e-Solar Concept – This way, the energy turnaround can succeed!

There is scientific evidence that man-made climate change is accelerating. NASA has shown this very clearly on their website[1]. How much time we have left to counter is controversial. However, it is clear that the sooner we get our energy emission-free, the greater will be our chances of mastering the consequences of climate change. Therefore, the rapid success of the energy turnaround is rightly one of the central demands of the "Fridays for Future[2]" - and the "Scientists for Future[3]" - movement. The energy turnaround will change many aspects of our lives: our energy supply, our mobility and large parts of industrial production. In 2018, we had a share of more than 40% [4] of renewable energies in electricity generation, and by the end of 2019 it might have been just under 50%. If we want to fully rely on renewable energies for power generation, we will have to roughly double the regenerative share. At the same time, this should be done without overburdening our electricity grids and us financially.

However, electricity generation in Germany[5] contributes with284 million tonnes just over one third of total German CO_2 emissions. So if we want to switch to 100% renewable energy, not only in electric power generation but also in sectors such as transport and industry, we will not only need to generate twice as much electricity from renewables to just make electricity production CO_2-free but about six times as much to get all sectors, including transport and industry, emission-free!

The most elegant way to do this is to rely on electricity as the main resource. It is therefore very interesting and helpful that a lot has happened in the storage of electricity and in photovoltaic power generation, especially in recent times. These recent developments will fundamentally change our energy mix, and we should be quick in order to have the maximum benefit of this new situation. The rapid expansion of electromobility is an essential building block for the transition of our electricity generation to regenerative sources. If vehicles can not only be charged at electric filling stations (at home or at the workplace), but if they also can *supply* power to the grid by injection of a part of their energy content will result in completely new possibilities. Therefore, the rapid expansion of electromobility parallel to the ecological transformation of electrical energy production is one of the most important keys to the success of the energy transition. In the following, therefore, photovoltaics, electromobility and ultimately the intelligent power grid are discussed in more detail as important pillars of the energy transition.

Photovoltaics (PV)

If one now thinks of the expansion of renewable energies, especially if one imagines a sixfold increase in the number of plants, this will not succeed only with the addition of wind power. Although the social support for wind energy and the associated wind turbines is broadly present, with a six-fold increase in the number of wind turbines, the acceptance would suffer greatly or even dwindle. Photovoltaics only provide a good 7% of energy in the current electricity mix in Germany[6]. This form of energy is widely accepted by the population, but this technology still faces many prejudices:

---

[1] https://climate.nasa.gov/

[2] https://fridaysforfuture.de/

[3] https://www.scientists4future.org/

[4] https://www.energy-charts.de/ren_share_de.htm?year=all&source=ren-share&period=annual

[5] The number of: https://www.umweltbundesamt.de/daten/energie/stromerzeugung-erneuerbar-konventionell#textpart-1 multiplied with the number of: https://de.statista.com/statistik/daten/studie/38897/umfrage/co2-emissionsfaktor-fuer-den-strommix-in-deutschland-seit-1990/

[6] https://de.statista.com/statistik/daten/studie/250915/umfrage/anteil-der-photovoltaik-an-der-stromerzeugung-in-deutschland/

The most common prejudice is that the production of the solar modules would consume more energy than the modules will generate during their entire lifetime. This was even valid in the 1960s, because processes and materials from the very expensive microelectronics were used for the production of the first solar cells and photovoltaics as an independent branch of industry has developed later in the following four decades. Today, solar modules have an efficiency of more than 20% and return the energy for their production, set up at an average location in Germany, in about 2.5 years[7]. Most manufacturers today give a module warranty of 20-25 years. If you take this period, so a solar module pays back about 10 times as much energy as it required for its production!

