IN THE DARK ON RENEWABLES

Rebutting Deloitte and Climate Reality – Insights for Investors, Policymakers and the Public

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ABSTRACT

Deloitte Insights and Climate Reality have recently issued reports making claims that renewables – especially wind and solar – are as cheap and as reliable as conventional coal-fired or natural-gas-fired power.

We demonstrate that these claims are not valid and show that wind and solar exist almost entirely due to preferential government programs and subsidies.

Mass deployment of wind and solar can destabilize power grids. Solutions like batteries, flywheels, and pumped hydro are exorbitant in cost. Renewables-plus-storage systems cannot reasonably be scaled up to meet society's demand for reliable power.

Large additions of wind and solar do not necessarily reduce carbon dioxide emissions. In any case, human-produced CO_2 is not a control knob that can fine-tune Earth's climate.

Friends of Science Society

Nov. 18, 2018

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In the Dark on Renewables:

Rebutting Deloitte Insights and Climate Reality

Deloitte Insights, an imprint of Deloitte LLC, recently published a report entitled *Global Renewable Energy Trends—solar and wind move from mainstream to preferred.*[1] Shortly thereafter, Climate Reality issued an e-book entitled *How Renewables Work: A Practical Guide to Wind, Solar and Geothermal.*[2] According to Deloitte, wind and solar are now benefitting from three enablers:

> *The first enabler is that wind and solar are reaching price and performance parity on the grid and at the socket. Second, solar and wind can effectively help balance the grid. Third, new technologies are honing the competitive edge of wind and solar.*

As this report shows, these claims are not valid.

The assertion that wind and solar are reaching *performance* parity on the grid and at the socket ignores the reality that they require nearly equal amounts of conventional power generation to back them up because the wind does not always blow and the sun sets every day. Since wind and solar power generation systems are paired with fossil fuel, nuclear, and/or hydro back-up generation, wind and solar are effectively *redundant,* which means consumers effectively have to pay for two sets of generators. And while the costs of wind turbines and solar panels may have dropped in recent years, successfully integrating those technologies requires transmission-system upgrades, energy storage systems, and certain technical upgrades that all come at an additional cost.

Regarding the claim that wind and solar can effectively help balance the grid, it is true that certain technical advancements can reduce the negative effects that wind and solar have traditionally had on system stability. However, no amount of technical wizardry will allow wind to contribute to system balancing when the wind is not blowing, and no amount of wizardry will allow solar to contribute to grid balancing at 3:00 a.m. local time.

The *price parity* claim, which is based on a value known as the *levelized cost of energy* (LCOE), is also invalid. Even if the LCOEs of wind and solar were lower than the LCOEs of conventional generation—a debatable proposition—that does not translate into lower overall costs for consumers. The problem with the LCOE as a cost metric is that it ignores all the peripheral costs of forcing wind and solar onto the grid that were just noted.

According to Climate Reality, the transition to 100% renewable energy systems will be helped along by geothermal energy for heating and cooling. This claim, too, is largely invalid. While geothermal is playing a role—and will continue to play a role—in the world's energy systems, it is simply not capable of replacing traditional heating and cooling systems in all situations or all locations.

The absurdity of the notion that it will now be easy and cheap to convert to 100% renewable energy systems is highlighted by the following chart, which comes from BP's Statistical Review of World Energy.[3] Renewables (excluding hydro), shown in dark orange, accounted for just 3.6% of world primary energy consumption in

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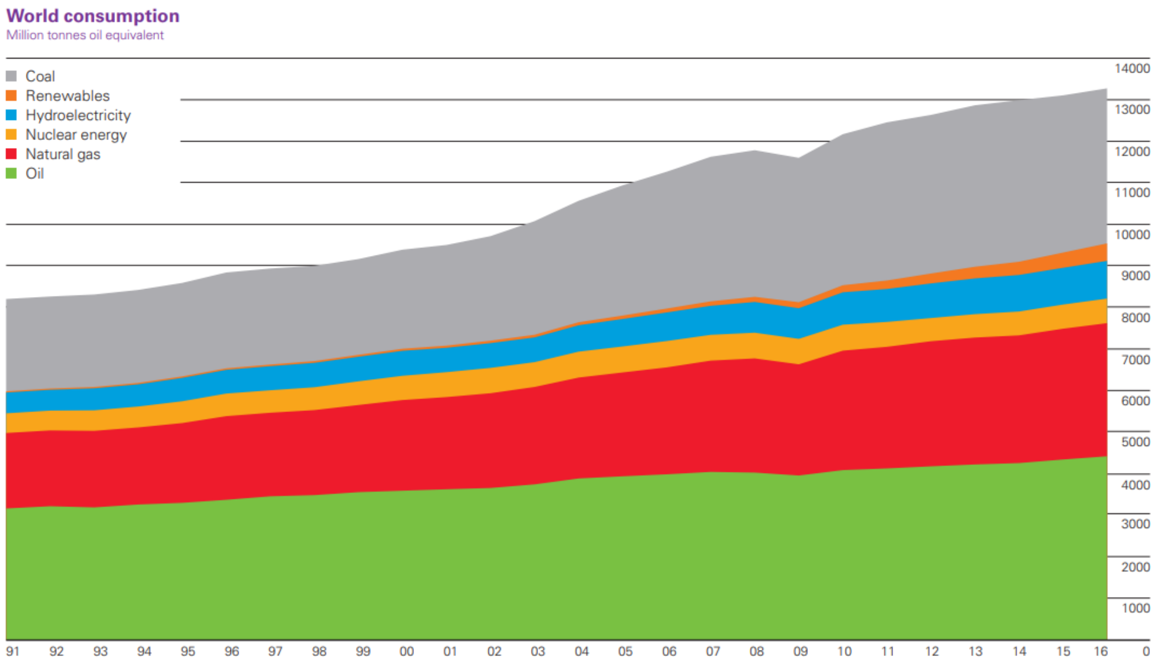
[1] https://www2.deloitte.com/insights/us/en/industry/power-and-utilities/global-renewable-energy-trends.html?id=us:2sm:3tw:4di4624:5awa:6di:MMDDYY:HANDLE::author&pkid=1005414

[2] https://www.climaterealityproject.org/sites/default/files/renewables_ebook_09_2018.pdf

[3] https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html

2017. Consequently, renewables advocates are effectively suggesting that we can rebuild the world's entire energy system while maintaining the existing one as a backup, and that we can do in a ludicrously short period while keeping costs low. This is simply not reality.



World primary energy consumption grew by 1.0% in 2016, well below the 10-year average of 1.8% and the third consecutive year at or below 1%. As was the case in 2015, growth was below average in all regions except Europe & Eurasia. All fuels except oil and nuclear power grew at below-average rates. Oil provided the largest increment to energy consumption at 77 million tonnes of oil equivalent (mtoe), followed by natural gas (57 mtoe) and renewable power (53 mtoe).

Solar and the Misleading Levelized Cost of Energy (LCOE)

The Deloitte report claims that solar is at or near price and performance parity with conventional generation. The claim is not true, and to see why we will compare the overall cost of supplying electricity to a single-family home in southern Alberta using fossil-fueled generation to the cost of supplying that electricity with solar plus storage. The supply problem being considered is admittedly highly simplified and the numbers used are purely fictitious, but since our intent is to illustrate the LCOE and the interpretation challenges associated with it, not to debate actual costs (which can vary from place to place) or study energy economics in detail, it will be quite sufficient. We will extend our consideration to wind and large-scale electric systems later.

In simple terms, a generator's LCOE is the net present value (NPV) of the stream of costs (including initial capital and financing costs, ongoing operating and maintenance expenses, and fuel costs) divided by the energy produced over its lifetime.[4] The concept seems straightforward enough, but as the United States Energy Information Administration (EIA) warns:[5]

4 There is some variation in how LCOE is calculated. For example, the electricity stream (annual kWh) is sometimes discounted.

5 https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

> *Because load must be balanced on a continuous basis, generating units with the capability to vary output to follow demand (dispatchable[6] technologies) generally have more value to a system than less flexible units (non-dispatchable technologies), or than units using intermittent resources to operate. The LCOE values for dispatchable and non-dispatchable technologies are listed separately in the tables, because comparing them must be done carefully.*
>
> *The direct comparison of LCOE across technologies is, therefore, often problematic and can be misleading as a method to assess the economic competitiveness of various generation alternatives because projected utilization rates, the existing resource mix, and capacity values can all vary dramatically across regions where new generation capacity may be needed.*

Let's now turn to our electricity supply problem. The owners of a new house located near Brooks, in southeastern Alberta, want to stay "off the grid." The house will use exactly 8106 kilowatt-hours (kWh) of electricity per year.[7] The three supply options are a Model A fossil-fueled generator, a Model B fossil-fueled generator, and solar photovoltaic (PV) panels. To keep things simple we assume that both the cost of the generator and the cost of the fuel, if any, will be paid in a lump sum at the end of each year.

The Model A generator costs $20,000 and consumes 8¢ worth of fuel for each kilowatt-hour of electricity produced. The annual payment is $1420 for the generator plus $648 for fuel, so the NPV of the payment stream at a 5% discount rate is $29,140. Dividing by total kilowatt-hours produced (202,650 over 25 years) gives an LCOE for Model A of 14.4¢/kWh. The Model B generator costs more up front ($23,000), but it is more efficient, using only 4¢ worth of fuel per kilowatt-hour. The annual payment is $1632 plus $324, which gives an NPV of $27,570 and an LCOE of 13.6¢/kWh. In this simple case we could have dispensed with the NPV calculation and simply looked at the first-year cost, but in the real world the cash-flow stream would be more complicated and the NPV calculation would be needed.

Both fossil-fueled generators are dispatchable, which means they can vary their outputs to match the amount of electricity the home is consuming at any moment in time. Since they are each capable of meeting the home's electricity needs on their own, the choice comes down to the LCOE. Model B is the clear winner.

Let's bring in the PV array. If we take the LCOE to be 10¢/kWh, we can work backwards and calculate an initial cost of $20,250 (since there is no fuel cost). The array has to be 6 kW to match the annual energy requirement, as we shall see in a moment, so the initial cost works out to be $3375 per installed kilowatt. Since the PV array has a much lower LCOE than Model B does, it would seem to be the best choice. However, whereas an LCOE comparison between Model A and Model B is an apples-to-apples one, an LCOE comparison between Model B and the solar array is an apples-to-oranges one.

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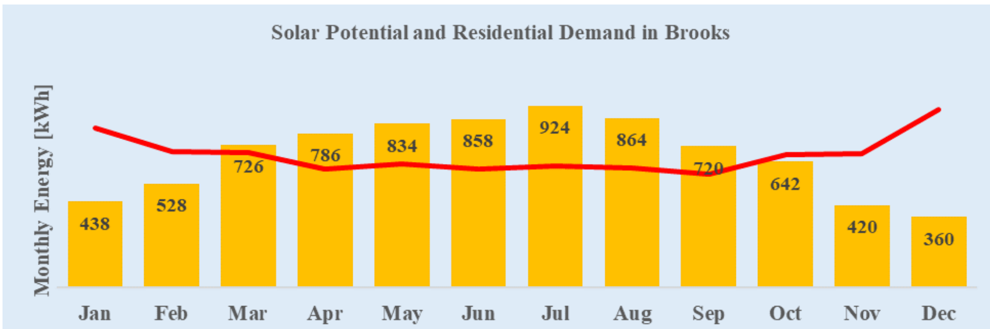
6 "Dispatchable" refers to resources, typically but not exclusively conventional generators, that can increase or decrease their power injections or withdrawals on demand. Responsibility for dispatch resides with the power-system operator, who will, for example, direct a gas-turbine generator to increase its output as the demand for electricity increases as people wake up in the morning or to address a supply/demand imbalance when another generator trips off line. Some actions are handled automatically by protection and control systems. Some wind and solar facilities can be dispatched down, but they generally cannot be dispatched up because the system operator cannot direct the wind to blow or the sun to shine. While it would be technically possible to withhold some wind capacity to allow for a dispatch up, doing so would defeat the purpose of building wind in the first place.

7 For the purposes of this example, our forecasts are perfect, all systems are perfectly reliable, and all systems have a useful lifetime of 25 years.

