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Electricity sector data for policy-relevant modeling: Data documentation and applications to the German and European electricity markets

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Data Documentation

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Electricity Sector Data for Policy-Relevant Modeling

Data Documentation and Applications to the German and European Electricity Markets

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IMPRESSUM

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Data Documentation 72

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Electricity Sector Data for Policy-Relevant Modeling: Data Documentation and Applications to the German and European Electricity Markets

Berlin, March 2014

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Executive Summary

1. Transparent and comprehensible numerical modeling can make a major contribution to the understanding of electricity markets and infrastructure needs, and is a critical element of any planning exercise as well as a requirement for public acceptance of any reforms. Yet one observes a rising discrepancy between, on the one hand, the increasing complexity of electricity sector models, and, on the other hand, the almost complete absence of easily accessible, high-quality, and transparent data used in these models.
2. Although the awareness of the data issue has improved over the last decade, the quality and availability of the data used in electricity sector models has not. Thus, the data provided by ENTSO-E on the European electricity sector, the so-called study model (STUM) is outdated, covers only few snapshots, and is not suited for model applictions; it is currently of no help in understanding, e.g. the results of the ten-year-network-development-plan (TYNDP). The same dilemma prevails at the national level, though some progress has been made recently, e.g. in Germany. Great Britain represents a very laudable exception from the rule, since detailed technical planning data is publicly provided.
3. Two recent developments have brought some momentum in the data issue, that suggest the need for action: i) Industry, policymakers, other stakeholders, and the interested public have realized the importance of independent modeling and have become increasingly critical upon the underlying data quality; TSOs are opening up to the exchange of transparent data; ii) at the academic end, standards vis-à-vis the transparency and quality of data used in scientific publications have been significantly raised, and it is no longer acceptable to publish anything without releasing the data and the code used. The ethical codes of all scientific associations, in particular in economics, have set out strict rules for data and methodological transparency; this will soon also oblige the consulting sector and policymakers to adopt higher standards.
4. The objective of this Data Documentation is to advance the discussion of data issues by providing a full set of data used for electricity market and transmission network

modeling, and to suggest similar action to academic research as well as the policy and business community. We provide a very detailed account of electricity generation, load data, the high-voltage transmission infrastructure, and price data, both for the German and the European electricity systems in 2012, and 2011, respectively.

5. We also present applications of the extensive datasets to some real-world modeling issues, using the Electricity MODel ELMOD; ELMOD was initiatlly developed at TU Dresden and is now constantly developed since in the context of engineering-economic electricity market research by a variety of research teams. For Germany, we provide an estimate of hourly electricity prices in 2012, that traces the wholesale prices in a very detailed manner; ELMOD also contains a very high spatial resolution and allows, amongst others, the comparison of uniform, zonal, and noal pricing estimates. The application to Europe compares generation mix and trade flows between all European countries (including Switzerland and Norway) and, likewise, reaches a very high level of convergence between the model results and real flows.
6. The Data Documentation is meant as one step towards the use of better and more transparent data for electricity sector modeling, but it also highlights the need for continued work on data shortcomings, model improvments, and organizational innovation. Future work needs to focus on transmission and demand data, both at the European and the national level. Model enhancements, such as combined heat and power, or the (in-)flexibility of power plants, require additional modeling and data efforts. Some technical IT-challenges also need to be addressed, to translate existing model software into user-friendly software interfaces.
7. Even more challenging, though, is the translation of modeling results for use in the policy arena, and the establishment of clarity and consistency that provide real value to the business community and policymakers alike. To that end, the pressure on the electricity industry itself and the public policymakers to release data and secure higher transparency of sector planning needs to be maintained, both in the interest of producers and consumers in the sector, and of public acceptance. More work also needs to be done to integrate the modeling world and the policy world, and to establish routines for interaction between the two levels.

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1 Introduction

1.1 Background: The Importance of Good, Transparent Data

Numerical modeling can make a major contribution to the understanding of energy markets and electricity network infrastructure. With the breakthrough of commercially available software and faster calculation capacities, it has become possible to develop real-world approximations of market developments, prices and quantities, the use of infrastructure and potential bottlenecks, and plausible medium-term developments in these long-lived sectors. Progress has been made in modeling the electricity sector: from the theoretical breakthroughs on electricity markets and on transmission networks, e.g. by Schweppe et al. (1988) and Hogan (1992), recent advances have facilitated the translation of these theoretical concepts into numerical models that fit real-world results surprisingly well. Gabriel et al. (2012) confirm the enormous progress of both conceptual and numerical modeling of the energy sector that has taken place over the last two decades.

Yet, amidst the developments in numerical modeling, one important aspect has not gained sufficient attention: the quality and the transparency of data. Since “models yield insights not numbers”, it is particularly important that the data of the deployed models be i) based on the latest available consistent and comprehensive dataset; and ii) transparently available to everybody to stimulate debate and the possibility to verify (or: falsify) existing results. However, both the quality and the transparency of data for numerical modeling have been neglected until recently: industry stakeholders never had an incentive to disclose data, and many modeling teams considered the obtained data as proprietary, and a competitive advantage in the quest for consulting contracts and publications. Instances where useful, authentic data is released for public use are rare, one notable exception being the publications on the European electricity market by Zhou and Bialek (2005) and Hutcheon and Bialek (2013).

1.2 Data Requirements for Electricity System Modeling

In liberalized electricity markets a series of sub-markets exist (Figure 1). Each one has certain characteristics in terms of market participants, technical requirements, the market settlement process, and the underlying uncertainty in quantities and prices. They also have a different time frame starting from several years (futures markets), to about one week (balancing markets), one day (day-ahead markets), and only hours (intra-day markets) before the physical delivery. Thus, depending on the own (generation) portfolio and the individual market strategy generation companies and large consumers place bids for supply and demand on different sub-markets at different points in time (Scharff et al., 2014).

Figure 1: Different sub-markets towards physical delivery

One general distinction for electricity market models is the time scope and the competition level (Ventosa et al., 2005). With the liberalization in the 1990s, researchers have applied electricity market models with an oligopoly or monopoly market approach to evaluate and quantify potential abuse of market power. Yet, the market liberalization also increased the complexity of market clearing as more heterogeneous market players developed. Last but not least, the sector is undergoing a major transformation towards (fluctuating) renewable generation, in order to meet the European reduction targets on carbon emissions. Both, the liberalization and the roll-out of renewables cause an increasing uncertainty throughout the sub-markets which raises questions regarding flexibility and risk management.

On the contrary, techno-economic electricity sector models gain momentum in understanding the transformation to low carbon electricity systems by a joint analysis of the entire infrastructure and additional technical constraints often neglected in other model approaches. Thereby, they abstract from strategic behavior and uncertainty and only consider the measured/observed parameters at physical delivery. Thus, results are driven by technical constraints and resulting costs of e.g. network constraints rather than by the market design and the behavior by market participants. These assumptions; 1) perfect competition, 2) a mandatory pool-market without bilateral contracts, and 3) perfect information have to be kept in mind when model results are compared to the historic market outcomes.

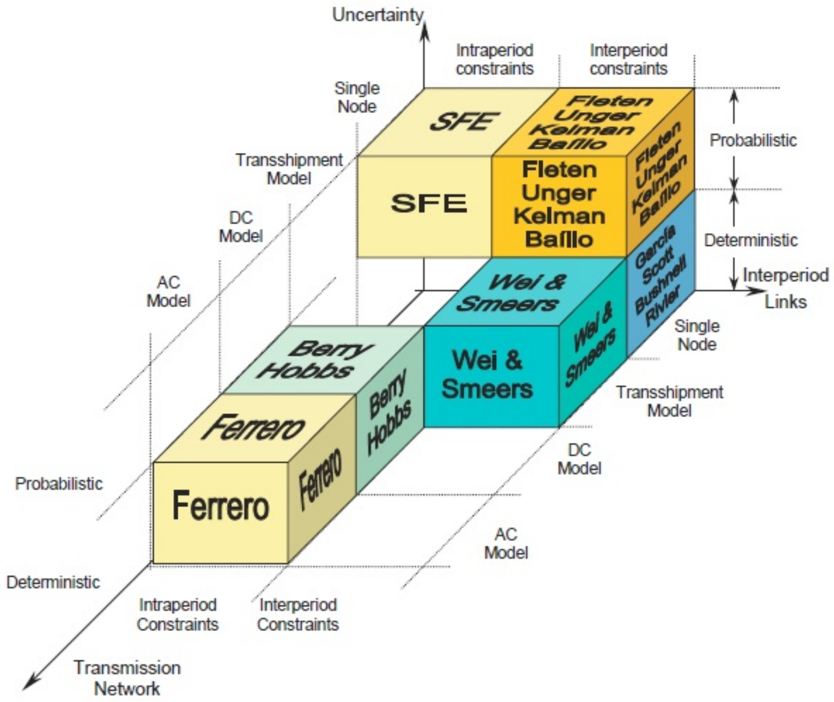

Figure 2: Characterization by uncertainty, transmission network, and interperiod links

Source: Ventosa et al. (2005).

In addition to highlighting the role of uncertainty, Ventosa et al. (2005) provide a classification of models that include the timing structure (intraperiod vs. interperiod constraints) and the degree of representation of the transmission network as well as the consideration of uncertainty (Figure 2). This Data Documentation is tailored for modeling approaches similar to the "Berry and Hobbs" box and the empty spot to its right, with no uncertainty in the market and a direct current (DC) load flow representation. The dataset on Germany includes hourly system data that allow implementing interperiod constraints in model applications, whereas the dataset on Europe currently reflects an average hour. The consideration of interperiod constraints is subject to the requirements of the individual analysis and the availability of hourly data.[5]

The electricity load in models with perfect competition is often assumed to be perfectly inelastic. Yet, also the implementation with a price-elastic inverse demand function is an option when analyzing social welfare effects. The inverse load function can be determined

[5] Examples are costs and constraints for ramping of the generation/load level within every 15min/hourly time step, the interperiod representation of pumped storage plants, and seasonal hydropower reservoirs in the Alps.

by the observable hourly points of load and supply and an additional assumption on elasticity.