Another prejudice is the seemingly high cost of photovoltaics. Also this was true until recently! The cost of PV modules[8] has fallen by about 97% since 1990, to about 3% [9]. So today (2019) each watt in terms of power of a PV module (Watt-peak or W_P) will cost about 30 cents, in 1990 it was about 10 Euros. There is hardly any other industry that has achieved such a price reduction over a period of almost 30 years through mass production and innovation. The importance of a W_P price of 30 cents is only clear when converted into a price per kWh of electricity generated. A large-scale plant with a PV output of 500 megawatts produces approx. 500 million kWh per year in Germany. The modules cost 30 cents per W_P, that is 150 million Euros. The inverters, which feed the electricity generated into the grid, cost another 50 million Euros for such a system. For the installation and assembly, you can add depending on local circumstances about 100 million Euros. This plant will produce 500 million kWh annually, or 10 billion kWh, within 20 years. If you divide the cost of 300 million by the 10 billion kWh, costs per kWh come out of about 3 cents. It is therefore not surprising that large solar plants are already being built in Germany today and can successfully sell their electricity without any subsidies on the market. For example, In March 2019, a tender for tendered electricity was granted for a PV system, which supplies electricity to the grid for 3.9 cents per kWh[10]. No other available and scalable power generation technology can generate electricity at this price level, neither wind, coal nor nuclear. In addition to the lowest energy prices of PV compared to all other techniques, another advantage is that this electricity does not usually have to be transported over long distances, but can be generated regionally, essentially wherever it is consumed or charged into cars.

In Germany, a good 500 terrawatt hours (one terrawatt hour is one billion kilowatt hours) of electricity were consumed in 2018[11]. Half of this, around 250 TWh, might be generated in about 2019 with renewable energies. In order to get an idea of the area that would be necessary to generate not only twice as much green electricity in Germany as before, but 6 times as much (~1,500 TWh), to fulfill the energy requirements of all sectors such as industry and transport would result in the following calculation:

A modern solar panel has an efficiency of approx. 20% and generates approx. 200 watts per square meter at full solar radiation. With the average radiation power in the federal territory this will result in an annual production of 200 kilowatt hours per square meter. For the 1,500 terrawatt hours it is required to have 7.5 billion square meters of area.

---

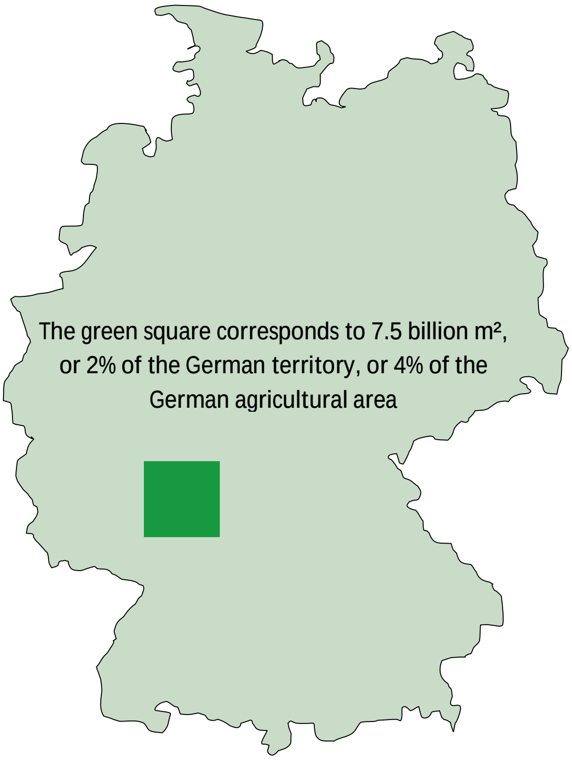
[7] Page 39 https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf

[8] Here, the normalized prices for every watt of module power (Euro per Watt-Peak) are meant

[9] Page 9 https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf

[10] https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Ausschreibungen/Solaranlagen/BeendeteAusschreibungen/BeendeteAusschreibungen_node.html

[11] https://de.statista.com/statistik/daten/studie/164149/umfrage/netto-stromverbrauch-in-deutschland-seit-1999/



Firgure 1: On an area of only 2% of the federal territory, the entire amount of energy consumed in Germany can be generated by photovoltaics..