Natural Resources Canada[8] provides monthly solar energy potentials for the Brooks area, at latitude 50.57°N, for a PV array having a peak output of 1 kW. Multiplying by six gives the monthly kilowatt-hours of production shown in the following graph. The total energy output is 8106 kWh per year, exactly the amount required by the house. Brooks' annual potential of 1351 kWh/kW puts it 154th out of 3516 locations in Canada, though that potential is only 2% below the 1380 kWh/kW available in the Canadian solar hot-spot of Regway on the Saskatchewan-Montana border.[9] Of the 1089 locations in Canada with a solar potential of 1200 kWh/kW/year or more, 298 are in Alberta and 616 are in the other two prairie provinces. The Canadian average is 1171 kWh/kW/year. Since an array that produces power at a steady rate of 1 kW for an entire year would produce 8760 kWh in a year, the average *capacity factor* for a solar array in Canada is 1171/8760 = 13%. The capacity factor is an important number, as we shall discuss presently.



In addition to the solar potential, the above graph shows the monthly electricity use by the house in our example (the red line).[10] Not surprisingly, a PV array that produces the right amount of energy over the whole year produces too much in the summer and too little in the winter. From October to February there is a total energy shortfall of 1383 kWh, which means there is a 1383 kWh surplus from March through September.

A common claim related to solar generation is that all we have to do is add some batteries to store electricity when the sun is shining and give it back when the sun goes down. Since the October to February shortfall is 1383 kWh, the house would have to go into October with 1383 kWh stored in its batteries to get through the winter.[11] **But that's more energy than is stored in 2000 typical 50-ampere-hour automobile batteries, so battery storage is clearly not a viable option.**

What about increasing the capacity of the PV array? Since the largest monthly energy shortfall is in December, when production is 360 kWh and consumption is 909 kWh, the house would in theory need an array that is just over 15 kW, about 2½ times larger than the original 6 kW. But that puts the initial cost of PV up by a factor of

8 https://www.nrcan.gc.ca/18366

9 This is for a south-facing panel with tilt angle equal to the location's latitude minus 15 degrees. This configuration produces the highest average annual energy of the configurations listed, though it may not produce the highest winter energy. As measured by global insolation in MJ/m^2, there is only a small difference between the monthly share of annual energy between the selected configuration and a configuration have two-axis tracking.

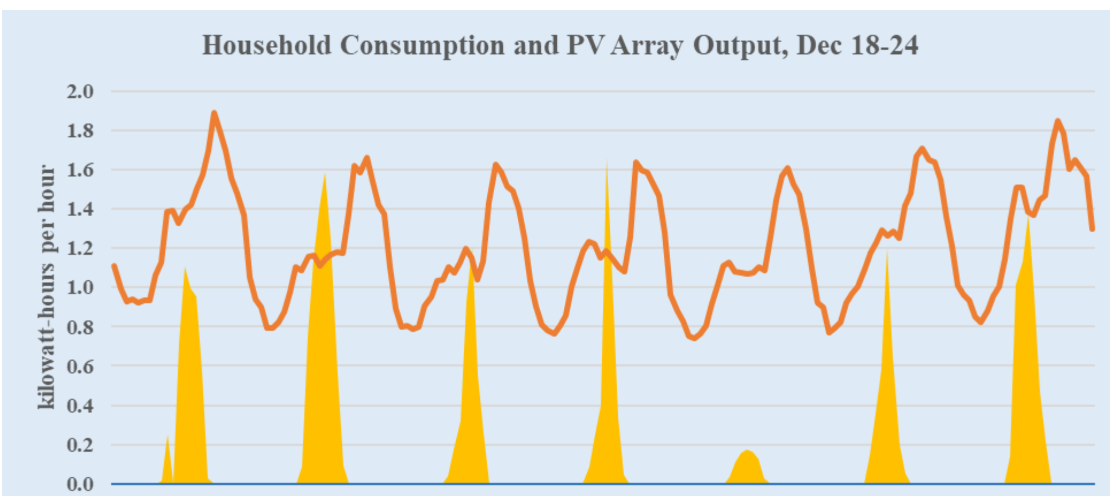
10 The residential profile is based on hourly data from 2016 for more than 100 Calgary residential customers, scaled to equal 8106 kWh per year. Individual consumption profiles vary enormously, so the average profile is perfectly plausible for Brooks. Calgary is roughly 150 km WNW of Brooks.

11 This assumes that batteries are perfect, i.e., that every kWh of stored energy can be delivered when needed. On November 8, 2018, a randomly selected solar PV deep-cycle battery that can store 100 ampere-hours, or 1.2 kWh, was advertised on batterystuff.com for a volume price of US$230. The number of batteries required to store 1383 kWh would be 1152 at a total cost of US$265,000.

2½. Since the amount of energy required each year has not changed, what started out as an LCOE of 10¢/kWh is now 25¢/kWh, far higher than the LCOE of the Model B generator. But even that is not the final cost of the PV system, because some battery capacity is still needed to get through the nights.

Read: "Solar Panels on the Prairies – Hope and Disappointment" A true story.[12]

The following graph shows the hourly output of a 15 kW PV system, along with the hourly electricity consumed by the house, for the week of December 18-24, 2017.[13] Despite having a 15 kW array whose maximum output is more than seven times the home's peak electricity demand, the output of that array was seldom above the house's consumption level. To get through this week, the house needed to start with 174 kWh (about 300 car batteries' worth) of stored energy. So now the true cost of the PV system is 25¢/kWh plus the per-kWh cost of 300 car batteries, compared to 13.6¢/kWh for the fossil-fueled generator.



12 http://blog.friendsofscience.org/2018/05/13/solar-panels-on-the-prairies-hope-and-disappointment/

13 The graph actually shows the hourly output of the 15 MW Brooks solar facility. Dividing its true output by 1000 gives us one of the infinite number of possible sets of hourly outputs for a 15-kW array.

The conclusion of this simple example is clear: even though solar was assumed to have a lower LCOE than the fossil-fuel options, the solar option is more expensive in total, and it still runs the risk of failing to meet the home's electricity needs if the sun is obscured by heavy cloud or the solar panels are covered with snow for several days in a row.[14]

Let's continue with the present example and look at what happens to LCOE when uneconomic choices are forced on consumers. If (hypothetical) government rules mandate that 50% of the home's energy must come from solar, the owner must buy a 3 kW PV array costing 3 × $3375 = $10,125 along with the Model A generator costing $20,000. The Model A unit is now less expensive than the more efficient Model B unit because there are fewer kilowatt-hours over which to allocate Model B's higher initial cost or to reap the benefit of the lower fuel cost. The LCOE of the Model A generator increases from 14.4 ¢/kWh to 24.3 ¢/kWh, not because of any change in the actual cost per kilowatt-hour of available energy, but because the forced adoption of uneconomic solar generation displaces some of the energy that it would have delivered. Moreover, the less efficient fossil-fueled generator—the one that produces higher CO_2 emissions—is being used. Since the LCOE of the solar generation is 10 ¢/kWh and it delivers half the electricity used, the homeowners pay an average price per kilowatt-hour of ½ × 24.3 + ½ × 10 = 17.6 ¢/kWh instead of the 13.6 ¢/kWh they could have paid.

Renewables advocates seize on this artificially rising fossil-fuel LCOE to claim that renewables can become even more economic relative to conventional generation. For example, the Deloitte reports states on page 5 that, *"As wind and solar capacities grow, many conventional sources will start operating at lower capacity factors, causing the LCOEs of both existing and new-build projects to increase. The cost of new solar and wind plants could eventually be not just lower than the cost of new conventional plants, but also lower than the cost of continuing to run existing plants globally."* This silly ascending-cost-spiral economics paints a very misleading picture of the true cost of renewable energy and is one of the reasons why the EIA separates dispatchable and non-dispatchable generation in its LCOE tables, as shown in a later section.

The above example used electricity supply and demand for a single house to keep things simple. Despite the simplicity, the same factors come into play on large-scale power systems. Relative to low-latitude parts of the world, high-latitude regions see:

- electricity demand driven as much or more by winter heating than by summer cooling, which means that peak demand occurs on cold winter evenings when PV output is zero instead of on hot summer days when PV output is high;
- more seasonal variability in the length of the day, and therefore more seasonal variability in the output of PV arrays;[15]
- earlier sunsets in the winter, which adds lighting to the after-sunset peak demand;[16] and
- less total solar energy received each year, as shown in the map below.[17]

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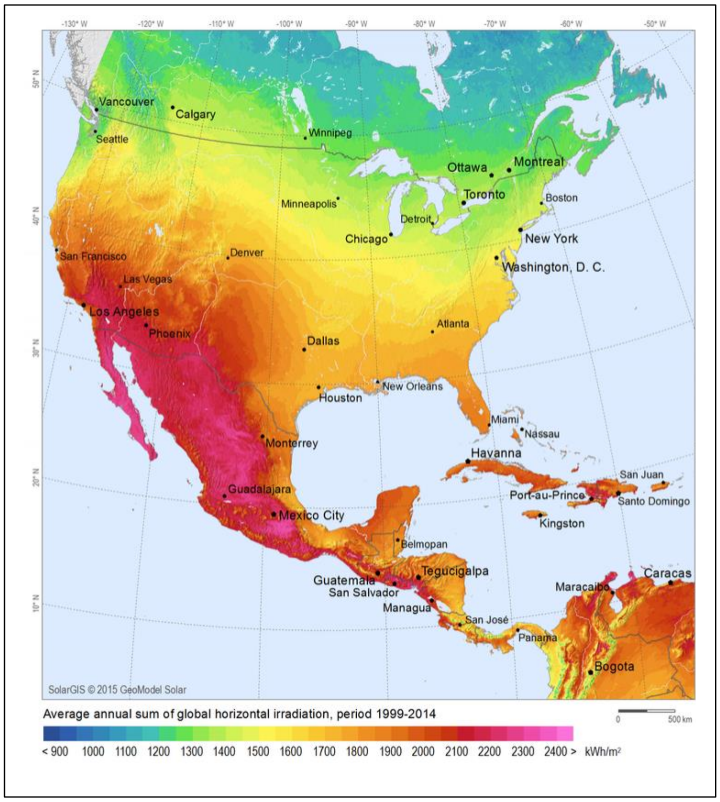
14 The level of certainty assumed in this simple example is far greater than exists in the real world, so in the real world a solar-plus-storage system would have to be even larger and even more expensive.

15 For example, based on data from the US National Renewable Energy Laboratory's PVWATTS calculator (https://pvwatts.nrel.gov/pvwatts.php), a PV array with tilt equal to latitude in Los Angeles produces 70% as much energy in the low month of December as it does in the peak month of August. Also according to PVWATTS, a PV array in Brooks produces only 41% of the energy in December that it does in the peak month of July. The PVWATTS number for Brooks is few percent different from the NRCAN values which, given the variations that occur from year to year, is not surprising.

16 This, along with evening activities such as cooking dinner, accounts for the sharp peak in demand in the early evening.

17 https://solargis.com/assets/Uploads/_resampled/ResizedImageWzc1MCw4MThd-1426148540051.png

As a result, the output of northern PV systems is likely to be lower and less correlated with electricity demand on both a daily basis and a seasonal basis than their more southerly counterparts.[18] Indeed, in every year since 2000 (the earliest year for which we have data), Alberta's annual peak electricity demand occurred between 5:00 p.m. and 6:00 p.m. on a day in either December or January, after sunset. So, even when the annual solar potential of a location in Canada approaches or even exceeds that of more southerly locations,[19] the need for storage or other forms of backup supply—and therefore the overall cost of solar—is likely to be higher.[20]



Renewable energy advocates point out that wind energy is often complementary to solar energy; that is, the wind may be blowing when the sun isn't shining and vice versa. While that is sometimes true, it is not always true. Let's turn to a discussion about wind.

Wind: A Half Truth is a Whole Lie[21]

The late J.A. Halkema of the Netherlands[22] was very critical of grid-scale wind projects. He went to great lengths to explain why. He pointed out that the density of moving air is very low, which means that large facilities are required to capture wind energy. He also pointed out that wind energy varies with the cube of the wind velocity (v^3). He said:

> *The term v^3 indicates that it is impossible to predict the power that drives the propeller of a wind turbine. For that reason, it is equally impossible to forecast the number of kilowatts that will be produced at any given moment, or the number of kilowatt-hours during a certain period. Likewise, a prediction of the production/capacity factor of a wind turbine is impossible. It will always be*

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18 The opposite is true in the southern hemisphere, but with the exception of Antarctica, there is very little land south of 40° S latitude.

