OPINION

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Why wind and solar energy cannot power modern civilization

In a few bullets

- Costs for renewable power generation have dropped faster than many anticipated, this is a good thing… but they will not improve 10-fold anymore, physical limits will be reached
- Common comparisons of renewables vs. conventional power generation are misleading and wrong. You cannot simply compare marginal costs for intermittent power with costs for base power
- Adding wind and solar to the power grid beyond a certain point is not only uneconomical but more importantly hurts the environment
- Gas' GHG emissions from production to combustion are essentially the same as for coal. Thus, replacing coal with gas will achieve nothing but increase costs
- The material needs and thus the environmental impact of today's renewables including batteries far out-shadow those for conventional power

"The reason renewables can't power modern civilization is because they were never meant to. One interesting question is why anybody ever thought they could." (Forbes, May 2019). I could not say it any better. The world has a new enemy: "fossil fuels and the carbon dioxide they emit". This new enemy has led most nations, large banks, and most large industrial corporations to run after every source of renewable power they can get their hands on. Billions and soon trillions of USD, mostly tax payers' money, is spend on building new wind farms and solar panels. Carbon credits are traded, money continues to flow from one hand to another (usually from poor to rich), somehow increasing cost of energy when we see everywhere in the press that today renewables have become so cheap? Have you also heard of those projects that promise solar power at 3 US cents per kWh?

Let me clarify first, I am all for renewable energy. Our long-term future will need to be and will be all renewable… but is what we are currently doing really good for our environment? Are today's wind and solar technology the solution to our energy problems? I would like to take you, the reader, on a journey away from current standard thinking. ***So, bear with me, forget for a second what you know and consider the following.***

The world today is inhabited by close to 8 billion people and we feed our hunger for power to almost 80% with hydrocarbons (coal, gas, oil), let's use the words "fossil fuels". Wind and solar make up an estimated 2% of 2017 primary energy, the remainder largely comes from nuclear, hydro and some biomass. Remember, only a 100 years ago we were 2 billion people. Of today's 8 billion people, there are at least 3 billion with no or only erratic access to power. We can expect to add another 3+ billion people in the next 50 years. Thus, we will have 6 billion new energy customers to join our increasingly loving planet. Not only will our population increase but as we crave for new iPhones and faster computers and planes and cars and space travel, the average power consumption per capita will increase dramatically.

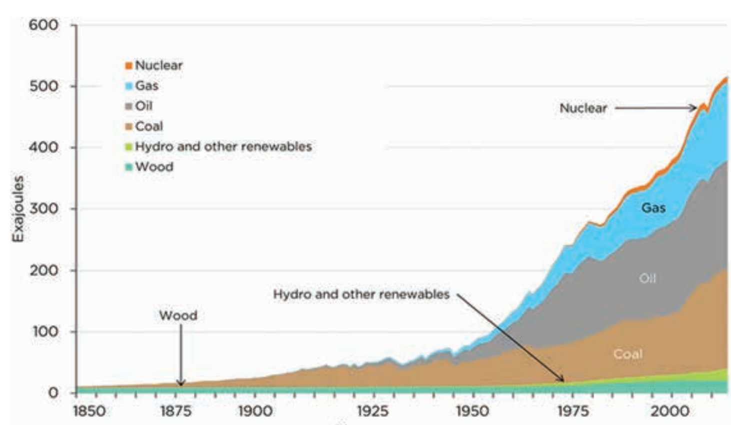

Figure 1: Graph on global energy
Note: Primary electricity converted by direct equivalent method
Source: Data compiled by J. David Hughes. Post-1965 data from BP, Statistical Review of World Energy (annual). Pre-1965 data from Arnulf Grubler, "Technology and Global Change: Data Appendix," (1998).

Now look at Figure 1 and extrapolate to the future. Do you truly believe that non-hydro renewables wind and solar will give you the energy we need? Will we have enough space for windmills and solar panels? Can they sustainably and environmentally friendly power the future? Are they the “New Energy Revolution” we have all been dreaming of? My answer to all those questions is NO. But if you don’t agree it is ok. I wouldn’t have agreed with myself either until not too long ago before I started studying this subject.

