# NEW CHALLENGES OF GERMAN ENERGY TRANSITION

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**Abstract:** The paper presents big challenges in front of German energy transition, the so-called Energiewende, first of all in the power sector. Very high electricity prices for households and industry (the highest in Europe) will continue to rise, despite some indications that EEG-surcharge will drop further and finally disappear completely. The market price will rise further and compensate the part of EEG-surcharge. Wind and solar generation have to rise with a considerably faster rate, leading to more challenging measures for grid stability. The total electricity production will not drop (as predicted in some previous forecasts), but will rise significantly. It has to cover new consumers, like mobility, heat pumps and $H_2$ generation through electrolysis. Electricity is planned to be the main energy carrier, reaching 49% in 2045. The energy storage is still not an important issue, despite of increasing hours with negative market price and very high price peaks in periods with lower supply. Hydrogen is seen as the main solution in covering required generation peaks, despite obviously very high costs. The energy solution is a must, but it will be expensive. For reach societies, like German, that will not be an unsolvable problem. Despite so high costs till now, Germany is not very successful in the reduction of $CO_2$ emissions, taking its place among the biggest European emitters per capita.

**Key words**: electricity price, EEG-surcharge, intermittent generation, storage, residual load

## 1. INTRODUCTION

German Energy Transition (Energiewende) has experienced and will experience some very intensive challenges, technical and monetary. However, those are inevitable in order to improve and accelerate the measures for the reduction of GHG emissions. The $CO_2$ emissions in Germany per capita are still among the highest in Europe. As the public opinion is strongly opposed to the usage of nuclear energy and biomass is considered as very limitted, the only way is to use solar and wind energy.

In this article, the main issues are the challenges in the power sector, including: electricity prices, EEG surcharge, wind and solar capacities, storage and covering of future residual loads.

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## 2. ELECTRICITY PRICES

At the moment, the German electricity prices are the highest in Europe, and even in the world (excluding some local cases, like some islands). That will probably stay so in the future, at least in the near future.

The development of the electricity prices for households in Germany is presented in Figure 1 [1]. In year 2000 it was less than 14 €c/kWh and this year (as of June 2021) it is already almost 32 €c/kWh, what means an increase of 129%! Presented figures are mean values: in some states it is considerably higher, like in Mecklenburg-Western Pomerania (35,9 €c/kWh) and especially Hamburg (37,1 €c/kWh), while in Bavaria the prices even below 30 €c/kWh are experienced.

The general trend is that in North of Germany, i.e. in regions with higher penetration of renewable electricity and especially wind, the prices are higher. The reason lies in the higher network charges, as in those regions there are more often bottle-necks in the parts of network and dispatches are regular there, including the curtailment of some wind generators.

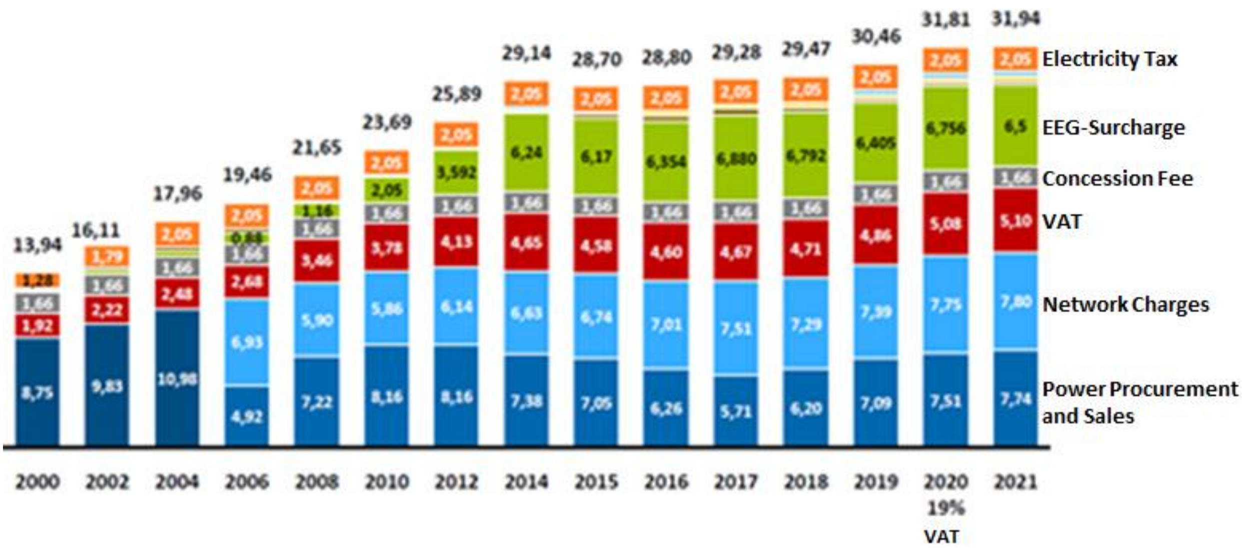


**Figure 1: Electricity prices for households (average in €c/kWh, 3.500 kWh/a) [1]**

It is obvious that there are three main components in the structure of electricity price:

- Power procurement and sales
- Network charges, and
- Taxes, duties and levy.

