between 2013 and 2016 net metering customers in BC increased from 154 to 900, with 3.8 MW of installed capacity, 95% of which is solar,[45] generating around 4.2 GWh of electricity a year. With the average 4 kW rooftop system producing 4,400 kWh a year, a million rooftops would generate 4,400 GWh a year.

Solar prices are falling, but the prospect of a million solar homes is still a long way off. The 2016 Greentech Media report estimated that residential solar prices would fall by 30% by 2020, reducing a 4 kW system to $9,100 plus taxes. With prices like this, the trickle of demand is going to turn into a rush, especially as hydro prices continue to rise, and it is only a matter of time before municipalities, states and provinces copy San Francisco's requirement that all new commercial buildings with ten stories or fewer must be built with solar panels. This may soon become California state law for all new buildings.[46]

In Germany, long a solar leader and with lower average solar irradiation than BC, the Fraunhofer Institute reports that the price of large (10kW to 100kW) rooftop PV has been falling by 13% a year and by 75% since 2006, from 5,000 to 1,270 Euros per installed kW, a price-reduction of 90% over 25 years, and an annually compounded price reduction of 9%.[47] In Canadian dollars that's around $2.00 a watt, compared to $3.25 a watt today. The reason is the advanced maturity of Germany's solar market, with prices falling due to competition, market size, and improved work-force efficiency.

As BC's solar market matures there's every reason to expect a similar fall in prices. Rooftop solar PV at $2.00 a watt has a levelized cost of 7.2 cents/kWh over 25 years and 6.5 cents over 30 years, [48] which will be highly enticing to customers who could be paying 20 cents/kWh after taxes for Tier 2 BC Hydro power by 2030, assuming an average 3% increase in rates per year.

At the utility-scale the solar numbers become even more interesting. The Fraunhofer Institute reports that utility-scale solar plants are producing energy for 12 cents/kWh. The Greentech report (see above) estimated that the installed cost of utility-scale solar will fall to $1.00 per watt by 2020 (5.4 cents/kWh).[49] The International Renewable Energy Association estimates between 6 and 12 cents/kWh by 2025, and the 2017 Deutsche Bank report estimates 70 cents/watt by 2022 (4.3 cents/kWh).[50]

When BC Hydro considered solar in its 2013 Integrated Resource Plan, it assumed a utility-scale solar price of 26 to 75 cents/kWh. In 2016 it reduced this to 14-17 cents, but as with wind energy, it assumed a fixed price going forward.[51]

Looking further ahead, researchers at Bloomberg New Energy Finance have predicted that the levelized cost of solar will fall by 66% by 2040, bringing utility-scale solar PV in BC into the same price range as power from an on-budget Site C. BC Hydro could then either decide to become a solar provider, or let the private sector do it for them, limiting their role to grid integration.[52]

So what is a reasonable estimate for solar production in BC? At a future residential price of 8 cents and a utility-scale price of 6 cents/kWh, the sky's the limit.

In the Philippines, a shopping mall has installed a 2.9 MW solar system on its roofs, generating 3.48 GWh a year.[53] Environment America has found that America's big box stores and shopping centers could host 62.3 GW of solar PV.[54] This suggests that shopping mall rooftops in BC, with 1.43% of the US population, could support 890 MW, generating 1,000 GWh a year at the BC rate of 1,100 kWh per kW. As the price falls further, commercial and industrial rooftop owners will doubtless do the same, saving money while contributing to the grid.

In Germany, with similar low solar radiation, solar PV supplied 7% of the electricity in 2016, which was a 7% increase in solar production over 2015. If solar PV was to provide 7% of BC's energy in 2030, currently forecast by BC Hydro to be 75,000 GWh, it would produce 5,250 GWh a year. The numbers in Table 5 assume a much slower uptake. If BC Hydro's rates continue to rise while the installed price of solar falls, the solar revolution will really take off. When the new Tesla solar roofs reach Canada, people needing a roof replacement may run the numbers and find that for south-facing roofs, solar shingles are more cost-effective than other forms of roofing.