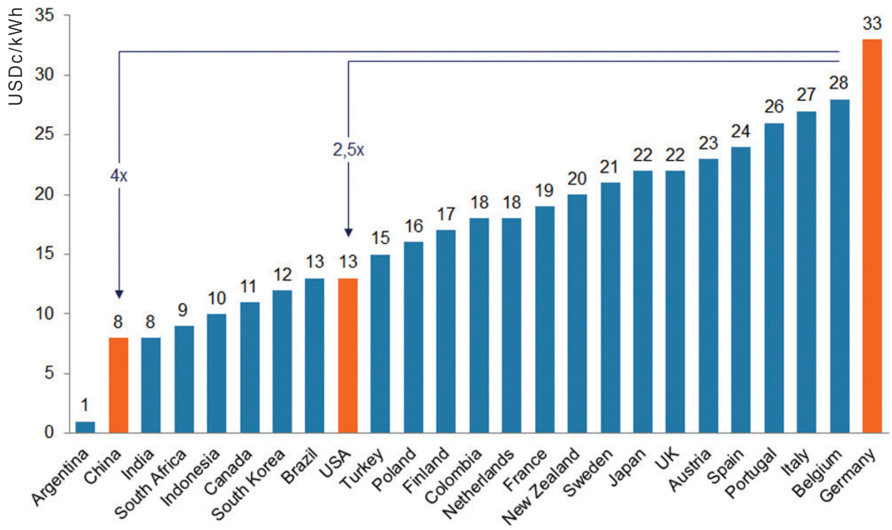

Figure 2: Global prices for power – power in Germany is the most expensive
Note: This statistic shows electricity prices in selected countries worldwide excl VAT
Source: Statista 2019, Release Date October 2018

Comparing apples with oranges

Solar and wind power are obviously not new, not new at all. There is not even something extraordinary or revolutionary about those two sources of power. However, over the decades we have greatly improved their efficiency. In fact, we have done such a great job that we are getting close to their physical limits. The Betz Limit states that a blade can capture maximum 60% of kinetic energy in air – modern windmills have reached 45%. The Schockley-Queisser Limit states that at maximun 33% of incoming photons can be converted into electrons in silicon photovoltaic – modern PV reaches 26%. ***“The era of 10-fold gains is over”[1].*** Don’t expect from energy what you see in computers. There is no Moore’s Law in energy. Costs will not continue dropping and in fact it is time that we are taking a whole-system view when looking at solar and wind, rather than pretending they will save us from whatever we are told to be afraid of and at the same time provide us with the power we require and replace coal, gas, oil and nuclear.

In this article, I will not speak of the components (or materials) that are required to construct solar and wind installations. I will not speak of the mining required and the energy needed to dig-up, process and transport the various materials required that include steel, cement, fiber glass, aluminum, silicon, and many more. I will also not speak of maintenance costs, or space requirements, or the impact on living and farmland, animals and insects, air speeds, noise pollution, low-frequency infrasound, or other. And I will not compare these various costs to the energy output of wind and solar installations.

What I WILL speak of here, however, is the need for backup for virtually every kWh of solar or wind power generated when employed on a large scale for the purpose of replacing fossil fuels. Remember the introduction *“The reason renewables can’t power modern civilization is because they were never meant to. One interesting question is why anybody ever thought they could”*. Today's wind and solar are inherently intermittent means for power generation, they cannot and will never replace conventional power. That means they only work when the wind blows or the sun shines. There is no area practically large enough to ensure that there is always wind or sun. Over the entire continent of North America, there are frequent hour-long periods with no wind or sun anywhere. It happens every few years, probably at least once a decade, that the continent experiences a full day or two of no sun or wind anywhere[1].

Thus, we need to account for the cost of batteries or the cost of conventional power as backup for wind and solar when comparing the cost of power. None of the current Levelized Cost of Electricity (LCOE) measures account for this. Neither do standard LCOE

[1] Mark Mills “The New Energy Economy”, Manhattan Institute, March 2019

measure account for (1) the additional cost of interconnections required, nor (2) the cost of managing networks with highly volatile energy inputs, nor (3) the efficiency losses resulting from keeping coal, gas, or nuclear power as backup. Number (3) is interesting and actually explains why the total cost of power goes up the more wind or solar you install beyond a certain point. What that certain point is depends on the country and region but one thing is sure: Germany is far beyond that point, clearly illustrated by their prohibitively high power prices (Figure 2).

Only recently has the IEA developed a new way of measuring cost of electricity with what they call Value-Adjusted Levelized Cost of Electricity or VALCOE. In February 2019, the IEA writes *"In India for example, the LCOE of new solar PV is projected to drop below that of coal power plants by 2025. But the story is different using VALCOE.* ***As the share of solar PV surpasses 10% in 2030, the value of [solar] daytime production drops and the value of flexibility increases."*** Figure 4 illustrates the misleading cost comparisons that the current LCOE would give vs. the more correct VALCOE. Imagine the economic and environmental impact of using LCOE vs. VALCOE. It is tragic that the awareness of the true cost of wind and solar is only becoming apparent now, but it is also good that it finally surfaces. Now we slowly start to understand why Germany has the highest power prices.