19 Locations that are colder (which increases the efficiency of solar panels) and less cloudy can have higher annual solar output potentials despite being further from the equator.

20 The LCOE for solar generation provided in the US EIA table shown below is based on a capacity factor of 33%. As noted above, the average solar capacity factor in Canada is 13%.

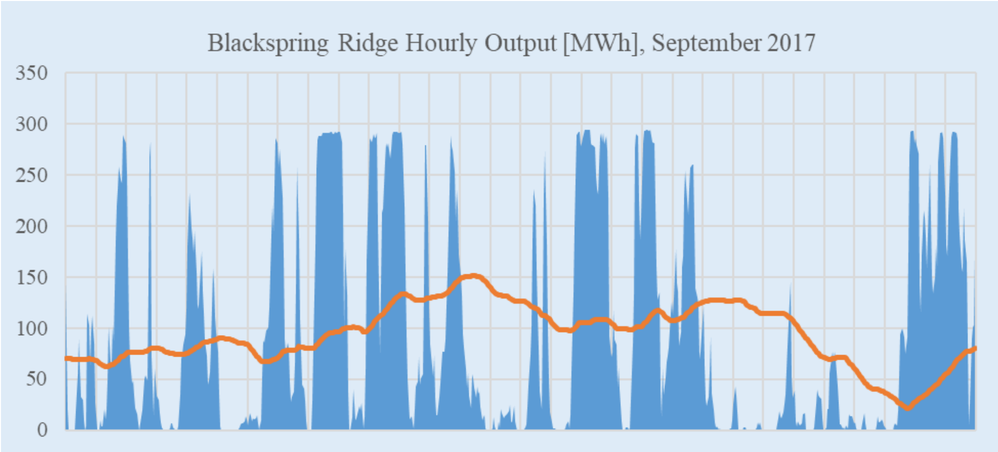
21 http://skepticva.org/energy.skepticva.org/halkema/halkemas.html#kinwind

22 Master of Science in Electrical Engineering, author, and former board member of Brown Boveri, Nederland. https://alternativeenergy.procon.org/view.source.php?sourceID=007492

guesswork. It is clear that the behaviour of the kinetic energy of the wind is the source of all miseries relating to the use of wind turbines. Without any exception.

Halkema noted that there can be excellent applications for wind turbines if operating in capacities where no reliability or heavy demand is required, as in the old days on most farms across North America, and in ancient times (grinding cereal grains) and contemporary times in Europe, primarily the Netherlands, where groundwater or sea water can be pumped from low lying land or dikes.[23]

Halkema's points about energy density and variability can be illustrated using the Blackspring Ridge wind facility in southern Alberta, Canada.[24] It consists of 166 wind turbines rated at 1.8 MW each, spread over an area of 194 km^2. In 2017 the facility produced 1014 GWh of energy, or about 5.2 GWh/km^2. Using this as a representative areal energy density for wind, meeting North America's 2017 primary energy consumption of 2773 Mtoe (32,249,990 GWh)[25] would require 31,800 similar wind farms occupying 6.2 million km^2, or about three quarters of the contiguous United States. By comparison, the 860 MW Shepard gas-fired power plant on the outskirts of Calgary produced 5314 GWh and sits on 0.24 km^2 of land, which gives an areal energy density of about 22,000 GWh/km^2, some 4200 times greater than that of Blackspring Ridge.



Regarding variability, the above chart shows Blackspring Ridge's hourly output for September 2017. The orange line is the one-week-moving-average, which late in the month drops to less than 10% of the plant's 300 MW capacity. Since the facility began operations in mid-2014, there were 98 hours in which its output increased by more than 150 MWh from one hour to the next, as well as 94 hours in which its output dropped by more than 150 MWh. This is why claims like Blackspring Ridge's energy "would be sufficient for approximately 140,000 Alberta households" must be taken with a grain of salt: the wind farm may produce the

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23 An intelligent and efficient use—during which there would be no disadvantage if the wind strength varied—include:

- Pumping water out of 'polders' (low-lying areas of land that have been reclaimed from water and are protected by dikes), which is how a large part of Holland was created;
- Driving mills for cereals and other products;
- Driving water pumps for the irrigation of agricultural areas;
- Charging small batteries at isolated locations for limited local use. For instance, this made it possible to listen to the BBC news during WWII Who still remembers the BBC call sign?

For these applications no heavy and reliable electricity generation would be necessary, and no serious risks would be involved if the turbine failed to produce constant and reliable power. Thus, the purpose of this treatise is certainly not to slate all wind turbine applications, but to expose the fallacy that wind turbines are a blanket solution to the planet's energy problems.

24 https://www.power-technology.com/projects/blackspring-ridge-wind-project-alberta/

25 Mtoe means "million tons of oil equivalent." One Mtoe equals 11,630 GWh.

amount of energy consumed by 140,000 homes, but it could only supply those homes in the way we normally think of "supply" if the home-owners don't mind using only the amount of electricity the wind can produce at any moment and are okay with sudden, dramatic increases or decreases in available power.

Renewables advocates claim that the extraordinary variability of wind and solar generation is being addressed, even going so far as to state that new technologies, including control systems and batteries, are allowing wind and solar to help balance power grids in real time.[26] While it is true that the very short-term fluctuations can now be better managed than they could be several years ago, wind and solar can still only help with real-time balancing when the wind is blowing or the sun is shining. So at 5 a.m. on a blisteringly cold winter morning somewhere in Canada (and sometimes almost everywhere in Canada), when any storage devices that might have been charged by yesterday's limited sunshine have been exhausted, no amount of technological wizardry will allow PV arrays to keep furnace motors running. And there is a good chance that, when the weather is dominated by deep cells of Arctic air, the wind won't be there to help. An example of this situation occurred in southern Alberta on the evening of December 30, 2017, when the temperature in Calgary was −30 °C.

Last Update : Dec 30, 2017 18:00 All values listed are in MW

INTERCHANGE

PATH	ACTUAL FLOW
British Columbia	-560
Montana	9
Saskatchewan	0
TOTAL	-551

GENERATION

GROUP	MC	TNG
COAL	6283	5054
GAS	7555	5142
HYDRO	894	214
OTHER	449	269
WIND	1445	1
TOTAL	16626	10680

WIND

ASSET	MC	TNG	DCR
Ardenville Wind (ARD1)*	68	0	0
BUL1 Bull Creek (BUL1)*	13	0	0
BUL2 Bull Creek (BUL2)*	16	0	0
Blackspring Ridge (BSR1)*	300	0	0
Blue Trail Wind (BTR1)*	66	0	0
Castle River #1 (CR1)*	39	0	0
Castle Rock Wind Farm (CRR1)*	77	0	0
Cowley Ridge (CRE3)*	20	0	0
Enmax Taber (TAB1)*	81	0	0
Ghost Pine (NEP1)*	82	0	0
Halkirk Wind Power Facility (HAL1)*	150	0	0
Kettles Hill (KHW1)*	63	0	0
McBride Lake Windfarm (AKE1)*	73	0	0
Oldman 2 Wind Farm 1 (OWF1)*	46	0	0
Soderglen Wind (GWW1)*	71	0	0
Summerview 1 (IEW1)*	66	0	0
Summerview 2 (IEW2)*	66	0	0
Suncor Chin Chute (SCR3)*	30	0	0
Suncor Magrath (SCR2)*	30	0	0
Wintering Hills (SCR4)*	88	1	0

BIOMASS AND OTHER

ASSET	MC	TNG	DCR
APF Athabasca (AFG1)*	131	55	10
Brooks Solar (BSC1)	15	0	0
Cancarb Medicine Hat (CCMH)	42	[illegible]	0
DAI1 Daishowa (DAI1)	52	47	10

As shown in the above snapshots from the Alberta Electric System Operator's (AESO's) Current Supply and Demand report,[27] the combined output of 20 wind plants was 1 MW and solar output was zero. Out of total generation of 10,680 MW (in the Total Net Generation [TNG] column), 5054 MW were supplied by coal, 5142

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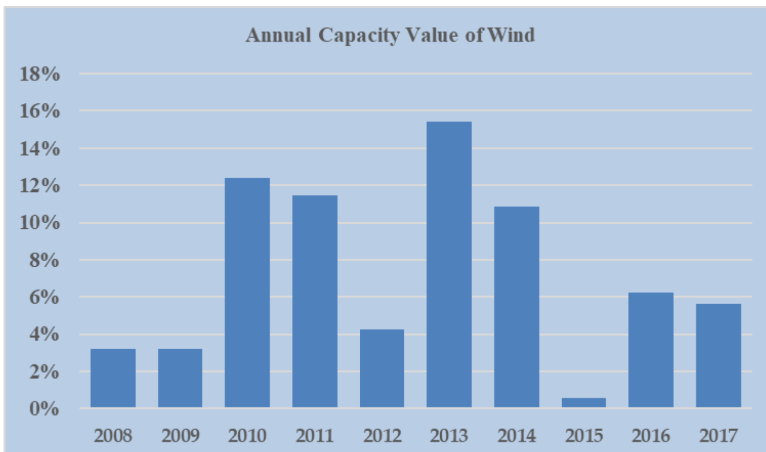
26 No electrical grid of the scale of (say) North America's Western Interconnection has ever operated exclusively with renewables, so the jury is still out on that claim.

27 http://ets.aeso.ca/ets_web/ip/Market/Reports/CSDReportServlet MC is "Maximum Capability," TNG is "Total Net Generation," and "DCR" is "Dispatched Contingency Reserve." Contingency reserve is typically provided by generators that are intentionally producing at less than their maximum capabilities so that they can ramp up at short notice to bring supply and demand back into balance if there is a sudden shortfall in supply, such as when another generator or a transmission line carrying import power trips off. Wind and solar alone (i.e., in the absence of storage) cannot be relied upon to provide contingency reserves.

MW were supplied by gas, 214 MW were supplied by hydro, 560 MW was supplied over the tie line from British Columbia to the west, and 269 MW came from other types of generation including biomass.

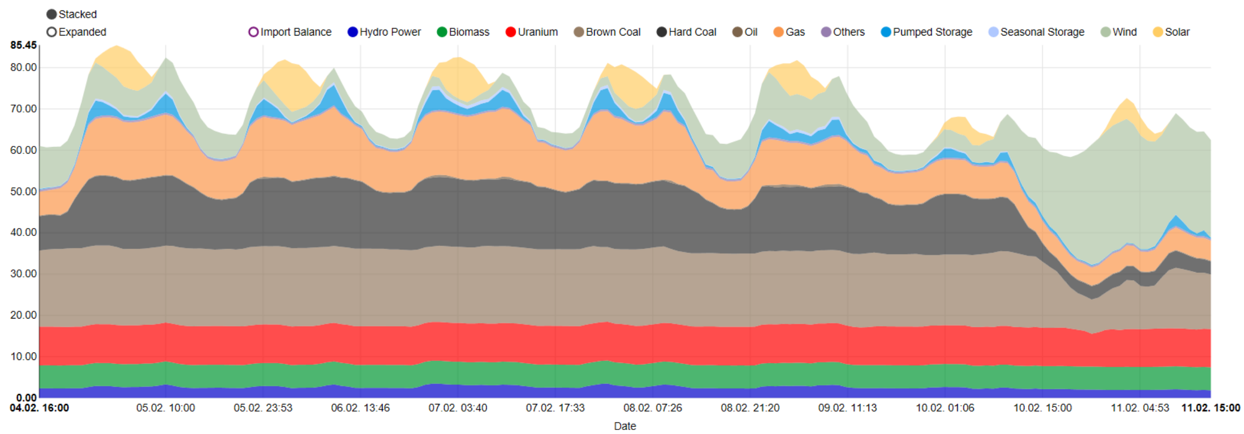
The next challenge with wind is its inability to reduce the amount of conventional generation needed by the power system. The annual *capacity value* (as distinct from the *capacity factor*) of wind can be calculated as the difference between the maximum electricity demand and the maximum electricity demand net of wind. For example, Alberta's peak demand in 2017 of 8625 MW was served by several types of generation including wind;[28] the maximum demand that was met by generators excluding wind was 8545 MW. Thus, wind reduced the need for other forms of generation capacity in 2017 by 80 MW or 5.5% of the total installed wind capacity of 1445 MW. As shown in the following graph, in 2015 wind generation reduced the need for other forms of capacity by a mere 0.6% of installed wind capacity. Clearly, wind must be fully backstopped by dispatchable conventional generation.



