ELECTRICITY FROM THE SUN: REALITY VERSUS FANTASY

In a recent article in the *Calgary Herald*,[1] journalist Licia Corbella was effusive in her praise of both solar energy and Alberta's competitive electricity market. In several places, her article quoted Robert Hornung, president and CEO of the Canadian Renewable Energy Association, who also extolled the virtues of solar generation and the competitive market. There are two very serious problems with their assessments. The first is that several of Mr. Hornung's statements are based on commonly held myths that are easily refuted using real-world data. The second is that one of the reasons why Alberta is favoured by renewables investors is that they receive hidden subsidies from the province's consumers. Those subsidies will grow rapidly as renewable generation is added unless some changes are made to the market rules.[2]

Solar Energy Myths

Corbella states:

> Hornung said a rooftop system that has the capacity to produce enough electricity over the course of a year to match a typical home's annual electricity demand would likely cost between $15,000 to $20,000 to install, but that's all dependent on numerous factors including the shape of the roof and whether the roof slants toward the south. Also, batteries have improved so much, homes and businesses can store the power to be used later in the evening, when the sun is no longer shining, or sell it back into the grid when the cost of electricity is higher.

She goes on to state:

> Obviously, one of the reasons Albertans are keen to take up solar is Alberta's grid is carbon intensive. In a province such as Quebec, for instance, where 98 per cent of the power comes from hydroelectricity, the impact of producing solar on your rooftop will be less than it would be in Alberta. [See endnote 3.]
>
> "There's a number of ways that those sort of distributed energy resources, which is what we call things like rooftop solar, can provide benefits," said Hornung.
>
> "One incentive is reducing greenhouse gas emissions . . . and another is to avoid the need to invest in new generation and transmission infrastructure. So, if you're actually producing a significant amount of power, for example on people's roofs or on the roofs of businesses or shopping malls, you need less power to be coming from a big generating station, whether it's renewable or fossil fuel or whatever. You also need less investment in transmission lines to carry that power so you can generate savings across the system in that way, and that will be very important in a world where we're talking about things like net-zero greenhouse gas emissions."

Let's take Mr. Hornung's example of a rooftop system that has the capacity to produce enough electricity over the course of a year to match a consumer's electricity demand. As he states, the consumer could be a homeowner, a business, or a shopping mall.

Anyone who lives in Alberta knows that, while skies can be bright and sunny at any time of the year, winter days are much shorter than summer ones. The sun is up for less than 8 hours in mid-December but for more than 16 hours in late June and early July. In mid-December the sun does not rise more than 16 degrees above Calgary's horizon, but in summer it rises to more than 60 degrees. So, no matter how cheap or efficient solar panels become, and no matter whether they're pointed south or in some other direction, they will always produce much less energy in December and January than in June and July. This can be seen in the following table, which shows the monthly output of a south-facing, rooftop solar panel that produced 10,260 kWh for the year.[4]

MONTHLY OUTPUT OF A SOUTH-FACING ROOFTOP SOLAR PANEL [kWh]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
424	596	876	1116	1195	1147	1319	1147	895	679	484	382

If we assume, just to keep things simple, that the consumer uses a constant 855 kWh per month, then the rooftop solar panels produce 464 kWh too much energy in July and 473 kWh too little in December. From October to February, solar output is 2565 kWh, 1710 kWh short of the 4275 kWh consumed.[5] If we put a dozen of these homes together, the winter shortfall is 20,520 kWh or just over 20 MWh.

Let's assume we want to supply these dozen homes with solar and batteries only. Here's a picture of TransAlta's $16 million, 20 MWh battery energy storage facility being built near Pincher Creek. According to the *Calgary Herald* article from which this picture was taken,[6] the project consists of three Tesla lithium ion battery storage groupings and is slightly smaller than a soccer pitch. So, the cost of battery backup for each home's solar energy system would be $1.3 million—and that would have to be repeated every ten years, which is the expected battery life. Now, imagine one of these for every dozen homes in your neighbourhood.