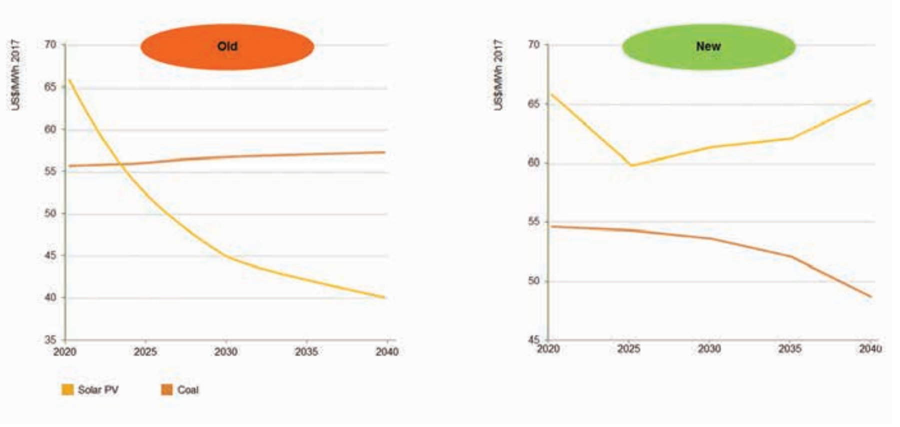

Figure 3: Levelized cost of electricity (LCOE) and value-adjusted LCOE (VALCOE) for solar PV and coal-fired power plants in India
Sources: IEA; WEO Analyst; February 12, 2019 by Brent Wanner

Coal vs. gas

Germany has become aware that they need conventional power despite its huge wind and solar capacity installed (Germany's installed wind and solar capacity by the end of 2018 was 59 GW for wind and 46 GW for solar or 51% of total German capacity; Germany's wind and solar share was 17% for electricity and only 4,6% for primary power in 2018[2]). You might have heard that Germany did not only decide to exit nuclear power after Fukushima but in 2019 also decided to exit coal power. Let's please not discuss energy policy sanity here, let's focus on the fact that Germany has realized they need backup power. Wind and solar will not suffice, thus they decided to build new gas-fired power plants instead. We know that in Europe gas is typically (a) more expensive than coal (not considering taxes), (b) more difficult and expensive to transport than coal requiring pipelines or LNG, and (c) more expensive, more dangerous and more difficult to store. So, what is the reason that Germany shuts down its existing coal-fired power plants and builds new gas-fired ones? Correct, the reason is green-house gas emissions. It is a very well-known fact that gas emits about half the CO_2 per kWh during combustion than coal. It is a simple chemical fact.

$$\textit{coal: } 1\ kg\ C + 2{,}7\ kg\ O_2 \rightarrow 3{,}7\ kg\ CO_2 + 32{,}8\ 10^6\ J$$

$$\textit{gas: } C_xH_y + (x + \frac{y}{4})\ O_2 \rightarrow Heat + xCO_2 + \frac{y}{2}\ H_2O$$

Though proven and a reality, what appears to be a less-known fact is that gas emits/leaks methane (a 28x more powerful green-house gas than CO_2 over a 100-year horizon and 84x more potent over a 20-year horizon[3]) during production and transportation. When you consider the total green-house gas emission and add leakages of gas from production to combustion and compare them to the total emissions of coal from production to combustion you quickly come the conclusion that ***gas' total green-house gas emissions are essentially the same.*** This has been documented in a number of studies including Poyry 2016[3]. Figure 4 illustrates this fact and compares direct emissions (direct = during combustion) with indirect emissions (indirect = during production and transportation):

- Gas emits about half of CO_2 compared to coal during combustion
- Gas emits far more CO_2^{eq} (mostly in form of methane) during the production stage

[2] Frauenhofer ISE 2018 reported in Clean Energy Wire April 2019
[3] Poyry 2016; German Study on "Comparison of greenhouse-gas emissions from coal-fired and gas-fired power plants"

