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# Unexpected Rapid Fall of Wind and Solar Energy Prices: Background, Effects and Perspectives

Renewable energies (RE) are playing an increasingly important role in the energy system: their share of global primary energy consumption was 9 percent in 2016, having risen 4 percent per year since 2000 and thus twice as fast as primary energy demand (IEA 2017). As early as 2015, 156 gigawatts (GW) of capacity had been installed worldwide in all renewable energy sectors. At around 44 percent, China had by far the largest share in the expansion of renewable energies (see Figure 1, upper diagram). The United States and Japan accounted for a further 10 percent and 7 percent, respectively, followed by Germany and India (each just under 5 percent). The worldwide installed wind and solar capacity alone increased by 126 GW in 2016, which was in line with newly installed capacities for fossil fuels.

The speed and scale of this growth by far exceeded expectations from scenarios and forecasts. In addition, in 2016 and 2017, falling prices for renewables made headlines. For the first time, auctions were carried out in many countries to set subsidy amounts. The successful bids were well below the previous feed-in tariffs and continued to decline from auction to auction – in some cases up to 0 cent/MWh. In the following, the background of these developments is examined in more detail and their significance for future developments of renewable energies expansion is outlined.

## PREVIOUS MISJUDGEMENTS OF RENEWABLES EXPANSION

Previous assessments stand in strong contrast to the observed development, especially for photovoltaics (PV). Conventional models, such as those used for future scenarios of the International Energy Agency (in the World Energy Outlook), the WBGU or Greenpeace, assumed that PV would account for 5–17 percent of electricity supply by 2050. In fact, PV has had the highest growth rate and steepest learning curve of all renewable energy technologies. A recent article in *Nature Energy* (see Creutzig *et al.* 2017) illustrates the previous underestimations: all scenarios examined were below the actual development of installed capacity. While updated estimations assumed realised capacity as a new starting point, they still underestimated growth. The reasons stated in the article are above all promotion policies, steep technological learning effects, and cost increases of technologies competing with PV:

- Due to political preferences, technology-specific subsidies (e.g. feed-in tariffs for PV) were introduced in many countries. As a result, PV established itself as a low-risk and long-term investment and the PV market grew strongly. In Germany, for example, this led to private capital inflows from home-owners and small interest groups. However, such technology-specific promotion models and preferences of small market participants are not shown in the forecasting models.
- The percentage price decrease for modules per doubling of installed capacity – the learning rate – is on average 22.5 percent for PV, which is significantly higher than the average learning rate for other technologies. This increases the potential for underestimating expansion, since larger installed capacities can quickly lead to lower costs and thus further accelerate expansion.
- In the models, the assumptions about cost, potential and acceptance of alternative $CO_2$ mitigation technologies were overly optimistic. An example of this is the assumptions on carbon capture and storage technologies. From the perspective of the entire energy system, these assumptions implied a too pessimistic outlook for PV.

## RESULTS OF RE AUCTIONS: SURPRISES IN COSTS

In recent years, more and more RE subsidies have been awarded based on auctions, i.e. the remunerations for operators of new RE systems are no longer based on fixed feed-in tariffs. Instead, countries set a certain amount of capacity to be built, and the remuneration paid per megawatt hour (MWh) of electricity generated depends on the bids in the auction. The auctions revealed that the actual cost reduction potentials for both solar and wind energy were significantly higher than often expected.

It is important to emphasise here that the auction bids must cover all costs of installation and operation of the equipment: while the learning rates mentioned above are usually based on module prices – i.e. the pure material costs for the technology – the auction prices also include the costs for on-site installation and maintenance, as well as frequently for land use and grid connection. This second cost block benefits less