Germany has an area of around[12] 360 billion m^2, of which around 50% (around 180 billion m^2) is agricultural land. For this reason, 4% of today's agricultural areas would be enough to generate three times the amount of electricity consumed in Germany today, or about six times the amount of green electricity generated in Germany today.

Firgure 2: Agro-photovoltaic system of the Hofgemeinschaft Heggelbach[13].
Agricultural production and energy production in the same place are not mutually exclusive.

---

[12] https://www.umweltbundesamt.de/daten/flaeche-boden-land-oekosysteme/flaeche/struktur-der-flaechennutzung#textpart-1
[13] https://hofgemeinschaft-heggelbach.de/energie

But that does not mean that these areas have to be lost to agriculture. There are already some examples of the so-called "Agro-Photovoltaics"[14], in which the solar modules are mounted above the agricultural land and below, partly shaded, agriculture is operated. This type of agriculture can proceed with less water, because of less evaporation under the shading. This may even result in higher crop yields for some plant species than would be the case without agro-photovoltaics. But the most important thing is that there is no conflict between energy production and food production with this strategy. Even biodiversity would receive a positive impetus, since the non-agricultural area in the area of the foundations and supports of the solar installations, which must be traversed by the tractors, insects and birds can find a home. Therefore, after easily accessible surfaces such as suitable roof areas and anyway used areas, such as along highways, would be expanded with photovoltaic systems, the agro-photovoltaic could open up conflict-free the necessary space.

A massive expansion of photovoltaics as one of the mainstays of our energy supply brings with it the problem that solar panels generate significantly more electricity in summer than on short winter days. Now it is the case that the heating of buildings in Germany consumes relatively much energy in winter, while the consumption by air conditioning in summer is relatively low compared to the southern countries. In Spain and the south of France it is the other way round. Here in summer you need very large amounts of energy for air conditioning, in winter, however, little for heating. Electricity trading with the southern European countries with the respective seasonal surpluses would therefore be a very efficient and helpful way to deal with energy surpluses and deficits. It is also conceivable to convert part of the summer excess electricity into hydrogen or e-gas[15] in order to be able to use it in stationary fuel cells or gas-fired power plants in the winter to generate electricity.

Electromobility

There are currently about 65 million vehicles registered in Germany. If one imagines in a fictive scenario that in the medium term 40 million vehicles are equipped with electric drive and, as it is already achieved today for larger electric vehicles from Porsche, Audi, Tesla, etc., achieve a range of about 500 km, so the battery has a capacity of approx. 100 kWh. In this example, we have 40 million vehicles, each with a capacity of 100 kWh. In this scenario, 4 billion kilowatt hours of energy are stored in the vehicle batteries when they are full. If, for comparison, one looks at how much storage capacity all German pumped-storage hydropower plants have, this number with around 40 million kWh[16], is only about one percent and is rather small compared with the energy stored in the described vehicle scenario.

The electricity supply of a future electricity mix from renewable energies will be subject to strong fluctuations. Sometimes strong wind blows and it is cloudless, then the PV plants produce power at rated level. But there are also days when the wind blows weak and it is cloudy. Now, the grid-friendly storage systems become very important. Massive expansion of pumped-storage hydropower plants and associated landscape consumption would be difficult to implement, and even with a tenfold increase in the number of pumped-storage hydropower plants, it would still only account for 10% of the energy stored in the vehicles from the above example. Now it is the case that not every car driver needs the full range of his vehicle every day. The vast majority, drive less than 100 km per day and require less than 20% of their car battery capacity. So if the car

---

[14] http://www.agrophotovoltaik.de/

[15] https://www.audi-technology-portal.de/de/mobilitaet-der-zukunft/audi-future-lab-mobility/audi-future-energies/audi-e-gas