What about Mr. Hornung's comment that solar can help to avoid the need to invest in new transmission or distribution infrastructure? This can be true in some very specific and controlled circumstances, and indeed there are applications in which solar and/or batteries are very good. However, his claim is usually not true. Not only will lots of solar not reduce the need for wires, it will actually increase it, and here's why. On a sunny day in July, the output of a system sized to meet the customer's annual consumption is almost guaranteed to be much greater than real-time demand; hourly data shows that it is not uncommon for the excess output to be five or six times greater than the customer's maximum hourly consumption. Since it is economically infeasible to buy enough batteries to cover the winter shortfall, it is also infeasible to buy enough to store the summer surplus. So, the excess solar energy must either flow out to a grid that is larger than today's or the solar array's output must reduced. In the latter case, the foregone energy production would prevent the system from meeting the annual consumption.

Everything just said about solar for individual customers scales up to commercial solar projects. While large-scale arrays could use tracking systems to allow the solar panels to follow the sun across the sky, thereby reducing the size of surpluses and shortfalls,[7] they can do nothing about sunrise and sunset. And while specific solar and/or battery installations could possibly be used to reduce the need for wires given very strict operational guidelines, any high-latitude power system that incorporates a high penetration of solar generation will have a *greater* need for wires, not a lesser one. It is important to understand that the attributes of renewable generation are inextricably linked to location, so what may be true in Alberta may not be true elsewhere and vice versa.[8]

The Competitive Market

Corbella's article opens with the following statement.

> How's this for irony: Despite what the rest of the country may think about Alberta, this province is now the fastest-growing market for solar energy in Canada. What makes it even more ironic is it's Alberta's deregulated electricity market — so detested by the Alberta NDP — that's behind Alberta increasingly soaking up the sun to make electricity.

She goes on to note Mr. Hornung's view that the declining cost and improved efficiency of solar is helping to increase its uptake, and then quotes him as saying,

> But it also really highlights the unique structure of the Alberta market within the Canadian context and how that provides Alberta with a pretty unique competitive advantage at this time to secure this type of investment.

In general, support for Alberta's competitive electricity market is well deserved. For two decades, the province has been provided with a reliable supply of electricity by private investors who spent billions of dollars to build thousands of megawatts of generation capacity—without incurring large ratepayer/taxpayer debt like some provinces did. That generation was developed in response to market forces: as demand grew and approached the available supply, the market price rose; investors saw the rising price, sensed an opportunity to make a profit, and retired old plants and built new ones; the gap between demand and supply temporarily widened, so prices dropped and investment slowed; then demand caught up to supply again and the investment cycle repeated. This is the way markets are supposed to work.

Unfortunately, the world's obsession with carbon dioxide has thrown a monkey wrench into the works.[9] Today, renewable generation is being built more to displace existing generation than to supply growing demand. Also, rather than being tied to the delivery to consumers of a measurable amount of a tangible product (electricity), a large fraction of the revenues earned by many renewable generators are tied to the *lack* of delivery of an unmeasurable amount of an invisible substance (CO_2). Several examples of these non-electricity-related revenue streams have appeared in the news recently. In one cited by Corbella and also reported by the CBC,[10] Amazon signed the largest *virtual power purchase arrangement* (VPPA) in Canada with an Alberta solar project developer. Since the Amazon deal is private, let's consider a hypothetical VPPA between Alberta solar generator Sol and a company named BigCorp, whose operations are outside the province.

The first part of the hypothetical VPPA is a *contract for differences* (CFD) with a strike price of $60/MWh. If Sol provides electricity to the market when the hourly price is $40, BigCorp pays Sol the difference of $20. If the market price is $75, Sol pays BigCorp the difference of $15. In the end, Sol receives $60 for every megawatt-hour of electricity it sells, regardless of the market price.

Under the second part of the VPPA, BigCorp gets the renewable energy certificates (RECs) that Sol earns for causing some assumed amount of CO_2 to not be emitted. Since there is no globally accepted and audited method for calculating how much CO_2 is offset by each megawatt-hour of solar energy, that number is left for Sol and/or BigCorp to determine.[11] Since BigCorp has no physical presence in Alberta, it never takes delivery of any of the electricity that Sol produces; instead, it buys electricity for its outside-Alberta factory from a local supplier, uses its purchase of RECs in Alberta to offset any emissions associated with that electricity, and advertises that it is "net zero."