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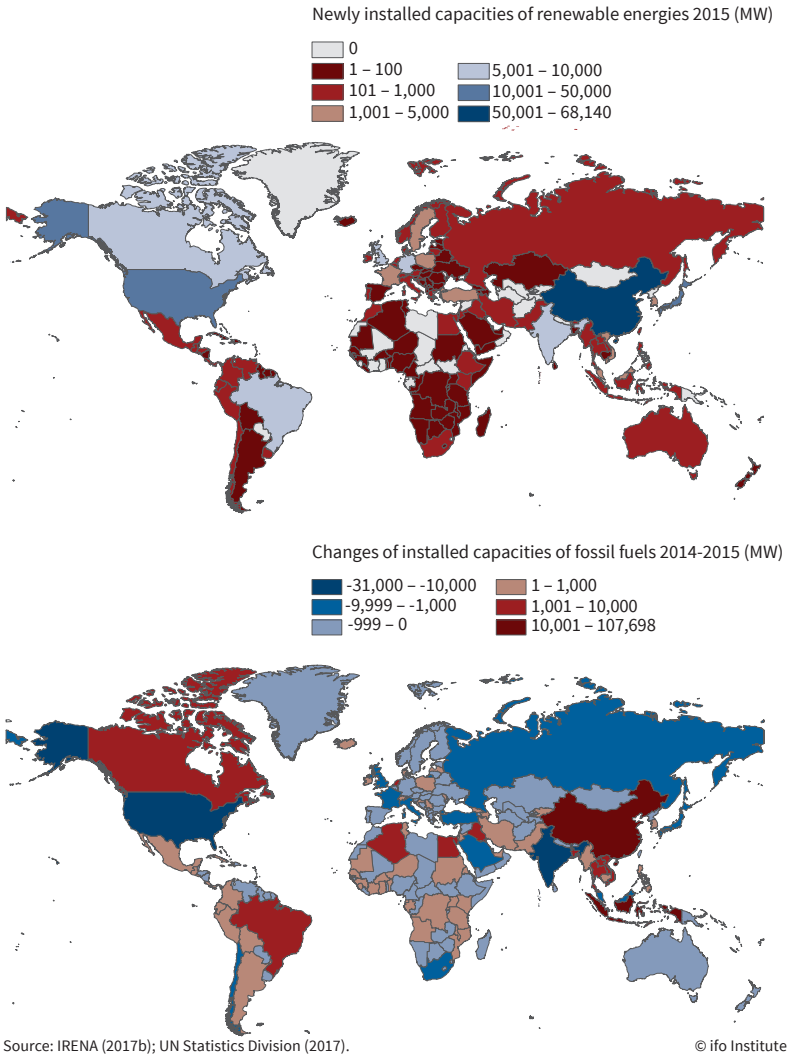
Figure 1
**Development of Renewable Energies and Fossil Fuels**




Source: IRENA (2017b); UN Statistics Division (2017). © ifo Institute

from technology development and thus accounts for an increasing share of total costs due to falling module prices. It is even more remarkable that the total cost of renewables also shows such a decline.

In Germany, subsidies for PV and wind energy+y projects with a capacity exceeding 750 kW were converted to an auction-based system in the context of the Renewable Energy Law (*Erneuerbare-Energien-Gesetz* EEG) 2017. The lowest bidders are awarded the contract for their wind power or PV system until the advertised capacity is exhausted. Since the subsidies of renewable energy are transferred from the state to the consumers *via* a fee on the electricity price, consumers benefit from lower subsidies *via* the electricity price.

Already at the first wind power auction in May 2017, the subsidies could be reduced from formerly up to €90/MWh to less than €50/MWh. At the second auction in October, the bids were even lower and averaged €42.8/MWh (BMWi 2017). Pilot auctions for photovoltaics have been carried out since 2015. It can clearly be seen in Figure 2 how the price fell from auction to auction and is currently lower than €50/MWh.

