Name: Dr. Felix Chr. Matthes
Division: Energy & Climate Division
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Öko-Institut e.V.

Subject: Costs of new electricity generation plants

1. Introduction «

The statement that "wind and solar power are now cheaper, like new power plants, new nuclear power plants and new gas-fired power plants"[1] is a correct reference to how new power plants compare, i.e. it is a correct comparison of the total costs arising when new renewable, fossil-fired or nuclear power plants are built today or in the new few years.

Several specific challenges (currently) arise for all cost comparisons of power plants based on renewable energies on the one hand and of fossil-fired or nuclear power plants on the other hand. These are:

- Reference area: The costs of renewable energies differ substantially for regions with different levels of solar and wind availability. In regions with particularly good topographical and meteorological conditions, the financing conditions (due to greater country-specific risks) and the infrastructure requirements (due to less well-developed grids) are more difficult in a number of cases than in regions with worse natural conditions (e.g. solar energy use in parts of Northern Europe).
- Framework conditions: The costs of fossil-fired and nuclear power plants crucially depend, first and foremost, on the operating conditions, i.e. whether a power plant is operated at full capacity for more than 1,000, 2,000, 5,000 or 7,000 hours a year (which has a total of 8,760 hours). In addition, the levels of the generation costs of fossil-fired power plants are essentially determined by the fuel costs, which can differ substantially for different world regions (e.g. very low costs in the USA, average costs in Europe with supply via pipelines from Norway or Russia, and high costs in Asia with supply based mainly on liquefied petroleum gas) as well as over time (energy market environment). Last but not least, the costs of fossil-fired electricity generation also substantially depend on whether their climate-damaging carbon dioxide (CO_2) emissions lead to costs (regulatory environment of carbon pricing). Also in this case there are considerable differences across the world: no carbon pricing in the USA apart from in California and some East Coast states; currently very low carbon prices (below 5 €/t CO_2) in the East Coast states, in Europe (apart from UK) and in India and China; low carbon prices in California (above 10 €/t CO_2); average carbon prices (30 €/t CO_2) currently in the UK and in the EU again in the future or higher carbon prices (above 50 €/t CO_2) in the long-term future.
- Current situation: While a large number of power plant projects are currently being implemented across the world in the case of renewable energies and there is thus an excellent data basis for classifying such project costs, comparatively few fossil-fired and nuclear power plants have been built in recent years and only a limited amount of current data is available, or the data is based on modelling rather than on real and reliable project data.

Against this background, it is necessary to differentiate the generation costs for renewable energies in the classification, especially for the relevant regions. In the case of the comparison power plants based on fossil fuels and nuclear energy, the respective framework conditions have to be taken into account,

« The author would like to thank Vanessa Cook (Öko-Institut) for translating the original German version of this paper.

