Negative Electricity Prices: Causes and Effects

An analysis of recent developments and
a proposal for a flexibility law

ANALYSIS

Agora Energiewende

Energy Brainpool
Analysis-Consultancy-Training

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IMPRINT

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An analysis of recent developments and a suggestion for a flexibility law

CREATED ON BEHALF OF

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Preface

Dear reader,

In the past year, electricity prices on the electricity market have repeatedly dipped into the negatives. This means that for these time periods, electricity producers have paid money for consumers to purchase their electricity. This occurred for a total of exactly 97 hours between December 2012 and December 2013, with an average negative price of negative 41.00 euros per megawatt hour. In the first months of 2014, negative prices once again occurred numerous times, especially during daylight hours.

The accepted consensus is that negative electricity prices are a result of a surplus of electricity from renewable sources. Looking back at 2013, however, it is clear that the percentage of electricity generation from renewables never exceeded the 65 per cent limit – therefore, renewable energies never produced more power than was used at any given time.

This raises the question of which other factors could explain the negative prices. We therefore tasked Energy Brainpool with investigating this question further. The answers they found are currently in your hands. A number of interesting and surprising results came to light as a result of their work. In short: the negative prices are caused by the lack of flexibility of the electricity system. Because this lack of flexibility burdens consumers in the form of an increased renewables surcharge, regulators must also act in order to insist on more flexibility.

We hope this pamphlet is informative and stimulating.

Sincerely, Patrick Graichen

Executive Director of Agora Energiewende

Results at a glance

1. **Negative electricity prices are not necessarily a bad thing, but they do greatly burden the renewables surcharge.** Even during hours when electricity prices are negative, electricity from renewable sources is still sold on the spot market. Between December 2012 and December 2013, this resulted in a burden of nearly 90 million euros on the renewables surcharge account

2. **Negative electricity prices are a result of the lack of flexibility of the conventional generation system.** During periods of increased wind and solar energy production, nuclear power plants, lignite power plants and combined heat and power (CHP) plants only partially reduced their output. This resulted in excess electricity, despite the fact that renewable sources never produced more than 65 per cent of the available electricity, even in peak hours.

3. **Without a significant increase in the flexibility of power plants and large consumers, the hours with negative electricity prices will increase drastically.** If 20 to 25 GW conventional power plants continue to produce electricity around the clock, the number of hours when electricity prices are negative will grow from 64 hours in 2013 to over 1,000 hours by 2022.

4. **A flexibility law would quickly remove the current obstacles to flexibility.** Various regulations regarding system services as well as a number of energy laws restrict the flexibility of both conventional generation systems and the electricity demand side.

Main results and action proposals

Main results and action proposals for decision makers from Agora Energiewende

1. Negative electricity prices are not necessarily a bad thing, but they do greatly burden the renewables surcharge.

Negative prices on the electricity market are the logical continuation of the market-based principle that price is determined by supply and demand. Negative electricity prices increase the incentives for power plant operators and electricity consumers to increase the flexibility of their plants and are therefore essentially a good control signal. However, negative prices on the spot market place a major strain on the renewables surcharge. Even during hours when electricity prices are negative, electricity from renewable sources is still sold on the spot market. Between December 2012 and December 2013, this resulted in a burden of nearly 90 million euros on the renewables surcharge account. If the amount of renewable energy on the market increases, this amount could grow significantly.

2. Negative electricity prices are not caused by an excess of renewable energies, but rather are a result of the lack of flexibility of nuclear power plants, lignite power plants and CHP plants.

Analysis of the 97 hours of negative electricity prices between December 2012 and December 2013 shows that in these hours, the percentage of electricity generation that came from renewables was never more than 65 per cent, even during periods of strong winds or increased solar energy production.
At these times, as you could expect from an economic standpoint, the electricity production from gas and coal power plants was reduced to practically zero. Nuclear power plants, however, only reduced their output by 35 per cent during periods with negative prices and lignite plants reduced their output by 50 to 60 per cent. Furthermore, heat-controlled CHP plants also continued producing electricity. As a result, 20 to 25 GW conventional power plants were always connected to the grid. The reasons for this are the economic aspects of the cost of starting up and shutting down these power plants, the current regulations for provision of system services, and the EPEX bidding design.