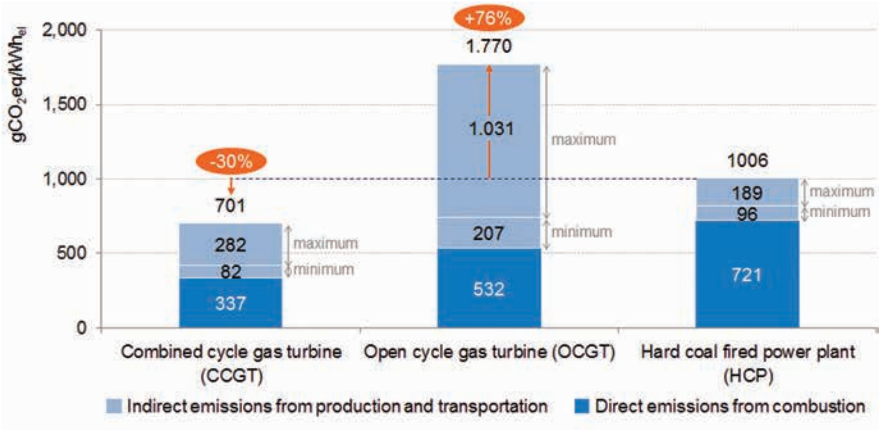

Figure 4: Coal vs. natural gas – green-house gas emissions during partial load operation[3]
Note: CO_2^{eq} emissions for LNG or shale gas are significantly higher than for pipeline natural gas (PNG); CCGT operation without bypass (incl. operation of the steam turbine)

- Methane leakages during transportation
- or processing add additional large quantities of CO_2^{eq}

Today's battery technology cannot save wind and solar

If gas is not the solution, then what is? Right, you will say *"what about those great batteries"*? It is correct that an affordable and sustainable storage system would be the solution to the intermittency problem of wind and solar discussed earlier. Over the years, batteries have become far more efficient and the recent move towards electrical vehicles has driven large investments in battery "Gigafactories" around the world.

The largest known and discussed factory for batteries is Tesla's USD 5 billion Gigafactory in Nevada which is expected to provide an annual battery production output of 50 GWh by 2020. By 2021, CATL in China is expected to double that. These factories will provide the batteries for our world's electric vehicles and also provide backup batteries for houses (see Tesla's Powerwall[3]). How about the environmental and economic impact of these current battery technologies?

Figure 5 below summarizes the environmental challenge of today's battery technology. The problem with current battery technology has to do with two main issues:

- Energy density
- Material requirements

Energy density: Hydrocarbons are one of the most efficient ways to store energy. Nature has done a miracle yet again. Today's most advanced battery technology (I assume Tesla's) can only store 1/40 of the energy that coal can store (and even more extreme for oil). This already discounts for the coal power plant efficiency of about 40%. What this means is that the energy that ***a 540 kg Tesla battery can store equals the energy that 30 kg of coal store.*** And remember, the Tesla battery still has to be charged with power (often through the grid) while coal is already "charged".

Of course, we can use the Tesla battery many times (coal we can only use once) but I believe you get the point.

As a result of the below calculation, you can calculate that one ***annual Gigafactory production of 50 GWh of Tesla batteries would be enough to provide backup for 6 minutes for the entire US.*** Thus, today's battery technology unfortunately cannot be the solution of intermittency. Rather, we will need to keep investing in base research to find truly sustainable and ecnomical storage solutions.

Material requirements: Next comes the question of the inputs and materials required to produce a battery. It is expected and conservatively calculated that each Tesla battery of 85 kWh requires 25-50 tons of raw materials to be mined, moved and processed[1]. These required materials include copper, nickel, graphite, cobalt, lithium and rare earths. Of course, we will likely also need some aluminum and copper for the case and wiring. Additionally, energy of 10-18 MWh is required to build one Tesla battery, resulting in 15-20 tons of CO_2 emissions assuming 50% renewable power.

Hold on… Am I telling you that one 540 kg Tesla battery can store as much energy as 30 kg of coal can? And now it takes 50-100 tons of raw materials to be mined, processed and moved to create a medium that can be compared to 30 kg of coal? Yes, that is what I am telling you! And in fact, I am not even considering the overburden that needs to be moved for each ton of minerals mined. On average, the overburden ratio can be estimated 1:10. Thus, you can 10x fold the numbers above. ***One Tesla battery requires 500-1.000 tons of materials to be moved/mined compared to coal which requires only 0,3 tons – a factor of 1.700 to 3.300.***