As presented in Figure 2 [1], the first item is the smallest, taking only 24% of the total costs! And that is the only part which value is formed on the free market, i.e. on the electricity exchange market. The second part, the network charges, is controlled through regulatory authority, as the network operators have a geographically defined monopoly and therefore a free market competition is not possible. It is slightly higher (25%) than the first one, but is increasing steadily, due to higher penetration of intermittent sources of electricity production.

The most important part of the electricity price (51%) is for taxes, duties and levy. Among them, the biggest issue is the so-called EEG-surcharge. That surcharge was introduced in the year 2000 as a part of the Renewable Energy Law (**E**rneuerbare**E**nergie**G**estz-EEG). That surcharge has experienced a dramatic increase from its introduction till nowadays, what will be discussed in the next chapter.

The first impression is that high taxes and duties are the main driving factor for so high electricity prices, not the production costs. That is a wrong conclusion, as the EEG-surcharge is used to compensate the cost for renewable energy sources (RES). The most of renewable electricity enters on the electricity exchange market with price 0 (zero). Therefore, the real cost of electricity production is the sum of stock market price and the EEG-surcharge, as detailed discussed in [2]. It will be clearer after the presentations in the next chapter.

If the procurement of electricity and EEG-surcharge are taken together, then their share on the total cost rises to 45%, and taxes and duties are reduced to 30%.

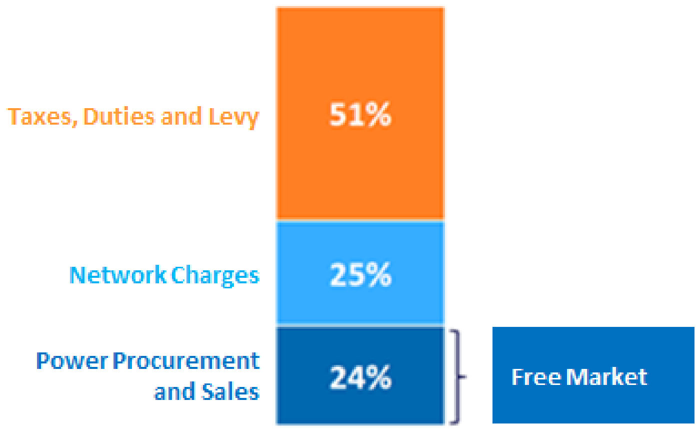


**Figure 2: Three main components of electricity prices for households [1]**


**Figure 3: Electricity prices for industry (average in €c/kWh, 160-20000 MWh/a, mid-voltage) [1]**

The electricity price for industry is given in Figure 3 [1]. It also raised dramatically, even more than in households. In the year 2000 mean electricity price was 6,05 €c/kWh and in 2021 (as of June) 19,09 €c/kWh, what gives 216% increase. That is also the highest value in EU.

Generally, the industry has to pay EEG-surcharge as well. In order to preserve the competitiveness of German industry, some big energy consumers are partially or in total exempt from EEG-surcharge, and the electricity tax is 25% reduced. Due to corona-19 pandemic and low demand for industrial power, the market prices in 2020 were lower than in previous years.

## 3. HISTORY OF EEG-SURCHARGE

In the year 2000, the new Renewable Energy Law together with corresponding EEG surcharge, was introduced. That was the main milestone for the increase of RES electricity. Every consumer (except some big industries, as mentioned above) has to pay that surcharge. It is used to cover the cost of renewable electricity generation, which has the feed priority in the electricity system, by entering the electricity exchange market with the price 0 (zero).