Because a large percentage of the energy produced by wind turbines is sold directly, their electricity production is shut in the negative price range starting around negative 65 euros/MWh. In periods with negative prices, there is an excess power situation because of the inflexible 20 to 25 GW conventional power plants – with the result that renewable electricity, which would be available at a marginal cost of zero, is limited.

3. Without a significant increase in the flexibility of conventional power plants and electricity demand, the hours with negative electricity prices will increase drastically.

Energy Brainpool has determined that in 2022, the number of hours in which renewable energies cover 65 per cent or more of the total load will increase to around 1,200. 65 per cent is approximately the percentage that renewable energies had in the hours when electricity prices were negative in 2013. That means that if 20 to 25 GW conventional power plants continue to be inflexible, meaning they produce electricity around the clock, and the demand for electricity does not react flexibly either, the number of hours when electricity prices are negative will grow from around 64 hours in 2013 to over 1,000 hours by 2022. As a result, on the one hand, large amounts of renewable energies that are currently sold directly would be shut down. On the other hand, the renewables surcharge would increase significantly because the transmission system operators would encounter negative sales revenue when selling electricity from renewable energy sources during these hours. Additionally, the costs of the market premium would increase for renewable energy plants that sell electricity directly. These results are inefficient from an economic standpoint.

4. The lack of flexibility is also caused by existing regulations. A flexibility law would quickly remove the current obstacles to flexibility.

There are a number of regulations that currently limit the amount of flexibility of conventional generation systems as well as the electricity demand side, which means they are one cause of negative electricity prices. These regulations should be changed in an amending act which will be written up soon or by revision of the relevant regulations for system services so that market players can develop their full potential for flexibility.

A flexibility law of this nature should include:

A. Modernising competition in the system services sector
The operating reserve market results in a high percentage of conventional must-run output because power plants that are contractually obligated to provide reserve power have to run 24 hours a day in order to reduce (negative balancing energy) or increase (positive balancing energy) their electricity generation on short notice as needed. This is why we desperately need to reform this system, for example through:

- → Reinforcing the balancing energy price system: The majority of balancing managers does not yet optimise their balancing by trading on an intraday basis because the cost of balancing energy is relatively low when there are balancing deviations. This results in an increased demand for operating reserve energy, which increases the must-run capacities of conventional power plants. Increasing the costs for the required balancing energy, for example by including the costs for the reserve capacity or by introducing administrative penalties, would strengthen short-term intraday trade and lower the demand for operating reserve energy.
- → Reducing tendering and provision periods for operating reserve energy: Calls for tenders for operating reserve energy are currently issued 5 to 12 days before service provision – and thus too early to use weather forecasts to predict the wind and solar power output levels (and there¬fore the spot market prices) at this time. The must-run output can be reduced if flexible and inflexible power plants are economically optimised by reducing the tendering and provision periods for operating reserve energy so that the tenders can be optimised on the day-ahead spot market.
- → Integrating renewable energies into the operating reserve market: The pre-qualification conditions for participating in the various operating reserve markets must be adjusted to allow renewable energies to participate and act as competitors to fossil fuel power plants. In order for direct selling wind and photovoltaic systems to participate in the operating reserve markets, the tendering and provision periods would also have to be reduced as specified under ii).
- → Procuring must-run-free reactive power: Grid operators should be obligated to procure the reactive power necessary to stabilise the grid so that it is primarily must-run-free. For this purpose, they could take measures such as using reactive power from renewable energies and network operating resources (e.g. power factor correctors or phase shift generators).