A huge consequence of this VPPA is that neither Sol nor other renewable generators with similar deals will care about the market price of electricity, at least for a while. As a result, we can expect significant growth in the amount of solar generation in the near term. Eventually, the average market price received by solar generators will be pushed down by the over-supply, the difference between CFD strike prices and the

market price will grow, RECs will become much more expensive, and investments in solar generation will slow. What we don't know today is: (i) whether the economic limit will be reached before Alberta's electricity grid becomes physically incapable of accommodating any more solar generation; (ii) whether large payments for "anti-CO_2" in what is supposed to be an electricity market prevent the proper functioning of that market; and (iii) how much it will cost Albertans in hidden subsidies related to wires costs and backup generation.

Some might argue that low power prices produced by an over-supply of solar will be good for consumers. But there's no such thing as a free lunch. Since BigCorp is paying for RECs, it must either recover the cost through the sale of its products or go out of business. If it gets a tax break, other taxpayers will have to make up the government's revenue shortfall, so citizens are on the hook one way or the other. More importantly, Alberta still needs all of its conventional generation—most of which is fossil-fueled (FF) generation—because every megawatt of solar must be backed up by a megawatt of generation that works when the sun is not shining.[12] (As already noted, battery backup is out of the question because commercial solar suffers from the same seasonal variation that rooftop solar does.[13]) Thus, Mr. Hornung's comment that distributed energy resources can reduce the need for generation infrastructure is generally not true.

Now, when renewable generators displace FF generators' CO_2 emissions, they also displace FF generators' energy sales. But the fixed costs of operating and maintaining the FF generators does not change, so their owners must either go out of business or receive a higher price for each megawatt-hour sold when the sun is not shining. FF generators going out of busines may be lauded by some as a desirable outcome, but those Albertans left to freeze in the dark would be unlikely to agree.

Perversely, some renewable energy advocates use the higher prices needed by FF generators in sunless hours to amplify their claims that renewable energy is getting cheaper every day compared to FF energy. To see that this is wrong, imagine that BigCorp builds a warehouse, puts solar panels on the roof, and disconnects from the electricity grid. Since its operations would be severely disrupted by passing clouds, rain, heavy snow, and sunset, and since batteries are out of the question, the company would likely choose to build backup generation.[14] The cost of the backup generation that is always required for solar generation is rarely, if ever, factored into cost comparisons by renewable energy advocates.

If the cost of backup generation, the cost of extra wires, and other costs imposed by renewable generators not discussed here were properly attributed to them, there would be no cause for concern among Alberta consumers. However, the existing market rules absolve generators of the vast majority of those costs. In our example, since BigCorp does not consume energy in the province, it pays nothing toward them either. Consequently, Albertans are on the hook. The implicit subsidies that are being paid to renewable generators have so far gone largely unnoticed because the amount of renewable energy in Alberta is still relatively small. However, as the share of Alberta's energy that comes from renewable generation grows, so will the cost of those subsidies—unless we change the rules.[15]

It is imperative to understand that Alberta's competitive electricity market and its rules are not to blame for the challenges discussed here. The governing legislation and rules have worked very well for a long time, and the Alberta government, investors, and market participants have collectively served Albertans very well. However, the world—or at least the part of it that does not include China, Russia, India, most other countries in Asia, or most of Africa—is changing rapidly as its CO_2 obsession grows, and the rules must keep up. If wind and solar are truly the most economic forms of generation *after all costs are properly accounted for,* they will (and should) prevail in the market. But if Alberta is the best place in Canada to invest in wind and solar only because it provides the largest subsidies, then let's stop being the best.

For the Sake of our Children and Grandchildren, can we *Please* Talk About Reality?