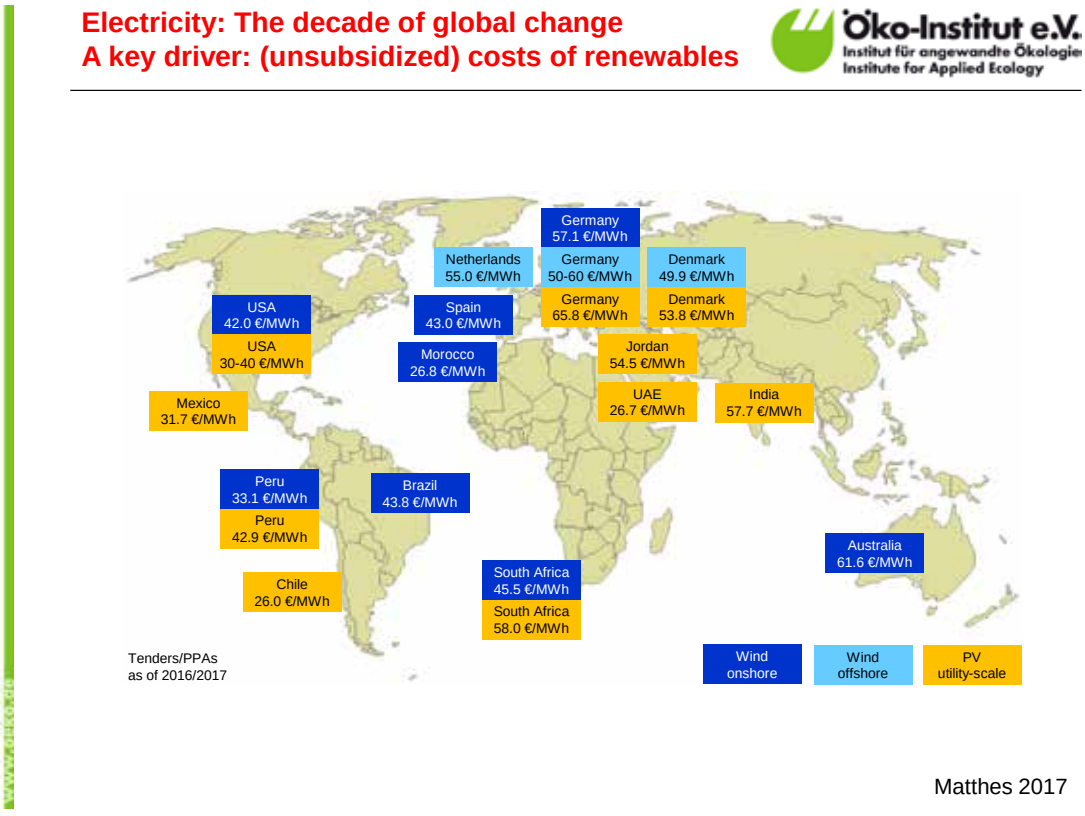
1 This memo was prepared at the request of ZDF as a fact-check for the film "Between wish and reality: How realistic is energy transition?" ["Zwischen Wunsch und Wirklichkeit. Wie realistisch ist die Energiewende?"], which aired on 3 August 2017. The fact check relates to the statement made by Cem Özdemir in the film that "wind and sun are now cheaper, like new power plants, new nuclear power plants and new gas-fired power plants" [„Wind und Sonne mittlerweile günstiger sind, wie neue Kraftwerke, neue Atomkraftwerke und neue Gaskraftwerke"].

which partly differ according to the regions in which they are built. The following data comparisons therefore refer primarily to Germany but also take into account important international trends.

Lastly – although not directly related to the opening statement – it should be taken into account that for an electricity system with very high shares of renewable energies (as will become relevant for Germany after 2030, and then includes a comparatively high share of storage, demand flexibility and greater grid expansion), the additional question arises of how the total costs of all elements (i.e. the "system costs") for an electricity system based on renewables are to be classified compared to a (new) conventional electricity system.

2. Costs of electricity generation based on solar and wind energy

The costs of solar energy, onshore and offshore wind energy have decreased hugely in recent years, especially in the case of photovoltaics (PV) and offshore wind power plants. Onshore wind power plants essentially went through this "learning curve" during the 1990s or around the turn of the millennium; while they are experiencing lower cost reductions at the moment, therefore, they have already reached comparatively low cost levels.



Source: Author's own

The overview shows the costs of solar and wind energy projects that arose in recent auctions and power purchasing agreements, without taking into account supporting financing schemes. [2] It shows that currently

[2] The results of the German tenders for onshore wind energy are published by the German Federal Network Agency at https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien

- onshore wind power plants in Germany enter the market with generation costs of less than 6 Eurocent per kilowatt hour (ct/kWh) or 60 Euro per megawatt hour (60 €/MWh) (in countries with a stronger wind availability, prices of less than 50 €/MWh are currently being offered);
- offshore wind power plants in Northern Europe are generating electricity at full costs of less than 60 €/MWh; and
- large PV systems in northern regions can generate electricity at total costs considerably below 70 €/MWh (in southern regions, these costs are in some cases considerably below 40 €/MWh).

