Daniel S. Aegerter
Chairman & Founder
Armada Investment

100% Wind and Solar? A Seductive Myth

"Perhaps the most iconic examples of a sustainable, low-carbon future are solar panels and wind turbines," writes Leonardo di Caprio in the opening of his blog article on 100 percent renewables[1].

The seductive vision that 100 percent renewable energy can become reality is gaining a large following, and countless publications are favorably reporting that a system based on the massive expansion of wind and solar capacity is the only way to reduce CO_2 emissions.

To tackle climate change, many experts believe the best strategy comes in two steps. First, clean up electricity generation and then expand clean power generation to electrify heat and transport. There is also a third, additional step, which is to make all devices using electricity as efficient as possible.

In the race to clean up electricity generation, the 100 percent renewables vision is dominant. Countries like Germany have so far invested and earmarked more than €500 billion to this vision. The result being that wind and solar make up 21 percent of the required electricity annually (2016). Can we go from 21 percent to 100 percent? Will the remaining 79 percent be less expensive or more expensive than the first 21 percent? Is there a real risk that this vision is just a seductive myth? Will it ultimately prove impossible to achieve 100 percent renewables? Instead, will countries that try, like Germany, remain dependent on coal and gas plants after the last nuclear reactors have been taken off grid?

When people say 100 percent renewables, they actually mean 100 percent solar and wind (plus some hydro wherever topographically possible). This has profound consequences on the potential success of this vision. It is therefore important to take a closer look at it and at the associated challenges.