This crucial point that wind does not reduce the need for dispatchable generation is reinforced by the next graphs, which shows the sources of electricity in Germany for week 6 in 2018.[29] During one hour on February 7 (the one under the red uranium dot), solar output was zero out of an installed capacity of 45 GW and wind was producing 2.85 GW out of an installed capacity 53 GW; gas provided 15.9 GW, hard coal provided 16.8 GW, brown coal provided 18.6 GW, and nuclear provided 9.4 GW. With an installed capacity of almost 100 GW, wind and solar together contributed less than 3 GW to meeting demand in that hour. **Again, wind and solar must be fully back-stopped by conventional generation.** Since consumers must pay the capital costs of conventional generation regardless of how much energy they get from wind and solar, it follows that the entire capital investment in wind and solar facilities must be paid for solely by the fuel-cost savings on conventional generation in order for wind and solar to be truly economic. Since this is not occurring, the claim that wind and solar are nearing price parity with conventional generation is simply wrong.

28 This figure excludes almost 3000 MW of industrial load served by on-site generation, most of which is fueled by natural gas. If we include the industrial load, peak demand was 11,473 MW and peak demand net of wind was 11,390 MW. This gives a capacity value of 83 MW instead of 80 MW.

29 https://www.energy-charts.de/power.htm?source=all-sources&year=2018&week=6



Another argument from renewables proponents is that we can link regions together so that when little renewable energy is available in one region it can be imported from another. But imagine that Regions A and B are served exclusively by wind, solar, and storage. If a situation like those just described for Alberta and Germany arises in Region A and persists beyond the time when its storage runs out, then Region B would be expected to supply both its own demand and that of Region A. Thus, as a first-order approximation, both regions have to build twice as much renewable generation as they individually need, which is already more than twice their own peak demands because of the low capacity factors of renewables. The level of renewables that each region would have to carry would be modified by the demand diversity that would likely exist (that is, both systems may not reach their peak demands at the same time), but combining the first-order estimate with the need to carry a huge level of renewable capacity to supply one's own region suggests that a 100% renewable electricity system is not in the cards—at least not at any rational cost—any time soon.

The concept of interconnecting regions depends on the claim that "the wind is always blowing somewhere." It turns out, however, that regionally this is simply not true. Euan Mearns and his contributors did a detailed study of wind output over most of Europe and found there were many periods where there were regional lulls with 'no wind nowhere.'[30] Even if multi-billion-dollar transmission lines had connected regional power grids, there would have been no reliable wind power.

Storage is not a Viable Solution

Because the wind does not blow and the sun does not shine all the time, a solution to the variability and unpredictability of renewable generation is essential if they are to become dominant sources of electricity. However, energy storage systems are still a long way from adequate or economic.

It was noted above that a generator's *capacity factor,* which is the ratio of the amount of energy it produces in a given period to the amount of energy it could produce if its output was at 100% of capacity for the entire period, is an important number. A critical consideration for storage is that capacity factors are averages. In the Brooks solar example, the annual capacity factor of the PV array was 15%. Since this is an average across many Decembers, actual capacity factors for the month can be much lower. And since there is no guarantee that the sun will shine the same amount every day in December, even within that month there will be periods of days

30 http://euanmearns.com/wind-blowing-nowhere/

or perhaps weeks in which the capacity factor is lower still. A similar problem is faced by wind generation: while the annual capacity factor of Alberta's existing wind fleet is about 35%, it varies from almost 50% in January to 20% in August. The lowest monthly capacity factor since January 2008 was 15%, while the highest was 66%. Extreme values are important because engineers design electric power systems for extremes, not averages. As such, storage volumes measured in hours or even days are simply not adequate for 100% renewable energy systems.

Energy commentator Roger Andrews,[31] writing on Euan Mearns' "Energy Matters" blog, noted in "The Holy Grail of Battery Storage" in 2016 that:

> *It is found that installing enough battery storage to convert intermittent wind/solar generation into long-term baseload generation increases total capital costs generally by factors of three or more for wind and by factors of ten or more for solar, even at $100/kWh. Clearly the Holy Grail of energy policy is still a long way off.*
>
> *First a simple calculation. $100/kWh = $100,000/MWh = $100 million/GWh = $100 billion/TWh. If everyone is happy with this, we can proceed. (Note that all the costs listed in this post are in US dollars unless otherwise specified).*[32]
>
> *It's probably not an exaggeration to say that the amount of energy storage capacity needed to support a 100% renewable world exceeds installed energy storage capacity by a factor of many thousands. Another way of looking at it is that installed world battery + CAES [compressed air energy storage] + flywheel + thermal + other storage capacity amounts to only about 12 GWh, enough to fill global electricity demand for all of fifteen seconds. Total global storage capacity with pumped hydro added works out to only about 500 GWh, enough to fill global electricity demand for all of ten minutes.*[33]

Pumped hydro is frequently touted as a solution to the variability of wind, but the scale,[34] environmental impact, and cost are often ignored. This US example is telling.[35]

> *The United States (U.S.) has over 30 PSH facilities with a combined capacity of 22 gigawatts. U.S. facilities generate around 23 000 gigawatt hours (GWh) per year,* ***and consume 29 000 GWh to operate their pumps****. Despite this net loss of energy, the grid reliability provided by PSH facilities and the ability to generate when demand is strong is highly beneficial and will become increasingly important as Canada and the U.S. integrate more renewable power into their grids. (underlining added)*

In other words, pumped storage hydro is a net energy sink. A further issue with pumped hydro is that most of the world's potential reservoirs have the capacity for only a few hours of power generation from the stored water. As Euan Mearns has pointed out, real battery or pumped storage must ultimately **address a week or two of potential loss of wind/sun** to be of any real benefit.[36,37] A project of this scale has been discussed for the Great Lakes, but it is fraught with many environmental and cost-benefit questions.[38]

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31 http://euanmearns.com/about-roger-andrews/
32 http://euanmearns.com/the-holy-grail-of-battery-storage/
33 http://euanmearns.com/is-large-scale-energy-storage-dead/
34 http://euanmearns.com/the-bingham-canyon-pumped-hydro-project-by-far-the-worlds-largest-but-still-much-too-small/
35 https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2016/10-03pmpdstrghdr-eng.html
36 http://euanmearns.com/is-large-scale-energy-storage-dead/
37 http://euanmearns.com/the-holy-grail-of-battery-storage/
38 http://euanmearns.com/the-pumped-hydro-storage-potential-of-the-great-lakes/

Real-World LCOE Values

It should be clear from the above discussion that wind and solar are not at performance parity with conventional generation. What about price parity?

The US Energy Information Administration provides the following table of LCOEs for new generation entering service in 2022.[39] The LCOE of solar PV is $59.1/MWh (5.91 ¢/kWh) before any tax credits, compared to $48.1/MWh for advanced combined-cycle generation. The tax credit does not reduce the cost of the system, it just means taxpayers are covering part of the true cost. The LCOE of onshore wind is $48.0/MWh, which makes it marginally less expensive than advanced combined-cycle generation, but the wind LCOE does not include the storage facilities and backup generation required. **Neither solar generation nor wind generation can provide electricity to consumers at a lower overall cost than advanced, combined-cycle fossil-fueled generators, and representations to the contrary are wrong.**

Table 1a. Estimated levelized cost of electricity (capacity-weighted average[1]) for new generation resouces entering service in 2022 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[3]	NB	NB	NB	NB	NB	NB	NA	NB
Coal with 90% CCS[3]	NB	NB	NB	NB	NB	NB	NA	NB
Conventional CC	87	13.0	1.5	32.8	1.0	48.3	NA	48.3
Advanced CC	87	15.5	1.3	30.3	1.1	48.1	NA	48.1
Advanced CC with CCS	NB	NB	NB	NB	NB	NB	NA	NB
Conventional CT	NB	NB	NB	NB	NB	NB	NA	NB
Advanced CT	30	22.7	2.6	51.3	2.9	79.5	NA	79.5
Advanced nuclear	90	67.0	12.9	9.3	0.9	90.1	NA	90.1
Geothermal	91	28.3	13.5	0.0	1.3	43.1	-2.8	40.3
Biomass	83	40.3	15.4	45.0	1.5	102.2	NA	102.2
Non-dispatchable technologies								
Wind, onshore	43	33.0	12.7	0.0	2.4	48.0	-11.1	37.0
Wind, offshore	45	102.6	20.0	0.0	2.0	124.6	-18.5	106.2
Solar PV[4]	33	48.2	7.5	0.0	3.3	59.1	-12.5	46.5
Solar thermal	NB	NB	NB	NB	NB	NB	NB	NB
Hydroelectric[5]	65	56.7	14.0	1.3	1.8	73.9	NA	73.9

Abbreviations: CCS-Carbon Capture and Storage; CC-Combined Cycle (gas); CT-Combustion Turbine; PV-Photo Voltaic

The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions in 2020–2022. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as NB or not built.

[39] https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Other Challenges with Integrating Renewables

The LCOE is not a reliable indicator of the cost of integrating renewable generation into the world's electric power systems because it ignores the cost of the backup generation, the additional transmission, and the storage required by renewables. Those costs, which are driven by the inherent intermittency of wind and solar, are considerable. Yet they are not the only costs. As described in an Allianz report that discusses the drawbacks of renewable energy:[40]

> *While renewable energy is on the rise in many countries, a major drawback is the 'volatility' of supply. This leads to several challenges. The unsteady production of energy, especially from wind or solar power, strains the stability of the network. Further, if wind turbines need to be stopped for safety reasons in extreme weather conditions, this can cause power gaps equal to the loss of two nuclear power plants within just one hour. In such cases, conventional reserve power plants would need to step in instantly. Last but not least, renewable energy has to be transmitted from sparsely populated areas to the metropolitan centers of demand.*

The issue of volatility of supply was recently at the forefront in Australia. Following a major blackout event that left 850,000 customers in South Australia without power, the Australian Energy Market Operator issued a report that states:

> *On Wednesday 28 September 2016, tornadoes with wind speeds in the range of 190–260 km/h occurred in areas of South Australia [SA]. Two tornadoes almost simultaneously damaged a single circuit 275 kilovolt (kV) transmission line and a double circuit 275 kV transmission line, some 170 km apart. The damage to these three transmission lines caused them to trip, and a sequence of faults in quick succession resulted in six voltage dips on the SA grid over a two-minute period at around 4.16 pm.*[41]

A contributing factor in the blackout was a rapid reduction in wind generation of 456 MW over a period of less than seven seconds as the wind plants' protection features activated. Less than one second after the reduction in output of the last wind generator, an import transmission line tripped, "islanding" the South Australia power system. While these events cannot be blamed on the wind generators, they highlight the inappropriateness of suggesting that, because the wind is blowing, or the sun is shining "somewhere," we can build 100% renewable power grids that rely on massive transmission interconnections for when the wind isn't blowing and the sun isn't shining "here." It is also noteworthy that the Australian Energy Market Operator has recommended a number of technical changes that are related to the characteristics of wind generators (such as increasing system inertia[42] and increasing the strength of the transmission system to allow wind facilities to ride through disturbances), all of which come at a cost.

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40 https://www.agcs.allianz.com/insights/expert-risk-articles/energy-risks/

41 https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

42 When a bicycle is upside-down, and the pedals are turned, the rear wheel will spin long after one stops pedaling because the spinning wheel has inertia which resists the stopping forces from friction and applying the brakes. In a power system, a temporary excess of demand over supply, such as occurs when a generator trips off line, is equivalent to applying the brakes to generators. The large inertia of typical fossil-fueled generators prevents them from slowing down so quickly that small imbalances become big ones very quickly. Wind generators themselves have no inertia (they are of a different type than fossil-fueled generators), though there is some inertia in the rotating blades. Solar PV panels have no rotating parts and therefore no mechanical inertia.