B. Making CHP plants more flexible and allowing power-to-heat

- → Promoting thermal storage systems: Equipping CHP plants with thermal storage systems would make the CHP plants' electricity production more flexible. They can then fill the thermal storage system when the market prices for electricity are high – and provide heat customers with heat from the storage system in periods when the electricity prices are low, without having to produce electricity.
- → Synchronising CHP internal consumption with the market price for electricity: Many operators of industrial CHP systems cannot make use of any of the advantages of situations with negative electricity prices because the exemption from charges and fees for internal consumption distort this signal. The exemptions should therefore be adjusted so that these systems can orient their production based on the spot market and can stop production in periods of negative prices and instead procure excess electricity from the market.

- Allowing power-to-heat during periods with negative electricity prices: In periods with negative electricity prices, it also make sense for CHP plants meet their heating requirements using electrode boilers (immersion heaters), which would use additional electricity. This would prevent renewable energy systems in direct sales from being curtailed, i.e. renewable electricity that would otherwise be curtailed is put to good use and the renewables surcharge is reduced for all electricity customers. However, power-to-heat systems would also have to be exempted from the renewables surcharge in periods with negative electricity prices in order for them to be effective.

C. Reforming the renewables surcharge structure and making renewable energy systems more flexible

- A dynamic renewables surcharge: The renewables surcharge severely distorts the market price signals that reach end customers, preventing more flexible behaviour from electricity consumers and those who produce their own electricity. If the renewables surcharge was dynamically linked to the market price for electricity, just the opposite would occur – and flexibility would be rewarded. Because the average renewables surcharge would remain constant, nothing would change for most customers, but flexible electricity consumers could reduce their renewables surcharge burden. In addition, those who produce their own electricity would reduce their own electricity production and draw power from the grid in periods with very low or even negative electricity prices.
- More flexible biomass operation oriented towards electricity: Biomass systems currently produce almost around the clock, and have similar full-load hours to lignite power plants. In future, biomass systems should be operated far more flexibly, i.e. the full-load hours should be reduced and the production times should be adjusted to the market price signals for electricity.

D. Making demand more flexible – allowing load management

- Due to the additional fees, grid charges, the renewables surcharge and electricity taxes that have to be paid, there is little incentive to shift demand (load transfer), even during periods when the market prices are negative.
- Reforming the grid charge structure for large-scale consumers: At the very least, grid charges should not counteract the incentives of the market price signal. In fact, they should reinforce it whenever possible so as to make load management profitable. To this end, the grid charges should not increase for load-profile industrial and commercial customers if these customers increase their demand in periods of low or negative market prices for electricity. In future, reduced grid charges for large-scale consumers should also no longer be based on the condition of consistently drawing from the grid, but rather on their ability to consume electricity flexibly.
- Allowing spot market rates for end customers: In the past, small and medium-scale customers have not had the ability to optimise their consumption based on the spot market price signal. However, the increasing prevalence of smart meters would also allow small and medium-scale end customers to do so. The relevant regulations must be designed to make the mandatory offer of a flexible rate stipulated in the German Energy Industry Act economically feasible, in particular by eliminating the additional costs associated with this type of rate.

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1. Summary

In 2012 and 2013, prices on the electricity market repeatedly dropped to negative figures. In the period from December 2012 to December 2013 alone, there were 97 hours with an average of negative 40.97 euros per megawatt hour (MWh). So far, the record for negative electricity prices occurred on Christmas Eve and Christmas Day in 2012, when a total of 18 hours of negative prices occurred in a period of 32 hours with a minimum of negative 221.99 euros/MWh.

Negative prices on the electricity market are not necessarily a bad thing, but rather the logical continuation of the market-based principle that price is determined by supply and demand. They would even out supply and demand even in excess-supply situations without resorting to pro rata allocations, which are generally difficult for market participants to calculate and a great deal of work to handle.