1 http://leonardodicaprio.org/100-renewable-energy-generation-2050/

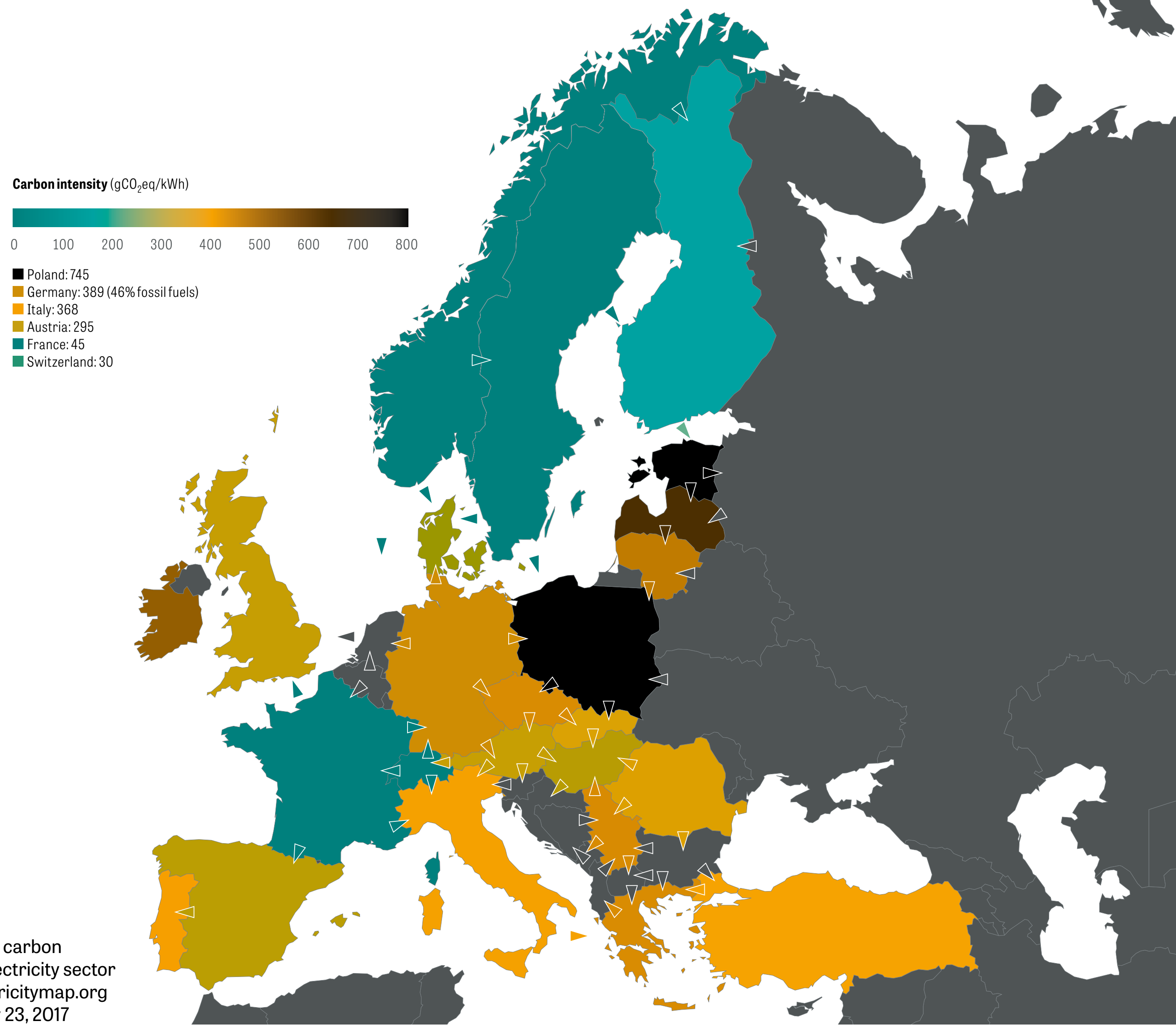

Figure 1: European carbon emissions in the electricity sector
Source: www.electricitymap.org
Screenshot on May 23, 2017

Germany – the poster child of the "energy transition"?

It turns out, however, that this massive increase of wind and solar capacity didn't really reduce carbon emissions because the conventional power plant system also remained connected to the grid to safeguard the electricity supply 24/7.

A wonderful, real-time visualization of the CO_2 emissions of the electricity production system by country is available at www.electricitymap.org. Many viewers are surprised to see that the differences in grams of CO_2 per kWh are stark and range from less than 10g in Norway to about 1,300g in Estonia. But what is truly astonishing is that despite installing record amounts of "low-carbon" capacity, Germany is the biggest polluter on a per kWh basis of the major European powers.

Why is that? Solar PV produces only 9 to 12 percent of the time and wind between 20 to 25 percent. Security of supply has to be ensured for the rest of the time. Germany had a system based on more than 50 percent fossil fuels 15 years ago and still has today. Solar PV and wind have, unfortunately, not replaced any fossil capacity.

WHEN PEOPLE SAY 100 PERCENT RENEWABLES, THEY ACTUALLY MEAN 100 PERCENT SOLAR AND WIND.

Renewables and security of supply

While countries can rely almost entirely on hydropower if there are enough mountains (for example in Norway), they cannot rely on solar PV and wind. The reason is that hydropower is not used directly ("power from the rain"), but after the rain has run into rivers or been stored in lakes with man-made dams. Unfortunately, hydropower is not available in most countries because there are not enough mountains to store the water or gradients to make use of the flowing water, and Germany is a prime example.

Electricity needs to be consumed when it's produced. Given the intermittent nature of wind and sunlight, this creates a fragile juggling act that relies on a conventional, fossil-based system as a backbone. Decarbonization by this means is limited until we can store electricity generated by wind and solar energy on a large scale. We have chosen to scale the capacity ahead of our ability to store this energy and make it available when needed rather than when produced. Unless we build storage capacities in line with generation capacity, we will always either have too little or too much. Imagine you have two suppliers for the same product. One delivers when you need, and the other delivers when they can. Obviously, the reliable supplier deserves the higher price. But reliable and clean hydro power is made uneconomical in many countries by misguided incentives and market-distorting laws. Suppliers who deliver only when they can (solar and wind) are heavily subsidized with the argument that the CO_2 price is not properly reflected in the other fossil-based energy production sources.

Batteries

What are the scalable options to solve the storage challenge so that intermittent renewables production can achieve its full impact? The expansion potential of pumped storage hydro is limited by topography, and power-to-gas-to-power has inherently very poor efficiency. Increasingly, however, there is considerable optimism about electrochemical batteries. Proponents anticipate development similar to the technological development in microchips following a curve as predicted by Moore's law. Can we compare what happened in the digital space to energy storage?