Waiting in the wings is floating solar. This is not a fantasy: China has just switched on a 40 MW solar array on a man-made lake in Anhui Province. As well as cooling the lake's water, offsetting the ecological impact of the rising temperature, it also cools the solar electronics, making it work more efficiently.[55]

In BC, 10% solar coverage of the Williston Reservoir behind BC Hydro's WAC Bennett dam would generate 13,500 GWh a year - more than twice as much as Site C while reducing evaporation, leaving more water in the reservoir to generate power.[56] This is proven technology, available for future British Columbians to tap into whenever it is needed.

From BC Hydro's perspective a solar panel is the same as a heat pump - it reduces demand. For this reason, BC Hydro offers $800 incentives to install ductless heat pumps.[57] It is logical, therefore, to propose that they might also offer a solar rebate. Incentives run the danger of appealing to free riders who would have installed the appliance anyway, but if BC Hydro wanted to ramp up solar uptake, enabling it to store water behind the dams longer into the fall, it could treat solar as a form of DSM and invest in subsidies or province-wide marketing to persuade more people to call a solar company and get a quote.

Table 5. Cumulative New Solar Energy
1 kW generates 1,100 kWh/year. 1 MW generates 1,100 MWh = 1.1 GWh/year.

			2016	2020	2025	2030	2035	2040
A	Price of Tier 2 power + taxes	Cents/ kWh	14	20	23	27	31	36
B	Price of solar PV cents/kWh	Cents/ kWh	20	18	14	10	8	7
C	Number of 4 kW rooftop installations	kW	900	5,000	15,000	100,000	500,000	1,000,000
D	Solar rooftops capacity	MW	3.6	20	60	400	2,000	4,000
E	Energy from residential solar PV, 4,400 kWh/system	GWh	4	22	66	440	2,200	4,400
F	Shopping mall rooftops	GWh	0	5	50	250	500	1,000
G	Other commercial rooftop systems	GWh	0	5	50	250	500	1,000
H	Total commercial solar	MW	0	11	110	550	1,100	2,200
I	Number of 5 MW utility solar farms	#	0	0	3	15	25	50
J	Utility solar capacity	MW	1	1	15	45	75	150
K	Energy from new utility scale solar	GWh	1	1	16.5	50	82.5	165
L	Total solar capacity (D+H+J)	MW	4.6	32	185	1,000	3,175	6,350
M	Total solar generation (E+F+G+K)	GWh	5	35	203	1,100	3,500	7,000

Does solar manufacturing consume a lot of energy and use toxic heavy metals?
Solar PV energy payback depends on technology and location. In Northern Europe, energy payback takes 2.5 years.[58] Solar modules are guaranteed for 25 years but they will generate energy for 50 years, so a plant constructed today will generate twenty-five times more energy than was used to manufacture the modules. As manufacturing processes and solar efficiency improve, the energy payback will fall.[59]

Manufacturing solar modules typically requires involves the use of silicon, boron and phosphorus. Only 5% of the module market uses cadmium, which is also used in cellphones. The conditions under which metals are mined and modules are manufactured vary according to regulatory enforcement and company decision-making. In 2015, the Silicon Valley Toxics Coalition published a Solar Scorecard, which ranks the top solar module manufacturers on everything from extended producer responsibility to biodiversity protection, the use of slave labour and module toxicity, enabling customers to choose their provider accordingly.[60]

How Much Energy Can Be Generated from Geothermal?

Geothermal energy is produced by drilling two to three kilometres down into hot rocks. Globally in 2013 there was 11,700 MW of installed capacity. A geothermal plant generates energy 80% to 90% of the time, making it dispatchable, base-load power.[61] Canada is the only major country along the Pacific Rim's Ring of Fire not producing geothermal energy.