[16] https://de.wikipedia.org/wiki/Pumpspeicherkraftwerk

owners would provide some of their battery capacity for the stability of the grid power, assuming only 25% of the battery capacity, that is already 25 times as much as the total storage capacity of all German pumped-storage hydropower plants together. In a future renewable energy mix, based on these considerations, electromobility will play a crucial role in the energy turnaround, since it is difficult or expensive to provide the necessary storage of the electricity without the electric vehicles. Another example may help to illustrate this better. If you consume 3,600 kWh of electricity per year in your household, which is a fairly typical value for Germany, you will need an average of 10 kWh per day. If your car has 100 kWh capacity in this example, you only need about 10% of that capacity per day in your household. The electric cars would thus be able to ensure the power supply for the households of their owners for a few days and this completely decentralized, even in the situation of a complete failure of the generation capacity. A prerequisite for the injection of energy from the vehicles battery to the grid would be DC charging stations with integrated inverter, in other words: bidirectional charging stations. Such systems are currently in field trials[17]. This technology is also referred to as vehicle-to-grid (V2G) or vehicle-to-home (V2H) [18] and would be immediately available with the appropriate political will and rapid expansion of PV and electromobility. Bidirectional home or office charging stations were launched in late 2018 and will be available on the market shortly[19].

But as with PV, there are big or maybe even bigger biases in electromobility, perhaps the biggest first:
"The electric cars cause more CO_2 emissions when producing the batteries than they can save during their car lifetime." At this point, again and again, a study from Sweden is quoted[20], which is basically no study, but a meta-study. This means that the Swedish authors did not investigate anything themselves in 2017, but merely compiled the results of other (even older) studies. Apparently, there were many who have spread this study despite their shortcomings, such as the "Focus"[21]. It was also quoted in many other papers and also by politicians, one could almost say, it has spread "viral". However, before political decisions are made on the basis of a poor, now completely outdated study, one should take a closer look at it. Meanwhile, some critical articles have been published that highlight the shortcomings of the study; E.g. in the "Handelsblatt": "Electric car batteries: That's how the myth of 17 tons of CO_2 [22] was born".
The production of lithium batteries requires a lot of energy, but, as with the example of photovoltaics, with increasing production volumes it becomes less and less per battery cell. The energy you need is, above all, energy in the form of electricity. If you now imagine a battery factory, which is operated CO_2 neutral with a solar power plant or with a hydroelectric power plant, so the CO_2 emission in the production of lithium batteries is very low. This is precisely what Tesla is doing, for example, in its final expansion stage of the so-called "Gigafactory" in Nevada, which is already in operation[23]. The electricity for the production of lithium batteries in this factory is produced almost directly from the solar and wind power plants located directly on (and around the plant). Anything else would be economically nonsense, since the cost of solar power in the Nevada desert are again significantly lower than in the example above in Germany - no other form of energy would be cheaper.

---

[17] https://www.mobilityhouse.com/de_de/magazin/pressemeldungen/v2g-hagen-elektroauto-stabilisiert-stromnetz.html
[18] https://www.mobilityhouse.com/de_de/vehicle-to-grid
[19] https://vision-mobility.de/news/emove360deg-wallbox-bringt-v2g-laden-und-google-assist-ins-spiel-1920.html
[20] http://www.ivl.se/download/18.5922281715bdaebede95a9/1496136143435/C243.pdf
[21] https://www.focus.de/auto/elektroauto/e-auto-batterie-viel-mehr-co2-als-gedacht_id_7246501.html
[22] https://edison.handelsblatt.com/erklaeren/elektroauto-akkus-so-entstand-der-mythos-von-17-tonnen-co2/23828936.html
[23] https://www.tesla.com/de_DE/gigafactory

The second big prejudice is the alleged lack of availability of raw materials. Now you need for the production of lithium batteries in addition to lithium carbonate also cobalt. Both are not unproblematic raw materials. The world's lithium reserves are estimated at over 50 million tons. This does not contain lithium, which is dissolved in the sea, at around 240 billion tonnes[24]. In 2017, forty-two thousand tons of lithium were produced. If this consumption stagnated, the reserves would be sufficient for good 1000 years. For the production of a battery for a car with 100 kWh capacity about 10 kg of lithium [25] [26] are needed. So you could build with the reserves of lithium about 5 billion vehicles. Furthermore, the recycling of lithium (and other raw materials contained in the batteries) from vehicle batteries is also almost entirely possible[27]. Another aspect is the recovery of lithium from the sea water, in particular from the brine, which is obtained in the seawater desalination. Sooner or later, this source will certainly complement lithium production and is the subject of much research[28]. The amount of lithium from the seawater is so large that it can be considered inexhaustible by human standards.