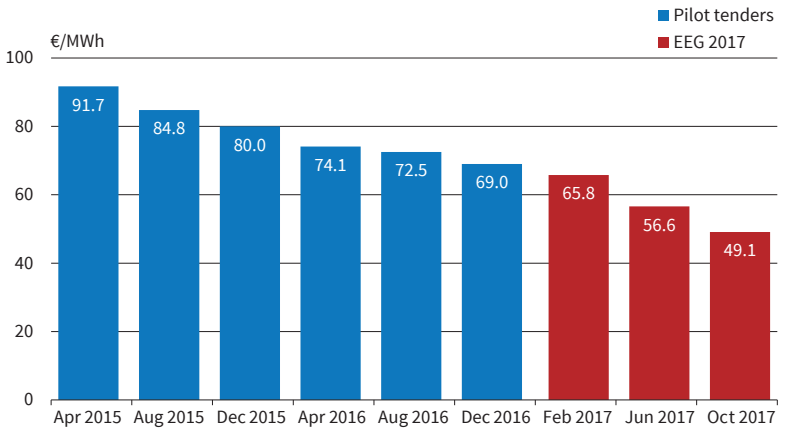
## REASONS FOR THE PRICE DECLINE

Some globally relevant factors have contributed to the collapse of the auction prices: initially, the components for solar and wind plants became increasingly cheaper. From the last quarter of 2015, average solar module prices fell by around 29 percent within one year. But even in the wind sector, the costs per MWh have fallen sharply due to ever larger turbines and efficiency gains (REN21 2017). These cost reductions can be attributed, among other things, to the above-mentioned high expansion rates, especially in developing countries, and the associated learning effects. Added to this is the historically low level of interest rates, inducing institutional investors to increasingly look for new investment opportunities – while they are also attracted by the guaranteed subsidy payments. Another factor is the increasing competition between the project developers and the fact that among them are now some state-supported companies that have other advantages in project financing (such as the Italian energy group Enel or the state-owned company Masdar from Abu Dhabi, lowest bidder at the 2017 auction in Saudi Arabia).

In addition, the invitations to tender and the announcement of the price bids generated a great deal of publicity. Market observers and participants were able to use the results to reach a more accurate estimate of prices realisable in the future – one possible reason why auction prices continued to fall from auction to auction: solar PV auctions in Mexico for €40.76/MWh in March 2016 were followed by bids for 34.17 €/MWh in August 2016 in Chile and 39.65 €/MWh in March 2017 in Dubai. Finally, the auction in Saudi Arabia, where a bid for 16.82 €/MWh won the auction, caused a sensation. However, the results in individual countries are only comparable to a limited extent. As is well known, the countries differ in their natural conditions, so of course Chile or Dubai have a very different solar radiation than e.g. Germany. Apart from that, the results are also

Figure 2

**Development of Auction Prices for Tenders for Photovoltaic Ground-mounted Systems in Germany**




Source : BMWi (2017). © ifo Institute

heavily dependent on the design of the auctions and the legal framework.

## SPECIAL CASE OFFSHORE WIND?

The offshore wind industry occupies a special position among renewable energies. For years, offshore wind was considered a more difficult and expensive technology than onshore wind; in the German EEG, the average subsidy for installations commissioned in 2016 was around €100/MWh. But in the case of offshore wind, the introduction of auctions has led to a radical change in thinking. After results of €72.2/MWh and €49.9/MWh had already been achieved in auctions in the Netherlands and Denmark in 2016, observers predicted values of between €60/MWh and €90/MWh for the first German offshore auction in March 2017. In fact, however, two candidates (the German EnBW and the Danish DONG Energy) submitted zero-bids: they were prepared to forego state subsidies altogether and, in fact, applied only for installation and operating licenses. Their revenues will come solely from the marketing of electricity on the stock market.

The zero bids mark a *caesura*. Not only has offshore wind overtaken the two 'classic' renewable technologies, onshore wind and solar, and shown that renewables can get by without subsidies; in addition, the auction results signalled that a subsidy-free expansion of offshore wind could also be possible at other locations. The Netherlands responded to the German auction results by changing their next call for tenders in December 2017: they simply set a maximum bid of 'zero euro' for the development of the section 'Hollandse Kust Zuid' and received applications from Statoil, Innogy and Vattenfall. In March 2018, Vattenfall was announced as the winner (Reuters 2018).

In the offshore sector, too, several internationally relevant factors have contributed to price erosion. Offshore technology is becoming cheaper and more efficient. As the German '0-euro projects' of the 2017 auction need to be completed in the years 2024 and 2025 respectively, the project developers can also include future technology improvements in their calculations. In addition, as everywhere, the low interest rate is noticeable. Nevertheless, the situation for offshore projects differs structurally from the onshore and solar sectors. Offshore wind power plants are more similar in size and investment volume to traditional large power plants; the development alone can cost between 10 and 30 million euros. As a result, large corporations are particularly active in this field. They are capable of projects of this size, and they had problems with the small-scale nature of decentralised renewables anyway. Since the technical risk has diminished over the last five years, the size of the projects and their operators also make the offshore facilities attractive for institutional investors such as insurance companies or pension funds, which tend to stay out of smaller projects due to the high transaction costs. While the decentralised expansion of wind and solar energy has led to a greater role for small investors in the energy sector, especially in Germany, the traditional large investors are dominant in the offshore sector.

## REALISATION RATES

When evaluating the recent auction results for PV, onshore and offshore wind, the biggest question currently concerns the realisation of the projects that were offered. When the record bids were published, many observers expressed doubts as to whether the project developers could meet their implementation obligations at these prices. Since most of the auctions are not so long ago, data on realisation rates are only available for Germany, France, Brazil and South Africa.