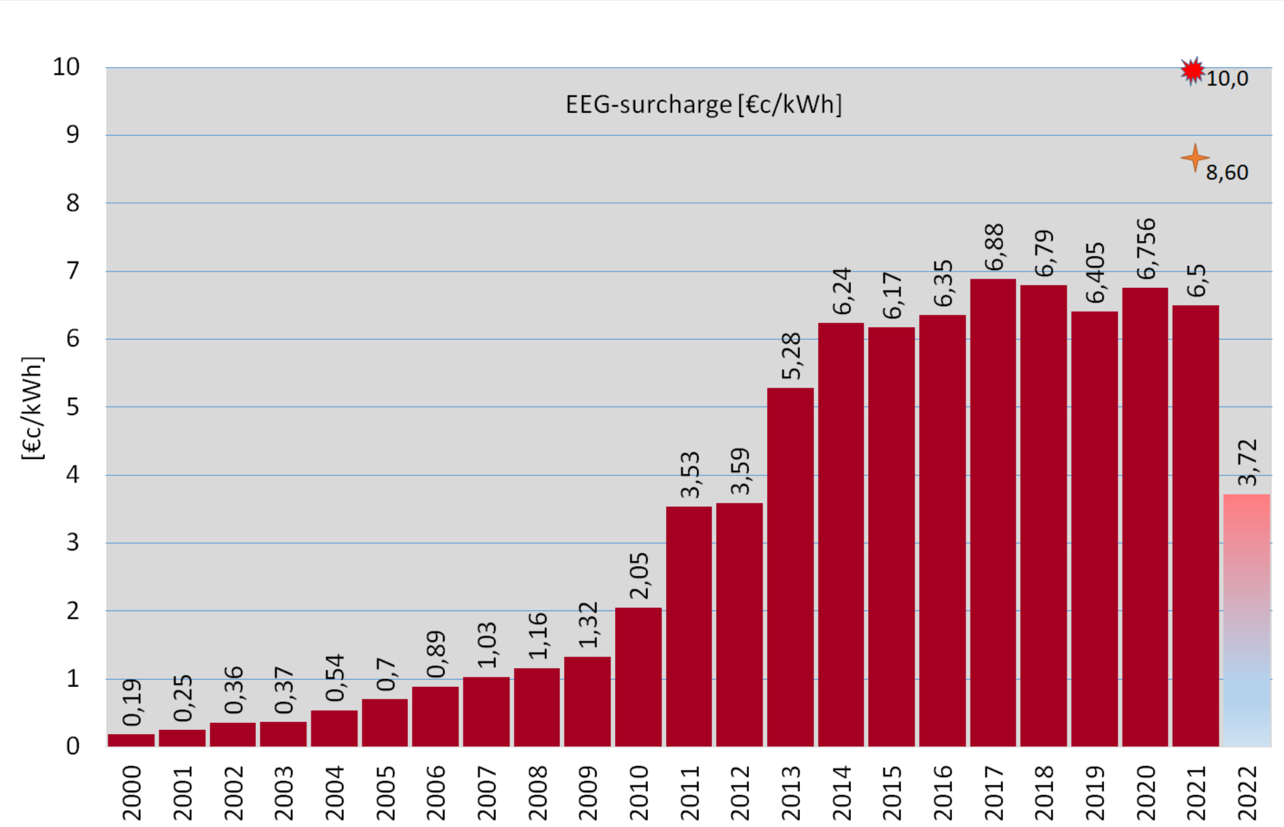


**Figure 4: Historical values of EEG-surcharge [3, 4]**

At the beginning its value was almost negligible, but reached a maximum in 2017 (and indirectly in 2021), as seen in Figure 4 [3, 4]. Its value for the next year is defined at the end of current year, depending on the present expenditure for renewable power generation. Due to corona-19 pandemic, the power consumption in industry in 2020 was lower than usual. At the same time, there were excellent conditions for wind and solar resulting in more electricity generated by RES than by the conventional sources. The demand for electricity handled on the exchange market dropped, so as the price. Therefore, the fund collected on the EEG account was not sufficient to cover the expenditure for such intensive RES power generation. As a result, that account experienced a very high deficit of 4,4 billion Euro at the end of 2020.

Using the old procedure for estimating the level of EEG-surcharge for 2021, its value would be 8,60 €c/kWh [5], or even 10,0 €c/kWh without income of $CO_2$ tax [6]. That would increase further the total price of electricity and would provoke resentments against Energy Transition process. In order to relax the situation and to help industry and households, as a part of corona-19 stimulus, the Government decided to limit the EEG-surcharge to 6,5 €c/kWh and to cover the rest through the Federal budget. The foreseen costs for that were about 10,8 billion Euros.

With the same Governmental decision, the EEG-surcharge for 2022 was limited to 6,0 €c/kWh. The process for abandoning the EEG-surcharge has started, as it was earlier foreseen that it would not be needed any more, when the RES power generation reach its maturity.

The extraordinary conditions during 2021 led to the situation that the mentioned limitation for EEG-surcharge was not required. On one hand due to unfavourable weather conditions, the RES generation in 2021 was considerably lower than in 2020. On the other hand, in the post-covid conditions the industry has required more electricity, the prices on the exchange market exploded and the conventional generation sources regained their primacy over RES generation. All that resulted in a very positive bottom line in the EEG account, reaching positive value of 4,5 billion Euros [4] in September 2021. Therefore, mid-October 2021 the EEG-surcharge was defined to be 3,72 €c/kWh for the year 2022! That is the historical reduction, as obvious from the graph in Figure 4, leading to the conclusion that the EEG-surcharge could be abandoned soon.

In conditions of high prices on the electricity exchange market EEX in Leipzig, that could be the case. Namely, the producers of renewable electricity may find that the market price is more attractive than the price guaranteed by EEG act. They may opt for one or another option on a monthly basis. In such case, the funding from EEG account will not be charged high, its bottom line will increase and further reduction of EEG-surcharge would be possible. It is a realistic scenario, having in mind that the feed-in tariffs are limited to 20 years and that many most expensive tariffs are expiring in following years.

Some politicians use that reduction of EEG-surcharge to make populistic promises that the electricity price will drop in the future. In fact, the sum of the lower EEG-surcharge and higher market price will stay more or less constant, at best. The graph in Figure 5 [7] shows that the average market price of electricity on EEX raised from 29,52 €/MWh in 2020 to more than doubled value of 74,19 €/MWh in 2021 (as of end of October), what will neutralize the reduction of EEG-surcharge. In some months of 2021 the average market prices were above 100 and even above 200 €/MWh. The highest daily average was 305,24 €/MWh on October, 7.