1.3 Absence of Coherent Public Data at European and Most Member State Level

Almost none of the data that is used for modeling the electricity system at the European or the national level is publicly available. This holds for network data that is proprietary with transmission operators, as well as for energy market modeling (e.g. cost assumptions). The absence of an established base of commonly agreed data obliges all modeling teams to make their own assumptions about technical and economic data. Besides the multiple efforts going into the data assembling, data divergence thus generated also leads to a very heterogeneous use of datasets in the modeling exercises.

Two reasons are generally evoked to justify the absence of publicly available data: i) confidentiality for system security reasons; and ii) economic sensitivity of the data. Concerning technical data of the infrastructure, the argument of confidentiality for system security reasons may be considered with some doubt as in the UK the relevant data is publicly disclosed on a webpage of the system operator.[6] However, some raise the aspect of economical sensitivity concerning historical feed-in time series of power plants which could be used to calculate ex-post historic revenues of power producers. As with the former reasoning ("confidentiality for system security reasons"), this latter one can be relaxed: historic producer time series are not likely to be of very high importance in the process of energy system planning and historical load data at transformer stations might be everything but commercially sensitive.

1.3.1 EU-level: absence of detailed, transparent data

Little progress has been observed over the past years at the European level: network and electricity sector data was made available by ENTSO-E, the body representing the (currently 42) transmission system operators, to an audience of experts who were given access to network data (topology, impedances, and transformers). The data format has changed over

[6] This includes (i) detailed data of existing generation plants, including reactive power capabilities and (ii) detailed information of the existing transmission network, including the assets of all owning companies as well as the geographic shape files with detailed information on line, cable, and substation locations by one owning company (National Grid, 2013).

time, it is currently provided in the CIM (Common Information Model XML format; IEC 61970). In the current dataset provided in the ENTSO-E Study Model (STUM), substations are assigned to countries but do not have any clear text names, because ENTSO-E's System Development Committee had decided to not disclose this information. This makes the data virtually useless. Additional to the static network data, which also includes aggregate information on generation, STUM contains a solution to flows, transformer tappings, and generation levels for a single hour. In earlier versions, the data provided within STUM could be matched to existing node names as the node identifiers could be used to guess the real name. Such an exercise was performed by Neuhoff et al. (2011).

A similar situation prevails with respect to the data basis of the European energy systems models, which are used for longer-term energy, transport, and climate scenarios. PRIMES, one of the models most commonly used, i.e. in contract work for the European Commission, is not well documented with respect to its theoretical structure; none of the basic data nor any code is available to the contractors of the model (mainly DG Ener, DG Move, and DG Clima), let alone the interested public.

1.3.2 National level: the United Kingdom as the positive exception from the rule

In general, at the level of the Member States, and similar to the situation at the European level, very little data is publicly available that would enable external modelers to catch up to the knowledge advantage TSOs in their central role do presumably have. This is the case, for example, in Germany, even though recent developments in the German electricity legislation have improved the availability of systematic datasets for at least some key data of the electricity sector: Since the 2011 amendment of the national energy legislation, especially with respect to the network planning procedure it is now possible for third parties to access planning data used by the TSOs for their network planning. This especially relates to network data, including impedances and transformers. However, access to the data is granted solely under a non-disclosure agreement (NDA), whose restrictions (§ 12f, Energiewirtschaftsgesetz 2011) prohibit to consider this arrangement anyhow related to public disclosure of relevant planning data (Weber et al., 2013). Apart from this, assumptions on primary energy prices, power plant de- and commissioning, and expected renewables deployment are subject to a publicly debated scenario framework (50Hertz et al., 2013a) which is publicly available (see below Section 2). Recent studies use the above mentioned data to contribute to a public debate on necessity and reasonable forms of national grid expansion, and what is more, national energy system planning (e.g., Agora Energiewende and BET Aachen, 2013). Yet, the combination of publically available datasets with own assumptions (expert guesses) and private data results in non-transparent model inputs and thus makes it difficult to compare results and to determine their main drivers.

A very notable exception to the rule is Great Britain (i.e. UK except Northern Ireland) where indicative transmission planning is carried out by the system operator, National Grid, within the so-called ETYS (Electricity Ten-Year Statement) process. It is notable that detailed technical planning data is publicly provided and freely accessible via a webpage (National Grid, 2012). This data is:

- Data on existing and planned generation plants (technology, rated power, and connecting network node);
- detailed data on the existing GB transmission network (i.e. including the assets of all three owning companies: NGET, SPT, SHETL):
    - A full connection scheme of the GB transmission grid, including substations, line resistances, impedances, and rated power values;
    - transformer ratings (including impedances, without tappings);
    - and information on reactive compensation equipment and respective capabilities;
- data on electricity load is available on an hourly basis from National Grid's website. The data includes national net demand, pumping, and imports/exports per interconnector.

Further to that, NGET provides geographic shape files with detailed information on line, cable, and substation locations (National Grid, 2013). Better data, especially on generation, and spatial distribution on load would improve the situation even more, yet the overall status can be judged satisfactory, and an encouragement for other countries to move into the same direction.

1.4 A New Momentum and the Objectives of this Data Documentation

Two developments have brought some momentum into the data issue recently:

- Industry, policymakers, other stakeholders, and the interested public have realized the importance of independent modeling of the political and business decision making process, and have become increasingly critical upon the underlying data quality, and in some (rare) instances even open for the exchange/reveal of transparent data. Advances in information technology and the internet have made the publication and dissemination of large amounts of data easier. Thus, all network planning procedures at the European level, e.g. ENTSO-E's 10-year network development plan (TYNDP) and at the national level (e.g. in the UK, Germany, and elsewhere) can now be easily presented to a large audience (see ENTSO-E, 2010, 2012, BNetzA Netzenwicklungsplan 2012);
- academic standards vis-à-vis the transparency and quality of data used in scientific publications have increased. Previously based on "gentlemen agreements" between good friends, the publication of used data, their sources, and proof of plausibility have been institutionalized in the profession recently. Thus, the "Ethical code for appropriate scientific behavior for economists" set out by the Verein für Socialpolitik (VfS, 2012) for German speaking economists, requires, amongst other things, that research be transparent and replicable, and that data, source code, and results be made publicly available; the disclosure policy of the American Economic Association stresses the same things (AEA, 2012).

Seizing this new momentum, the objective of this Data Documentation is to provide insights into the public availability of data sources used for electricity market and transmission network modeling of the German and European power system, and thus to advance both the level of discussion, and the transparency of contributions, both to academic research and the policy and business community. The data gathered in this exercise refers to electricity generation, load data, the high-voltage transmission infrastructure, and price data. It is mainly used in modeling exercises using the ELMOD framework, an Electricity MODel developed initially at TU Dresden by Leuthold et al. (2008) and Leuthold et al. (2012) and constantly developed since in the context of engineering-economic electricity market research, led by Weigt et al. (2010), Abrell and Weigt (2011), Kunz and Zerrahn (2013), and Egerer et al. (2013).

This Data Documentation is structured along the technical elements of the electricity sector and contains all stages of the value-added chain including generation, transmission, and consumption of electricity. After this introduction, Section 2 focusses on the data and an application in Germany, whereas Section 3 covers European issues in the same manner; Section 4 concludes.

2 Germany

2.1 Electricity Data

2.1.1 Data sources

Obligations for data publication by German TSOs are defined within § 17 I of the "Stromnetz-zugangsverordnung - StromNZV" (Deutscher Bundestag, 2005). The data has to be published at least on the internet and includes hourly vertical load, annual peak load and quarter-hourly load measurement, network losses, quarter-hourly balance of the control area and called minute reserve, quarter-hourly exchange flow aggregated for each cross-border exchange point with outlook on power allocation, outages, planned revisions of the network which are relevant for the market, quantities and prices of lost energy, and data on projected and actual wind feed-in. Rising concerns on security of supply led to monitoring of power plant capacities on plant (and block) level by the German regulator. The data is frequently updated and available for download on the website of BNetzA (2013).

Full transparency and traceability as main objectives of this Data Documentation allow only the use of open data sources. Thus, the sources include a limited number of publications by different institutions, organizations, associations, exchanges, and companies which are publicly available (Table 1). Commercial datasets (e.g. on power plants), information only available under non-disclosure agreements (e.g. on network data), and references for individual infrastructure objects are not considered. We provide parameters of our dataset in the appendix.

Table 1: Public data sources

Institution	Type of data
ENTSO-E	- Time series on: • German load data (hourly) • Cross-border flows (Baltic cable)
TSOs (50Hertz, Amprion, TenneT, and TransnetBW)	- Transmission network map - Generation capacities in the renewable support scheme (with ZIP code) - Time series on: • Renewable generation output (15min) • Cross-border flows (15min)
German regulator (BNetzA)	- Generation capacities (with address) • Conventional power plants (block level) • Renewable (>10 MW), rest as aggregation
Energy exchange (EEX)	- Price data: • Emission allowances for carbon • Day-ahead market prices for electricity
Association (Statistik der Kohlenwirtschaft e.V.)	- Price data: • Natural gas, hard coal, and fuel oil
Association (AG Energiebilanzen e.V.)	- Load statistics for 2012 - Generation statistics by fuel for 2012
Aerial Imagery / Other	- Geographic information on: • Power plants • Transformer stations • Transmission lines

2.1.2 Spatial electricity infrastructure data

The dataset combines information on infrastructure, operational data, resource prices, as well as CO_2 allowance and electricity prices for the German electricity sector in the base year of 2012. The parameters on infrastructure are fixed for the base year and consist of the high-voltage transmission network, conventional as well as renewable generation capacities, and the spatial distribution of electricity load. Neither investments nor investment costs are considered in this Data Documentation.[7] Time dependent parameters are discussed in the consecutive Section 2.1.3.

