Agorameter Documentation

Version 13

Contact at Agora Energiewende:

Katharina Hartz
katharina.hartz@agora-energiewende.de

Contact at Öko-Institut:

Hauke Hermann
h.hermann@oeko.de

8 September 2023

Content

Introduction

This documentation describes the functionality of the Agorameter tool, including in particular its methodology, calculation techniques, balance sheets and data sources. The Agorameter was developed by Agora Energiewende with the scientific support of Öko-Institut. The source data underlying the presented figures for electricity generation, demand, exports, imports and wholesale prices can be accessed at www.agora-energiewende.de.

The Agorameter provides charts displaying current electricity generation and demand in Germany. This allows visitors to track progress being made in the transition to renewables. The charts, which are accessible to the general public, are updated on an hourly basis (with a time delay of about three to four hours). A key aim of the Agorameter is to display electricity generation from renewables broken down by source (wind, sun, water and biomass). The charts also show generation from conventional power plants, subdivided by type (nuclear energy, lignite, hard coal, natural gas, pumped storage, and others). Furthermore, the Agorameter details domestic electricity demand, commercial electricity imports and exports, the day-ahead exchange price and the greenhouse gas emissions from electricity generation.

All of the charts are based on data from third parties and, in cases where complete data sources are not available, on our own calculations and estimates. The individual metrics are presented according to their current availability. All data are presented for identical points in time, even if individual data groups (e.g. price data) are available earlier than others. The dataset extends back to 1 January 2012. All data sources and calculations are documented below, for increased transparency and understanding. We welcome suggestions on how to improve our dataset and estimation methods.

1   Method

Display

For display periods of up to 30 days, the time resolution of the diagram is one hour. For longer display periods, the temporal resolution is reduced to one day in order to ensure the diagram is displayed rapidly. To this end, hourly values are extrapolated to calculate daily mean values. Data gaps are not closed by interpolation, but treated as blanks, such that mean values are calculated based on a correspondingly reduced number of figures. In general, it takes longer to generate a chart for a given time period when longer time periods are selected.

Gross / Net

Electricity generation can be reported in terms of gross or net generation. Gross generation includes on-site consumption by the generating facility, while net generation excludes this consumption. Our charts are based on net generation figures, since net electricity generation describes the amount of electricity that is actually available to the electricity system. The self-consumption of the different generation plants is therefore not part of the presentation on the website.

It should be noted, however, that the German government's targets for renewable energy are based on gross electricity generation as a share of gross domestic consumption.

Primary data

Agora Energiewende does not collect any primary data itself. All of the raw data used by the Agorameter originate from the publicly accessible transparency platform that is maintained by the European transmission system operators ENTSO-E. Prior to 2018, the primary data was obtained from the Leipzig European Energy Exchange (EEX). As the primary data from ENTSO-E are occasionally corrected retrospectively, the Agorameter updates the data of the last 30 days on a daily basis.

Since not all power plants are subject to mandatory reporting, the data provided by ENTSO-E do not represent the total power generation for all technologies. In order to represent the actual power generation as best as possible, the primary data from ENTSO-E are therefore statistically corrected live in the Agorameter. The calculation methods used for this purpose are described below.

2 Calculation of key parameters

→ *Power generation:* Power generation data are based on the hourly figures released by ENTSO-E[1] (2018 onwards) and EEX (2012–2017), which are broken down by energy source. However, the ENTSO-E and EEX data usually only express a fraction of actual generation. The discrepancy between reported and actual generation varies by energy carrier and associated reporting requirements. To address this problem, we adjust the ENTSO-E and EEX data series.

→ *Electricity demand:* Domestic electricity demand is calculated as the difference between hourly net electricity generation and the corresponding balance of trade with foreign countries.

→ *Electricity imports and exports:* The day-ahead electricity import and export data originate from ENTSO-E and are adopted unchanged. These data reflect market transactions and not physical flows.

→ *Electricity exchange prices:* The published electricity exchange prices are the results of the day-ahead auctions on the European power exchange EPEX Spot for the German-Luxembourg market area and before October 1, 2018, for the German-Luxembourg-Austrian market area. The prices are published by ENTSO-E every quarter hour.