It should also be noted that the process of cost reductions for wind and solar power plants is still far from over and the costs will continue to decrease substantially in the years ahead.[3]

3. Costs of fossil-fired electricity generation

The electricity generation costs for fossil-fired power plants vary, depending above all on their application, the market environment and the framework conditions for carbon pricing. These depend, first of all, on the region in which the fossil-fired power plants are built and then on the situation in the global fuel markets.

It is especially important to take into account these factors when international comparative studies are being used, especially in relation to the USA (largely due to the very low natural gas prices in that country).[4] Comparative studies of the OECD[5] which are somewhat older but are still relatively reliable due to the slightly less pronounced dynamics of cost changes for fossil-fired power plants show the following:

- for natural gas-fired power plants, generation costs (Levelized Costs of Energy – LCOE) in the USA amount to approx. 60€/MWh, in Europe approx. 100 €/MWh, in the industrialized countries of the Far East approx. 120 €/MWh and in China approx. 85 €/MWh;
- for coal-fired power plants, total costs (LCOE) of electricity generation amount to approx. 75 €/MWh in the USA, 70 to 80 €/MWh in Europe, 75 to 100 €/MWh in the industrialized countries of the Far East and approx. 75 €/MWh in newly industrialized countries with a high affinity for coal (China, South Africa).

CO_2 costs of 30 US$ per tonne were used in the above-mentioned comparative studies conducted by the OECD. Without these CO_2 costs, the costs of natural gas-fired power plants would decrease by

/Ausschreibungen/Wind_Onshore/Wind_Onshore_node.html, for offshore wind energy at https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien/Ausschreibungen/Offshore/offshore-node.html and for ground-mounted solar power plants at https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien/Ausschreibungen/Solaranlagen/Ausschr_Solaranlagen_node.html.

[3] This is particularly striking, for example, in the cost estimates that the investment bank Lazard conducts for the US market on an annual basis and which give a good impression of the time distribution and the dynamics of cost reductions (for the most recent analysis see https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf). The annual cost analyses of the US Energy Information Administration (EIA, for the latest analysis, see https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf) provide a similar impression. The International Renewable Energy Agency (IRENA) publishes corresponding cost data and developments with an international coverage, albeit at a lower frequency (see http://costing.irena.org/about-costing.aspx). In terms of renewable energies, the last systematic comparison of the Organization for Economic Co-operation and Development (OECD) is clearly obsolete (for the most recent version, see https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf).

[4] See analyses by Lazard (cf. the latest version at https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf) and by the EIA (cf. the latest version at https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf).

[5] For the most recent available analysis, see https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf.

approx. 10 €/MWh and for coal-fired power plants by approx. 20 €/MWh. However, a comparison of this data with a study conducted by Öko-Institut on current costs and cost projections for Germany[6] shows that, taking into account the most recent investments in fossil-fired power plants, especially in coal-fired ones, these costs are even significantly higher (by approx. 10 €/MWh), above all in the case of Germany.

4. Electricity generation costs of nuclear power plants

Nuclear power plants have the highest uncertainties in terms of the electricity generation costs. Only a few nuclear power plant projects are being pursued at present and there is very little real data available that is comprehensible and transparent, with the result the analyses presented here are based above all on modelling[7]:

- for the USA, costs of 90 to 125 €/MWh are calculated in the more recent analyses; the older OECD studies calculate costs of 70 €/MWh;
- for Europe, more recent analyses have values ranging from 100 to 140 €/MWh; the feed-in tariff agreed for the construction of the new Hinkley Point C power station in the UK also falls within this range (109 €/MWh); the older OECD study calculates values of 70 to 90 €/MWh;
- for countries in the Far East there are currently no cost analyses available; the older OECD analysis calculates a cost range of 35 to 80 €/MWh.

It should be explicitly pointed out that the cost estimates for nuclear power plants do not include full insurance for large accidents and that the costs of radioactive waste management are very difficult to estimate.