On the spatial level exact geographic data is collected for all relevant infrastructures. This allows a representation of different market designs, e.g. nodal pricing or an aggregation to zonal or even to uniform pricing representing the current design (Table 2).

Table 2: Spatial aggregation levels of electricity system data

Nodal pricing	Zonal pricing			Uniform pricing
	Individual	DENA zones	Federal states	
				

Source: Own depiction based on VDE (2010), OpenStreetMap contributors (2013), Dena (2010).

2.1.2.1 High-voltage transmission network

As of today, there is no open platform which combines all relevant data of the German transmission network for spatial electricity network models. Necessary information comprises data on transformer stations, the topology of the transmission network, and technical information for each individual transmission circuit.

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[7] For PV and onshore wind power monthly capacity data is considered in the dataset. Schröder et al. (2012) provide a detailed analysis on fixed and variable cost components in electricity generation as well as their development over time.

In our network topology (Figure 4) we combine information from different public sources on the German high-voltage transmission network (Table 3). The topology consists of network nodes (transformer stations) connected by transmission lines (individual circuits).[8] Each line has one start and end node, its line length, and its voltage level. With the focus on Germany, the principle source for the topology is the map of the German transmission network (VDE, 2013) which is more detailed compared to the European map of the interconnected network of Continental Europe (ENTSO-E, 2013a). While being a good starting point for a detailed representation, the VDE map contains some topology errors and is only schematic. It does not provide exact geographic and topology information for individual circuits and transformer stations. Thus, we apply additional sources for geo-referenced data and for topology information (OpenStreetMap contributors (2013) and Table 3).

However, for two TSOs (Amprion and TransnetBW) topology data is rare and there are limitations to the digitalization of stylized network maps. On some network elements, several data sources exist that include partially opposing information. Thus, subjective decisions on the network topology in several parts of the network needed to be done.

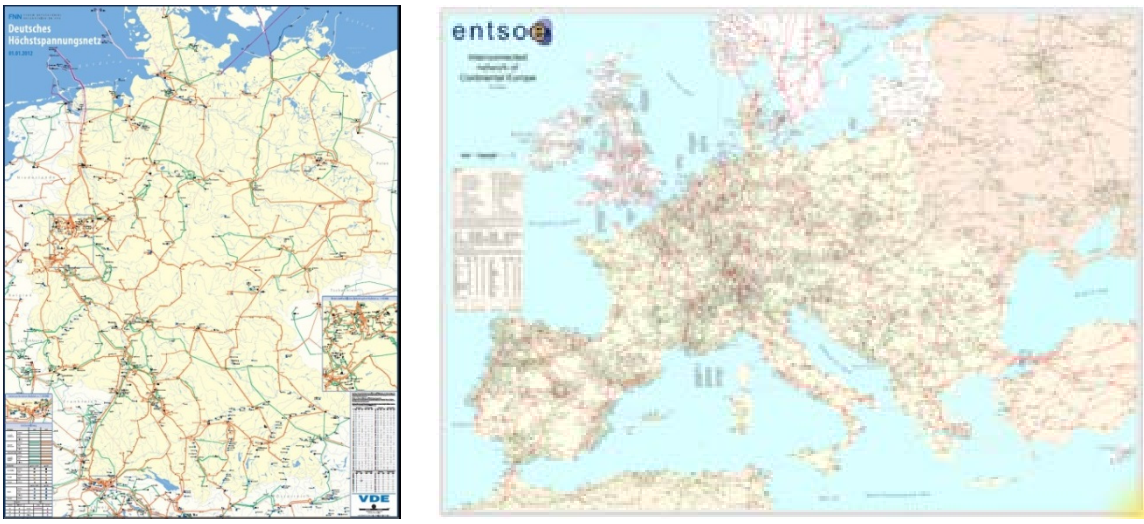

Figure 3: Transmission network map for Germany and Europe

Source: VDE (2013), ENTSO-E (2013).

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[8] In some cases network nodes are auxiliary nodes at direct line crossings. The dataset consists of the network nodes and transmission lines for the voltage levels of 220 kV and 380 kV.

Table 3: Information on TSO network data

	50Hertz	Amprion	TenneT	TransnetBW
Network topology map	 (50Hertz, 2013a)	 (Amprion, 2013a)	 (TenneT, 2013a)	No map available
Information content	Topology with individual nodes and circuits.	Topology but no individual circuits and simplified representation.	Topology with individual nodes and circuits.	No data
Other sources	Historic network flows and thermal line capacity (50Hertz, 2013a).	Amprion grid map with individual circuits (Joost, 2013).		

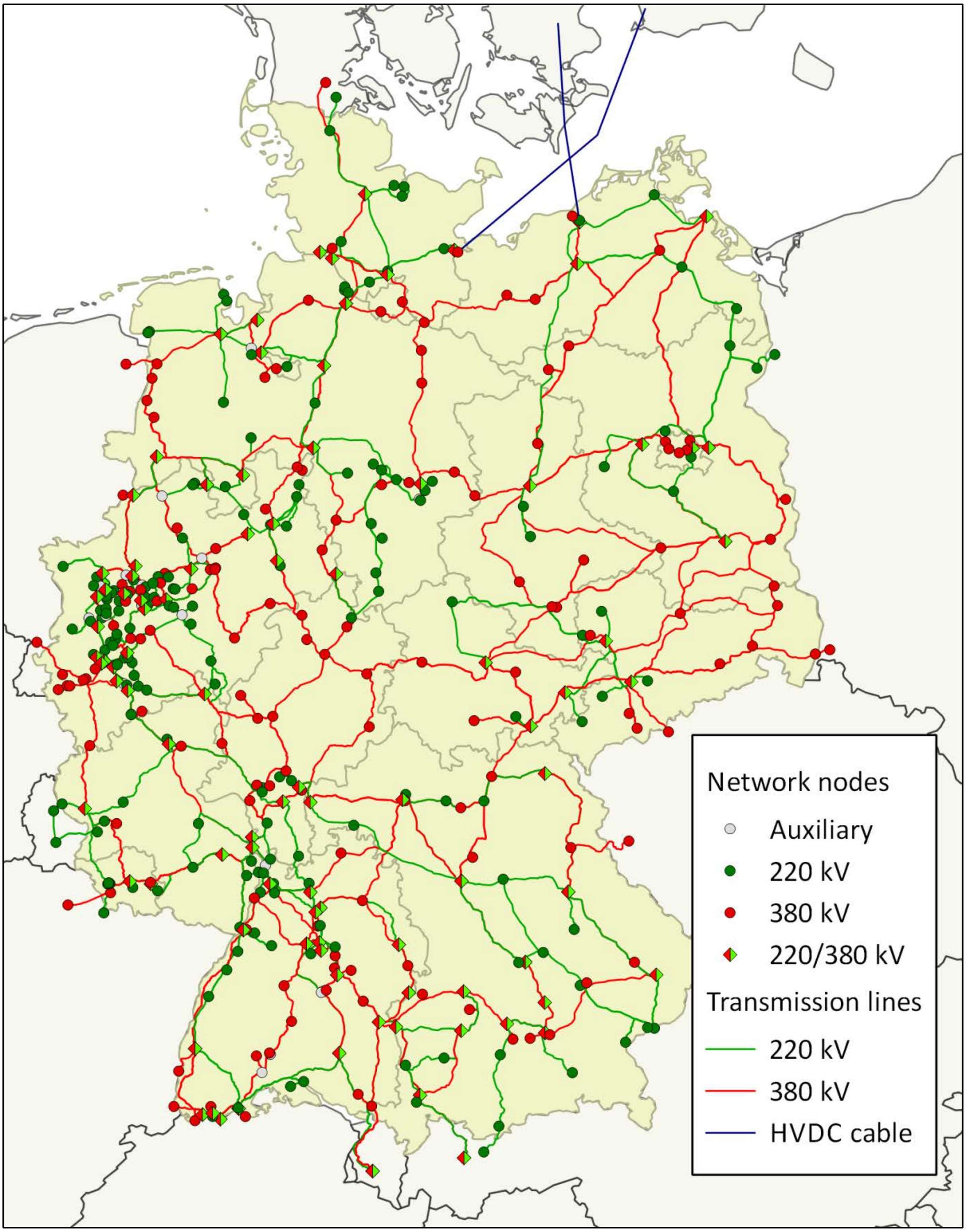


Figure 4: The German high-voltage electricity transmission system in 2012

Source: Own depiction based on VDE (2010), OpenStreetMap contributors (2013), 50Hertz (2013a), TenneT (2013a), and Joost (2013).

Our topology for 2012 (Figure 4, Table 4) includes 438 nodes (393 in Germany, 22 in neighboring countries, and 23 auxiliary nodes where two lines are linked without a transformer station), and 938 transmission lines. The network nodes are important for the spatial allocation of load and individual power plant blocks. 220 kV and 380 kV transformer stations in close proximity are condensed to one node. The voltage level of 220 kV includes slightly more of the circuits compared to the 380 kV level.

The topology information of the transmission lines contains one start and one end node. Knowing the voltage level and the line length we determine the physical line properties of each circuit in the network by assumptions on specific technical parameters for overhead power lines (Table 5). While 50Hertz (2013a) provides information on the capacity of its transmission lines, this Data Documentation, in order to adhere to data consistency, applies the technical assumptions to the entire transmission network.