The Agorameter calculates an hourly average from this.

→ *Carbon dioxide emissions:* The emissions data reflect carbon emissions that result directly from power generation in Germany. The revised, hourly electricity generation data from ENTSO-E and EEX are multiplied by emissions factors in order to determine total emissions. The Agorameter only displays the direct CO_2 emissions that result from fossil fuel combustion for the purpose of electricity generation. Upstream emissions and emissions of other greenhouse gases are therefore not included.

3 Power generation

The energy sources wind, solar, biomass, hydro, lignite and hard coal, nuclear power and the category other are methodically treated equally in the correction of the primary data:
Data for these generation technologies are multiplied by a monthly factor for past years, while an annual correction factor based on the previous year is used in the current year. Only gas-fired power plants are treated methodologically differently due to poorer data availability (see section "g. Natural gas").
The monthly correction factors are calculated from the difference between the complete monthly and energy carrier-specific electricity generation balances of BDEW[2] and the monthly sum of the ENTSO-E feed-in time series.
For the current year, these monthly balances are not yet available, so that instead the annual sum of the ENTSO-E generation of the previous year is compared with the complete annual balance of the AG Energiebilanzen[3].
Due to the historically different availability of data, past periods are sometimes treated differently from current data:

1   https://transparency.entsoe.eu/
2   https://www.bdew.de/service/daten-und-grafiken/mo-natliche-stromerzeugung-erneuerbare-energien/
3   https://ag-energiebilanzen.de/daten-und-fakten/zusatz-informationen/

a. Wind power

As wind turbines consume very little of the elec‑tricity they generate, gross generation is essentially identical to net generation.

The wind energy generation data presented here originate from ENTSO‑E (2018 onwards) and EEX (2012–2017) and are updated hourly, as soon as they are available. The data are based on measurements by transmission system operators (TSOs) at various reference locations. TSOs extrapolate these data to produce generation estimates for all of Germany. These data are used by TSOs to balance grid loads. Our method of calculating and presenting wind power generation has changed over the years, first and foremost due to data availability:

2012 to 2014: For the years 2012 to 2014, no sepa‑rate generation time series are available for onshore and offshore plants. Based on monthly generation data, the joint (incomplete) hourly feed‑in time series published by EEX is multiplied by a monthly correction factor. Subsequently, the hourly values of the common time series are divided according to the annual shares of the two technologies onshore and offshore in the total wind power generation with a constant factor.

2015: Onshore and offshore wind generation is re‑ported separately from 2015 onwards. However, due to data availability issues, a supplemental calculation must be performed for 2015 data. As was done with 2012–2014 data, we adjust the feed‑in figures for all wind turbines using a monthly correction factor in order to calculate total wind energy generation with an hourly resolution. The 2015 EEX feed‑in data for offshore turbines are then multiplied by an annual correction value (2016: 2.04,). As this calculation method can generate a figure that is higher than ac‑tual offshore turbine capacity in Germany, the out‑put figure is capped at 3,294.9 megawatts (available capacity at the end of 2015). In order to obtain the

feed‑in figures for onshore wind power, estimated offshore generation is then deducted from the total generation on an hourly basis.

Since 2016: Separate time series for onshore and offshore feed‑in have been available since 2016.

b. Photovoltaics

As photovoltaic systems (PV systems) consume almost no power themselves, gross generation corresponds to net generation.

As with wind power, the PV generation data pre‑sented here originate from ENTSO‑E (2018 onwards) and EEX (2012–2017) and are updated hourly, as soon as they are available. The data are based on measurements by transmission system operators (TSOs) at various reference locations. TSOs extra‑polate these data to produce generation estimates for all of Germany. These data are used by TSOs to balance grid loads.