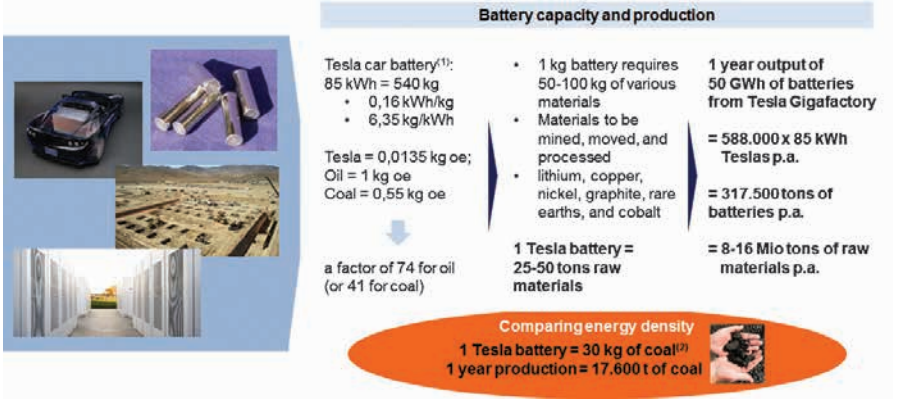

Figure 5: Case in point: Tesla's batteries – energy density & environmental impact[4]

"What do we do now? Are we all doomed?"

A young student from the audience at one of my recent presentations on the subject asked me this question after realizing the environmental mistake we are making by employing current wind, solar and battery technologies at very large scale. From the media, we are taught that if we don't move now, if we don't expand solar, wind and electric vehicles very fast, we will all head into a catastrophe very, very soon. This article cannot discuss the details of global warming. However, it is very worrying that young people are taught in school to be scared of the warming created by fossil-fuel burning. Students are taught to urgently expand utilization of current solar, wind and battery technology without being made aware of their huge environmental burden.

We had 1 degree of warming in the past 200 years. A portion of this warming is human-caused, but this "human cause" has much more to do with the heat that our existence and energy consumption produces rather than with CO_2. The majority of warming is natural, caused by the sun as we are coming out of the Little Ice Age that ended about 300 years ago. We are not heading into a catastrophe, no worries. But yes, ***we need to worry about our environment and the waste and emissions we create. We need to start acting fast and clean up the mess behind us.***

Either way, even if you believe that global warming alarmism is the correct way to approach environmentalism, from the above discussion it becomes clear that current battery technology, wind, and solar – while certainly being appropriate for certain applications such as heating a pool, and thus earning a place in the energy mix – cannot and will not replace conventional power. In order to move forward, we need a "New Energy Revolution". Future energy will be entirely renewable but will have little to do with wind and today's PV. ***We need to invest more in base research to reach this New Energy Revolution. In parallel, we need to invest in, and not divest from, conventional power to make it more efficient and environmentally friendly.*** We need to continue doing this until the New Energy Revolution has reached us, which unfortunately, is many, many decades away. This is the most environmentally friendly and economical solution to save our planet from the negative impact that our existence has.

I am writing this in the interest of humanity and my four children. ***Open your eyes, calculate the cost and impact of today's renewables, and deploy money where it helps our environment and reduces the negative impact that we humans have on our planet.*** C

[4] Note: 1 kWh = 860 kcal = 0,086 kg oe = 3.600 kj; 1 kcal = 4,1868 kj; 50 GWh = 50.000.000 kWh = 317.500 tons batteries
(1) Tesla's Powerwall has a usable capacity of 13,5 kWh and weighs with frame 125 kg. Assuming 100 kg is net battery weight this means 0,135 kWh/kg, so even less effective than Tesla's battery
(2) Tesla battery 90% efficient = 76,5 kWh; assuming 5.500 kcal per kg for coal, 40% power plant efficiency to generate 76,5 kWh requires 191 kWh or about 30 kg of coal
Sources: Author's Analysis and Research based on Mills „The New Energy Economy, an Exercise in Magical Thinking", Manhattan Institute March 2019; Matthew R. Shaner et al., "Geophysical Constraints on the Reliability of Solar and Wind Power in the United States," Energy & Environmental Science 11, no. 4 (February 2018): pp 914–925, pictures taken from: https://www.tesla.com

About the author

Dr. Lars Schernikau has extensive knowledge and experience in the raw material and energy sector. Lars has founded, worked for, and advised a number of companies and organizations in the energy, raw material, and coal sectors in Asia, Europe, Africa and the Americas.

Lars finished his PhD on the economics of energy, commodities, and the global coal business and published two industry trade books on the Economics of the International Coal Trade (Springer, available on Amazon) in 2010 and 2017. He is a member of various economics, energy and environmental associations including the non-profit CO_2 Coalition in the US. He is a regular speaker at international energy and coal conferences and advised governments and leading energy organizations.

This article was inspired by two great thinkers: Mark Mills "The New Energy Economy" Manhattan Institute (March 2019) and Dr. Patrick Moore "The Positive Impact of Human CO_2 on the Survival of Life on Earth" (February2017)