The dataset with individual circuits allows for a detailed analysis of the n-1 criterion or of topology switching. In more general modeling exercises, the n-1 criterion can be approximated by the limitation of network flows on each line with a transmission reliability margin (e.g. 20% of line capacity).[9]

Table 4: Quantitative network statistics

	220 kV	380 kV	Total
Nodes	289	246	439
Circuits	496	453	949

Source: Own calculations.

[9] In addition to topology, the publication of further technical data on individual circuits and transformer stations would allow a more transparent analysis of the German transmission system. One example is the upgrade of existing corridors with high-temperature cables, which is on top of the agenda in the network development plans. Yet related parameters are not publically available for the German transmission system on individual lines. This leads to non-transparent assumptions or the usage of private knowledge for any studies supporting or criticizing the benefit of high temperature cables in network planning. Consequently, not one of these studies could possibly claim transparency.

Table 5: Technical line characteristics

Voltage [kV]	Specific resistance [Ohm /km]	Specific reactance [Ohm /km]	Thermal transmission limit [MVA]
220	0.075	0.40	490
380	0.029	0.33	1,700

Source: Kießling et al. (2001).

2.1.2.2 Electrical load

The dataset uses national demand data from ENTSO-E with a simple linear scaling factor to 557.9 TWh in 2012.[10] While four time series are available by the German TSOs the datasets are difficult to apply in terms of distributed generation and accuracy of data measured at the connection points to the distribution network by TSOs in the high-voltage network. Yet, a more detailed analysis of existing demand data, its discussion concerning distributed generation, network losses, pumped-storage demand, and spatial aggregation would be valuable.

In this work, the spatial allocation of the German electricity load is conducted using several sources. Firstly, we use the lowest and highest load on federal state level (Figure 6a) to distribute load. The load share of national demand differs greatly between the two extreme load levels for the federal states (Figure 5). Assuming full correlation between load and spatial load shares, the load share is calculated with a linear interpolation between the two extreme load levels for every federal state and every hour.[11]

Secondly, for each NUTS-3 zone within one federal state a weighted load share is calculated for the lowest and highest load case based on information on the zone's GDP and population (Eurostat, 2013a, 2013b). The allocation of load shares is illustrated in Figure 6b.

[10] Regarding the applied linear factor, section 3.4.3 in the 'Netzentwicklungsplan 2012' (50Hertz et al., 2012a) discusses more sophisticated methods to scale demand profiles. In the 'Netzentwicklungsplan 2013' (50Hertz et al., 2013b) nodal demand profiles measured by TSOs in 2007 are scaled and applied in the calculation. However this data is not publicly available.

[11] We have to make the assumption of perfect correlation between the lowest/highest load levels in all federal states due to the lack of open data.

Thirdly, as multiple nodes may be present in one NUTS-3 zone or zones may contain no node at all, we calculate the load distribution from the NUTS zones to the nodal level based on the weighted distance from nodes to the NUTS-zone's center point by the formula

$$load\_share_n = \sum_{NUTS3} \left[\left(\frac{\left(Distance_{n,NUTS3}\right)^{-weight}}{\sum_{nn}(Distance_{nn,NUTS3})^{-weight}} \right) * load_{NUTS3} \right]$$

In the allocation only a certain number of the closest nodes are considered for each NUTS zone.[12] The calculation determines a distance related distribution but prevents extreme load shares on nodes very close to the geometric center of one zone. Finally, it results in a percentage of the total German electricity load for each node for the lowest and highest load states (Figure 6c). The final nodal load shares can then be adjusted by linear interpolation between the two extreme points. The values are calculated according to the respective hourly system load in relation to the lowest and highest load level in the dataset.

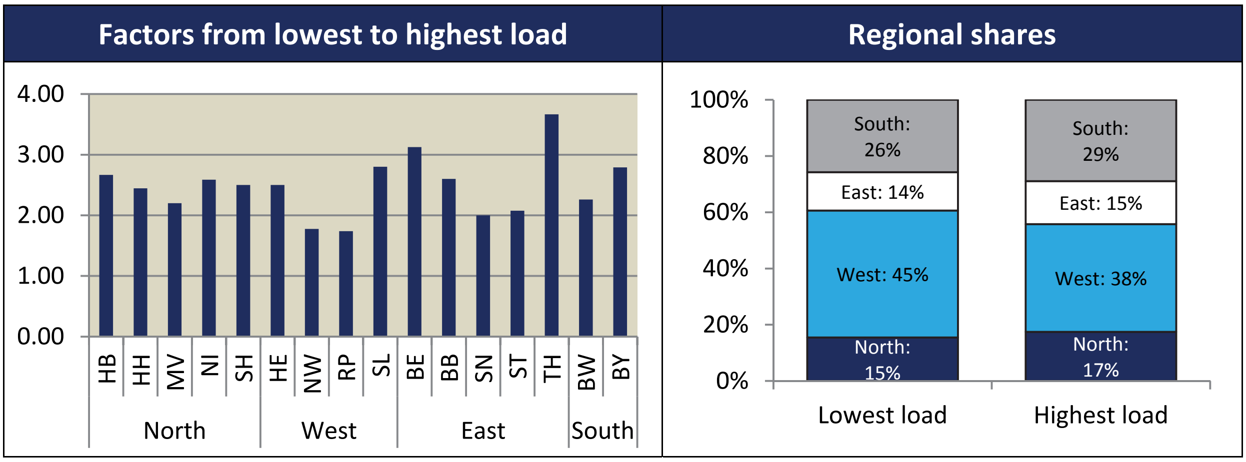


Figure 5: Allocation on federal states for state of lowest and highest load

Source: 50Hertz et al. (2013c), own calculation.

[12] We use the following parameters: Allocation of each NUTS-3 load to the ten closest nodes and a weight of 0.3.

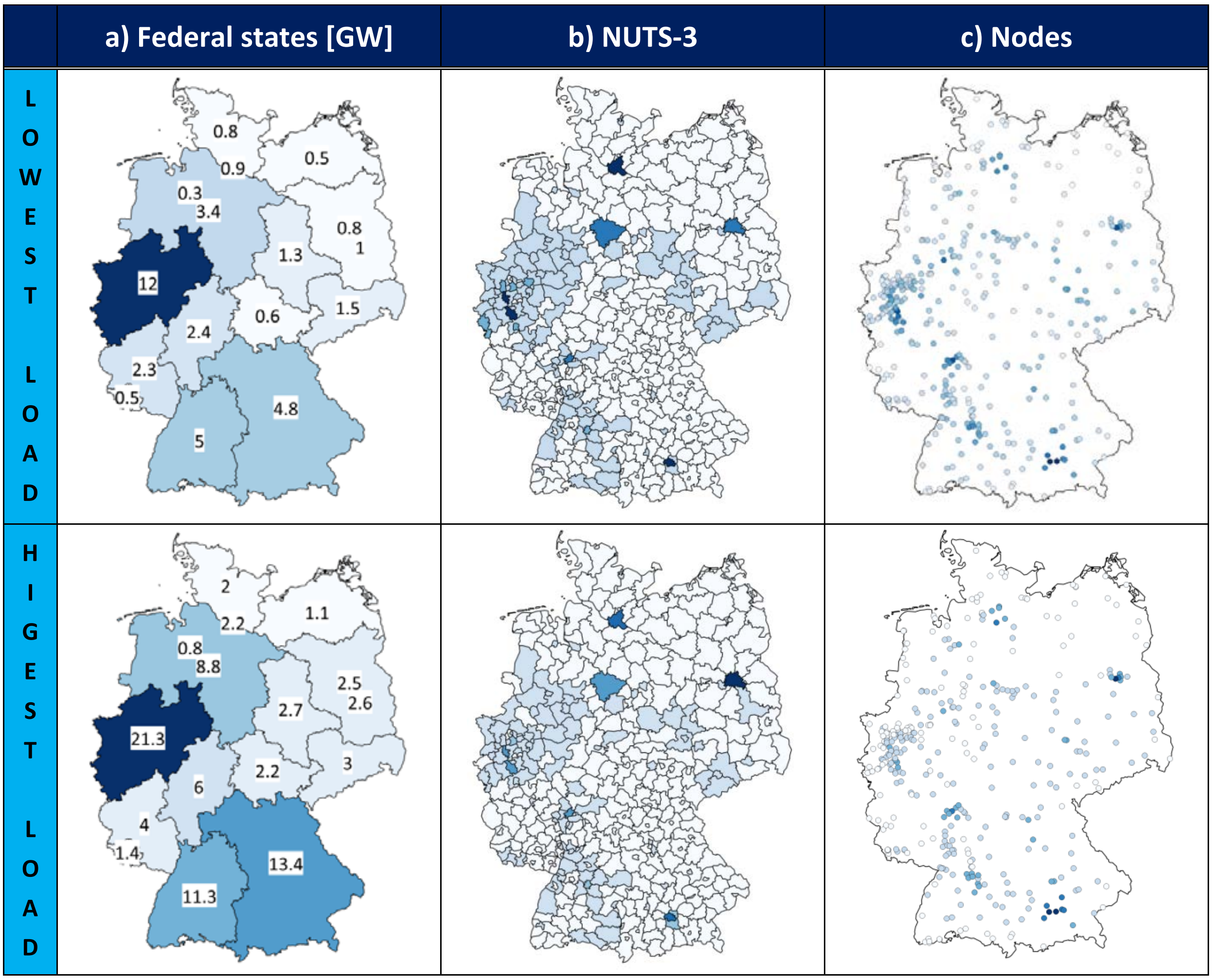


Figure 6: Stages of spatial load allocation

Source: Own depictions with input from 50Hertz et al. (2013c) and Eurostat (2013a, 2013b).