TSOs cannot measure how much electricity is directly consumed[4] and therefore not fed into the grid. The Agorameter therefore systematically un‑derestimates the electricity generation from photo‑voltaics. As the photovoltaic share in the electricity mix becomes more and more relevant, a future ver‑sion of the Agorameter should include a method to estimate the directly consumed electricity behind PV plants.

c. Hydropower

The feed‑in figures for hydropower plants are calculated based on the time series for run‑of‑river plants published by ENTSO‑E (2018 onwards) and EEX (2012–2017). As for other technologies and as described in the introduction of "3 Power Genera‑tion" it is multiplied by a correction factor. Past years are multiplied by a month‑specific factor; the current year by last year's annual correction factor.

---

4   While "self‑consumption" refers to the electricity that a plant consumes itself to be able to run, "direct consump‑tion" refers to the electricity that is directly consumed af‑ter its generation before it is fed into the public grid.

d. Biomass

2012 to 2016: Prior to 2017, data on electricity production from biomass (including biogenic household waste) was spotty, as no current and regularly updated time series existed. Accordingly, generation figures for the period 2012–2016 have been estimated based on known total electricity production in past years. From an economic standpoint, biomass and waste incineration plants are generally most efficient when they operate on a continuous basis. It was therefore assumed that biomass plants furnish a marginally variable base load of electricity over the entire year. In order to more accurately estimate power production on certain days in the past, however, we must also take into account the commissioning of new biomass plants within a given year. To this end, we distributed the annual increase in output evenly across the year, with a step-wise addition each month. Average mean production is assumed to have taken place at the middle of the year (specifically, in July). Accordingly, the annual increase is spread over 12 months from the middle of one year to the middle of the following year. Our data

yield a monthly increase of 63 megawatts in 2011/12, 16 MW in 2012/13 and 19 MW in 2013/14 (see Figure 1). From July 2014 onwards, we drew on the expansion foreseen by the 2014 Renewable Energy Sources Act, but limited the increase to 100 MW per year. If we assume an average of 6,000 full utilization hours per plant, this corresponded to a monthly increase in generation capacity of 5.3 MW per month.

**2017:** Since 2017, hourly figures are provided.

e. Nuclear power

2012: As monthly generation data are not available for 2012, an annual correction factor is used instead of the monthly correction factors described in section "3 Power generation".

f. Lignite and Hard Coal

2012 to 2017: To calculate the hourly feed-in from lignite-fired power plants from 2012 to 2017, a distinction is first made between CHP and non-CHP electricity generation. For the calculation of generation that is not CHP-based – i.e. which does not

Figure 1: Agorameter data on average feed-in from biomass generation
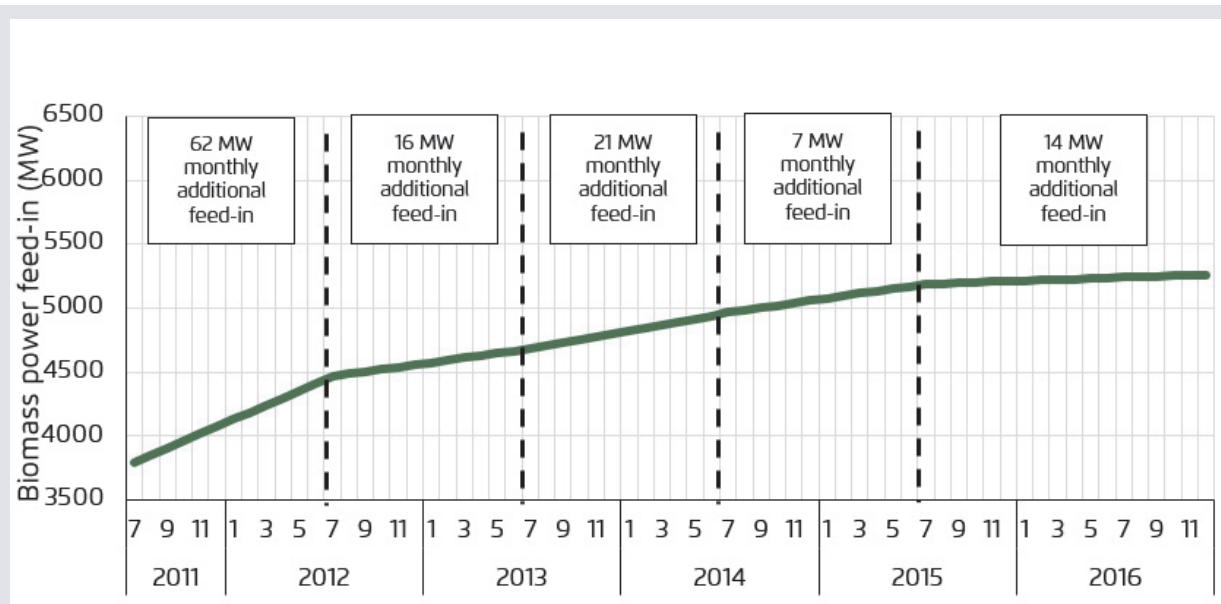
¹⁾ ENTSO-E 2015