In Germany, 90 percent of the third round of tenders for PV systems has already been connected to the grid. 40 applications for eligibility were received in time. For this entitlement, the facilities must be in operation and be online on time, otherwise they lose their entitlement to the subsidy and they will receive a fine (Bundesnetzagentur 2018). For tenders for onshore wind farms, special regulations exist in Germany. These relate to the so-called 'citizens' energy companies' (*Bürgerenergiegesellschaften*), which may apply without a construction and operating license and only need to obtain a license in case their bid is successful. As a result, the implementation deadline for these citizens' energy companies is extended to 4.5 years,

and the planned grid connection will be postponed by ca. 2 years. The reason for this special arrangement is the intention of the legislator to allow citizens from the affected areas to participate in the market. The exemption for citizens' energy companies applied to around 92 percent of the successful bids in the first round of onshore wind tenders (Enervis 2017).

In Brazil, the timely implementation rate in 2016 was 14 percent and the late realisation was 89 percent. The reasons for delay relate e.g. to network expansion and compliance with environmental compatibility requirements. Adjusting the auction design could control these factors, but project management and bankruptcy also affect timely implementation. In France, 44 percent of the projects were realised. It was not possible to investigate which factors influenced the timely completion because the companies that were successful in the auctions were not named (Bayer *et al.* 2016). South Africa, on the other hand, realised all projects on time.

To increase implementation quotas, countries resort to various measures in addition to penalties. In Brazil, participants in the auctions are required to provide extensive supporting documents, such as a positive environmental impact assessment, grid access approval or wind reports from independent authorities. In France, PV systems in buildings only require a completed $CO_2$ assessment form. In Brazil, Italy and Denmark additional guarantees must be submitted as security (Agora Energiewende 2014).

## OUTLOOK

The ever-decreasing prices for renewable energy projects and the rapid expansion in recent years will lead to a re-evaluation of the potential of wind and solar energy in the medium term, even if the actual realisation rates remain to be seen. Obviously, there are a variety of different factors that have led to ever new record results. Some are country-specific and especially due to particular aspects of the auction design: in some cases, the design of auctions reflects more policy goals than just the achievement of additional renewable energy generation at the lowest possible cost, as the German example of preferred citizens' energy companies shows. Other factors are important worldwide, such as current low interest rates and institutional investors search for safe returns, as well as underestimated learning rates in wind and solar technology. A weakening of these factors is not in sight for the next few years, but could change the outlook over the long term.

For a final evaluation, some questions remain. For example, the record results for solar energy in the Middle East, as well as those for offshore wind energy in Europe, seem to be driven by bidding competition in which losses or very low profits are accepted to secure market share. It is difficult to say if such strategies will be pursued in the future. Moreover, the worldwide success of renewable energies does not change the fact that the expansion of fossil fuels continues in some countries. In addition to regenerative energies, about 108 GW of conventional power plants (excluding nuclear energy) were built in China in 2015 (see Figure 1, lower diagram). Something similar was observed – albeit to a lesser extent – for Canada and Brazil (just under 5 GW or almost 2 GW of new fossil capacity). Significant expansion rates were also recorded in other emerging and developing countries in 2015. In contrast, there is a significant decline in these power plant capacities in countries such as India, the United States and Russia. After deducting the dismantling of fossil power plants in the period 2014/2015, the installed net capacity worldwide amounted to 81 GW, well over half the increase in renewables.

Nevertheless, fossil power plants often have lifetimes of up to 50 years, so they are expected to emit $CO_2$ for a very long time. In addition, Creutzig *et al.* (2017) show that the current tendency in models to underestimate wind and solar energy goes hand in hand with the overestimation of the potential of biomass. The increased and faster than expected expansion of wind and solar capacity cannot translate directly into reduced emissions; this requires further efforts in the electricity sector as well as in other sectors such as transport and heat. It is also evident that the increasing proportions of intermittent renewables necessitate an adjustment of the energy system. In particular, storage technologies will be crucial to their system integration.

## REFERENCES


Agora Energiewende (2014), *Ausschreibungen für Erneuerbare Energien. Welche Fragen sind zu prüfen?*, https://www.agora-energiewende.de/fileadmin/downloads/publikationen/Hintergrund/Ausschreibungsmodelle/Agora_Ausschreibungen_fuer_Erneuerbare_Energien_web.pdf.

Bayer, B., D. Schäuble and M. Ferrari (2016), *Internationale Erfahrungen mit Ausschreibungen für erneuerbare Energien*, IASS Working Paper.