Bloomberg New Energy Finance recently published an article about rapidly falling battery prices. For electric vehicles, an astonishing 55 percent cost reduction was shown in only the last four years from 2013 to 2016. It is tempting to extrapolate this trend into the future, but, unfortunately, it is unlikely to be that simple.

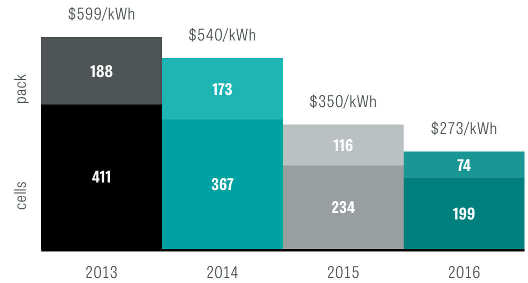

Figure 2: Reduction in battery prices
Source: Bloomberg New Energy Finance
https://www.bloomberg.com/news/articles/2017-01-30/tesla-s-battery-revolution-just-reached-critical-mass

Material usage, cobalt, and prices

Raw materials are a significant share of the manufacturing costs of batteries. In a typical electrochemical battery, materials such as aluminum, copper, and steel are used, but also nickel, lithium, cobalt, and graphite. The production volume of batteries has increased and will need to grow exponentially. This increase in demand will require a corresponding expansion in raw material supplies. Not only is there no reduction in price, but for some materials like lithium, graphite, and, especially, cobalt, the supply chain is already constrained.

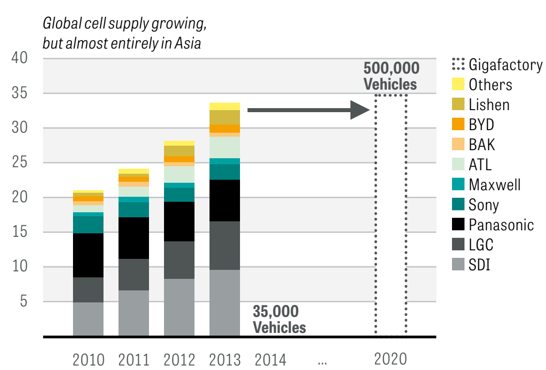

Figure 3: Development of global cell supply compared with projected output of Tesla Gigafactory in GWh/year production; Battery pack cost/kWh reduced > 30% by GEN III volume ramp in 2017
Source: https://www.tesla.com/sites/default/files/blog_attachments/gigafactory.pdf

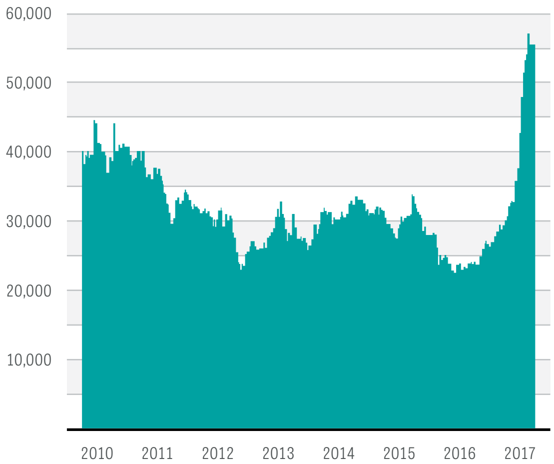

Figure 4: Price development of cobalt in US dollars/ton
Source: https://www.nzz.ch/finanzen/batterie-euphorie-am-kobalt-markt-ob-die-riskante-spekulantenwette-aufgeht-ld.1289460

Since the middle of 2016, the price of cobalt has already more than doubled from around $25,000/ton to $55,000/ton. What will happen if not only e-mobility adds to the demand, but also batteries for the storage of fluctuating electricity?

Global battery production adds up to about 40 – 50GWh annually, and with announced projects it should grow to about 100GWh annually by 2020. This rapid growth means a huge increase in raw material volume. For reference, 1kWh of battery storage weighs about 4.5kg so, 100GWh would weigh about 450,000 tons. The global production capacity of cobalt is about 80,000 tons per year, and already today over half is used in battery production. Tripling the volume would be impossible without mining significant additional supplies which is not easy to scale. But in situations like this, there is often a quick price jump to bring supply and demand back into equilibrium. So, rather than lower costs due to larger volume, there are higher costs because increases in the cost of raw materials are a distinct possibility.