occur in a combined heat and power plant – we draw on the hourly feed-in time series for lignite-fired power plants published by EEX. In 2017, non-CHP generation was 132 terawatt hours. An annual correction factor (2017: 0.99) is applied to correct deviations. The feed-in time series for CHP electricity generation is determined as the sum of two feed-in time series. It is assumed for simplicity's sake that the CHP generation is heat-driven:

→ The first feed-in time series is modelled on the basis of process heat production. Due to limited data availability, it must be assumed for simplicity's sake that production volumes are distributed evenly throughout the year.

→ The second feed-in time series is for electricity generation coupled to heating, which is modelled dynamically on the basis of the hourly temperature curve.

Electricity generation with the simultaneous production of heating energy dominates CHP generation with lignite, accounting for 3.7 terawatt hours in 2017, compared to 0.01 terawatt hours for generation with simultaneous production of process heat.

Since 2018: In order to calculate the hourly feed-in from 2018, no differentiation is made between non-CHP and CHP generation. Instead, for past years (between 2018 and the current year), the hourly feed-in time series for lignite-fired power plants published by the ENTSO-E is adjusted using a monthly correction factor based on the available monthly generation data. For the calculation of the current year, the annual total correction factor from the previous year is used.

g. Natural gas
To calculate the hourly feed-in from natural gas power plants between 2012 to 2019, a distinction is made as to whether the electricity is generated by a public utility or by industrial firms (specifically, in the manufacturing and mining sector).

→ To calculate the net electricity generation from public utilities (2019: 52.4 terawatt hours), we draw on the hourly feed-in time series for natural gas power plants published by ENTSO-E (2018 onwards) and EEX (2012 to 2017). We then add an hourly feed-in time series in order to correct deviations in the calculation. For simplicity's sake, it is assumed that the remaining generation by public utilities is heat-driven, i.e. the generation simultaneously produces heating energy. The level of generation is modelled dynamically on the basis of the hourly ambient temperature curve.

→ To calculate net electricity generation from industrial plants (2019: 35.4 terawatt hours), we draw on the hourly feed-in time series for natural gas power plants published by EEX (2012 to 2017) and ENTSO-E (2018 onwards). We then add an hourly feed-in time series in order to correct deviations in the calculation. This time series is estimated based on the assumption that process heat is being produced. Due to limited data availability, it must be assumed for simplicity's sake that production volumes are distributed evenly throughout the year.

In order to calculate hourly feed-in for the current year, it is necessary to differentiate between generation by public utilities and industry, since the use of a general correction factor would otherwise lead us to significantly overestimate the generation from natural gas power plants in individual hours. For this reason, we use the same method to calculate current year generation as we do to calculate historical generation. In each case, we draw on data from the previous year for net generation from public utilities (2019: 52.4 terawatt hours) and from industrial plants (2019: 35.4 terawatt hours). Net power generation from gas-fired power plants of industrial and public power generation is summarized in one category in the Agorameter.

h. Pumped storage

Since pumped storage power plants generally optimise their operations based on market sales, it is reasonable to assume that net electricity generation is fully covered by the feed-in time series for pumped storage power plants provided by ENTSO-E (2018 onwards) and EEX (from 2012 to 2017). Accordingly, we adopt the feed-in time series provided by ENTSO-E (2018 onwards) and EEX (from 2012 to 2017) unchanged, both for historical and current generation. Some of the plants that are included in the data are allocated to the German system by ENTSO-E but are not actually placed on German grounds but are (primarily) connected to the German electricity system.

i. Other generation sources

The figures presented for the category of "Other" include generation data from oil-fired power plants as well as other plants (conventional and industrial waste incineration plants, etc.). For the purpose of enhanced clarity, generation from these sources is presented as an aggregate figure.