At the end of 2022 all other nuclear power plants will be decommissioned and some further coal power plants will be closed. That will result in 22,5 GW less capacity in the base load generation. As already predicted in 2019 [2], further price increase is expected. Especially having in mind that the natural gas price has experienced even higher explosion. (Natural gas is foreseen for simple cycle plants which should close the gaps in peak load).

The remaining coal power plants will also increase their production costs, due to ever higher costs of the $CO_2$ certificates (see Figure 5). This year (as of October) they are doubled, reaching 48,40 €/t, compared to average price of 24,52 €/t in 2020. Current value is already above 60 €/t. A further drastic increase may be expected – in Norway there is a prediction that their price will reach 200 €/t till 2030.

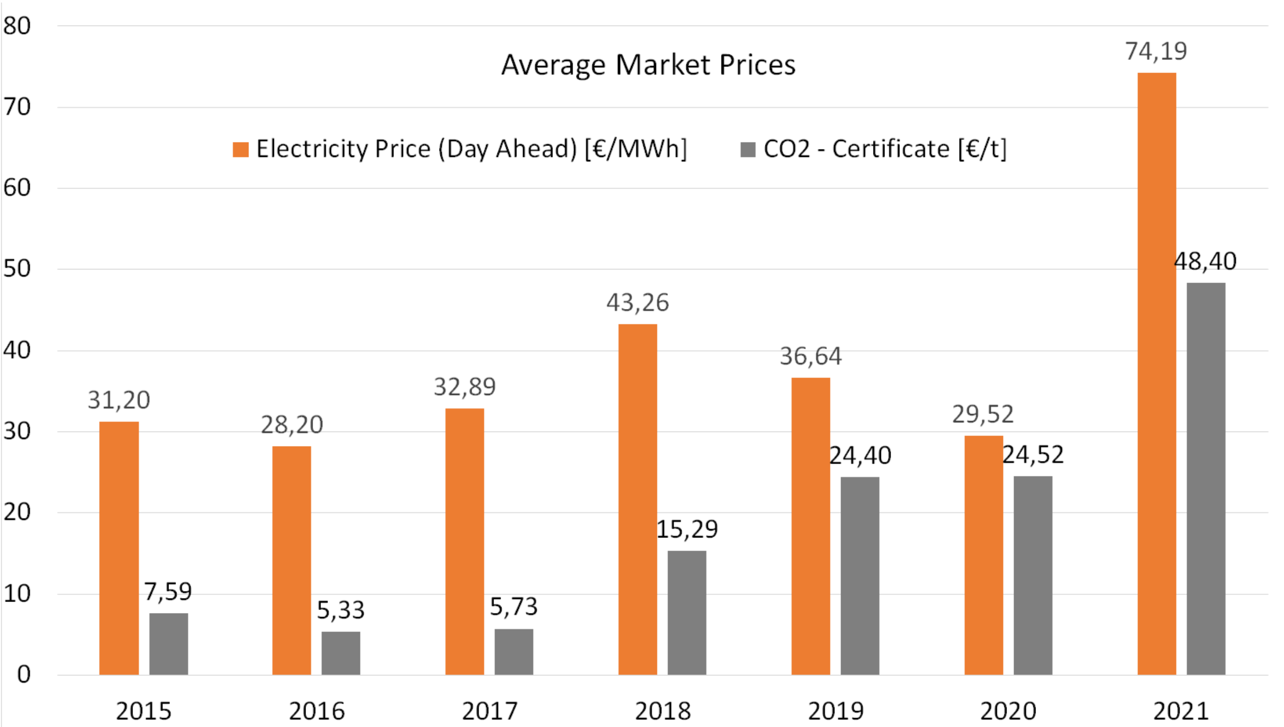


**Figure 5: Market price of electricity and $CO_2$-certificates [7]**

## 4. INCREASE OF WIND AND SOLAR CAPACITIES

The electricity generated from solar and wind is foreseen to be by far the most important source of electricity, according to the newly published study [8]. They will be required not only to cover the closed nuclear and fossil power plants, but even more to increase the total electricity generation required for mobility, heat pumps and Hydrogen generation. From nowadays (as of 2018) gross generation of 595 TWh/a, it has to rise to 695 TWh/a in 2030 and further to 910 TWh/a in 2045 (the year when the net CO2 emission would be zero).