The Geological Survey of Canada has found that northeastern B.C. has the highest potential for the development of geothermal energy in Canada. In 2014, the Canadian Geothermal Energy Association published a series of Geothermal Resource Estimate Maps indicating that BC has 5,700 MW of potential capacity at shallow depths down to 3,000 metres, rising to 8,500 MW at 4,000 metres, capable of generating 36,450 GWh and 54,350 GWh a year respectively at a unit energy cost of 7.3 cents/kWh for favourable projects.[62] At the time, BC Hydro agreed that geothermal energy had a range of costs between 7 and 40 cents/kWh.[63]

In 2016, however, a report financed by Geoscience BC examined 18 specific geothermal sites, including two at Meagre Creek, northwest of Pemberton, with 178 MW of capacity costing 11.7 cents/kWh and capable of generating 1,400 GWh a year at an assumed 90% capacity factor. Other sites had prices ranging from 17 to 39 cents/kWh.[64] Unlike wind and solar, there is no indication that geothermal costs are falling. Bloomberg New Energy Finance reported in 2014 that geothermal power had a levelized cost of US 6.3 to 9.7 cents/kWh (CAN 8 to 12.4 cents/kWh).[65]

The primary reason why BC's geothermal potential has not been developed is that you have to drill deep underground to estimate the energy at a proposed location, and the financial risks have deterred investors. The International Geothermal Association has recommended solutions to the start-up problems including cost sharing of exploration costs, a one stop-shopping regulatory set-up, and strong strategic support from governments.[66] By 2030, we can assume that these problems will have been solved, enabling the first of BC's geothermal resources to be developed, contributing 1,400 GWh a year.

Table 6. Geothermal Energy

		2016	2020	2025	2030	2035	2040
Installed capacity at Meagre Creek	MW	0	0	0	178	178	178
Geothermal energy	GWh/yr	0	0	0	1,400	1,400	1,400

Wave and Tidal Energy
BC has low tidal but huge wave energy potential off its coast. The Pacific Institute for Climate Solutions found that a single wave energy device deployed at Amphitrite Bank off Barclay Sound could generate 525 MWh a year, and that Vancouver Island's shoreline has 500 MW of potential capacity. The World Energy Council has estimated the cost of wave energy at between 35 cents and $1.27/kWh, however, making it an expensive option at least for the next few decades.[67] There are also some ecological concerns associated with wave power.

Will The New Power Be Dispatchable?

The third critical question concerns dispatchability - the ability of a utility engineer to press a button and deliver power when and where it's needed. With hydropower this is easy, since the water sitting behind a dam is stored energy waiting its moment of release. For utility engineers, this is a big advantage of the Site C dam.

Faced with the rapid increase in intermittent wind and solar energy, however, thinking about dispatchability is changing. In August 2017, US Energy Secretary Rick Perry's commissioned Report on Electricity Markets and Reliability emphasized the importance of smart control systems and electric cars:

"An aggregated fleet of vehicles or chargers can act as a [demand response] resource, shifting load in response to price signals or operational needs; for example, vehicle charging could be shifted to the middle of the day to absorb high levels of solar generation and shifted away from evening hours when solar generation disappears and system net load peaks."[68]

In BC, most EV drivers will charge their batteries at night, so their power draw won't impact the periods of peak demand when dispatchability is needed. BC's future EV owners could also have the ability to sell their battery power back to the grid in what's known as Vehicle to Grid (V2G), helping

BC Hydro provide power to its customers at critical times of peak demand. In Denmark, EV owners are already earning money by plugging their cars into two-way charge stations.

In 2016, Greentech Media research found that in 2025, in America, 11.4 million EVs could be adding 5 GW of storage capacity to the grid. BC's equivalent would be 72 MW.[69] By 2040, if all of America 265 million vehicles were electric, they would add 116 GW of storage capacity to the grid. BC's equivalent with our smaller population would be 1,656 MW. This is significant, since it is more than would be provided by Site C.

Dispatchability can also come through 'demand response' whereby industrial and commercial customers are given advance notice and paid to reduce their demand at certain times.[70] In Texas, with six times BC's population, half of their dispatchable power is already being obtained in this way.[71] In January 2014, when a polar vortex knocked out several Texas power plants, "demand response provided 496 MW of capacity to the grid within 46 minutes of being called."[72]

Cold ice storage is another form of demand response: large cold ice storage managers are paid a small incentive to add extra cold to their storage in the hours before peak demand, enabling them to switch off during peak demand.[73] Home-owners can participate through the use of grid-interactive water heaters that are set to heat the water at night and avoid periods of peak demand.[74]

Perhaps counter-intuitively, increased wind energy also enables improved dispatchability. The larger the volume of energy from wind, the greater the chance that some turbines will be generating energy somewhere, creating improved predictability through forecasting. The use of smart inverters on solar equipment, and in future on wind farms, can also increase a utility's control over energy entering the grid.[75] Germany, Spain, Portugal and Scotland sometimes generate up to 100% of their electricity from intermittent forms of renewable energy on certain days without grid problems. Spain was 40% wind-powered for the first six months of 2013, [76] leading the Rocky Mountain Institute's Amory Lovins to suggest that much of the current thinking on base-load power is out-of-date.