The second often discussed material is cobalt. Cobalt is currently needed in small quantities in the traction batteries (NCO cells) for electric vehicles. For example, VW incorporates batteries in its e-Golf that contain about 10% of cobalt[29]. Tesla installs in its "Model 3" batteries with a cobalt content of less than 3%, so a fraction of it. However, it is by no means the case that cobalt is absolutely necessary for the operation of a battery[30]. There are already many lithium-ion batteries that can operate without cobalt, such as the lithium-iron-phosphate battery, whose higher weight for vehicles, however, is a disadvantage and are therefore used mainly for stationary storage. Therefore, intensive work is being done on the development of cobalt-free drive batteries. The University of Maryland, in partnership with the US military, has recently unveiled a cobalt-free lithium-ion battery that is not only safer, but promises even more than twice the capacity of previous batteries[31]. If you look at the number of publications in this area, the innovation fireworks seem to have just been ignited.

Alternative Vehicle Drives

What technical options do we have beyond the battery-powered electric vehicles (BEV)? Electric vehicles with hydrogen fuel cells would be such an option. But it is also worth a closer look here: Hydrogen is produced by electrolysis from water using electricity, then enormously compressed, transported, stored and finally converted back into water in a fuel cell with the release of electricity. This electricity can then e.g. drive an electric vehicle. So this process involves many transformation processes that reduce the overall efficiency. The highest efficiencies of fuel cells

---

[24] http://scienceblogs.de/wasgeht/2015/08/20/wenn-geht-uns-das-lithium-fuer-elektroautos-aus/

[25] https://de.wikipedia.org/wiki/Lithium-Ionen-Akkumulator

[26] https://images.homedepot-static.com/catalog/pdfImages/22/2266fab5-0182-44f1-9a71-c8ca2d81398c.pdf (From the proportion of lithium-containing components in the battery can be derived on the atomic weights of the lithium content per kWh storage capacity; The type of battery to which the publication relates is described e.g. installed in the Tesla Model S and X)

[27] https://www.duesenfeld.com/effizienz.html

[28] https://www.jstage.jst.go.jp/article/apcche/2004/0/2004_0_995/_pdf

[29] https://ecomento.de/2019/03/29/vw-elektroauto-batterien-deutlich-mehr-kobalt-als-tesla-akkus/

[30] https://www.hs-karlsruhe.de/fileadmin/hska/EIT/Aktuelles/seminar_erneurbare_energien/Sommer_2018/Folien/180418BatteriespeicherVetter.pdf Page 14 - alternative cathodematerials

[31] https://www.nature.com/articles/s41586-019-1175-6

currently achieved are about 60% [32]. In the production of hydrogen by electrolysis, one can assume an efficiency of about 70 %[33]. The problem is:

In the calculation of the overall efficiency you have to multiply the individual efficiencies, so in the above figures, the 0.6 times 0.7 is 0.42 or just a total efficiency of 42%. For a kilowatt-hour of electricity from a hydrogen-powered fuel cell, therefore, you must initially spend almost 2.5 kWh of electrical energy. The compression, transport and storage worsen the efficiency again. So if we change vehicles not to battery-powered ones but to hydrogen fuel cell electric vehicles, we would need more than two and a half times the amount of electricity in the transport sector. The grid stabilization by recharging from the vehicles into the electricity grid, which is fundamentally important for the success of the energy turnaround, would not be so readily possible. Another significant disadvantage of these vehicles is the lack of recuperation, so the return of kinetic energy in the battery. It is precisely this feature that makes electric vehicles in the city so efficient, since accelerating and braking at the next traffic light makes even large and heavy vehicles, converted into diesel fuel, consume just over a liter. To at least compensate for this disadvantage, there are developments, in addition to the fuel cell still a battery to install, as it was implemented for example in the Toyota Mirai[34]. However, this leads to even more technology on board and drives the costs up considerably. The safety aspect of sitting on a 700 bar hydrogen pressurized tank, which can form an extremely explosive oxyhydrogen gas mixture with the surrounding oxygen, is another point to consider in the discussion.