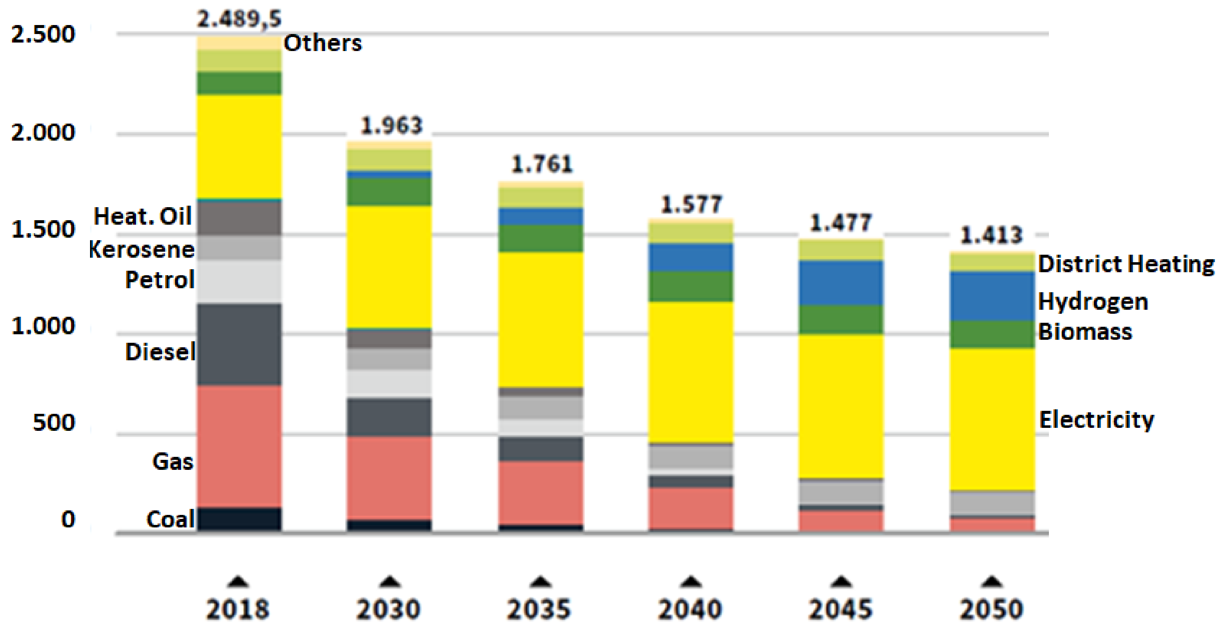


**Figure 6: The foreseen change of energy demand and of energy carriers [8]**

The total final energy demand would drop for 41%, reaching 1477 TWh in 2045, as indicated in Figure 6 [8]. On that way, the electricity would be the most important energy carrier with 49% in 2045, starting from 20% in 2018.

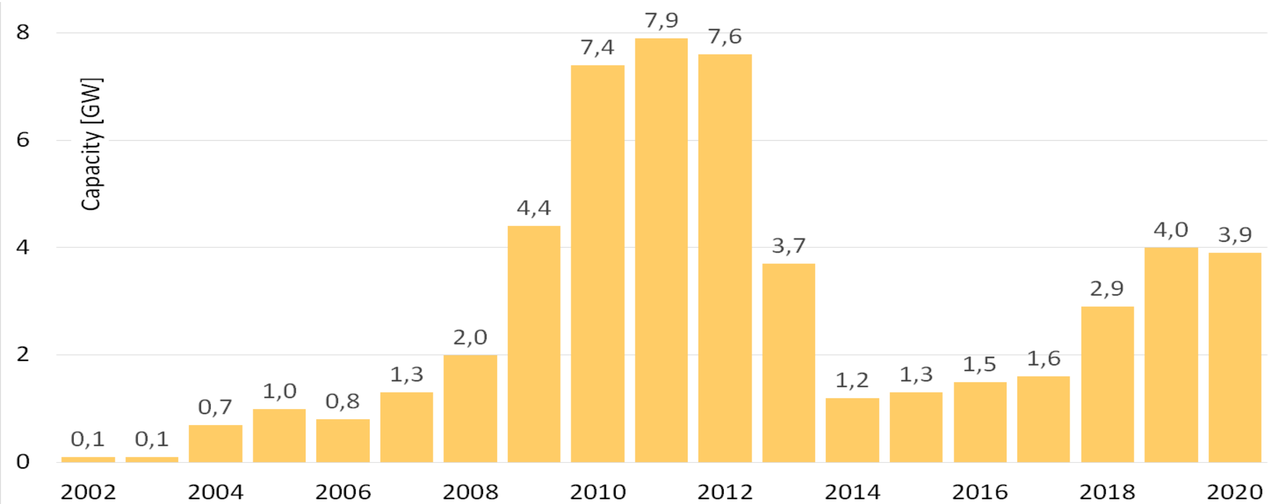


**Figure 7: Yearly increase in the PV capacities [9]**

In order to reach that goal, the yearly increase of onshore wind capacity has to be doubled compared to nowadays, and the PV and offshore wind capacity has to rise three times faster as nowadays [10]. The graphs on Figures 7, and 8 shows that in all three generation sectors there is a very unstable development, with lot ups and downs. The problems are political, as well as public acceptance. E.g. in Bavaria there is a 10H regulation - it is not allowed to erect a wind generator closer than tenfold of its hight to a closest settlement or house. In North of Germany that was not the case and there are many objections on low frequency noise and other health influences. In case of photovoltaics (PV) the most successful were big “farms” from several MW up to 30-40 MW. Most of them were built on agriculture land, what started again “Tank or Teller” (tank or plate) discussion and would be forbidden. Knowing all that, the problem is where to find the propriate locations for further wind and solar generation. The roof concepts will gain on its importance again, but that will not be sufficient. However, in situation when the market price of electricity increases, as well as the price for $CO_2$ certificates, it could be expected that economical interest will push search for solutions.