After 2030, in this scenario, geothermal power also provides firm dispatchable power.

Putting it All Together

As the savings from demand-side management and the energy from wind, solar and geothermal add up, especially in light of falling prices, it is clear that we are capable of meeting our future power needs without Site C.

Table 7 summarizes this chapter's findings in a rough back-of-the envelope manner that needs all sorts of disclaimers, and is no substitute for thorough analysis by energy specialists, enabling BC Hydro to develop a new portfolio of options for its next Integrated Resource Plan.

The accumulating numbers show that even with greatly increased demand to account for rapid electrification, BC has the resources needed to meet our future electrical demand without natural gas and without Site C. To understand Table 7, follow it line by line.

Table 7: Energy-Saving and Generation Potential without Site C (GWh/Year)

		Cost/kWh	2020	2025	2030	2035	2040
A	BC Hydro's Load Forecast including LNG, not including DSM[77]	-	62,000	70,000	75,000	80,000	*84,000*
	Expected LNG Load		252	2,848	2,848	2,848	*2,848*
B	Load Forecast without LNG, without DSM	-	62,000	67,000	72,000	77,000	*81,000*
C	Power needed for rapid electrification (Table 2)	-	510	11,250	23,500	35,500	44,625
D	New Load Forecast (B+C)[78]	-	62,510	78,250	95,500	112,500	125,625
E	Forecast total supply from existing + committed heritage resources and IPPs, without Site C	-	64,000	64,000	64,000	65,000	65,000
F	New Cumulative Demand-Side Management Energy (Table 3)	2 -5 cents	3,600	8,600	13,600	18,000	23,000
G	New Wind Energy (Table 4)	8 cents and falling	0	6,000	15,500	25,000	30,000
H	New Solar PV Energy (Table 5)	20 cents falling to 7	35	203	1,100	3,500	7,000
I	Geothermal Energy (Table 6)	11.7 cents	0	0	1,400	1,400	1,400
J	Total (E+F+G+H+I)	-	67,635	78,803	95,600	112,900	126,400
K	Surplus Energy (J minus B)	-	5,000	0	0	0	0

Full electrification will bring additional needs I have not included, including BC's share of the electrification of Canada's railways, the electrification of the short-haul ferries, and the possible electrification of short-haul flights, since Airbus is working with Siemens to develop a prototype for regional passenger aircraft requiring up to 20 MW of capacity[79] and Boeing is partnering with Zunum Aero to manufacture a Hybrid to Electric aircraft.[80] More wind and solar energy can be called into service as needed.

In the non-Site C scenario described here the big emphasis for the next ten years is on demand-side management, which is also the best way to control costs.

By 2025, as electrification ramps up, BC's huge reserves of wind energy are brought into service, along with geothermal power by 2030. The solar revolution, meanwhile, keeps growing.

BC Hydro's load forecast without much electrification calls for an additional 5,000 GWh every five years. If the forecast turns out to be an over-estimate, that much less energy will be needed.

A Renewable Energy Economy

There will be huge benefits to the transition to 100% renewable energy, as well as the climate benefit. Almost all air pollution will disappear, to the relief of those who might otherwise suffer from associated heart and lung diseases, and the transition will be a huge driver for BC's economy.

First benefit: The US-based Solutions Project has estimated that 100% renewable energy in Canada would generate $110 billion in annual avoided health costs.[81] For BC, this would be a $14 billion annual benefit, perhaps falling to $10 billion because BC does not have coal or gas-fired power plants.

Second benefit: Every EV driver will save up to $2,600 a year on the energy cost of driving. For the province as whole, this is another $10 billion a year benefit by 2040, with the money being available for other activities. A further $10 billion a year will be saved by trucking and transit companies. Home and building owners will also save on the cost of heating, freeing up income to be spent on other things.