5. Overall comparison of costs of electricity systems based on renewables and fossil fuels

Electricity systems with a full supply based on renewable energies require more comprehensive storage, grids or demand flexibility than electricity supply systems based completely on conventional power plants. It is therefore necessary and useful, at least when looking at the long term, to analyze the total system costs of these different kinds of electricity systems. Öko-Institut has recently conducted such an analysis of different designs of electricity systems based on renewable energies or fossil fuels for full supply in Germany[8]. These calculations show that:

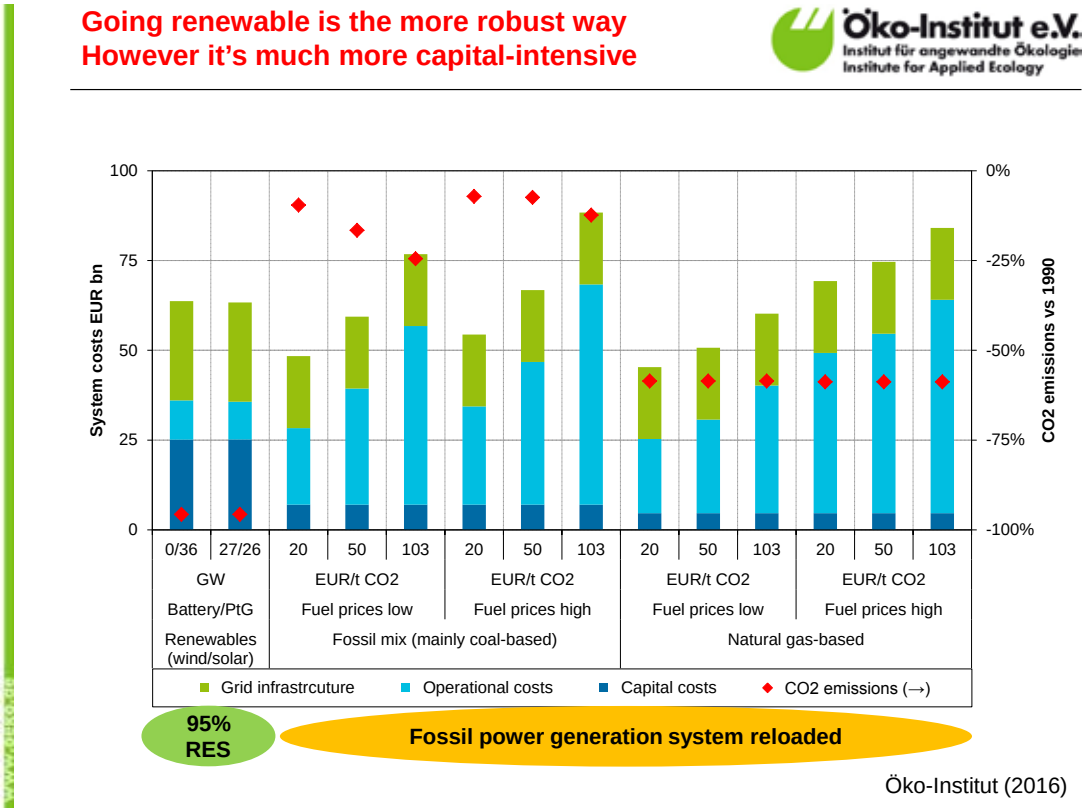
- new fossil-based electricity systems, even those with the state-of-the-art technologies, do not allow national and international climate protection targets to be met; for this, the transformation of the electricity system to one based on renewable energies would be necessary;

[6] For Öko-Institut's system cost comparison, see https://www.agora-energiewende.de/de/themen/-agothem-/Produkt/produkt/353/Erneuerbare+vs.+fossile+Stromsysteme%3A+ein+Kostenvergleich/.