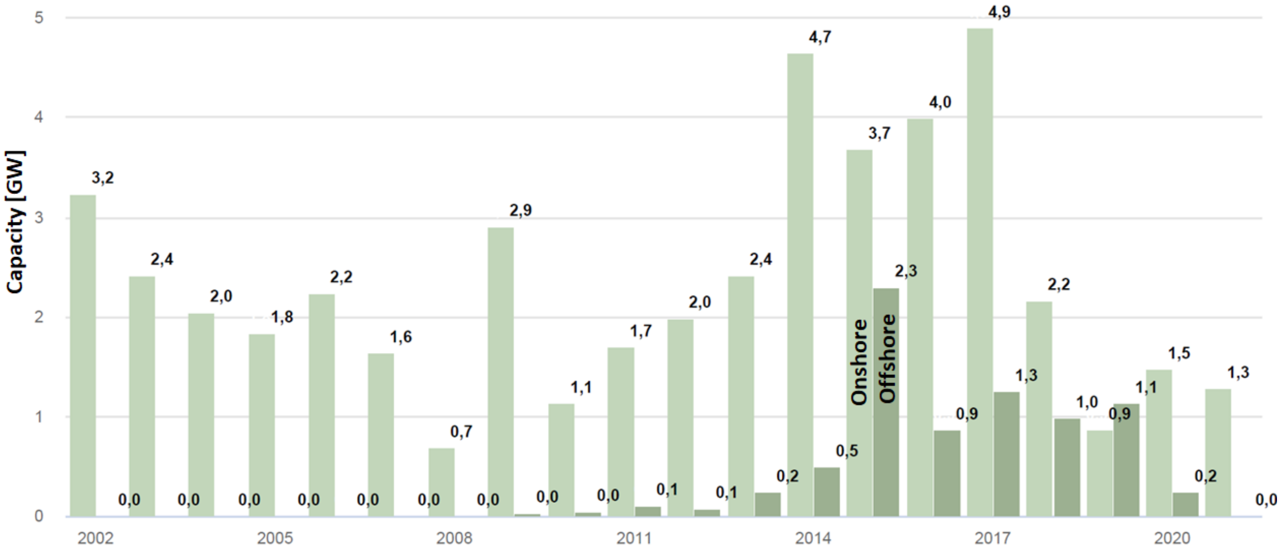


**Figure 8: Yearly increase in the wind generation capacities [9, 7]**

## 5. STORAGE AND POWER GRID

Energy storage and the extension of existing power grid are inevitable preconditions for a successful energy transition in the electricity sector. They have to cope with geographically and timely imbalance in the system due to intermittent generation. However, both are getting stuck, especially the energy storage.

The construction of additional grid capacities, in order to transport renewable wind electricity from the North to the South is in a considerable delay. Yearly goals are reached only for 30%. The biggest problem is low public acceptance of new, both above and underground power cables, in the areas where they are planned. On the other hand, they are absolutely needed for a successful energy transition. Even bigger problems will arise at the end of 2022 when big nuclear power plants in the South Germany will be decommissioned and more power from the North should be transported, but the grid capacities are limited, already in the present situation.

Even with those delays, the situation with new grids is considerable better that with the storage capacities. The power storage is still not an important political and/or technical issue. Only the operators of high voltage grids are really aware of needs for storage capacities, in order to maintain the grid stability. In year 2013 in a study [11] it was proposed not to build storage capacities at all, but only new grids. For peak loads it is much cheaper to use shortly simple cycle gas power plants (what is correct) and when some base load is missing, to use interconnection with other European states and to import failing power (of course, mainly nuclear!). It was not analyzed that in situation when the energy transition in other European countries goes forward, there will not be such possibilities, except nuclear power, if not required in the country of origin.

In the new report [8] where the energy conditions till 2050 are analyzed and discussed, the energy storage is again not a big issue, only mentioned few times. The term "Carnot battery" was not mentioned at all! In the hype of Hydrogen strategies, it is assumed there, that $H_2$ (produced from electricity surplus) will be stored and used for peak loads in gas turbines readjusted for Hydrogen combustion. At least, that is a clear statement that such kind of storage is required, despite of high costs and low efficiency. However, there is no mention about base load storage and other technologies.

The main problem is that presently there is no economic interest for energy storage and the politics is not ready to establish such incentives. That had to start together with incentives for renewable energy, at least some ten years ago. The increasing number of hours with negative prices on the exchange market indicates clearly the need for that (see Figure 9). In year 2020 it has reached 298 hours and the total traded volume was 9,1 TWh or 4,2% [9]. At the same time, the extremely high prices (e.g. peak of 442,9 €/MWh and daily average of 305,24 €/MWh on October, 7 [7]) indicates that there are hours with very low electricity supply. The curves of residual load show that phenomenon.