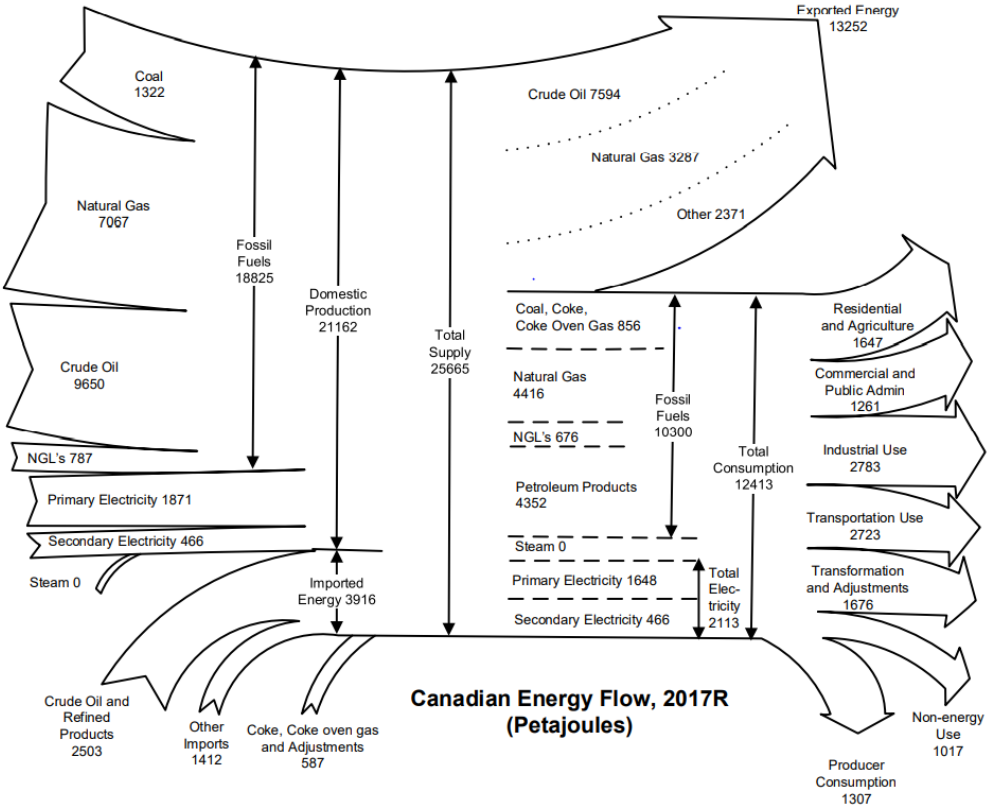
If you listen to the majority of journalists, politicians, and renewable energy advocates, you might feel as though you're a passenger on a train to the city of Utopia. When you get there, you and your adult children will have high-paying jobs that don't involve disturbing the earth in any way. The lights will come on when you flip the switch and the power will be supplied by gently spinning wind turbines and glimmering solar panels surrounded by yellow canola fields. Your home will be heated with wind and solar electricity instead of natural gas. And, any time you want, you will be able to drive through pristine wilderness in your environmentally friendly electric car. The problems with nonrecyclable materials and toxic chemicals from retired wind and solar plants will have been solved. Energy might cost a bit more than it does today, but it will be worth the extra cost because we will have saved the world from the ravages of "carbon pollution." The train is just leaving the station, but it is picking up speed and you should be in Utopia City by 2030, or 2050 at the latest.

Unfortunately, Utopia is exactly the fantasy that its name suggests. Between here and there lies a canyon that makes the Grand Canyon seem like a crack in the sidewalk, and building a bridge across it will cost an eye-watering amount of money. That's because fossil fuels still provide the lion's share of Canada's total energy consumption. As the graphic on the next page shows, of 12 413 petajoules, 10 300 of them, or 83%, were provided by petroleum products, natural gas (including liquids), coal, and coke.[16]

If we consider just Canada's end-use energy, 77% was provided by fossil fuels.[17] For Alberta, that number was 89%. Lest anyone think that this province is the lone "bad guy," the share of end-use energy provided by fossil fuels was 80% in Ontario, 75% in British Columbia, and 58% in hydro-rich Quebec. For the world as a whole in 2019, the energy came from oil (33%), natural gas (24%), coal (27%), nuclear (4%), hydro (6%), and non-hydro renewables (5%). In total, the fossil fuel share was 84%.[18]