Another problem with integrating (typically subsidized) renewables is that they create severe distortions in energy markets. Renewables advocates claim that wind and solar generators bring down power prices for consumers because they burn no fuel and can therefore offer energy into electricity markets at lower prices. While the price-lowering effect is real, it does not translate into a benefit for consumers for the following reasons:

- The wind and solar generators probably receive side payments, such as market-price top-ups or payments for renewable energy certificates, that consumers and/or taxpayers ultimately have to pay. The fact that these payments may not show up in the energy price causes additional economic distortions and unfairness as the total cost of electricity is not properly apportioned to electricity consumers and non-renewable generators are forced to compete on an unlevel playing field.
- As discussed above, the conventional generators that suffer from lower prices in hours when the wind is blowing or the sun is shining are still needed. For those generators to recover enough money to stay in business, either prices have to rise dramatically in hours when the wind isn't blowing and the sun isn't shining (leading to extremely volatile prices) or the conventional generators need to receive their own side-payments. Such a side payment—called a *capacity payment*—is being implemented in Alberta right now as the province redesigns its electricity market in preparation for bringing on massive quantities of intermittent renewable generation by 2030.
- As all-in electricity costs rise, costs rise for virtually all goods and services and businesses become less competitive compared to those in jurisdictions that do not have rules imposing higher electricity costs. The economy in general suffers.
- In some markets, an influx of renewables can lead to *negative* electricity prices. Certain generators, either because of their technical characteristics or because they would lose revenues by not generating, may be willing to pay to be allowed to run. What is particularly egregious about this state of affairs is that consumers in one jurisdiction can end up paying consumers in an adjacent jurisdiction to take their power. According to a 2015 report by Ontario's Auditor General,[43] between 2006 and 2014 there were almost 2000 hours in which the hourly Ontario electricity price was negative, and Ontario paid exporters a total of $32.6 million to take its power.

Denmark faces a similar challenge to Ontario's. It is a country often touted as a leader in renewable energy. Geographically, it is a tiny place with no spot more than 58 km from the sea, but Denmark has built vast offshore wind resources. Nonetheless, seven conventional power plants backstop the wind power. In addition, Denmark's power grid is connected to Sweden (nuclear) and Norway (hydro). When there is an oversupply of wind, Denmark can "spill" the excess wind power to either of these countries, which can absorb the additional power by modifying the output of their nuclear or hydro facilities. As the World Nuclear Association notes, wind is heavily subsidized in Denmark, so when excess wind power is exported, so are the subsidies.[44] In overall terms, since the wind is typically exported to low-CO_2 Sweden and Norway, there is no net reduction in global CO_2 emissions.

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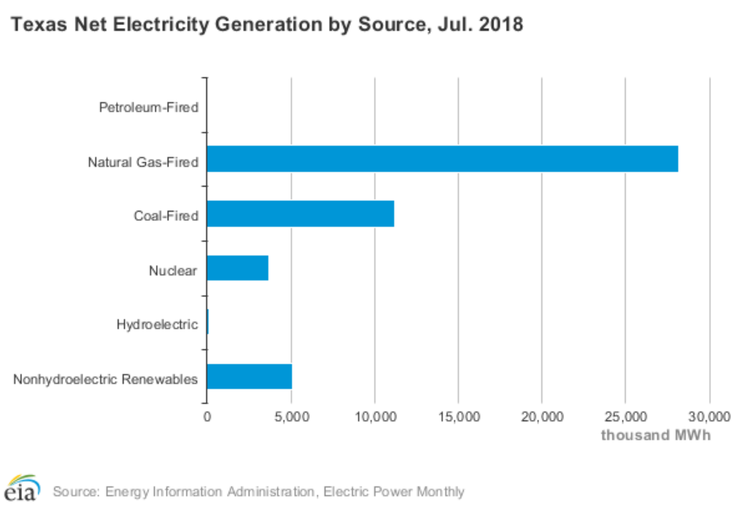
43 https://www.macleans.ca/economy/the-hard-truths-behind-ontarios-pricey-electrical-system/
44 http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/denmark.aspx

Texas also faces challenges. It is often cited as an example of the successful integration of wind, perhaps because in 2013 it was ranked number one in the United States for tax subsidies.[45] The US EIA reports that *"Texas leads the nation in wind-powered generation capacity with more than 21,450 megawatts; since 2014, Texas wind turbines have produced more electricity than both of the state's two nuclear power plants."*[46] But what has this done for Texas? According to the Texas Tribune: [47]

> *It's 2018, and the days of warm, evening sun setting on scenic Texas plains are gone for some rural areas like Comanche County. Folks accustomed to unencumbered views will have to look elsewhere. Now, those views are pierced by the sharp teeth of a wind turbine. Summer breezes have transformed into the cyclical swooshing—and occasionally loud creaking—of nearby machinery.*
>
> *Yet the summer heat remains, reminding us that Texas is facing a tight energy supply—with less reliable energy sources. Three coal plants shut down this year, pulling reserves below the desired target level to meet the energy demands of scorching August afternoons. Many things led to the closures, but the profitability of coal plants in the face of billions of dollars of subsidies for renewable energy—particularly wind—is certainly among the most powerful.*
>
> *Wind developers are the beneficiaries of disproportionate levels and types of government aid. At the federal level, they receive a production tax credit, which costs taxpayers over $5 billion per year. On top of that, Texas stepped in, providing billions of dollars of additional state and local subsidies.*

Yet Texas still runs on natural gas and coal, as the following chart shows.



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Unfortunately, Canada is not immune from burdening taxpayers with renewable energy subsidies. Robert Lyman, Ottawa energy policy consultant, former public servant and diplomat, describes the complex web of financial aid and other direct and indirect support that Canadian governments uniquely provide to the suppliers and users of solar and wind energy in Canada.[48]

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45 https://www.texaspolicy.com/texas-ranks-1-for-federal-wind-subsidies-2/
46 https://www.eia.gov/state/?sid=TX#tabs-4
47 https://www.tribtalk.org/2018/08/10/renewable-energy-subsidies-are-wrong-for-texas/
48 http://blog.friendsofscience.org/2017/11/05/subsidies-to-solar-and-wind-energy-in-canada-an-inventory/

The Whole Truth – Not Half

As noted above, J. A. Halkema said a half truth is a whole lie. LCOE only tells half the story. As we have been discussing, certain fundamental factors limit the ability to move the world's electricity systems to 100% renewables. Statements to the effect that wind and solar are now "preferred" and that their LCOEs are lower than the LCOEs of conventional generation are, at best, highly misleading. The real enablers of wind and solar are government policies, subsidies, and the mistaken belief that CO_2 is a pollutant that causes global warming, as the following quote from a 2007 IMPAX Environmental Markets placement document illustrates:

> *Also in Europe, following the Renewables Directive, which stipulates that twelve per cent of gross internal energy in the European Union should, by 2010, come from renewable sources, larger markets for clean power have developed across the region. Meanwhile, despite resistance, there is a broad international consensus on policies to tackle global warming.*[49]
>
> *The Directors believe, based on advice from the Manager, that the key drivers of the Environmental Markets, being market liberalisation, tightening environmental policy and falling costs of new technology, continue to generate attractive opportunities. In the energy sector, these drivers have been reinforced by rising energy prices, concerns over energy security, blackouts and global power quality issues as well as increased government commitment to reducing carbon dioxide emissions. For example, this year there has been a landmark ruling by the US Supreme Court that carbon dioxide is a pollutant which the government has a legal duty to mitigate while, in Europe, the European Commission has proposed new targets for renewables of 20% by 2020.*[50]

For its part, the Deloitte report, that is a subject of discussion here, claims that *"…consumers are seeking the most reliable, affordable and environmentally responsible energy sources."* It goes on to claim that Smart Cities are instituting 100% renewables and that *"Most countries and regions are at renewable penetration levels that require minimal adjustments to the grid."* But this claim is deceptive. If consumers were aware of the actual cost of wind and solar (as opposed to the misleading LCOE), it is unlikely that they would see wind and solar as reliable or affordable. Likewise, if they were aware that wind and solar devices require wasteful quantities of fossil fuels in their manufacture, such that their total return on energy invested is very low (see below), they would likely not see them as "preferred." And if investors understood that there may be long-term liabilities for the fact that wind and solar devices are made from bonded materials that cannot be easily or cost-effectively recycled at this time, or that governments are almost unilaterally giving wind/solar companies a pass on environmental concerns regarding reclamation, recycling and sustainability, it is unlikely they would see renewables as "responsible energy sources."

Regarding the claim that *"renewable penetration levels require minimal adjustments to the grid,"* there is enough flexibility on many existing power grids in the western world to manage the ebb and flow of *reasonable* amounts of wind and solar with the whims of Mother Nature. But Deloitte and Climate Reality are advocating for a dramatic increase in wind and solar on the grid; Climate Reality advocates for 100% renewables. As we saw in the foregoing discussion of LCOE, that is not a reasonable economic choice.

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49 https://www.impaxam.com/sites/default/files/PROSPECTUS%202007.pdf pg. 22
50 https://www.impaxam.com/sites/default/files/PROSPECTUS%202007.pdf pg. 24

Wind and Solar Don't Always Reduce CO_2 Emissions

Renewable wind and solar are ostensibly meant to decrease reliance on fossil fuels and reduce carbon dioxide emissions. Leaving aside the question of whether this is a useful objective, it is often the case that additions of wind and solar don't accomplish either objective. There are several reasons.

- As we have seen, wind and solar are highly variable on timescales of minutes, hours, months, and years. In the absence of viable storage options, highly flexible generating units such as simple-cycle gas turbines (SCGTs) are needed to "follow" the frequent ups and downs. This flexibility comes at a price of lower fuel efficiency, and therefore higher emissions, than less flexible plants. As the amount of wind grows, so does the magnitude of the potential short-term changes in generation and the need for backstop generation to be available. Environmentalist Robert Kennedy acknowledged this fact in 2010 when he said, "*For all of these big utility scale power plants, whether it's wind or solar, everybody is looking at gas as the supplementary fuel. The plants that we're building, the wind plants and the solar plants are gas plants.*" [51]
- Renewables are typically granted priority when it comes to dispatch, i.e., they are the first to be selected from among the generators that could be called to run. When the volume of wind and solar gets large enough, baseload plants—which were designed to run essentially full out in all hours—have to be scaled back. Not only does this put additional wear and tear on these plants, but the cycling reduces fuel efficiency, again leading to higher CO_2 emissions.
- If wind and solar displace nuclear power, there is no reduction in CO_2 at all. The Ontario Society of Professional Engineers notes that adding more wind and solar to their power grid, which largely relies on nuclear and hydro, will increase CO_2 emissions due to the requirement for natural gas generators to ramp up and down (nuclear being too inflexible).[52]

In Germany, the "poster child" of renewable energy, the installed capacity of wind increased from 22 GW to 60 GW and the installed capacity of solar increased from 4 to 49 GW between 2007 and 2016.[53] Yet emissions from that country's coal-fired power plants only decreased from 282 to 240 million tonnes. And coal does not appear to be going away any time soon: the BBC recently reported that China has 259 GW of new coal-fired generation capacity under development,[54] and new High Efficiency Low Emissions (HELE) and Ultra HELE coal-fired power plants are being built in Japan.[55]

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51 https://atomicinsights.com/robert-f-kennedy-jr-tells-the-colorado-oil-and-gas-association-that-wind-and-solar-plants-are-gas-plants/

52 http://www.kingstonfieldnaturalists.org/wind/2015_Presentation_Elec_Dilem.pdf Slide 15

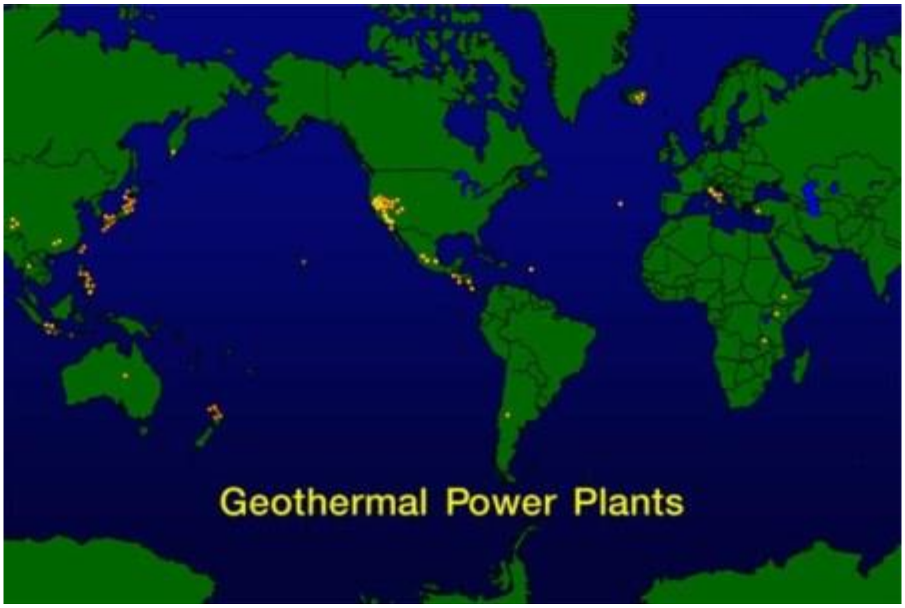
53 All data from the Fraunhofer Institute for Solar Energy Systems at https://www.energy-charts.de.