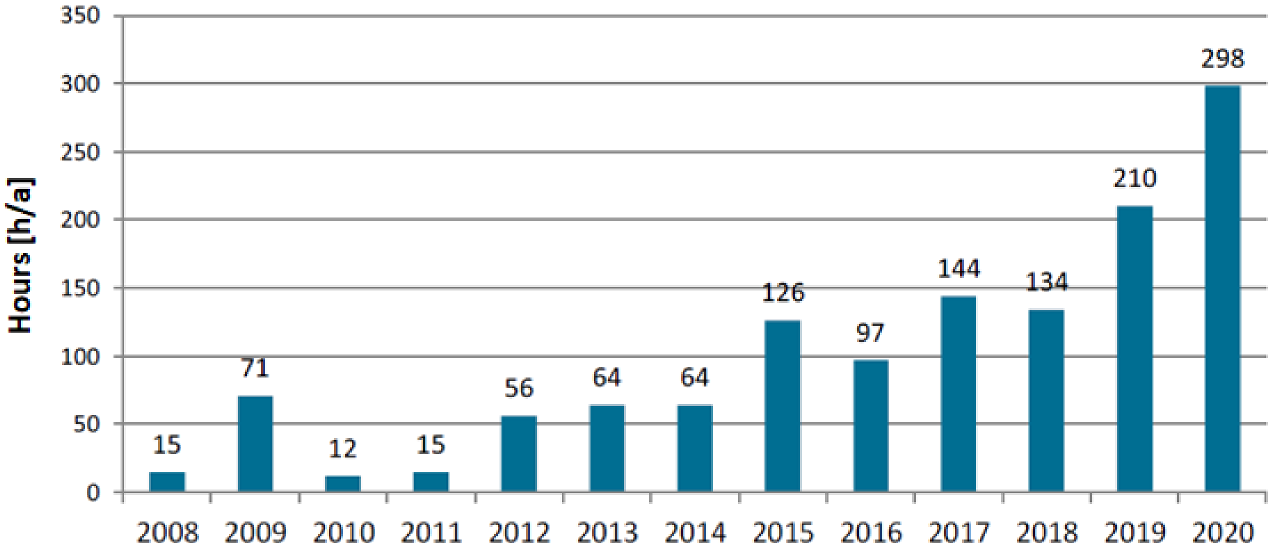


**Figure 9: Yearly increase of hours with negative prices on the market [9]**

## 6. RESIDUAL LOAD

The residual load is difference between the total load and power supplied by RES. As the main RES, wind and solar, are very intermittent, the residual load curve has also very strong fluctuations. Nowadays, that difference is covered mostly by conventional power plants (nuclear and fossil) and with import, when there is a strong ramp in the load curve, which cannot be followed by so rapid load increase of conventional plants.

What will be with residual load in the future, without nuclear and fossil plants? There are consideration concerning the future and some forecasts, as presented in the following Figures 10 and 11 [12].

The first one (Figure 10) shows the historical data from four days (28.-31.07.2021) in July 2021 and the forecasts for the same days in 2040. The foreseen increase of the total load is presented and the required increase in the wind and solar capacities are clearly to be seen in these comparisons. The over-production would be exported (if possible), additional consumers (electro-chargers for mobility, H2-electrolysys, heat pumps…) would be turned on, but still curtailment for some facilities would be inevitable.