Bundesministerium für Wirtschaft und Energie (2017), *Dossier – Erneuerbare Energien*, https://www.bmwi.de/Redaktion/DE/Dossier/erneuerbare-energien.html.

Bundesnetzagentur (2018), *Realisierungsrate der dritten Ausschreibungsrunde für Photovoltaik-Freiflächenanlagen*, https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2018/20180109_PVFreiflaechenanlagen.html.

Clover, I. (2016), "Danish Solar Auction Delivers European Low Cost of US 1.81 Cents/KWh", *PV-magazine*, https://www.pv-magazine.com/2016/12/28/danish-solar-auction-delivers-european-low-cost-of-us-1-81-centskwh/.

Creutzig, F., P. Agoston, J.C. Goldschmidt, G. Luderer, G. Nemet and R.C. Pietzcker (2017), "The Underestimated Potential of Solar Energy to Mitigate Climate Change", *Nature Energy* 2, https//www.nature.com/articles/nenerrgy2017140.epdf.

Danish Energy Agency (2016), *Pilot Tender of Price Premium for Electricity from Solar PV*, https://ens.dk/en/our-services/current-tenders/pilot-tender-price-premium-electricity-solar-pv.

Dipaola, A. (2017), "Saudi Arabia Gets Cheapest Bids for Solar Power in Auction", *Bloomberg Markets*, https://www.bloomberg.com/news/articles/2017-10-03/saudi-arabia-gets-cheapest-ever-bids-for-solar-power-in-auction.

Enervis (2017), *Wind-Auktion: Unsicherheit beim Zubau – Politik reagiert kurzfristig*, https://enervis.de/wp-content/uploads/2017/12/enerviews_2017_07_Auktion_1_Wind.pdf.

Erneuerbare Energien (2018), *Realisierungsquote bleibt hoch*, https://www.erneuerbareenergien.de/realisierungsquote-bleibt-hoch/150/406/106089/.

ET Bureau (2017), "HC Puts Gujarat Wind Power Auction on Hold", *Economic Times*, https://economictimes.indiatimes.com/industry/energy/power/hc-puts-gujarat-wind-power-auction-on-hold/articleshow/61211612.cms.

Global Climatescope (2016), *Download Climatescope Model*, http://global-climatescope.org/en/download/data/climatescope-full-2016.csv.

Huebler, D., D. Radov and L. Wieshammer (2017), *Hart am Wind: Einsichten aus der Optionsbewertung zu den Ergebnissen der ersten deutschen Offshore-Wind-Ausschreibung und ihren Auswirkungen*, NERA Economic Consulting, http://www.nera.com/content/dam/nera/publications/2017/PUB_Offshore_EMI_German_A4_0417.pdf.

IEA (2016), *World Energy Outlook 2016*, OECD/IEA, http://www.oecd-ilibrary.org/docserver/download/6116221e.pdf?expires=1518085830&id=id&accname=ocid56012597&checksum=A69AEFF8A95CF71671566A58F3FA9905.

IEA (2017), *World Energy Outlook 2017*, OECD/IEA, http://www.oecd-ilibrary.org/docserver/download/6117271e.pdf?expires=1518085868&id=id&accname=ocid56012597&checksum=66019896DA09997C6E7BB4A059F0D5B2.

IRENA (2017a), *Renewable Energy Statistics 2017*, http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jul/IRENA_Renewable_Energy_Statistics_2017.pdf.

IRENA (2017b), *REthinking Energy 2017: Accelerating the Global Energy Transformation*, http://www.irena.org/documentdownloads/publications/irena_rethinking_energy_2017.pdf.

Morning Consult (2016), *Coal Plants Are Shutting Down, with or without Clean Power Plan*, https://morningconsult.com/2016/05/03/coal-plants-shutting-without-clean-power-plan/.

Newbery, D. (2016), *Pricing Electricity and Supporting Renewables in Heavily Energy Subsidized Economies*, EPRG Working Paper 1618.

PV Insights (2018), *Index*, http://pvinsights.com/index.php.

REN21 (2017), *Renewables 2017 Global Status Report*, http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf.

Reuters (2018), *Sweden's Vattenfall Wins Dutch 700MW Offshore Wind Tender*, https://uk.reuters.com/article/uk-netherlands-windpower/swedens-vattenfall-wins-dutch-700-mw-offshore-wind-tender-idUKKBN1GV2BP.

UN Statistics Division (2017), *Electricity Profiles*, https://unstats.un.org/unsd/energy/Eprofiles/default.htm.