54 https://www.bbc.com/news/science-environment-45640706. The article points out that this is the same capacity as the entire US coal fleet.

55 https://www.sciencemag.org/news/2018/05/bucking-global-trends-japan-again-embraces-coal-power

Geothermal is also not Viable

It is not only wind and solar that are touted by renewables advocates. Climate Reality makes a push for geothermal, discussing it as if it is a given that deep within the earth there is heat from magma and that it can be tapped. The truth is much more complex.



In certain places, there is ideal access to geothermal resources. As shown on the above map,[56] these are typically regions where tectonic plates come together or where some form of geological structure allows magma to come near enough to the surface of Earth's crust that people can actively or passively tap into the heat. Of the countries today that claim to be running on 100% renewables, most have a large component of geothermal energy in the mix. But the opportunities for successful geothermal are limited because of these geological factors.

Geothermal can be developed in two forms, one of which is a Ground Source Heat Pump (GSHP). In a GSHP system, relatively shallow bore holes are drilled, allowing heat to be pumped from a building into the ground in summer and from the ground into the building in winter. GSHP systems are only suitable for locations where the weather is not subject to large and frequent fluctuations because they are not rapid-response systems.[57] Likewise, a considerable amount of electrical energy must be available (and affordable) to power the pumps. High power prices sometimes defeats the intended purpose.

Geothermal for energy generation uses a system in which pipes are set deep into the earth; cold water is pumped down which then turns into steam as it hits the super-heated rock deep in the ground. That steam drives above-ground turbines to generate electricity. California successfully uses geothermal. However, even though the US is the world's largest generator of geothermal energy, it is still a tiny portion of the country's

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56 http://euanmearns.com/geothermal-energy-in-perspective/

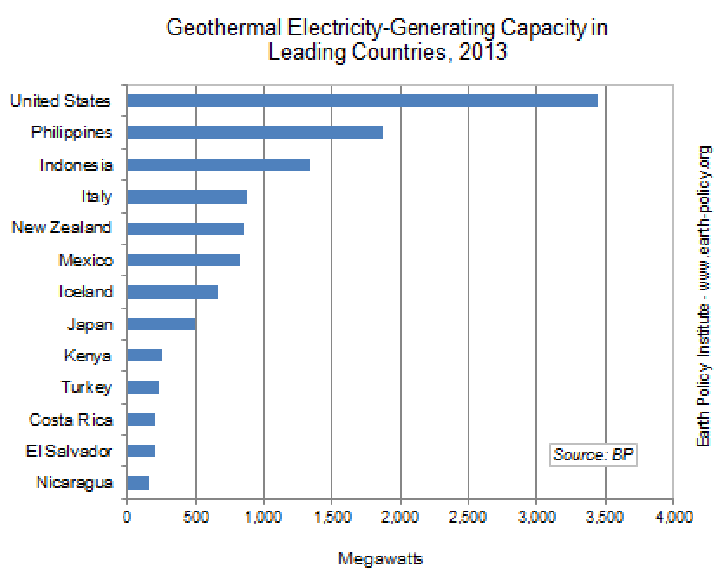
57 Over the last 130 years in Calgary, there were 315 months in which the temperature varied by more than 25°C (45 °F) in a single day. In 33 of those months the single-day variation exceeded 30 °C (54 °F). Over that same period there were 341 months in which the monthly temperature range exceeded 40 °C and 30 months in which it exceeded 50 °C.

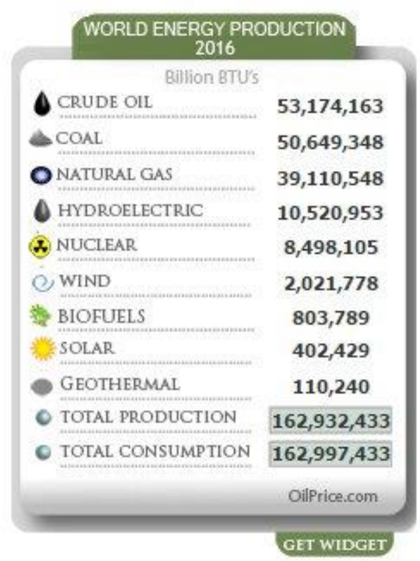
energy generation because of geology and many complications in finding the right location. Worldwide, geothermal supplied less than one tenth of one percent of total energy demand (as shown in the table below). Notably, in some areas, H_2S (hydrogen sulfide) gas can be released from within the earth; it is highly toxic at very small concentrations.

Friends of Science Society has issued a report on Geothermal for Alberta which gives an overview of global issues related to geothermal: "Geothermal for Alberta? A Case for Caution."[58]

Major energy sources and percent shares of U.S. electricity generation at utility-scale facilities in 2016[1]

- Natural gas = 33.8%
- Coal = 30.4%
- Nuclear = 19.7%
- Renewables (total) = 14.9%
  - Hydropower = 6.5%
  - Wind = 5.6%
  - Biomass = 1.5%
  - Solar = 0.9%
  - Geothermal = 0.4%
- Petroleum = 0.6%
- Other gases = 0.3%
- Other nonrenewable sources = 0.3%
- Pumped storage hydroelectricity = -0.2%[4]





[58] https://friendsofscience.org/assets/documents/Geothermal_Alberta_A_Cause_for_Caution.pdf

Why Are We Doing This?

All this cost-benefit analysis and debunking of the claims of Deloitte and Climate Reality might lead you to ask, "So why are we doing this? Why build wind and solar at all?"

In some remote locations, solar can be useful where intermittency is not a problem or where there are simply no other viable options. Wind, in suitable locations, can complement the grid or provide useful abatement of diesel—as in the El Hierro experiment.[59] Also, some people are honestly convinced that human-produced CO_2 will cause catastrophic changes in Earth's climate. (While Friends of Science and many reputable scientists dispute the "catastrophic" view, the motives of those people at least appear to be altruistic.) In these cases, the appeal of wind and solar is obvious—albeit sometimes misguided, as we have shown. However, many wind and solar advocates—including influential billionaire-funded environmental groups—are pushing for 100% renewable energy systems. Unfortunately, they have been operating on faulty climate change and renewable energy premises for over a decade.[60]

> *In 2006, several of the country's wealthiest foundations hired a consulting firm to comprehensively survey the available scientific literature and to consult more than 150 leading climate change and energy experts. The result of this intensive undertaking was the 2007 report "Design to Win: Philanthropy's Role in the Fight Against Global Warming."*
>
> *Leading the report was the recommendation that "tempering climate change" required a strong cap and trade policy in the U.S. and the European Union, and a binding international agreement on greenhouse gas emissions. The report predicted that passage of cap and trade legislation would "prompt a sea change that washes over the entire global economy." The report included little to no discussion of the role of government in directly sponsoring the creation of new energy technologies. The report was additionally notable for the absence of any meaningful discussion of social, political or technological barriers. Instead, the authors offered a decidedly optimistic outlook: "The good news is that we already have the technology and know-how to achieve these carbon reductions—often at a cost savings." (underlining added)*

Given the discussion above, it is clear that we do not have the technology and know-how to achieve carbon reductions *at a cost savings.* If we did, billionaire funding, environmental organizations' advocacy (including illegal anti-pipeline antics), subsidies, carbon-dioxide taxes, and special government programs would all be unnecessary: consumers would simply "vote" for wind and solar with their wallets.

CDP Worldwide[61] and UNPRI,[62] both influential investment organizations whose signatories hold some $100 trillion in assets under management, are premised on the notion that there is an imminent climate crisis and only by investing in "low-carbon" technologies like wind and solar can we save the planet. Notably, UNPRI's main consultant on ESG (Environment, Social and Governance) issues and "fiduciary duties" is Al Gore.[63] A related body called the Task Force on Climate-Related Disclosures is chaired by Michael Bloomberg.[64] In 2014,

[59] http://euanmearns.com/el-hierro-first-quarter-2018-performance-update/
[60] http://climateshiftproject.org/nisbet-m-c-2014-engaging-in-science-policy-controversies-insights-from-the-u-s-debate-over-climate-change-handbook-of-the-public-communication-of-science-and-technology-2nd-edition-london-r/
[61] https://www.cdp.net/en
[62] https://www.unpri.org/
[63] https://www.unpri.org/sustainable-markets/sustainable-financial-system/fiduciary-duty
[64] https://www.fsb-tcfd.org/

many of the UNPRI signatories also signed the "Montreal pledge," which encouraged investors to become activists with "climate laggards" and "recalcitrant" corporations and governments, especially in countries like Australia, Canada and the United States (see the following excerpt from UNPRI's 2016 Annual Report). For its part, ClimateWorks has funded hundreds of environmental groups to campaign for wind and solar. People who are truly interested in doing the right things for the environment have been misled into thinking that this demand is a grassroots movement and that wind and solar are both cleaner and cheaper than the conventional alternatives.

...ON CORPORATE CLIMATE LOBBYING

The PRI brought together a worldwide group of more than 60 investors, representing over US$3.8 trillion, who have signed a **statement outlining investor expectations** that company lobbying on climate change related policy and regulation must be in line with the universally accepted goal of limiting global temperature rises to two degrees Celsius. They are explicitly calling for improvements in practice and transparency from investee companies on aspects such as their governance processes for climate policy engagement and their membership of or support for all third-party organisations that lobby on climate change.

The PRI is continuing to coordinate **a working group of 22 investors** engaging companies in Australia, Canada and the USA on their climate-related lobbying activities, in particular where the company's public position is inconsistent with the positions of trade associations it belongs to. We are working with the **Institutional Investors Group on Climate Change (IIGCC)** on their parallel initiative in Europe. The statement and working group also bolster existing efforts underway including the UN's Caring for Climate programme on **responsible corporate engagement in climate policy**.

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According to Matthew Nisbet's research[65] and the ClimateWorks Wikileaks "Design to Win" case study,[66] Bloomberg is a renewables investor and a party to ClimateWorks, and he and other billionaires have spent millions demarketing coal. When all costs are included, coal is a cheaper form of generation than wind, which is why campaigns like "Beyond Coal" and *#poweringpastcoal* are necessary. Consumers would not knowingly choose a less reliable yet more expensive form of power generation like wind or solar unless they truly believed that coal is dangerous to them or the planet—which is the idea the demarketing campaigns promote. Modern supercritical coal plants are a far cry from early ones.[67] But carbon taxes make coal operations unprofitable.

All of this shows that there are very influential parties promoting the notion that carbon dioxide—an odorless, colorless gas that humans breathe out and that is essential for all life on Earth—presents an imminent risk to health and the future of the planet, and that CO_2 taxes and subsidies are the solution. It may seem counterintuitive that investors would support more expensive and less reliable generation technologies, but subsidies and long-term taxpayer-funded contracts can guarantee healthy returns. Additional financial benefits are likely to accrue to those who invest in related projects like multi-billion-dollar wind-integration transmission lines and who can play in carbon (dioxide) markets—one example being the $1.2 billion that the World Bank and a private investment fund generated in 23 minutes in 2007 by trading Certified Emissions Reduction credits via the UN Clean Device Mechanism on emissions from a plant in China. There are no other investments we know of that can provide the level and stability of returns that some of these investments do.

What about saving the planet? The production of wind turbines and solar panels has largely moved to developing nations where there are few environmental regulations, no particular labour codes, no special

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65 https://onlinelibrary.wiley.com/doi/full/10.1002/wcc.524

66 **ClimateWorks Foundation - WikiLeaks** https://wikileaks.org/podesta-emails/fileid/57594/16165

67 https://www.power-technology.com/features/featurelean-and-clean-why-modern-coal-fired-power-plants-are-better-by-design-4892873/

hazardous materials gear for workers, no emissions management and no reclamation requirements. How can anyone call this 'green' or 'clean?'