While renewable resources have been providing an increasing share of Alberta's electricity, wind, solar, and hydro still provided only 14% of the total in 2020.[19] Yet even that relatively small number does not begin to convey what a transition to an all-electric future would mean for Albertans. Let's assume we eliminate the oil and gas industry completely, lose everything shown in the adjacent box,[20] and write off trillions of dollars' worth of provincial oil and gas assets even though the world will still be using those commodities for a long time.[21] To eliminate residential natural gas, most of us would have to replace our furnaces and water heaters and rewire our houses to accommodate electric heaters; some would have to replace their gas stoves with electric ones. To eliminate commercial and industrial natural gas—assuming we have any industry left—we would have to replace the heating systems in restaurants, hospitals, office towers, shopping centres, and public buildings throughout the

province. To convert our vehicle fleet to electric, we would have to buy new vehicles, scrap our existing ones, and build innumerable vehicle charging stations in homes, in parking lots, in provincial and national parks, and on streets in front of apartment buildings.[22] And unless we build localized power grids supplied by small modular nuclear reactors (a nascent technology), we would have to increase the capacities of the province's transmission and distributions systems to about six times what they are today.



Since a total energy transition is not achievable any time soon, let's get back to the idea of transitioning just Alberta's *existing* electric system to renewable generation. The aforementioned article on RBC's signing of a long-term power purchase agreement says:

> The bank has agreed with green energy retailer Bullfrog Power to buy the majority of the electricity produced by the project to be designed and built by BluEarth Renewables of Calgary.
>
> The project is to provide enough power for over 6,400 homes and the panel installations will cover 120 hectares, the size of 170 soccer fields.
>
> The solar installation is to be built in the County of Forty Mile, a hot spot for renewable power that was also chosen by Suncor Energy Inc. for its $300-million 200-MW wind power project (approved last year and then put on hold during the COVID-19 pandemic).
>
> BluEarth says commercial operations at its Burdett and Yellow Lake Solar Project are expected to start up in April 2021.
>
> It says the agreement shows that renewable energy can be cost-competitive in a deregulated electricity market like Alberta's, adding the province has some of the best solar and wind resources in Canada.

This is a perfect example of why the public may be imagining Utopia. When they read, "The project is to provide enough power for over 6,400 homes," they likely don't think about the seasonality of solar energy, the additional wires investments that are needed, the effect of solar power on other generators and the cost of backup generation, or how to ensure the stability of the power grid in the face of renewable generation's

erratic output. Mr. Hornung's comment that "batteries have improved so much, homes and businesses can store the power to be used later in the evening, when the sun is no longer shining, or sell it back into the grid when the cost of electricity is higher," is unlikely to help the public understand that a solar-and-batteries power supply for a single-family home would cost more than a million dollars. And BluEarth's claim that renewable energy can be cost-competitive in a deregulated electricity market is true only if renewable generators continue to receive hidden subsidies from consumers.

Here is a simple, irrefutable, inescapable fact that journalists, politicians, and renewable energy advocates need to understand and speak truthfully about: ***a megawatt-hour of wind or solar electricity is not the same as a megawatt-hour of fossil-fuel electricity for the very simple reason that renewable electricity shows up when it wants to while fossil-fuel electricity shows up when we want it to.***

When we need electricity from FF generators to power a hospital's ventilator, keep the lights on, or run the fans in our furnaces when it's −30°C outside, we can be very confident it will show up. Of course there are times when FF generators fail, but a reasonable level of redundancy provides us with electricity more than 99.99% of the time.[23] Now imagine trying to keep your food fresh, run your business, or perform surgeries according to whether the wind is blowing and the sun is shining. The fact is, no solar farm will ever be able to power 6400 homes by itself—at least not in Alberta. And as we saw above, the use of batteries to manage the variability of wind and solar generation is far beyond our economic reach.

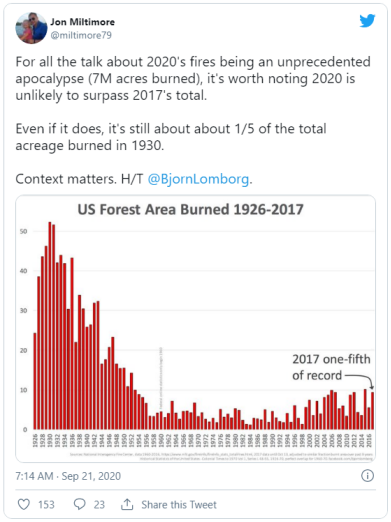
It should be obvious by now that the push for renewable generation has nothing to do with better economics or higher reliability. Moreover, renewables have environmental problems of their own, including the use of nonrecyclable materials and toxic substances. The only real driver—aside from the private motivations of certain individuals and groups—is the elimination of what some call "carbon pollution," a term invented for the sole purpose of scaring people.[24] But even with respect to CO_2 emissions it is difficult to see Canada's effort as anything other than a horrendously expensive exercise in futility. Canada's emissions account for just 1.6% of the world total, and few Asian, African, or South American countries have any intention of following us down the green road any time soon. So, while Alberta is on track to replace its remaining 4700 MW of coal-fired generation within a few years, China alone commissioned 38 400 MW of it in 2020. That country also approved another 36 900 MW—three times more than it approved the previous year—bringing the total under construction to 88 100 MW.[25] Another 158 700 MW is proposed.[26]