However, the negative prices occurring at the moment do not indicate excess electricity from renewable energy, but rather a lack of flexibility in the electricity system. Even with strong winds or high solar power production, renewable energies have up to now never accounted for more than 65 per cent of electricity consumption.

A look at the hours with negative *day-ahead* prices on the EEX/*EPEX Spot* shows that, despite the negative prices, conventional power plants produced significant amounts of electricity. This is described on the basis of selected sample days in the period from January 2012 to December 2013. There were also many hours whose prices were positive, but with amounts between zero and ten euros/MWh, putting them below the short-term marginal costs of all nuclear and conventional thermal power plants. This begs the question of why these power plants still produced electricity.

That is also the central question of this study. Note that the database includes some gaps in the range of several GW, which cannot be explained.

The analysis' results and consultations were discussed and compared in the course of a large-scale anonymous survey of participants in the energy industry such as conventional power plant operators, direct sellers of renewable energies, operators of combined heating and power plants, electricity traders, grid operators and scientists at other institutes. The knowledge gained in this process was included in this study.

1.1 Possible Explanations for the Negative Prices in 2012 and 2013

To answer the question of why conventional power plants continued to produce electricity even in periods with negative electricity prices, a closer look was taken at possible explanations, including: the short-term marginal costs of the various power plant technologies, auctioning processes on the *day-ahead* market of the *EPEX Spot*, the necessary capacities for system stability and generation of electricity from heat-driven combined heating and power plants, as well as operative, technical and regulatory obstacles.

Drawing on these possible explanations, the situations were analysed in detail on concrete days with negative electricity prices (section 5), with the following results:

- → Negative prices occur in situations characterised by a large supply of renewable energies coinciding with relative low levels of demand. Periods with low levels of demand are more likely to occur on Sundays or holidays and during the night.
- → Hard coal and natural gas power plants generally have very low production levels in the market situation analysed, which was also to be expected. In this respect, they were generally very flexible. The remaining production using these technologies is probably due to restrictions on the use of combined heating and power in these power plants.

- The German nuclear power plants and lignite power plants respond flexibly to the occurrence of negative prices to a limited extent. However, even in periods with negative prices, the nuclear power plants always produced electricity with at least 65 per cent of their available capacity; for lignite power plants, this value was 40 to 50 per cent. The flexible range of aggregate infeed corresponds roughly with the expected technologically flexible range of these types of power plants before a complete shutdown.

This means that the inflexible behaviour observed on the part of the conventional generation systems and the resulting negative electricity prices can primarily be attributed to the following key factors:

- A lack of technological flexibility and relatively high costs for the starting up and shutting down processes of conventional power plants justify operation at minimum production levels even when the prices are between zero and ten euros/MWh over a period of 24 hours or as low as negative 60 euros/MWh in individual hours from an economic standpoint
- High real power infeeds between 13 and 20 GW[1] for the performance of system services, in particular for the provision of primary operating reserves and provision of reactive power
- Significant restrictions in shutdown orders caused by the auctioning process on the *day-ahead* market[2]
- Heat-driven mode of operation for combined heating and power plants (resulting in inflexible electricity generation)

1 Research Foundation for Electrical Systems and the Electricity Industry (FGH) (2012)

2 The introduction of the North-Western Europe (NWE) Market Coupling on 4 February 2014 brought with it changes in the auctioning process, which eliminated some of these restrictions.

1.2 Further Development in the Negative Price Range

As the share of renewable energies increases, production of electricity from wind and solar power in particular will increase constantly, meaning that fluctuations, and with them the number of hours with high renewable energy levels, will also increase drastically. Based on the fundamental model Power2Sim from Energy Brainpool by the year 2022 – assuming that renewable energies will be expanded based on the plans currently in place – there will be approximately 1,200 hours in which the percentage of power consumed from renewable energies will be 65 per cent and higher, whereas there will only be around 150 hours in which renewable electricity production covers the entire load. If the entire system does not become significantly more flexible, we can expect negative prices to no longer be the exception, as previously, but rather to become the rule.