Third benefit: Almost all the oil we use for transportation today is imported, so the money leaves the provincial economy. Much of the expenditure for renewable energy, by contrast, is local, allowing the money to stay in the economy.

Forth benefit: Jobs. In this scenario, the investment in demand-side management and renewable energy will generate almost 240,000 new direct and indirect jobs over 20 years. For the explanation, see the Endnote.[82]

Table 8: Renewable Energy Jobs 2020-2040

	Jobs
Demand-side management	25,000
Solar	126,000
Wind	86,000
Geothermal	1,900
Total	238,900

BC Hydro says Site C will create 10,000 person-years of direct employment during construction and 33,000 person-years throughout development and construction.[83] The indirect jobs multiplier for construction jobs is 0.6, so this would imply 52,800 total direct and indirect jobs (48 jobs per MW).

Navigant Consulting's 2010 study for the American Hydropower Association, by contrast, found that hydro dams generate between 5 and 6 full-time direct jobs per MW, with a 0.6 multiplier increasing this to 8 to 10 direct and indirect jobs per MW. This would suggest that Site C will generate between 8,800 and 11,000 full time direct and indirect jobs.[84]

If wind was used to produce all Site C's 5,100 GWh, it would need 1700 MW and generate 14,500 jobs. Solar PV would need 4,600 MW of capacity and generate 83,000 jobs.

What is the Cost of Completing or Cancelling Site C?

With $2 billion spent and a further $2 billion issued in contracts that doubtless include financially termination clauses, Site C has already incurred up to $3 billion in sunk costs. Cancellation will also bring site restoration costs.

If Site C is completed it will generate 5,100 GWh a year from 2024 onwards. In this rapid electrification scenario there would be no surplus power, and the power produced would substitute for wind. The argument that BC Hydro would be forced to sell the power at a loss on the spot market would not apply.

If BC Hydro has already spent a third of its budget for Site C, this is a sunk cost, and the marginal cost of its energy going forward falls to 4.5 cents/kWh.

From a financial perspective, if we accept the need for rapid electrification to tackle the climate crisis, and that new power will be needed after 2024, and if we accept that Site C's sunk costs are thoroughly sunk, the power from Site C would be cheaper than the equivalent from wind on one condition: that the project comes in on budget. A 50% cost overrun would neutralize the advantage over wind; a 90% overrun, which has been the norm for many large dam projects around the world, would pass the advantage back to wind. The Catch-22 is that we will not know for sure that there will be a cost overrun until it is too late to cancel the project.

In Conclusion

So there you have it. Financially, Site C will only be a win if it comes in on budget, which based on BC Hydro's record and the record of large hydro projects around the world is highly unlikely. We do need the power. Of that there's no mistake, unless you ignore the urgency of the climate crisis.

We can find the power we need elsewhere, however, without a devil's trade-off. We can do it without sacrificing Nature, without sacrificing farmland, and without sacrificing the treaty rights and cultural wealth of the First Nations who have occupied this land for thousands of years.

The belief that money is what matters most is perhaps the defining error of our time, of our economic system, and of the MBA and economics courses that train their students to think and act more narrow-mindedly in pursuit of financial gain, and to look on social and environmental losses as externalities, unfortunate collateral damage in the pursuit of monetary gain.

The *only* grounds for favoring Site C over a portfolio of affordable alternatives operating with dispatchable technologies is the financial argument, based on the high stakes gamble that nothing will go wrong and the project will be competed on budget, and the willingness to accept the loss of Nature, farmland and First Nations rights as an unfortunate externality - or the price of progress, as some prefer to call it.

For so many people, however, progress itself is becoming the price, and a price we are no longer willing to pay. Our civilization's fixation with material progress and never-ending economic growth is a poison that is distorting our values and our ability to appreciate what really matters.

The Site C dam project is an economic white elephant, a holdover from a previous era when people had less regard for nature, less regard for non-material values, and little regard for Canada's First Nations.

We do not need the Site C dam. It is time to close the project down.

*

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Wind energy generates 8.6 direct and indirect jobs per MW, so installing 10,000 MW by 2040 would generate 86,000 jobs.

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