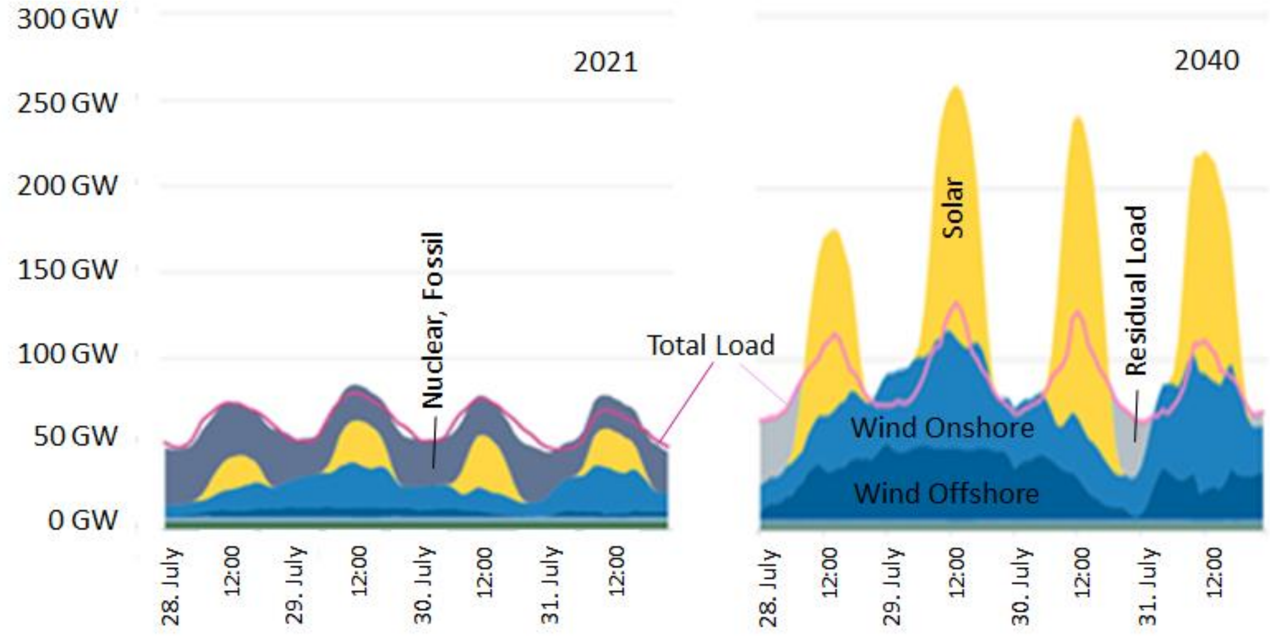


**Figure 10: Historical (2021) and predicted (2040) load data for four days in July (28.-31.07.) [12]**

The challenges for the situations presented in Figure 11 would be considerably higher. The historical data from four days (6.-9.01.2021) in January 2021 and the forecasts for the same days in 2040 are given. The residual load presented there would be covered by import from neighboring countries (probably mostly by nuclear power?), switching-off some flexible loads (not clear which?), energy storage (there are no plans for building some, as it was concluded they are too expensive!), gas power plants powered by green $H_2$ (it will be extremely expensive to run such facilities for days!). Those are really big challenges which have to be cleared in the coming years. Without that, the energy transition in power sector will not be successful.

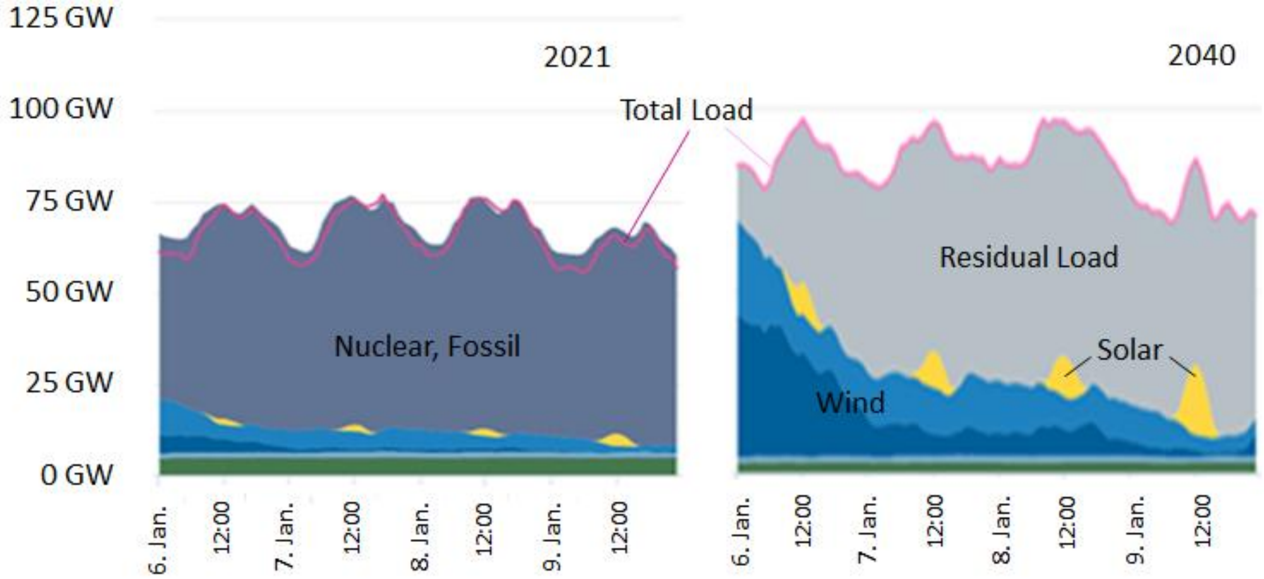


**Figure 11: Historical (2021) and predicted (2040) load data for four days in January (6.-9.01.) [12]**

## 7. CONCLUSIONS

The energy transition is expensive, but necessary. Some politicians like to say that renewable electricity is the cheapest generation possibility, but that is only a populistic statement. The system solutions, which have to lead to the same quality and reliability of the electricity supply, will be more expensive than nowadays. However, it has to be stressed that the usage of fossil fuels is so cheap only due to the lack of costs for the climate changes and for the environment protection at the beginning.

That expected rise of electricity costs is already confirmed through the development in the years from 2000 till now. The pure generation costs from PV and wind have demonstrated considerable reduction. Due to the erection of new transmission grids, and especially due to incorporating the solutions for energy storage and covering the residual load, the total costs will have to rise further on. In case that Hydrogen would be used for covering the residual loads in the future, it would lead to further cost increase (having in mind high cost for its generation and transportation and low transformation efficiency).

The Energy Transition in Germany has led to a fast penetration of RES in power sector. However, despite high investments and very high electricity price, the main goal – reduction of $CO_2$ emissions – has not been achieved to a satisfactory extent. Some other sectors, like space heating and transport, have performed weak in this issue. Germany is among the highest $CO_2$ emitters per capita in Europe, with 8,6 $tCO_2/a$ [13]. Even Poland (8,2 $tCO_2/a$), with its high coal usage, is behind

Germany, as well as other big economies: UK 5,4 t$CO_2$/a; France 4,6 t$CO_2$/a; Italy 5,4 t$CO_2$/a. The best in Europe is Sweden, with almost 60% lower emissions than Germany: 3,5 t$CO_2$/a per capita.

Despite the obvious successes, there is still a long way in front of German society, policy and technology, with considerable challenges, in order to reach the main goals of Energy Transition: net zero GHG emissions till 2045.

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