The hourly load data for Germany is built upon ENTSO-E (2013b) consumption data (469.6 TWh). In early 2013, only estimated data on net electricity demand was available (BDEW, 2013a) with 526.6 TWh for 2012 (Table 6). In general, the reported statistics are often non-transparent in regard to electricity that is used for own consumption. The BDEW numbers do not differentiate by that at all. The BNetzA numbers explicitly state 32.8 TWh for this type of supply but overall net electricity generation is 15.3 TWh lower than the BDEW numbers (576.6 TWh instead of 591.9 TWh).

In the dataset the annual demand builds on the BNetzA numbers. By backward calculation from net electricity generation we arrive at 550.9 TWh for 2012. This figure assumes 576.6 TWh in net generation; a trade surplus of 15.4 TWh (chapter 2.1.3.2) as well as pumped storage demand (10.3 TWh) is subtracted. Exports and imports are considered separately from demand by being added to the respective nodes and pumped storage is modeled endogenously. Network losses and other non-accountable demand (not modeled endogenously) remain within the demand value.

As the ENTSO-E consumption data does not include the country's entire net electricity demand, it is scaled up to 550.9 TWh. Thus, we add a fixed load block to all hours for one third of the increase while the other two thirds are put on top of the load by a fixed relative factor (results in peak load of 86.0 GW).

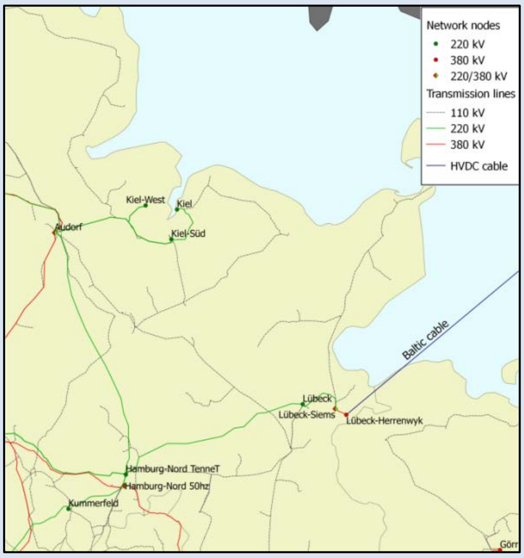
Additional sources, not considered in the calculation of nodal load shares, are the aggregated time series on load which are provided by each TSO for its own control zone. Historical load data, broken down to individual network nodes, is applied in the German network development plan 2013 but not available as open data (50Hertz et al., 2013b).

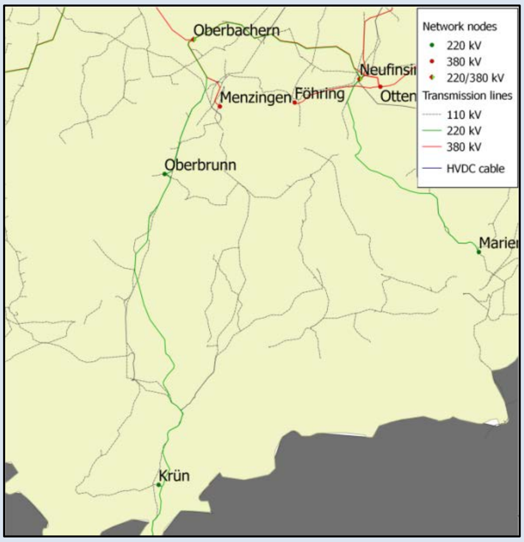
Table 6: Calculation of gross and net electricity generation and demand of 2012

[TWh]	AGEB 03/2013[1]	BDEW 12/2013[2]	BNetzA 12/2013[3]
Gross electricity generation	617.6	-	-
Own demand power plants	-35.1	-	-
Net electricity generation	582.5	591.9	576.6
Delta electricity trade	23.1	-	21.7
Net domestic supply	559.4	-	554.9
Network losses / other	24.6	-	23.4
Net electricity demand	534.8	-	531.5
Pumped storage	8.2	-	10.3

Source: [1]AG Energiebilanzen e.V. (2013a) p.30, [2]BDEW (2013b), and [3]BNetzA and Bundeskartellamt (2013).

Manual adjustments of the load allocation

<table>
<tr><th>Network map</th><th>Description</th></tr>
<tr><td>
</td><td>The high-voltage network has only one 220 kV line (two circuits with 392 MW each) between Lübeck and Hamburg. It connects Lübeck (three nodes with about 400 MW of load at peak load) and the Baltic cable to Sweden (capacity of 600 MW). In 2012, in the week starting February 1st at 9 a.m. the model data results in insufficient load of up to 125 MW in 51 hours. This week combines high load and rarely observed exports to Sweden at full capacity.

The transmission system is not capable to supply 1,000 MW to Lübeck and there is no conventional and only limited renewable local generation capacity. What is not considered in the dataset is the transmission system on 110 kV which has three connections from Lübeck (to Audorf, Hamburg, and Krümmel). By itself it is capable to supply the load of Lübeck so we assume that half of the load of the three nodes in Lübeck is allocated to the nodes Audorf (30%), Hamburg-Nord TenneT (40%), and Krümmel (30%).</td></tr>
<tr><td>
</td><td>The second adjustment relates to the 220 kV transmission line from southern Germany to Austria (two circuits with 392 MW each). The load at the network node Oberbrunn (peak load of 534 MW) cannot be supplied in about 30 hours in January and February in 2012. The combination of export flows on the line towards Austria together with the load level of a node in the 220 kV system causes the insufficient local electricity supply.

Again the dataset does not consider the grid system on 110 kV level. It connects large regions to Oberbrunn but also to other network nodes. We assume therefore that half of the load from Oberbrunn is instead allocated to the network node Oberbachern.</td></tr>
</table>

Sources: Own illustration based on TenneT (2013a) and OpenStreetMap contributors (2013).

2.1.2.3 Generation capacity

The general data availability for power plants has improved with the data collection by the German regulator (BNetzA, 2013a) and the publication of plant data of the renewable support scheme. As highlighted before, the focus of this chapter is a transparent dataset for the

German electricity system based on open data. Concretely, two developments in Germany have improved open data availability on power plants in the last years:

i) The German regulator initiated a list with block specific information on generation infrastructure feeding into the German transmission network (BNetzA, 2013a). The main reasons have been more transparency in the German network development plan and the security of supply considerations after the second German nuclear phase-out decision following the partial meltdowns in the nuclear reactors of Fukushima;

ii) the German TSOs collect spatial data (ZIP codes) on all installations which are in the renewable support scheme (Erneuerbare-Energien-Gesetz (EEG), Deutscher Bundestag, 2011). While also updating on a sub-annual level, the TSOs publish a final national dataset for the previous year in late summer (50Hertz et al., 2013c).

Non-EEG generation capacity

Comparing the two datasets, the EEG dataset includes spatial information (ZIP codes) for all EEG installations whereas the BNetzA dataset aggregates renewable installations of less than 10 MW on a state level. Therefore, only non-EEG capacity with spatial information is being processed from the BNetzA list, while the larger share of EEG capacity has no spatial information included (Figure 7).

In a first step, from the regulator's list of 16th November 2013 (i) only the power plant blocks a) marked 'in operation' and b) built at the latest in 2012 and shut down after 2012 are considered. This results in a data sample of 178,182 MW (out of the 186,579 MW in the BNetzA list). When neglecting the EEG capacity (76,165 MW), the remaining data[13] consists of 98,544 MW with spatial information (whereof 4,395 MW are not located in Germany but feed into the German system) and 3,473 MW in capacity aggregated by technology without

[13] The Appendix shows the resulting power plant data on block level. It distinguishes in conventional power plants feeding directly into the 220 and 380 kV system (Table 28), conventional power plants connected to lower voltage levels (Table 29), pumped storage power stations (Table 31), renewable power plants (Table 31), and cross-border capacity (Table 32).

spatial information (Table 7). The technology with the largest share of capacity without spatial information is natural gas (2,124 MW).

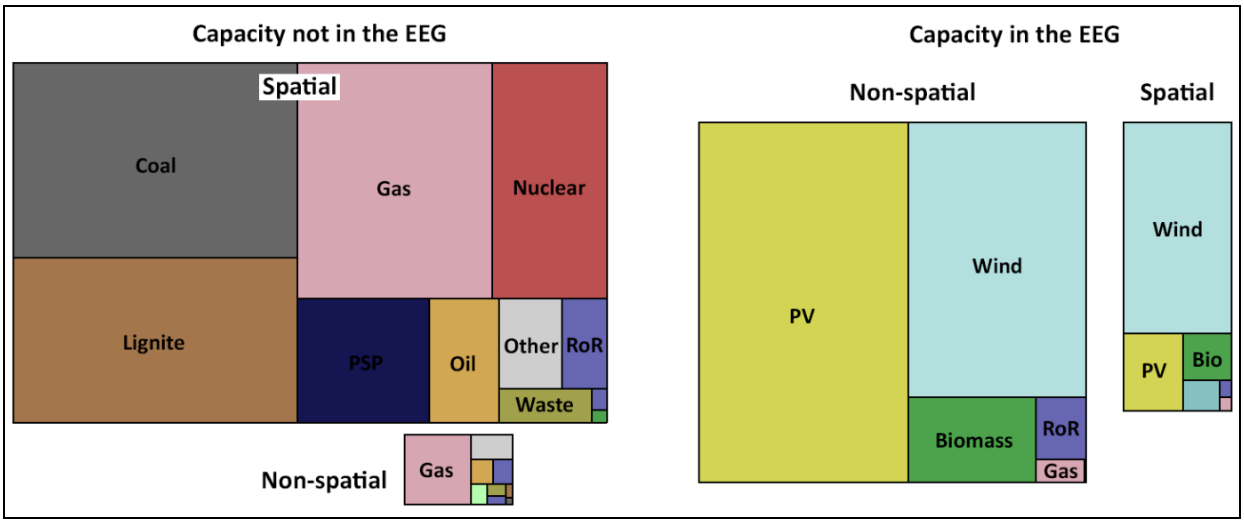


Figure 7: BNetzA data with capacity regarding spatial information and the EEG
Source: Own illustration based on BNetzA (2013a).