[7] See the analyses by Lazard (https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf), the EIA (https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf), the IEA (https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf) and the corresponding compilation of the UK's *National Audit Office* (NAO, see https://www.nao.org.uk/wp-content/uploads/2016/07/Nuclear-power-in-the-UK.pdf).

[8] For the corresponding study on system costs, see https://www.agora-energiewende.de/de/themen/-agothem-/Produkt/produkt/353/Erneuerbare+vs.+fossile+Stromsysteme%3A+ein+Kostenvergleich/.

- new fossil-based electricity systems only result in lower system costs if it is assumed that the fuel costs remain, in the long term, at the extremely low levels they reached at the beginning of 2016 and that there are no serious attempts to introduce carbon pricing;
- an electricity system based fully on renewable energies is more advantageous in terms of overall costs if the fuel prices develop along the current projections of IEA and EIA and/or CO_2 prices are higher; with CO_2 prices of approx. 100 €/t CO_2[9], electricity systems based on renewables are always the more advantageous option with regard to overall system costs.



Source: Öko-Institut

In view of the considerable uncertainties, especially with regard to the development of the market environment of the global fossil fuel supply, an electricity supply system based entirely on renewable energies is the more cost-effective option in many cases and is, in all cases, the more robust system in terms of costs (KWYK – *Know What You'll Pay*).

6. Conclusions and final remarks

The following conclusions are derived for the direct comparison of electricity generation options from the evaluation of highly diverse data sources and analyses for power plants based on fossil fuels or nuclear energy on the one hand and solar and wind power plants on the other hand:

[9] This figure is roughly the same as that specified by the High-Level Commission on Carbon Prices as an upper range for 2030 to fulfil the terms of the Paris Agreement (see https://www.carbonpricingleadership.org/s/CarbonPricing_Final_May29.pdf). For one to two decades after 2030, at which times the option of full supply based on renewable energies becomes relevant, this CO_2 price level should no longer correspond to the upper range value.

- new onshore and offshore wind power plants and large solar power plants in Germany and Northern Europe have lower or at most the same total costs (50 to 70 €/MWh) than all fossil-fired power plants (70 to 100 €/MWh at current CO_2 prices; and correspondingly more at higher CO_2 prices);
- new solar and wind power plants in regions with a more favourable wind and solar energy availability have lower total costs, at approx. 40 €/MWh, than any form of fossil-fuel-based electricity generation;
- new solar and wind power plants at correspondingly cheaper locations have lower total costs, at 30 to 40 €/MWh, than natural gas and coal-fired power plants (50 to 55 €/MWh without CO_2 costs and 60 to 75 €/MWh with higher CO_2 prices), with the result that the assumption of significantly lower natural gas prices in the USA results in, as a maximum, similar price levels as those for solar or wind power plants;
- even if a data basis were available for industrialized countries of the Far East that is comparable to the one for Europe or the USA, it can be assumed that solar and wind power plants are likely to have lower or, at most, similar total costs since fossil-fired power plants tend to be more cost-intensive;
- new solar and wind power plants also have – assessed on a weaker data basis overall – lower or, at most, similar total costs[10] at 30 to 60 €/MWh in developing and newly industrialized countries compared to coal- or natural gas-fired power plants; and
- new solar and wind power plants lead to significantly lower costs, at 30 to 70 €/MWh, for almost all world regions than for nuclear power plants (80 to 140 €/MWh); the only exception here – based, however, on older analyses that are very optimistic compared to newer analyses – is Korea and China, for which total costs of 35 €/MWh are calculated, at least at the optimistic end of the range.

New solar and wind power plants are therefore associated with lower full costs than new nuclear power plants or new power plants based on fossil fuels such as coal or gas. This is particularly true and especially pronounced in the case of Germany, Europe and the USA and at least structurally for most other regions of the world. The costs of solar and wind power plants, which are expected to decrease further, and the costs of fossil-fired power plants which are expected to increase (due to CO_2 prices tending to increase) will further buttress the cost advantages of power plants based on renewable energies worldwide. Thus, their significant cost advantages compared to nuclear power plants with a view to Europe and the USA is also expected to apply in world regions for which such a cost advantage cannot yet be reliably demonstrated based on currently available data.