Effluent of Rare Earth Mineral extraction for Wind Turbines: Villagers Su Bairen, 69, and Yan Man Jia Hong, 74, stand on the edge of the six-mile-wide toxic lake in Baotou, China that has devastated their farmland and ruined the health of the people in their community. Daily Mail.[68]

The Effect on Society

Despite strong evidence to the contrary, such as that reported above, Deloitte, Climate Reality, and other commentators promote the idea that renewables can economically replace all or most fossil fuel use.[69] Unfortunately, this fallacy is having—and unless it is stopped will continue to have—seriously negative effects on consumers. Dr. Benny Peiser of the Global Warming Policy Foundation (GWPF) explained the energy quagmire in his 2013 testimony to the US Senate regarding the situation in Europe:

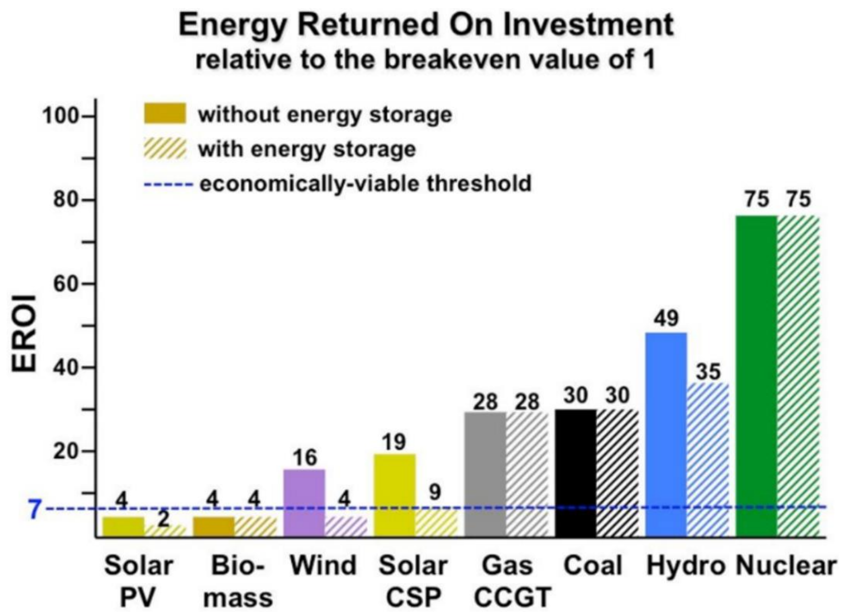
> *The EU's unilateral climate policy is absurd: first consumers are forced to pay ever increasing subsidies for costly wind and solar energy; secondly they are asked to subsidise nuclear energy too; then, thirdly, they are forced to pay increasingly uneconomic coal and gas plants to back up power needed by intermittent wind and solar energy; fourthly, consumers are additionally hit by multi-billion subsidies that become necessary to upgrade the national grids; fifthly, the cost of power is made even more expensive by adding a unilateral Emissions Trading Scheme. Finally, because Europe has created such a foolish scheme that is crippling its heavy industries, consumers are forced to pay even more billions in subsidising almost the entire manufacturing sector.*[70]

Additional commentary on the societal impacts of current renewable energy policies was provided by Professor Michael J. Kelly of Cambridge University. He had the following to say about energy return on investment (EROI),

68 https://www.dailymail.co.uk/home/moslive/article-1350811/In-China-true-cost-Britains-clean-green-wind-power-experiment-Pollution-disastrous-scale.html
69 https://www.fiduciaryinvestors.com/wp-content/uploads/sites/61/2018/09/A-farewell-to-fossil-fuels.pdf
70 https://www.thegwpf.com/content/uploads/2014/12/Peiser-Senate-Testimony-2.pdf

which is the ratio of the useful energy produced by a particular power plant to the energy needed to build, operate, maintain, and decommission it.[71]

> *To get a society that can feed itself and provide a basic educational system we need an EROI of our base-load fuel to be in excess of 5, and for a society with international travel and high culture we need EROI greater than 10. The new renewable energies do not reach this last level when the extra energy costs of overcoming intermittency are added in. In energy terms the current generation of renewable energy technologies alone will not enable a civilized modern society to continue!*



Abbreviations: Solar Photovoltaic panels (PV); Concentrating Solar Power Plant (CSP); Combined Cycle Gas Turbine (CCGT)

With respect to consumer prices the experience in Germany is highly informative. The first chart below shows the composition of power prices for German households using 3500 kWh per year in 2017 and 2018.[72] (This is about half the quantity of electricity that an average Calgary household uses.) The renewables surcharge is 6.79 Euro cents/kWh, which is more than the 6.18 cents/kWh cost of the energy itself. As shown in the second chart, the energy component of the bill in 2006 was 4.92 cents/kWh, while the renewables surcharge was 0.88 cents/kWh. Since 2006, the energy charge has risen by 25% and the renewables surcharge has risen by 771%. Sadly, each year between 2011 and 2015, electricity providers cut off power to at least 300,000 German families who could no longer afford to pay their bills.[73] And in Britain, a million families face a heat-or-eat choice in the winter.[74,75] It would, of course, be irresponsible to blame renewable energy alone for a family's need to choose between heating and eating; however, it is even more irresponsible for billionaires and green-

[71] https://www.cambridge.org/core/journals/mrs-energy-and-sustainability/article/lessons-from-technology-development-for-energy-and-sustainability/2D40F35844FEFEC37FDC62499DDBD4DC/core-reader

[72] https://www.cleanenergywire.org/factsheets/what-german-households-pay-power. At least by Alberta standards, 3500 kWh/year is a small amount of electricity.

[73] https://www.thelocal.de/20170302/over-300000-poverty-hit-german-homes-have-power-cut-off-each-year

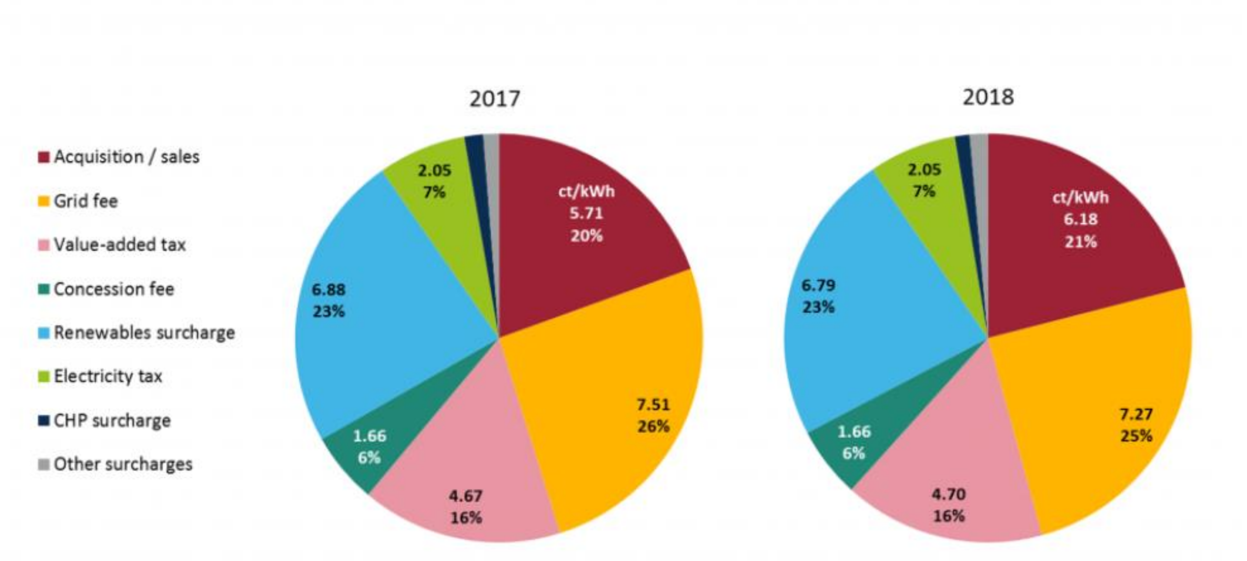
[74] https://www.mirror.co.uk/money/million-families-face-choice-between-11442587

[75] https://www.bbc.com/news/av/uk-42220561/pensioner-poverty-it-s-heat-or-eat

energy advocates to tell these families they should pay significantly more for electricity based on the exceedingly remote possibility that switching from fossil fuels—assuming it is even possible to do so in their lifetimes—will have any measurable effect on Earth's climate.

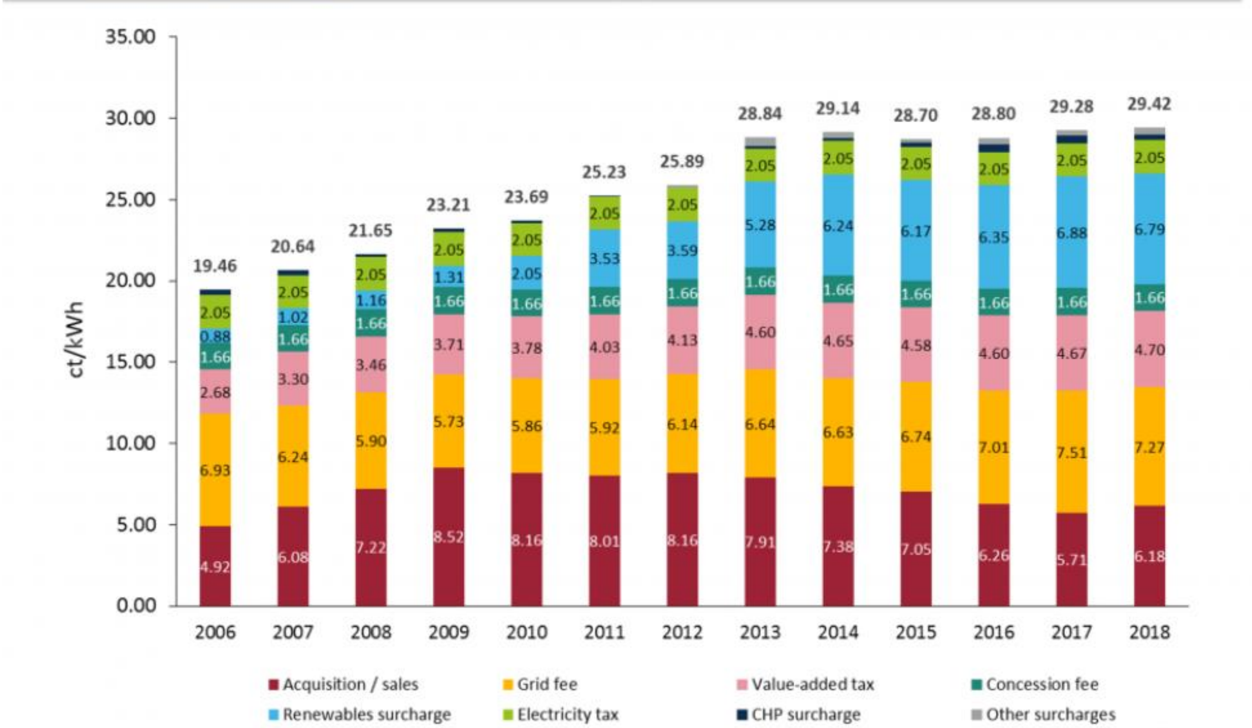
Composition of power price for German households using 3,500 kWh per year in 2017 and 2018.

Data: BDEW January 2018.



Composition of average power price in ct/kWh for a German household using 3,500 kWh per year, 2006 - 2018.

Data: BDEW January 2017.