Table 7: Spatial and non-spatial capacity in the BNetzA list (and not in the EEG)

	Spatial capacity [MW]	Non-spatial capacity [MW]	Share of non-spatial [%]
Gas CCGT / GT-ST-CB	7,500 / 12,898	*0 / 2,124	(w/o CCGT) 16.47%
Other	2,474	474	16.09%
Oil	3,833	239	5.87%
Run of river	1,821	224	10.97%
Waste	1,452	95	6.16%
Reservoirs	153	83	35.15%
Lignite	20,990	48	0.23%
Coal	24,671	25	0.10%
PSP	7,286	2	0.02%
Biomass	99	0	0.08%
Other renewables	0	159	N/A

Source: Own calculation based on BNetzA (2013a) and *own assumption.

The number of conventional power plants (375) and power plant blocks (559) from the BNetzA list in our dataset and their relation to installed capacity is illustrated in Figure 8. Additional sources available like the power plant list of the scenario framework for the German network development plan (50Hertz et al., 2012b), commercial power plant databases (e.g. Platts, 2013), information from large generation companies and other additional sources are not included to keep the data as transparent and tractable as possible. The information regarding the location of the power plants (Figure 11) is collected from the address in the regulator's power plant list which in some cases is adjusted by aerial imagery (Google, 2013; Microsoft Corporation, 2013) and provides the basis for additional spatial aggregation.

Table 8: Efficiency values based on installation year and fixed growth rates

[%]	Uranium	Lignite	Coal	Natural gas				Fuel oil		
Year	ST	ST	ST	CCGT	CB	ST	GT	CB	ST	GT
1950	-	28.0	30.0	-	-	33.0	25.0	-	33.0	25.0
1960	33.0	30.4	32.5	-	-	34.1	27.6	-	34.1	27.6
1970	33.0	32.8	35.0	-	40.0	35.2	30.2	40.0	35.2	30.2
1980	33.0	35.2	37.5	45.0	41.4	36.3	32.8	41.4	36.3	32.8
1990	33.0	37.6	40.0	49.5	42.8	37.4	35.4	42.8	37.4	35.4
2000	33.0	40.0	42.5	54.0	44.2	38.5	38.0	44.2	38.5	38.0
2010	33.0	42.4	45.0	58.5	45.6	39.6	40.6	45.6	39.6	40.6
2020	33.0	44.8	47.5	63.0	47.0	40.7	43.2	47.0	40.7	43.2

Source: Own assumptions.

Our dataset differentiates into combined cycle gas turbines (CCGT), steam turbines (ST), open cycle gas turbines (GT) and combi-block systems of steam and gas turbines (CB). The fuels are differentiated into uranium, lignite, hard coal, natural gas, oil, waste and other fuels. The efficiency of each power plant block is approximated by linear formulas based on the fuel/technology and the year of first operation (Table 8). Nuclear power plants are assumed to have an efficiency of 33% (EURELECTRIC and VGB PowerTech e.V., 2003). For waste and other technologies, considered as must-run, the efficiency value is neglected. For hydro pumped-storage plants, (PSP) assumptions on the storage size are added (Table 31) and the value 0.75 is used for the cycle efficiency.[14]

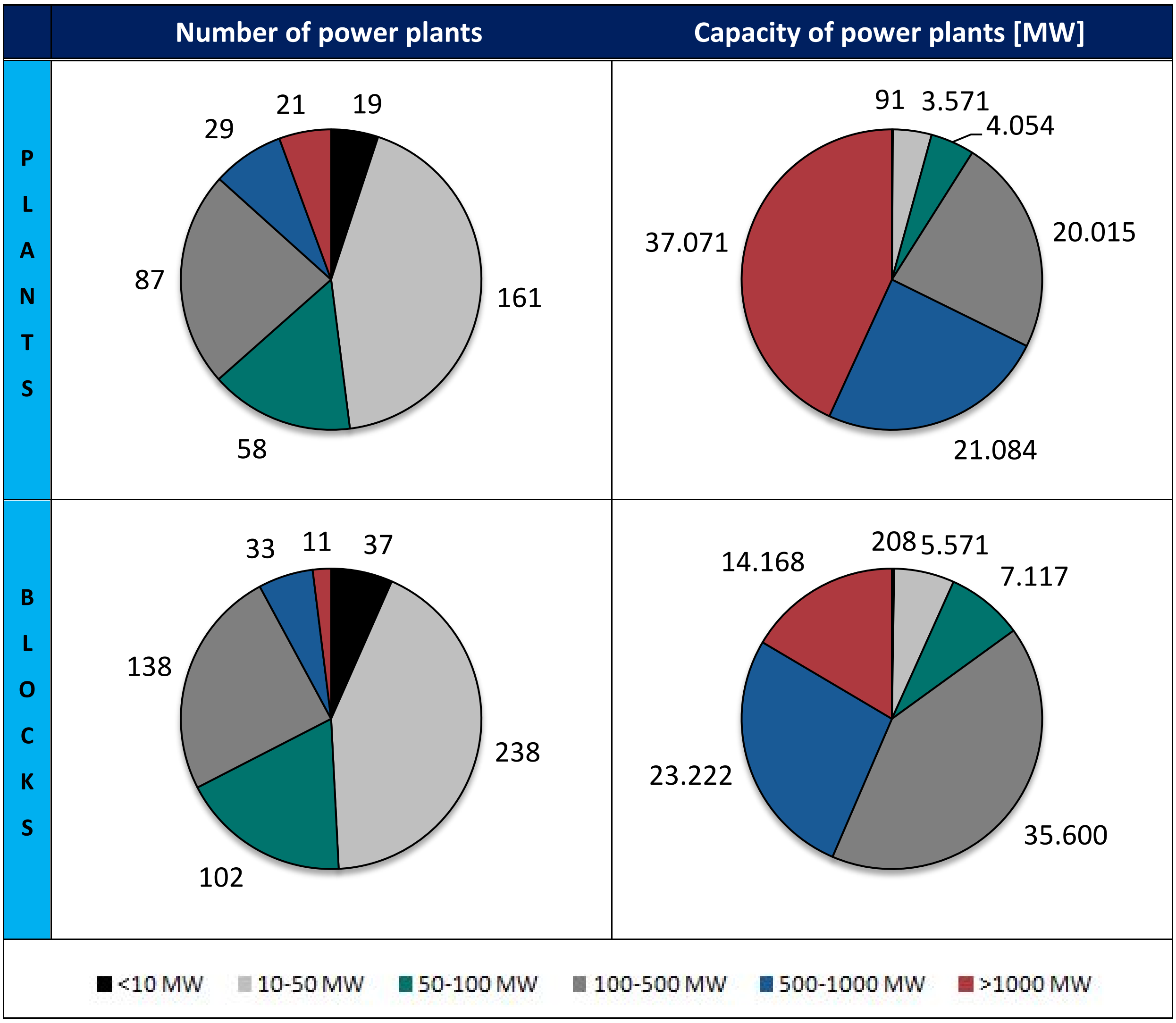


Figure 8: Comparison of number and capacity of conventional power plants [15]

Source: BNetzA (2013a) and Table 28 to Table 31.

[14] Additional information on technical parameters of the conventional power plants would still be very useful. They include efficiency values and turbine types (at least the information whether it is a gas, steam, or combined cycle turbine) and additional aspects like minimum generation level and must-run constraints. The availability factors of conventional power plants could be derived by the status reports of outages to transparency platforms. While technical outages can only be applied to represent a historic situation, the data also gives insight in the seasonal scheduling of revisions. Thus, our crude assumption on seasonal availability of conventional power plants could be replaced by more educated estimates.

[15] The presented figure includes all power plants of the BNetzA list with spatial information that are not included in the EEG data and excludes PSP, hydropower, and biomass plants.

EEG generation capacity

1. Capacities per ZIP code	2. Allocate ZIP areas to nodes	3. Table: Capacity per node
Allocate the renewable capacities per technology by ZIP code.	Application of Voronoi polygons for 220/380 kV nodes in QGis and cut layers.	Aggregation of ZIP code shares per node to capacity table (Figure 12).