Oil-fired plants: To calculate the hourly feed-in of oil-fired power plants from 2012 to 2017, a distinction is made between non-CHP and CHP electricity generation, analogous to lignite and hard coal. In addition, monthly correction factors for the past year and the annual correction factor of the past year for the current year are used analogously.

2012 to 2014: As EEX data only covered a small fraction of the actual generation, missing generation data from 2012 to 2014 is filled with a uniform generation band.

From 2015: As the EEX feed-in time series represents an increasingly large share of net electricity generation from 2015 onwards, a uniform scaling factor is used starting in this year. This

scaling factor is also used to calculate hourly feed-in for the current year.

4 Electricity demand

To represent the current hourly net electricity demand, the corresponding ENTSO-E time series is adjusted with a monthly correction factor similar to the generation technologies.

5 Imports and exports

ENTSO-E's transparency data are used to determine imports and exports. These data, which we adopt unchanged, express the reported day-ahead cross-border commercial exchanges.[5]

The only exception are the electricity trade flows between Germany and Luxembourg (from 2012 to 2015), as hourly time series for these flows have only been available since March 2016. Net exports from Germany to Luxembourg in recent years have consistently amounted to 4.6 to 4.8 terawatt hours per year and also fluctuate only very slightly during the year (cf. Öko-Institut 2013). Exports to Luxembourg are therefore presented up to 2015 as a continuous generation band based on total generation in the previous year. From 2016 onwards, we adopt the ENTSO-E data unchanged.

---

5 Physical flows are not used because the declared trade flows for exports and imports are economic variables that reflect commercial electricity transactions. The physical current flows that actually occur at any given time can deviate due to varying voltage and control energy situations. In addition, the ring flows that occasionally occur (e.g.

electricity transport from France to Switzerland via Germany) should not be regarded as imports and exports in a real sense, but rather as transit flows. However, the Final Cross-Border Schedule is only available seven days after the fact and therefore cannot be used. Moreover, since 15 January 2014, ENTSO-E no longer publish these data.

Table 1: Annual export balance and hourly production band to Luxembourg				
	2012	2013	2014	2015
Export balance from Germany to…	**TWh**			
Luxembourg	4.6	4.6	4.8	4.8
Hourly generation band	**MW**			
Luxembourg	524	524	551	546

6   Electricity prices

The Agorameter shows day-ahead electricity prices on the EPEX Spot Electricity Exchange for the market area of Germany, Luxembourg and Austria (up to September 2018). Austria departed from this market area on 1 October 2018. Accordingly, from this date onwards, only the day-ahead electricity market prices for the market area of Germany and Luxembourg are shown. The data are taken from the ENTSO-E database.
At 12 noon each day EPEX holds an auction for electricity deliveries and purchases on the following day. The prices for each hour are determined on this day-ahead market. These electricity prices are used because the majority of renewable energy is sold in the day-ahead market, which has greater liquidity than the intraday market.

7   Emissions

To calculate total hourly emissions from electricity generation (in tonnes of CO_2), the hourly feed-in time series for fossil fuels published by ENTSO-E (from 2018) and EEX (from 2012 to 2017) are multiplied by an emissions factor (see Table 2) and then added up after adjustment in accordance with the

methods described above. The specific emissions factors are taken from publications released by Germany's Environmental Agency (UBA), and are continuously updated.[6]

The hourly emission factor of the electricity mix (in g/kWh) is calculated according to the UBA formula. For this purpose, the hourly emissions from electricity generation are divided by total net electricity generation (excluding pumping) minus grid losses. Since no known public source publishes hourly grid losses, we apply a grid loss rate that is calculated as a share of net electricity demand based on the previous year's data (in 2020, this loss rate was 5% per hour). The emissions per energy source are then added up and expressed both as a specific sum per kilowatt-hour and in absolute tonnes.