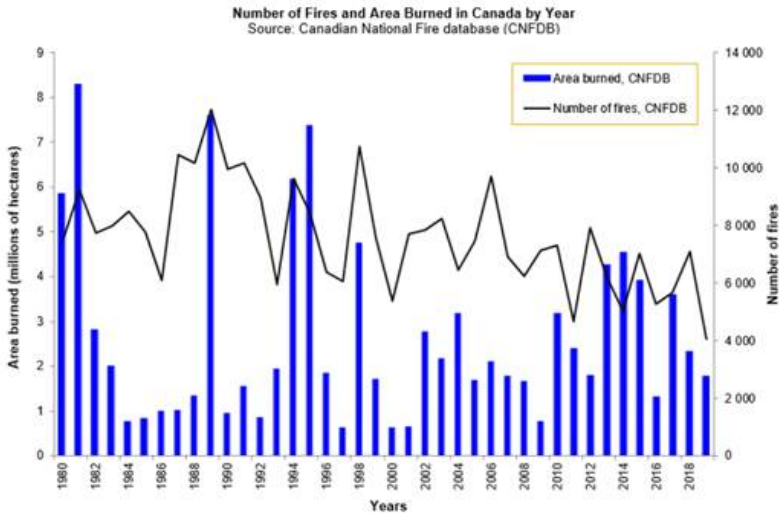
Some would argue that, regardless of the cost, we have to stop emitting CO_2 because the earth is burning up before our very eyes. As one tranche of evidence, the media provided us with an endless stream of commentary on how climate change caused, among other things, the Fort McMurray fire in 2016, the intense forest-fire seasons in British Columbia in 2017 and 2018, and the California wildfires of 2020. As shown by a 2019 tweet (see below), the Prime Minister has become convinced that Canada's forests are burning because of CO_2 and that the solution is a tax on "pollution." Yet as the Natural Resources Canada chart below the Prime Minister's tweet shows, both the number of fires and the hectares burned have been on a downward trend for forty years,[27] even as the CO_2 concentration in the atmosphere increased from 338 ppm to 420 ppm. Is anyone who believes that human CO_2 emissions are now responsible for all our major weather events prepared to argue that it is CO_2 that has caused the reduction in fires?

While the Fort McMurray fire was economically unprecedented and had a terrible impact on the people of that city, it was certainly not unprecedented from an environmental or death-toll perspective. The Miramichi fire of 1825 burned over one million hectares (almost double the area burned by the Fort McMurray fire) and it killed at least 160 people—and possibly more as people drowned trying to escape into the water. The single largest fire in recorded history in North America was the Chinchaga fire in northern British Columbia and Alberta in 1950, which burned about 1.4 million hectares. That fire was

allowed to burn freely due to local forest management policy and a lack of human settlements in the region.[28] Regarding California, the 2020 fires were tragic for those involved, but as the chart of US wildfires shows, 2020 was nowhere near the worst year in US history. Ironically, the picture the Prime Minister attached to his tweet was of the Parry Sound 33 fire in 2018, which was accidentally started by a crew building a wind farm.[29]

The Prime Minister says our kids and grandkids are counting on us, and of course they are, but how can we make good decisions on their behalf when we are basing our actions on fake news? And what will happen if government "fact checkers" start censoring information just because it is not consistent with the ruling party's ideology? Perhaps Ms. Corbella can be the journalist who starts others of her profession down the road of providing readers with credible news stories based on real-world data instead of green propaganda and politically motivated fear-mongering. Surely she, other journalists, politicians, renewable energy advocates, and the rest of us, owe that much to our kids and grandkids.