Even if other costs of an electricity system based on renewable energies (power grids, storage, demand flexibility) are taken into account, the comparison of system costs based on current data and knowledge show advantages for a renewable electricity system if a moderate increase in fossil fuel prices and/or an average CO_2 price (or a climate protection policy effective in the long term) is assumed.

How, then, can the cost advantages of climate-friendly renewable energies be classified with a view to the currently relatively high surcharge for the financing of renewable energies via the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG)? The following should be taken into account in this context:

[10] For India it has been reported that new solar power plants now have lower costs than coal-fired power plants (see https://www.bloomberg.com/news/articles/2017-06-01/cheaper-solar-in-india-prompts-rethink-for-more-coal-projects).

- The EEG surcharge does not finance the costs of renewable energies but rather the difference between these costs and the price on the wholesale electricity market. If the wholesale electricity price drops due to low fuel or CO_2 prices, the EEG surcharge increases, even if the costs of renewable energies do not increase. If the wholesale electricity price increases, the EEG surcharge decreases even if the costs of renewable energies remain unchanged.
- The EEG balances the difference between the revenues from the sale of electricity on the wholesale market and the total costs so as to cover the full costs. Such a mechanism does not exist for conventional power plants, with the result that currently only conventional power plants earn their remaining costs (and sometimes not even these) if the investment costs have already been recouped. Investors who have built new (mostly coal-fired) power plants in recent years had to write off a large portion of these investment costs since they would not be able to recoup them. For this reason European electricity suppliers have announced that they will no longer invest in coal-fired power plants. In order to secure the (very expensive) financing of the new British nuclear power plant Hinkley Point C, a mechanism comparable to the EEG – “Contracts for Difference” – had to be created. For new investments in conventional power plants, a mechanism that closes the remaining refinancing gap would have to be created sooner or later so that the full costs are covered if the wholesale electricity prices remain at a low level. The EEG surcharge is thus in no way a suitable indicator for the costs or the cost comparison of renewable energies.
- The costs of renewable power plants that arose in the past, i.e. before the huge cost reductions of recent years, are financed substantially via the EEG. However, this portion of the financing has contributed significantly to bringing about the huge cost reductions and was therefore necessary (it should be noted that, in addition to Germany, further significant contributions to the financing of the “learning curve” have been made by China and Spain in the case of solar power and the Netherlands, Denmark and the USA in the case of wind power). If all plants based on renewable energies financed by the EEG were financed based on the current costs of new power plant, the EEG surcharge would be only about half its current value of 6.88 ct/kWh. The remaining half amounts, therefore, to an advance investment that enables the further expansion of renewable energies with considerable cost advantages – in Germany, but also and especially worldwide. These so-called “early innovation investments” were predominantly profitable and led to considerable cost reductions for solar energy (approx. 50% of Germany’s early innovation investments) and wind power (approx. 25% of Germany’s early innovation investments). It was only not possible to achieve significant cost reductions in the case of bioenergy (approx. 25% of the early innovation investments).
- The costs of the electricity-intensive consumers of German industry and the operators of electricity generation plants for own consumption are limited by the EEG since the other electricity consumers pay part of the contribution attributable to these consumers for the financing of renewable energies. This reallocation, which is justified in part and motivated by industry policy considerations, accounts for approx. 30% of the current EEG surcharge.

If these special factors are taken into account, the refinancing gap for new power plants based on renewable energies arises, by implication, for today’s electricity market environment; this gap is likely to amount to about 2.5 ct/kWh. This value and the fact that a larger refinancing gap would likely need to be closed for new conventional power plants in the vast majority of cases explain why solar and wind power plants are highly attractive options for the future electricity system, not only from the perspective of climate protection but also in terms of their total costs. This is the case not only for Germany but also in most, if not already all, countries around the world.