Other greenhouse gases that may be emitted during electricity production or in the upstream and downstream stages (e.g. during the installation or dismantling of a power plant) are not taken into account. In addition, neither the CO_2 emissions from imports nor those from exports are added or subtracted. Accordingly, only the CO_2 emissions that ultimately affect the overall German CO_2 balance are displayed. An overview is given in Table 2.

---

6   The average emission factor of an energy carrier changes as a result of the addition or elimination of generation plants, as the generation plants usually have different efficiencies and emission factors.

Table 2: Annual emissions from fossil power generation and emission factors											
Emissions [1]	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
	Mt CO_2										
Lignite	166	163	159	157	153	149	146	115	94	113	119
Hard coal	94	104	97	92	86	70	62	44	32	41	48
Natural gas	27	24	22	22	28	30	30	33	34	33	29
Other (incl. fossil waste and oil)	34	35	34	34	33	33	31	31	30	33	33
Emission factor of electricity generation per energy source [3]	**t CO_2/MWh**										
Lignite	1.12	1.10	1.11	1.10	1.11	1.09	1.09	1.10	1.11	1.12	1.10
Hard coal	0.88	0.89	0.89	0.85	0.85	0.82	0.82	0.83	0.81	0.82	0.81
Natural gas	0.37	0.37	0.37	0.37	0.37	0.36	0.38	0.38	0.37	0.38	0.39
Other (incl. fossil waste and oil)	1.56	1.57	1.63	1.59	1.68	1.69	1.57	1.43	1.48	1.57	1.64
Average emission factor of the electricity mix [1]	**g/kWh**										
	574	573	557	527	524	487	473	411	375	420	444

[1] UBA 2020
[2] The annual value of the previous year is used for the extrapolation of the current year.
[3] Authors' calculation based on UBA 2020.

References

AG Energiebilanzen (2023): *Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern*, available at: http://www.ag-energiebilanzen.de/

Arbeitsgruppe Erneuerbare Energien Statistik (AGEE Stat) (2023): *Monatsbericht zur Entwicklung der erneuerbaren Stromerzeugung und Leistung in Deutschland*

BDEW (2012-2023): *Aktuelle Daten der Elektrizitätswirtschaft*

EEX (2012-2017): Marktdaten zur Stromerzeugung; (for presentation in the Agorameter, data are obtained directly from EEX through a fee-based server; however, all data on electricity generation from the plants reporting to EEX are also published at the EEX transparency page at: http://www.eex-transparency.com/)

ENTSO-E (2012-2023): Scheduled Commercial Exchanges, available at: https://transparency.entsoe.eu

ENTSO-E (2015): Marktdaten zur Stromerzeugung, available at: https://transparency.entsoe.eu/dashboard/show

EPEX SPOT SE (2013): Market Data from Day-Ahead Auctions, available at: https://www.epex-spot.com/de/marktdaten/dayaheadauktion

Öko-Institut (2013): *Vorschlag für eine Reform der Umlage-Mechanismen im Erneuerbare Energien Gesetz (EEG).* Study commissioned by Agora Energiewende, available at: http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Impulse/EEG-Umlage_Oeko-Institut_2014/Impulse_Reform_des_EEG-Umlagemechanismus.pdf

Statistisches Bundesamt (2012-2023): *Erhebung über die Stromerzeugungsanlagen der Betriebe des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden*, available at: https://www.destatis.de/DE/Methoden/Qualitaet/Qualitaetsberichte/Energie/einfuehrung.html

Statistisches Bundesamt (2012-2017): *Erhebung über die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen für die allgemeine Versorgung*, available at: https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/Energie/Methoden/Erzeugung.html

Umweltbundesamt (2022): *Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix in den Jahren 1990-2019*, available at: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-04-10_cc_10-2019_strommix_2019.pdf