However, the occurrence of extreme negative prices will become less likely in the immediate future, as indicated by evaluations of the *EPEX* bidding curve. Bids that are limited when negative prices occur create a price buffer to prevent extreme negative prices. This price buffer primarily consists of three price levels:

- Price limitation in exceptional cases in accordance with section 8 of the Equalization Scheme Implementation Ordinance (§ 8 Ausgleichsmechanismus-Ausführungsverordnung) represents a generally-applicable lower price corridor between negative 350 and negative 150 euros/MWh. It is specified for renewable electricity quantities that receive feed-in compensation, meaning that they are accepted, paid for and sold by operators of transmission networks.
- The second level of the price buffer consists of directly-sold renewable electricity quantities in a market premium model and covers a price range of approx. negative 500 to negative 50 euros/MWh with accumulation in the range between approx. negative 150 and negative 50 euros/MWh.

- With a lower proportion, wind energy and PV systems in direct sales without financial support make up the third level in a very slim price range between 0 and just over 0 euros/MWh.

If negative prices occur in future, this price buffer means that, barring extreme situations, these prices will generally fall in a price range between 0 and negative 150 euros/MWh.

In addition to this price buffer, the learning effects of the market agents as a reaction to the previous negative prices are already making an impact. As a result, electricity generation from conventional power plants at Christmas 2013 was already much lower than the level from Christmas 2012.

- Thirdly, the use of the interconnector coupling capacities was optimised with the introduction of the *North-Western Europe (NWE) Price Couplings* for the *day-ahead* markets in north-western Europe on 4 February 2014. As a result, the use of power plants in the countries involved should become more efficient, which will in most cases have a cushioning effect on negative electricity prices. Simultaneously with the introduction of the *NWE Price Couplings*, the lowest price limit in the *day-ahead* auctions was unified and was raised in Germany and Austria from negative 3,000 euros/MWh to negative 500 euros/MWh. This means that prices lower than negative 500 euros/MWh can no longer occur.

1.3 Action Proposals

The question of what causes negative electricity prices is extremely relevant. Hours with negative electricity prices place a considerable strain on the renewables surcharge – after all, electricity from renewable energy sources is also sold on the spot market in the hours with negative prices. On the days observed in the period from December 2012 to December 2013, the renewables surcharge account was burdened with an additional 86.6 million euros as a result of renewable energies being sold at negative prices.

In order to introduce the necessary flexibility in the electricity system and to avoid negative electri-city prices, we propose the following measures for implementation or inspection by regulators or by grid operators:

- Reduction of the *must-run* minimum at conventional power plants that provide system services (in particular operating reserve energy and reactive power), for example by integrating renewable energies into their system services
- An amendment to the combined heating and power plant law (KWKG) for reduction of the CHP-based *must-run* power input
- Expansion of the balancing energy price system in order to increase schedule compliance, as well as an increase in short-term trading

Plant operators should take on the following measures:

- Making conventional energy systems and renewable energy sources that can be controlled (more) flexible when generating electricity
- Provision of system services using renewable energies to reduce the conventional *must-run* minimum
- Elimination of operative obstacles

The following measures should be taken or reviewed by electricity sellers/suppliers:

- Increase in the flexibility on the consumption side and integration of load shifting potentials by electricity distributors
- Optional electricity tariffs with spot pricing for end customers that only allow for short-term forecasting of electricity generation from fluctuating plants.

First and foremost, of course, we should avoid any and all "useless" electricity consumption (energy wasted for example by unused electric arcs, earth leakage, conversion of electricity to heat without using the heat, etc.) when the prices are negative. Rather, the negative prices and price spreads should act as direct incentives to make the electricity system more flexible. This flexibility should go hand-in-hand with the goal of achieving dynamic efficiency.

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