Fuel cells, such as those used today in vehicles, contain platinum as an important material. For a fuel cell with 100 KW power today you need about 43g of platinum[35]. The problem is: platinum is extremely rare. Globally, only about 200 tons of it are produced per year[36] and the production of platinum is anything but an environmentally friendly and clean thing. For the 65 million German vehicles alone, 43g per vehicle would require 2,795 tonnes. If we were to move globally to fuel cell vehicles, with 1.2 billion vehicles estimated globally[37], well over 50,000 tons would simply need 250 times the current annual world production of platinum[38]. Even if it succeeds in reducing the platinum content in fuel cells to only 25% of today's value, it would still be more than 60 times as much as we can produce today.

Alternative fuels

Today, 10% so-called bioethanol is usually added to the gasoline in order to reduce the CO_2 emissions of the German motor vehicle fleet. Would an expansion be a sensible option? The consideration of the efficiencies gives a somewhat better insight into the situation here: plants that produce biomass through photosynthesis do so with an efficiency between one and two percent of the incident solar energy[39]. In addition, fertilizer is still needed for the plants and diesel for the agricultural vehicles. The conversion of biomass into bioethanol further reduces the efficiency. Ultimately, the use of bioethanol in an internal combustion engine with an efficiency of also below 30% is very low. Since we have to multiply efficiencies, we come to an overall efficiency

---

[32] https://www.sonnenseite.com/de/wissenschaft/reversible-brennstoffzelle-bricht-wirkungsgrad-rekord.html

[33] Alexander Stubinitzky: *Ökoeffizienzanalyse technischer Pfade für die regenerative Bereitstellung von Wasserstoff als Kraftstoff*. In: *Fortschritt-Berichte VDI*. 6: *Energietechnik*, Nr. 588. VDI Verlag, 2009, ISBN 978-3-18-358806-0, ISSN 0178-9414.

[34] https://www.toyota.de/automobile/mirai/index.json

[35] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/news/2019/ISE_Ergebnisse_Studie_Treibhausgasemissionen.pdf Page 25

[36] https://www.goldsilber.org/artikel/2-peak-platin-produktion-hochpunkt-hubbert.php

[37] https://www.live-counter.com/autos/

[38] https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-plati.pdf

[39] Barber, J. (2009): *Photosynthetic energy conversion: natural and artificial.* In: *Chem Soc Rev*. **38**(1); 185–196

of less than 0.5%[40]. If we compare this with the PV and a battery-powered electric car, we need for each kilometer we want to drive, more than 30 times the area for energy production. This area is not available in Germany! And here, there is a significant ethical conflict between food production and the production of energy crops.
Another technical option is the conversion of electricity into a synthetic fuel, with which conventional internal combustion engines can be operated. On the vehicles one would not even have to make any major changes for these "e-Fuels"[41]; they could basically be driven directly with such fuels. Here is the problem especially the low efficiency. If we completely shifted our mobility to e-fuels, we would need around 5 times more renewable electricity than battery-powered vehicles for the transport sector alone.