End Notes

[1] Corbella: Lots of irony in Alberta leading the country in new solar projects | Calgary Herald

[2] The word "rules" is being used in a generic sense and includes legislation, regulations, energy-market rules, and transmission and distribution tariffs.

[3] Corbella's statement that 98% of Quebec's electricity comes from hydro is correct. However, as discussed later, more than half of Quebec's total energy still comes from fossil fuels.

[4] This data comes from the US National Renewable Energy Laboratory's PVWATTS web program. Default system parameters were used for a 4 kW (dc) rooftop array, the location for which was Calgary. The data was scaled up to a total of 10,260 kWh because, according to the article on the Amazon power purchase agreement that will be discussed later (see Footnote 10), the referenced solar project will produce 195,000 MWh, or enough energy to power more than 18,000 homes. If we assume 19,000 homes to account for the "more than," the consumption is 10,263 kWh per year or 855 kWh per month. PVWATTS uses simulated weather based on historical data, so running it again may produce slightly different results.

[5] The shortfall is 1710/10,263 = 17% (two months) of average consumption. The notion that solar needs only enough backup to get through a few cloudy days does not apply in Alberta.

[6] Varcoe: TransAlta set to flip switch on Alberta's first large-scale battery storage project, using technology from Tesla | Calgary Herald

[7] Even two-axis tracking cannot reduce the surpluses and shortfalls enough to make batteries a realistic backup option. See The True Cost of Wind and Solar Electricity in Alberta.

[8] For example, based on PVWATTS data, the highest monthly output of a standard 4 kW rooftop solar array in Las Vegas is 684 kWh. The lowest output is 392 kWh, which is 57% of the highest output. The same array in Medicine Hat produces 162 kWh in December, which is only 25% of July's 643 kWh. The annual totals are 6750 kWh in Las Vegas and 4915 kWh in Medicine Hat, which makes solar energy 37% more expensive in Medicine Hat, all other things being equal. The attributes of renewable generation are inextricably linked to location, so what may be true in one place may not be true in another.

[9] Regardless of what fraction of "climate change" one believes is caused by the burning of fossil fuels, it would be several orders of magnitude more efficient and effective, from the engineering, economic, *and* environmental perspectives, to adapt to climate change rather than trying to prevent it. But that's for another day.

[10] Amazon unveils plan for major solar power project in southern Alberta | CBC News. Other deals have also been reported; see, for example, RBC agrees to buy electricity from new southern Alberta solar power farm project | The Star

[11] There are some international *guidelines*, but they are not mandatory and are not universally accepted.

[12] In Germany, often considered the poster child for renewable generation, the installed capacity of wind and solar generation exceeds its peak demand, and when its conventional generation is included, installed generation capacity is more than double its peak load. So, Germans are paying roughly twice as much in fixed costs as would be required for a reliable fleet of conventional generators. A good website for German electricity data is Energy Charts (energy-charts.info)

[13] Given the preceding discussion of the cost of battery backup for solar, readers will not be surprised to learn that the cost of supplying batteries to backstop enough commercial solar generation to supply Alberta's annual electricity demand would be about **two trillion dollars,** or about $1.9 million for an Alberta family of four. Note that there *are* very good applications for batteries; long-term energy storage is just not one of them. See The True Cost of Wind and Solar Electricity in Alberta.

[14] Ironically, not only here in Alberta but throughout the world, the only viable option for local dispatchable generation is generally FF generation.

[15] To be fair, no Alberta generator pays a meaningful amount for T&D beyond its local connection facilities and no generator is responsible for backup costs. And if all generators imposed the same T&D and backup costs, there would be no implicit subsidies. However, intermittent, nondispatchable renewable generators imposed much higher wires and backup costs than convention generators, and the fact that they don't pay those higher costs means they are receiving implicit subsidies. Regardless of how the market rules may evolve in the future, it is imperative that all generators be treated in a fair and nondiscriminatory manner.

[16] https://www150.statcan.gc.ca/n1/en/pub/57-003-x/57-003-x2020001-eng.pdf?st=MQ6dnDdr, p. 133.

[17] See "Energy use, final demand" rows in Tables 2-1, 2-7, 2-8, 2-11, and 2-12 in the Statistics Canada report. The numbers in the text were calculated under the assumption that the x values, which are values that were suppressed to meet the confidentiality requirements of the *Statistics Act,* are negligible. If they are not negligible, the fossil-fuel shares would increase.