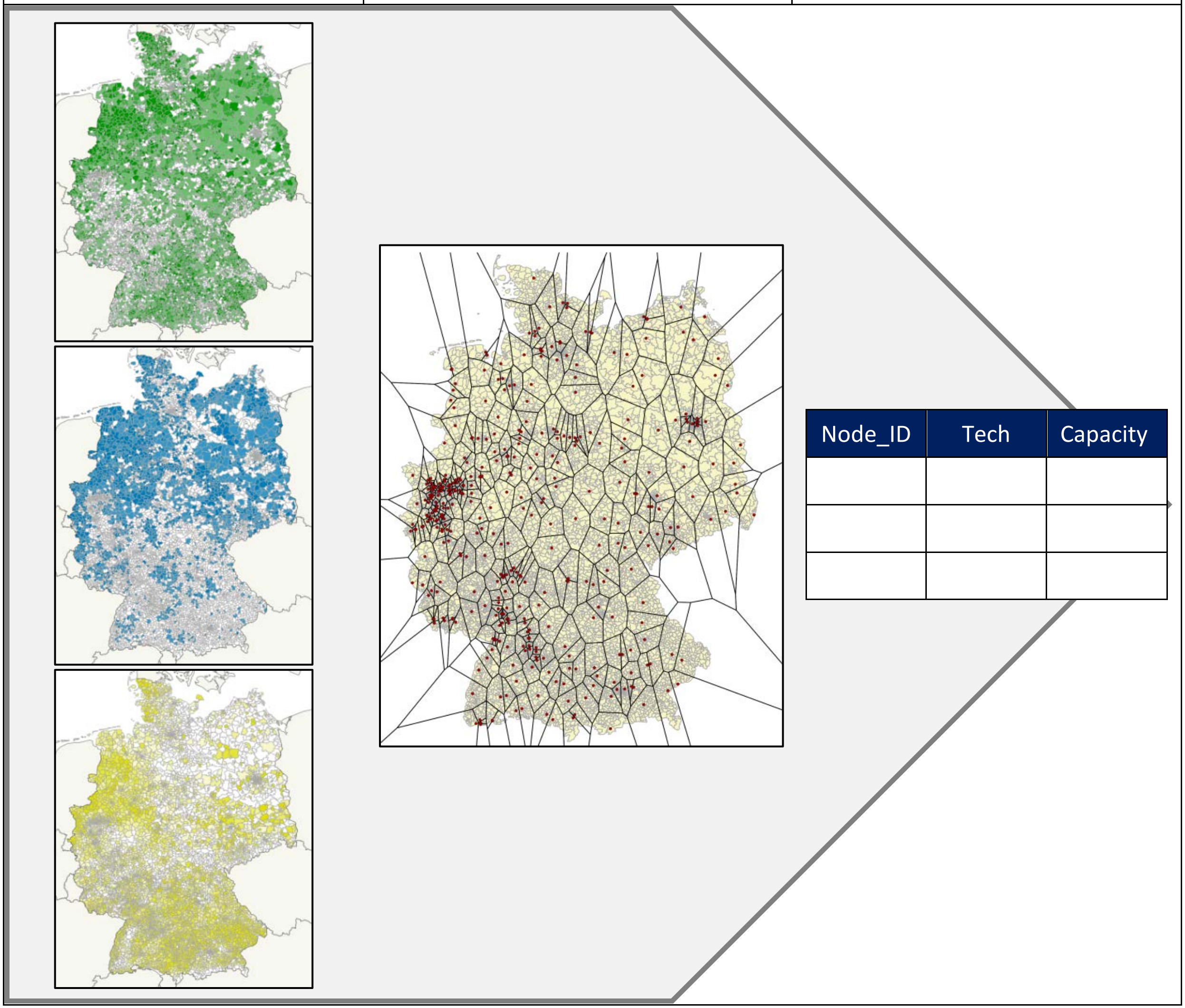
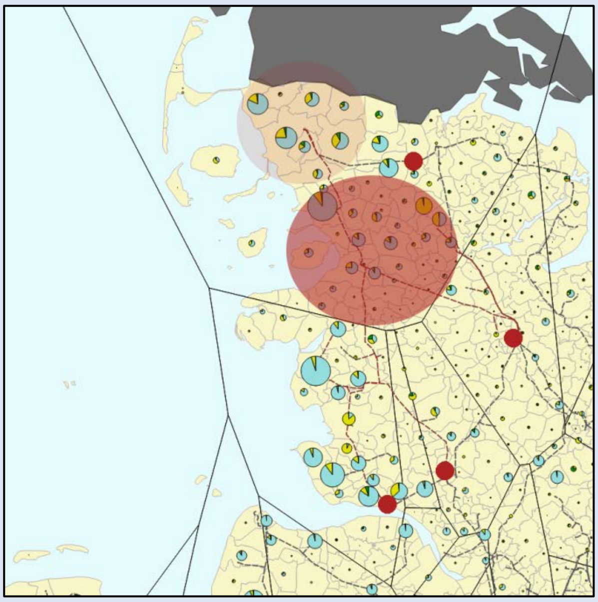


Figure 9: Data processing for renewable capacities in the EEG dataset

The largest remaining share of renewable generation capacity is included in the EEG dataset, which requires reporting of all installations in the scheme. We use the database ("EEG-Anlagenstammdaten") with the cutoff date of 31.12.2012 (50Hertz et al., 2013c) and trans-form the source data to an aggregated installed capacity for each ZIP code and technology.[16] This generation capacity is then connected to the closest transformer station of the high-voltage transmission network (Figure 9). Some hydropower and biomass plants outside the support scheme are included in the BNetzA list as individual power plants (Figure 7 and Table 31). Renewable fuels (and technologies) are biomass (ST), hydropower (RoR/Res), solar radiation (PV), wind power (On/Off), and geothermal (ST). Wind power is differentiated into onshore (On) and offshore (Off) wind and renewable hydropower into run-of-river (RoR) and reservoirs (RES).

Exception for the allocation of large-scale onshore wind in the north of Germany

Map of northern Germany	Description
	The map shows the Voronoi polygons for each network node, the allocation of renewable generation on ZIP code areas, the high-voltage nodes (four red dots), and the 110 kV network. The allocation of EEG data locates almost 2 GW (68% wind, 25% PV, and 7% biomass) to the most northern network node in Germany (red dot close to Denmark). Yet only two 220 kV circuits in both directions connect the node.

Considering the western location of most capacity (larger red circles) and the topology of the 110 kV lines it is likely that a significant share is transported in the 110 kV network to other connection points. Therefore we assume that 60% of the capacity is connected to the three other transformer stations on the map (40% center station and two times 10% percent to southern stations).

[16] The German renewable support scheme requires a data set (the so-called “Anlagenstammdaten”) with information on all installations. This data is published on a monthly basis by the TSOs and a final annual data set is prepared on an additional online platform (50Hertz et al., 2013c).

The consecutive pages provide a graphical representation of the processed generation capacities:

- Figure 10 illustrates the aggregated renewable and conventional generation capacity on a state level and for DENA zones;
- a disaggregation to the nodal level is presented for conventional (Figure 11) and renewable (Figure 12) capacities;
- statistics for all technologies aggregated to different levels are included in the Appendix (Table 26 and Table 27).

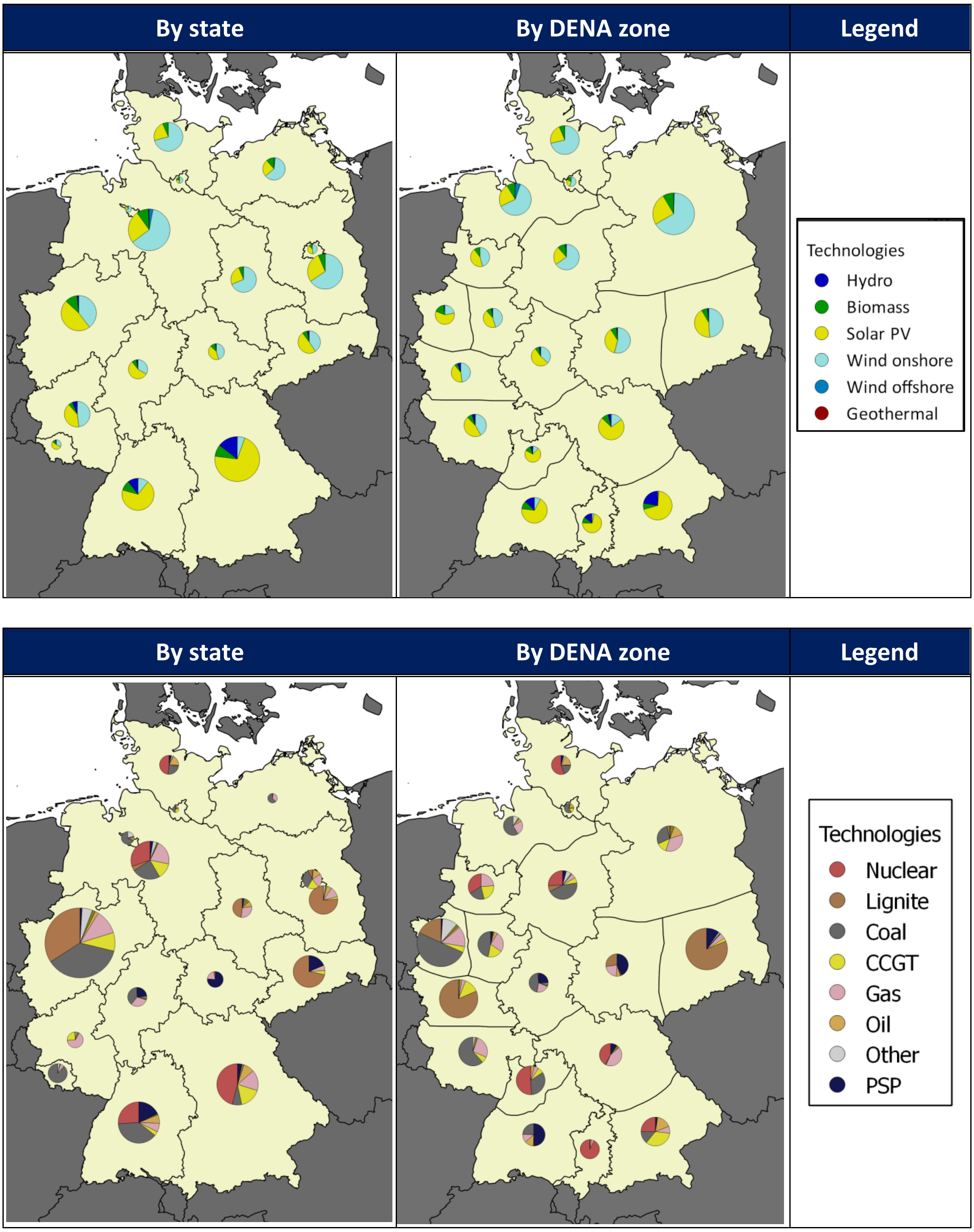


Figure 10: Aggregated renewable and conventional generation capacities[17]

[17] Aggregation by location of the plants for states and by location of the network node for DENA zones.