Sometimes, even *potential* consumers speak for themselves:[76]

> *"I am tired of being lectured by people in rich countries who have never lived a day without electricity," he said.*
>
> *"Maybe they should just go home and turn off their fridge, geyser [electric hot water tank], their laptops and lights. Then live like that for a month and tell us, who have suffered for years, not to burn coal."*
>
> *Masiala agrees.*
>
> *"Aid groups come to Africa and give out solar lamps the size of a pumpkin," he said.*
>
> *"But no one in London or Los Angeles would be willing to make do with that. Don't tell me that China, Russia and the West should have electricity and black people in Mali or Mozambique should live in huts with light from a solar toy. We need power for cities, factories, mines and to run schools and hospitals."*

Sadly, governments have not done due diligence on renewables performance or cost-benefit assessments on climate and energy policies. In fact, many governments have been complicit in spreading the "climate catastrophe" message instead of examining any real evidence. Bjorn Lomborg, a former director of the Danish government's Environmental Assessment Institute, the director of the Copenhagen Consensus Center, a visiting professor at the Copenhagen Business School, and one of the world's most influential thinkers, has the following to say:

- The climate impact of all Paris climate-treaty promises is miniscule. If we measure the impact of every nation fulfilling every promise by 2030, the total temperature reduction will be 0.048 °C by 2100. Even if we assume that these promises would be extended for another 70 years and that there is no CO_2 "leakage" to non-committed nations, the entirety of the Paris promises will reduce temperature rises by just 0.17 °C by 2100.[77] If all the promises in the treaty are kept, the resulting global hit to growth will reach $1 trillion to $2 trillion a year by 2030. Those resources could have been used to make everyone more resilient and prosperous.[78]

- Many of the elaborate and expensive actions now being considered to stop global warming will cost hundreds of billions of dollars, are often based on emotional rather than strictly scientific assumptions and may very well have little impact on the world's temperature for hundreds of years. We should first focus our resources on more immediate concerns, such as fighting malaria and HIV/AIDS and assuring and maintaining a safe, fresh water supply—which can be addressed at a fraction of the cost and save millions of lives within our lifetime.[79] Dr. Lomborg asks why the debate over climate change has stifled rational dialogue and killed meaningful dissent.

- "Cutting CO_2 emissions is incredibly expensive. Green energy is not yet able to compete with fossil fuels to meet most of humanity's needs. Forcing industries and communities to shift — or plying them with expensive subsidies — means everyone pays more for energy, hurting the poorest most. … What's needed is a vast increase in spending on green energy research and development. Instead of trying to

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76 https://www.dailymaverick.co.za/article/2018-03-15-op-ed-clean-coal-is-the-way-to-power-africa-and-sa-academics-know-how/
77 https://www.lomborg.com/press-release-research-reveals-negligible-impact-of-paris-climate-promises
78 http://www.climatedepot.com/2018/10/11/bjorn-lomborg-dont-panic-over-un-climate-change-report/
79 https://www.lomborg.com/cool-it

force people to replace cheap, efficient fossil fuels with inefficient technology, we need to ensure that green energy is the first choice for all."[80]

- Cutting CO_2 emissions is incredibly expensive. Green energy is not yet able to compete with fossil fuels to meet most of humanity's needs. Forcing *industries and communities to shift — or plying them with expensive subsidies — means everyone pays more for energy, hurting the poorest most. What's needed is a vast increase in spending on green energy research and development instead of trying to force people to replace cheap, efficient fossil fuels with inefficient technology*

Dr. Lomborg cannot be dismissed by renewables advocates as a "climate-change denier;" he argues that climate change is real and that it is man-made. Friends of Science agrees that Earth's climate is *affected* by humans and our industrial activities, but 4.5 billion years of geologic evidence shows that natural factors, driven mostly by the sun and ocean cycles, are far more influential—and uncontrollable. Friends of Science completely agrees with Dr. Lomborg that renewable energy is not in a position to displace fossil fuels and that attempts to force it to do so will hurt the poor the hardest. We also agree with him that there are many more valuable and achievable goals than trying to change the climate by reducing CO_2 emissions. Moreover, money spent on humanity's more immediate needs—including weather-resilient infrastructure—will produce benefits regardless of the relative magnitude of human versus natural influences on climate. Society must not collapse into energy poverty by pursuing a Utopian dream of 100% renewables based on faulty premises and a lack of cost-benefit and performance analyses. (Professor Kelly has pointed out that rapid decarbonization of our energy systems, as proposed by the UN climate panel (the IPCC), would lead to mass deaths.[81]) When—and *if*—research into renewable energy systems can bring the *true* cost and reliability of renewable energy systems into line with conventional forms of energy, there will be no need for billionaires and well-funded environmental advocacy groups to demand changes to the world's energy systems; those changes will occur because they are economically rational and beneficial for humanity.

CO_2 is not a Control Knob to Fine Tune Climate

The fear of global warming due to industrial emissions of CO_2 and other greenhouse gases (GHGs), as well as the push to "save the planet," formally began in 1992 with the United Nations Framework Convention on Climate Change (UNFCCC) and its Article 2 Objective:

> *The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention,* ***stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system****. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.*[82]

80 http://www.climatedepot.com/2018/10/11/bjorn-lomborg-dont-panic-over-un-climate-change-report/
81 https://www.rbkc.gov.uk/pdf/Prof%20Mike%20Kelly%20-%20FENand%20ER.pdf
82 https://unfccc.int/resource/docs/convkp/conveng.pdf

While the atmosphere's CO_2 concentration and perceived global warming increased in lock-step from the early 1970s to the mid-1990's, there has been no statistically significant global warming since before the Kyoto Accord was ratified in 1997, despite a dramatic rise in carbon dioxide concentration.

In 2003, scientists convened to review how other human influences, such as deforestation, land use, and water diversion could affect the climate.[83] In 2005, another large group of scientists convened to review whether the radiative forcing theory (i.e., the theory that GHGs cause warming) was the best explanation of climate change.[84] They met because it was becoming clear that factors other than CO_2 and other GHGs affect climate. However, in 2005 the ClimateWorks Foundation was formed to fund environmental organizations to promote global cap and trade, renewables, and the "climate crisis." In 2006, Al Gore's "An Inconvenient Truth," billed as "by far the most terrifying film you will ever see," was distributed worldwide. In 2007, Al Gore and the Intergovernmental Panel on Climate Change (IPCC) won the Nobel Prize.

Who could argue with Al Gore and the IPCC? Well, Mother Nature could. After the release of the 2013 IPCC AR5 report, wherein it was revealed that global warming had stopped for 15 years prior to the report's release, Dr. Judith Curry and many other scientists began challenging the "consensus" view on climate change.[85] Based on their analyses, CO_2 from human industrial activity does not appear to be the main driver of climate change or global warming; rather, natural factors like ocean currents, solar cycles and geophysical changes (e.g. tectonic movement, volcanoes, ocean cycles, etc.) appear to be more influential.

So, for many years, while being led to believe they were saving the planet through the implementation of wind and solar to reduce CO_2 emissions, people have been paying billions for volatile, expensive power generation under the guise of it being "clean and green." Few investors or policymakers have done proper due diligence, and now as a consequence, millions of consumers face heat-or-eat poverty. In return for these billions, there has been no benefit for the environment. This must stop.

83 https://www.springer.com/us/book/9783642623738
84 https://www.nap.edu/catalog/11175/radiative-forcing-of-climate-change-expanding-the-concept-and-addressing
85 https://curryja.files.wordpress.com/2014/01/curry-senatetestimony-2014-final.pdf

Conclusion

The reports by Deloitte and Climate Reality claim that wind and solar generation are now at or near price and performance parity with conventional forms of generation. As this report has demonstrated, their assertions on price parity are based on the levelized cost of energy (LCOE), a flawed metric that fails to include many of the costs imposed on consumers by the use of intermittent resources. When consumers are forced by government fiat to buy wind and solar energy ahead of energy from conventional sources, their costs rise. The reason is simple: wind and solar generation suffer from extreme variability over periods of minutes to years. While technology can solve or at least mitigate the shorter-term variability, longer-term variability requires a level of energy storage that only fossil fuels can provide. The energy density of wind and solar is also extremely low, so these renewables would require impossibly large facilities to meet the world's energy needs. Wind and solar energy systems in Canada and other places at similar latitudes and with similar climates are even more technically challenging and more expensive. In the absence of any *breakthrough* technological advances, attempting to also wean transportation, industrial heat production, and heating/cooling systems off fossil fuels is a complete pipedream.

The "need" for renewable energy systems is ostensibly driven by the need to save the world from climate change. As Friends of Science discusses in many other documents, the main direct and indirect driver of climate change is the sun, and Earth's vast oceans are the main internal responsive element of the climate system. Carbon dioxide is not a control knob that can fine tune climate change. Efforts and resources are far better directed to adapting our infrastructure to the weather events and climate cycles that are a natural and inescapable fact of life on this planet. Further, bringing the enormous benefits of electricity to the billions who do not yet have access to it will ultimately also "save the planet" by providing proper waste water treatment, sanitation, safer and less life-threatening industrial occupations, and the pleasures of life and comfort that people enjoy in the industrialized world.

As noted by Bjorn Lomborg, climate change is not a main concern for most people of the world.[86] Most people want security, affordable energy, viable industry and jobs that are only possible with reliable, affordable power. Many of the world's poor are now in danger of being denied access to affordable power because billionaires with vested interests in renewables[87,88,89] and climate activists[90] are pushing banks and insurance companies to stop financing or backstopping the development of these essential operations.[91,92,93] Some church pension funds are making money from the world's poor through lend-lease programs for solar panels. While the panels are undoubtedly useful in remote locations and there's nothing wrong with making a profit, one might question the ethics of a multi-billion-dollar church pension fund profiting from the poorest while proclaiming that they

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86 https://www.theguardian.com/commentisfree/2006/jul/02/comment.internationalaidanddevelopment

87 https://www.bloomberg.org/press/releases/bloomberg-philanthropies-announces-partnership-powering-past-coal-alliance-strengthen-global-efforts-phase-coal/

88 https://www.washingtontimes.com/news/2015/jul/20/drew-johnson-sierra-club-has-become-front-group-do/

89 https://onlinelibrary.wiley.com/doi/full/10.1002/wcc.524

90 https://content.sierraclub.org/coal/

91 https://unfriendcoal.com/

92 http://blog.friendsofscience.org/2017/10/21/saving-the-planet-on-the-backs-of-the-worlds-poor/

93 https://www.reuters.com/article/us-worldbank-climate-coal/world-bank-to-limit-financing-of-coal-fired-plants-idUSBRE96F19U20130716

are achieving the UNPRI's goals of being ethical, environmentally conscious, socially and sustainably concerned, and dedicated to good governance.[94]

What is very clear is that the current path is unsustainable. We cannot continue to build wind and solar generating facilities that provide unsustainably low energy returns on energy invested. We cannot continue to turn a blind eye to the environmental degradation occurring in the developing world—where solar panels and turbine components are manufactured, and materials are mined without adequate environment regulation—so that we can feel good about saving the planet while not actually saving the planet. We must find ways to recycle the existing wind turbine blades, solar panels, and footings that are piling up worldwide.[95,96,97] Industrialized nations cannot afford to pour exorbitant amounts of money into electricity generation, leading to "industrial massacres." [98] We cannot continue to pretend that wind and solar, which have ludicrously low energy densities, can meet the energy needs of the world's increasing population. We cannot deny access to affordable electricity to the billions of people who have no such access today. The public and policymakers must not remain in the dark on renewables. We must not be greenwashed any more.[99] [100]

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94 https://www.pv-tech.org/news/church-pension-fund-provides-us17-miilion-for-off-grid-solar-loans-in-afric

95 https://climatechangedispatch.com/germanys-wind-energy-mess-as-subsidies-expire-thousands-of-turbines-to-close/

96 https://asia.nikkei.com/Business/Technology/Japan-tries-to-chip-away-at-mountain-of-disused-solar-panels

97 http://insideenergy.org/2016/09/09/where-do-wind-turbines-go-to-die/

98 "We face a systemic industrial massacre," said Antonio Tajani, the European industry commissioner. Mr Tajani warned that Europe's quixotic dash for renewables was pushing electricity costs to untenable levels, leaving Europe struggling to compete as America's shale revolution cuts US natural gas prices by 80pc. https://www.telegraph.co.uk/finance/financialcrisis/10295045/Brussels-fears-European-industrial-massacre-sparked-by-energy-costs.html

99 https://www.canada.ca/en/competition-bureau/news/2017/01/not-easy-being-green-businesses-must-back-up-their-words.html

100 https://www.masterresource.org/climate-policy/who-was-ken-lay-the-senate-should-know-the-industry-father-of-us-side-cap-and-trade/
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About

Friends of Science Society is an independent group of earth, atmospheric and solar scientists, engineers, and citizens who are celebrating its 16th year of offering climate science insights. After a thorough review of a broad spectrum of literature on climate change, Friends of Science Society has concluded that the sun is the main driver of climate change, not carbon dioxide (CO_2).

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