Storage capacity required

What adds to the challenge is that the storage capacity volume needed for the energy sector alone (without e-mobility) is gigantic. Germany produced 37.5TWh of electricity with solar PV over the course of 2016 (seven percent of total generation). A total of 77 percent of this electricity was produced in the months of April to September, and 23 percent in the winter months. Wind produced 77.8TWh (14 percent of the total), with 62 percent of that generation being in the winter and 38 percent being in the summer. Solar and wind are complementary over the year to a certain extent, however, there are still huge differences on a week-to-week basis (see figure below), making fossil plants necessary to balance supply. One of the goals of future storage would be to "flatten out" the generation from day to night, from summer to winter, and from week to week.

In order to have a noticeable and positive impact, an electricity storage capacity in the range of at least 1TWh would be necessary to store some of the generation of a windy/sunny week and transfer it to a less windy/sunny week.

How much is 1 TWh of electrochemical batteries? Tesla's Gigafactory will be by far the largest factory and is projected to have an annual output of 35 GWh battery cell capacity after its completion in 2020. This is more than the worldwide annual battery cell production capacity in the world in 2013 and will be enough for 500,000 Tesla cars per year.

So, in order to flatten out part of Germany's renewable electricity generation of wind and solar today (1TWh of battery storage capacity as we assumed above), 28 times the Tesla Gigafactory's annual output in lithium-ion battery capacity would be necessary. This means the Gigafactory in Nevada would have to produce exclusively for German energy storage demand for 28 years to produce the volume of batteries needed today.

For countries like Switzerland, which has very few sites suitable for wind generation, the amount of seasonal storage needed is even much higher. If Switzerland produced 15 percent of its electricity generation with solar PV (about 10TWh per year), the seasonal storage necessary is estimated to be more than 3TWh from summer to winter. It would take the Gigafactory 85 years to produce those battery capacities for Switzerland alone.

Figure 5: The Tesla Gigafactory battery cell output capacity should be 35GWh per year as of 2020
Source: https://www.tesla.com/gigafactory

Conclusion

Further migrating from carbon-intensive fossil fuels to solar and wind will actually be more expensive, even if solar panels were free, due to expensive storage requirements. It is highly unlikely that electrochemical batteries can become sufficiently affordable and scalable to enable the 100 percent solar PV & wind vision. Prices for some of the raw materials are already increasing today, and there is no significant miniaturization anticipated in technologies that could come to market within 10 years. Leonardo di Caprio and the 100 percent renewables advocates are selling the public a vision to scale capacity first and solve storage later (trust us, it will get solved), but the CO_2 intensity isn't improving because Germany is turning off its most reliable source of CO_2-free electricity – nuclear.

Renewables are important and should be supported with policy measures. But increasing the share of renewables – or nuclear – is not the goal. Renewable and nuclear energy are a means to an end, not an end in itself. Society also cares about other things, like cost, reliability, and other environmental impacts. Nuclear energy has green credentials like being emissions-free and a million times denser than coal. It has a tiny ecological footprint throughout its whole life cycle. The climate and energy discourse is dominated now by a focus on 100 percent renewables and efficiency, which is a seductive vision, but which will, on its own, not solve climate issues. Do we care about decarbonization or about boosting renewables?

If we are serious about reducing CO_2, we need to be willing to consider all sources of reliable and clean electricity as part of the solution. We need a new and open debate on how to significantly reduce our carbon emissions and get rid of coal-fired power plants. It might be inconvenient for many, but nuclear power will have to play a role. Otherwise, decarbonization will remain unachievable.

We need to create a technology-neutral approach that is focused on the larger goals such as reducing carbon intensity, tackling air pollution, and providing low-cost and clean power to millions of people. Only then will it be possible to establish the fastest, most feasible and cost-effective route to achieving meaningful outcomes, for the environment and for society.

Figure 6: Weekly electricity generation from solar and wind in Germany in 2016 in TWh
Source: https://energy-charts.de/energy_de.htm