Smart Grid

The generation and demand in a power grid with an increasing share of renewables will hardly be reconcilable without large storage and reserve capacities. The possibility to use the fleet of electric vehicles both as a power sink in times of overproduction, as well as to take at times of low production energy from the vehicles back to the grid stabilization, has already been addressed. However, the question is: what should motivate car owners to wear their batteries to the community, even if this wear is very low[42]? In order to regulate supply and demand, one usually uses the price in a market economy. Amazingly, the consumer always pays the electricity supplier the same, regardless of whether he is drawing electricity when it is scarce, or when there are massive surpluses. These fluctuations in supply and demand can be clearly seen in the spot prices of the power exchange[43], which provide daily information about the available amount of electricity and thus the associated price for every hour of the day. With a relatively simple trick, you could implement nationwide energy management: put a signal on the power line that tells the device at the end of the line (such as a washing machine or electric car charger) the current electricity price. If you then as a consumer of your washing machine specify a maximum price of electricity such as 10 cents per kWh, the washing machine "waits" with the start until the power overproduction has reached a level that drops the price to less than 10 cents. Naturally, with increasing over-production of electricity, the price of electricity will become lower and more and more devices will be switched on in this way, until, similar to the stock exchange, a certain price level has settled. Cars with a large battery will therefore be charged from an economic point of view during times of overproduction. However, if the electricity demand is greater than the power production, the car owners will "allow" their vehicles from a certain price per kWh, again to give a portion of the energy of their battery into the grid. They do so for purely economic reasons. A modern battery in an electric vehicle can be charged more than 2000 times in about 8-10 years. With a range of about 500 km of these cars, this results in a possible mileage of 500 km times 2000, so theoretically about one million km. Half of them, half a million km, have already covered a Tesla Model X in the US and the battery still has more than 90% of its initial capacity[44]. Since hardly a car owner will cover such long distances within the lifetime of his vehicle battery, he can thus behave grid-friendly without having the risk of heavy wear of his battery, and he can at the same time earn something by the electricity sales in times of low power generation in the wind and solar power plants. Of course, this is not possible when you are on your way to vacation. If you

---

[40] http://www.energieinfo.de/eglossar/biomasse.html
[41] https://ineratec.de/prozesse/
[42] Lithium ion batteries wear very little in a SOC range between 50-75%, and this is the range that would be favored for grid stabilization
[43] https://www.eex.com/de/marktdaten/strom/spotmarkt/auktion#!/
[44] https://ecomento.de/2018/07/24/643-738-kilometer-in-teslas-elektroauto-limousine-model-s/

are at work during the day and the vehicle is parked at the company car park, or at night in the garage, or in the parking lot connected to a bidirectional charger, that would be easily possible because an average car is idle for more than 90% of its time.

Conclusion

The energy turnaround will succeed if the transition to electromobility takes place in parallel with the expansion of power generation from renewable sources. A very important aspect is to create and promote the possibility that the vehicles are available both as a current sink and as a power source for the power grid. This would create a gigantic collective power storage without it, our security of supply would not be guaranteed! And that, since the batteries for the cars are necessary anyway, without additional costs. The photovoltaics has become from one of the most expensive to the cheapest energy source, which is now available with less than 4 cents per kilowatt hour (tendency falling annually). The expansion in the form of agro-photovoltaic would quench our thirst for energy and at the same time enable food production - without additional land use.

An intelligent grid, that tells the connected devices what the current electricity price is, would provide a simple way to make meaningful use of the fluctuating energy production in a future energy mix. At the same time it is supporting the grid when it becomes necessary - all with market-based rules. All these described techniques and building blocks for the success of the energy turnaround already exist. So we just have to promote, expand and use them!

About the Author: Dr.-Ing. Titus J. Rinke studied electrical engineering at the University of Ulm, then received his doctorate at the Institute of Physical Electronics with the topic "Monocrystalline Transfer Solar Cells". He then founded two technology companies, whose managing director and shareholder he is. The company building is at the level of the passive house standard. It consumes no oil and no gas. The powerful solar system generates electricity and heat. The seasonal storage unit absorbs heat in summer and releases it in winter for heating purposes. The largely self-developed energy management and smart building ensure a high degree of self-sufficiency. The electric filling stations on the company parking lot are available to employees free of charge to absorb parts of the surplus electricity. This company is one of the few with negative energy costs! Even the private house of the author has neither oil tank nor gas connection. The concept here is similar to the company building described above.