[18] bp Statistical Review of World Energy 2020. The total is not 100% due to rounding.

[19] 2020-Annual-Market-Stats-Final.pdf (aeso.ca), p. 16.

[20] Oil and natural gas: backbone of the Alberta economy - Context Magazine by CAPP

[21] The reference case in the US Energy Information Administration's 2021 long-term outlook has US oil production rising slightly through 2030 and then holding at that level through 2050 (EIA's AEO2021 Reference case shows crude oil production plateauing after 2030 - Today in Energy - U.S. Energy Information Administration (EIA)). A report from McKinsey suggests that world crude oil use will increase from 92 MMb/d in 2020 to 101 MMb/d by 2040 (global-oil-supply-and-demand-outlook-to-2040-online-summary.pdf (mckinsey.com)).

[22] With the exception of electric vehicles, for which a 20% efficiency gain was assumed for the conversion, all other estimates were based on MWh for MWh swaps. Except for residential natural gas, the electric load was assumed to increase the same amount in every hour of the year. Because residential natural gas demand is much higher in the winter, January's value divided by 744 hours was taken to be the required capacity increase.

[23] Very few of the outages consumers face are the result of generation shortages. Most are related to transmission or distribution facilities being knocked out by lightning, high winds, icing, cable faults, animal contacts, and vehicle accidents.

[24] Pure carbon (C) comes in several forms, including diamonds, graphite, and fullerene. The purest form of coal, called anthracite, can have up to 98% carbon. There are no diamonds coming out of power-plant stacks, so the term "carbon emissions" is misleading. The use of the even worse "carbon pollution" is a politically motivated scare tactic. Combining a carbon atom with one oxygen (O) atom produces carbon monoxide (CO), a toxic gas, but combining a carbon atom with *two* oxygen atoms produces carbon dioxide (CO_2), a gas that is essential for life. The CO_2 content of Earth's atmosphere is currently 417 ppm (0.04%). The level of CO_2 in the atmosphere was 20 times higher than present levels 500 million years ago; it dropped, then rose again some 200 million years ago to four to five times higher than present levels, and it was on a slow decline till recent pre-industrial times (Climate and CO2 in the Atmosphere (ucsd.edu)). Plants evolved when the CO_2 content was much higher than today, and most plants grow best at CO_2 levels between 1000 and 1300 ppm (Carbon Dioxide In Greenhouses (gov.on.ca))—which is why we pump "carbon pollution" into greenhouses. At levels below about ~150 ppm, plants die—and so does all life on this planet. The US Occupational Safety and Health Administration provides a Recommended Exposure Limit of 5000 ppm based on the weighted average concentration for up to a ten-hour workday during a 40-hour workweek (OSHA Occupational Chemical Database | Occupational Safety and Health Administration); the short-term (15 minute) exposure limit is 30,000 ppm. Why, then, did Canada's Liberal government sponsor radio ads several months ago that claimed "carbon pollution" is making our children sick?

[25] China's new coal power plant capacity in 2020 more than three times rest of world's: study | Reuters. These plants alone will produce an estimated 556 Mt of CO_2 per year, while Alberta's public electricity and heat production produced 36.3 Mt in 2019.

[26] China Started More Coal Plants Than The Entire World Retired In 2020 | OilPrice.com

[27] Canadian Wildland Fire Information System | Canadian National Fire Database (CNFDB) (nrcan.gc.ca)

[28] Wikipedia. *Chinchaga fire.* Downloaded 2019-12-01 from https://en.wikipedia.org/wiki/Chinchaga_fire Reference: C. Tymstra. *The Chinchaga Firestorm: When the Moon and Sun Turned Blue*. Edmonton, Alberta: University of Alberta Press, p. 248, ISBN 978-1772120035. See also R. Field: "*Revisiting the 1950 Great Smoke Pall"* in *The Canadian Smoke Newsletter,* Fall 2000. Downloaded 2019-12-03 from https://cloud1.arc.nasa.gov/arctas/docs/CanadianSmokeNwsltr_Feb2009.pdf

[29] Parry Sound 33 wildfire investigation wraps up | CTV News