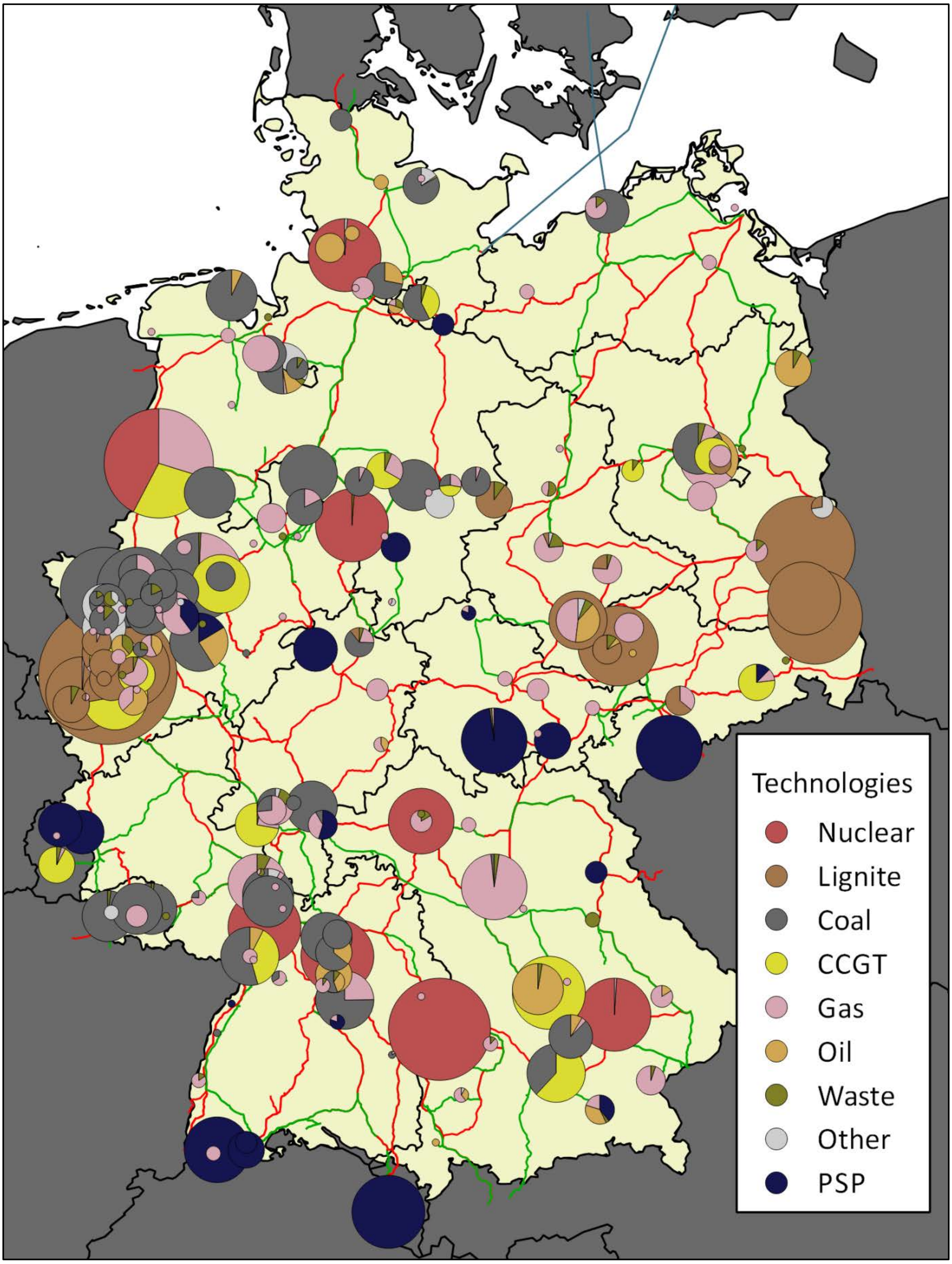


Figure 11: Conventional generation capacity on a nodal level

Source: Own illustration based on Figure 4, BNetzA (2013a), and collection of geo-data.

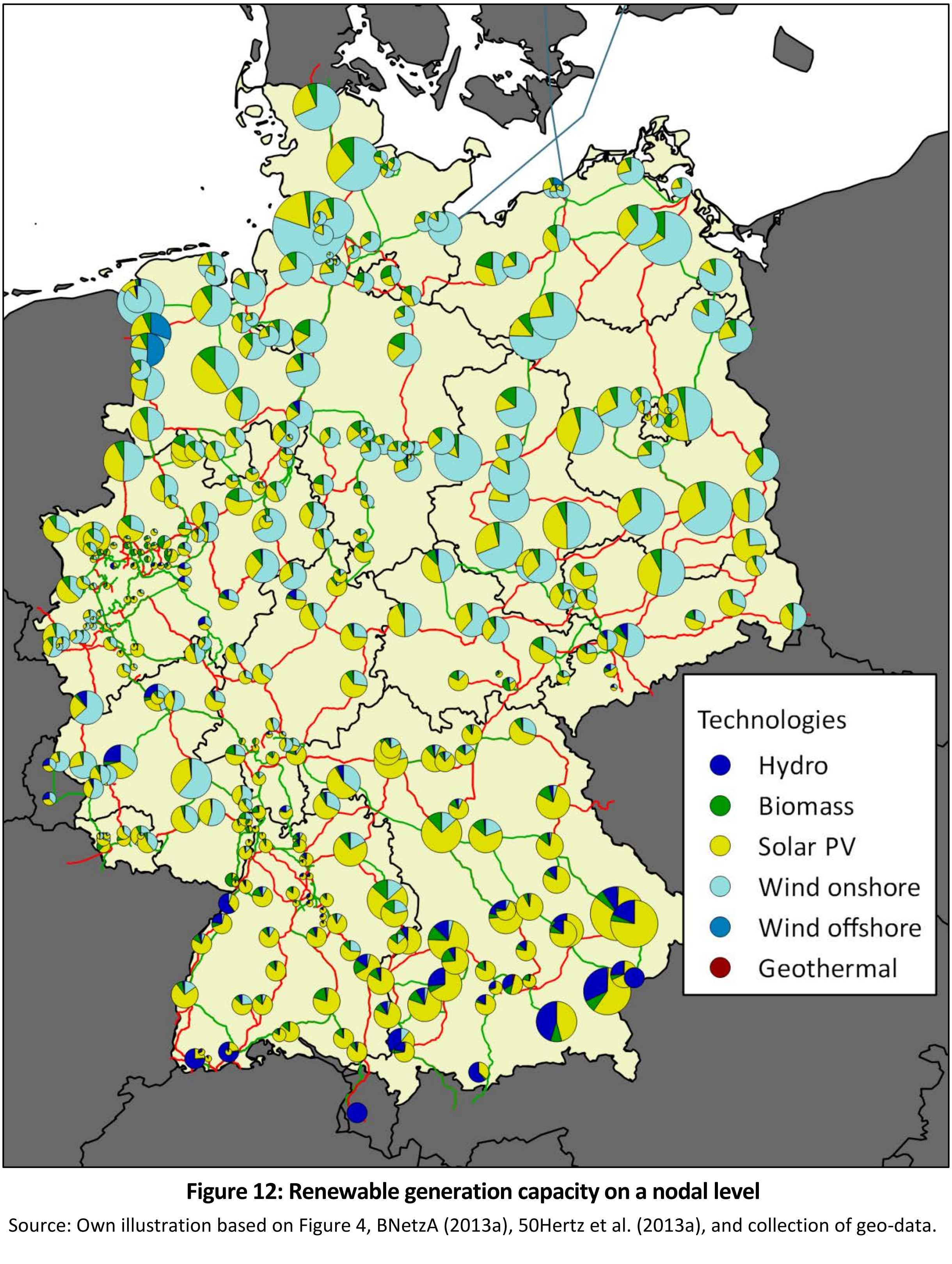


Figure 12: Renewable generation capacity on a nodal level

Source: Own illustration based on Figure 4, BNetzA (2013a), 50Hertz et al. (2013a), and collection of geo-data.

2.1.2.4 Electricity sector data for Luxemburg

The transmission system of Luxemburg is operated within the German system and cross-border flows are neither reported by the TSOs nor by ENTSO-E. Thus, the data for Luxemburg is referenced in this documentation. Depending on the application it can be reasonable to include the country into a model representing the German market. The data on Luxemburg has two additional nodes in the topology of the 220 kV network and two cross-border lines with Germany.

The hourly load for 2012 is available at ENTSO-E (2013b) and adds up to 6,327 MWh/year. We assume that the hourly values are allocated with 20% to the northern node (Flebour) and 80% to the southern node (Heisdorf) due to the higher concentration of population in the south. A generation capacity of 1,640 MW is considered (Table 9). The hydro pumped-storage plant Vianden (1,100 MW) which is connected to two 220 kV transformer stations in Germany together with the CCGT plant Esch-sur-alzette (375 MW) have the largest share. For the availability of wind and PV the availability factors of the closest region in Germany are applied.

Table 9: Information on power plants in Luxemburg included in the dataset[18]

Source	Power plant	Type Technology	Capacity [MW]	Year	Node
*	Vianden	Hydro PSP	1,100	See Table 32	
**	Esch-sur-alzette	Gas CC	376	2002	Heisdorf
***	Sidor	Waste ST	17	1985	Heisdorf
****	Wind aggregation	Wind onshore	45	-	½ in Heisdorf ½ in Flebour
	PV aggregation	Solar PV	41	-	
	Hydro aggregation	Hydro RoR	32	-	
	Gas aggregation	Gas GT	29	1990	

[18] Sources: *BNetzA (2013a), **Enipedia (2013a) and Power Plants Around the World (2013), ***Enipedia (2013b), ****Eurostat (2013b).

2.1.3 Time dependent electricity data

2.1.3.1 Generation cost

The variable costs of electricity generation are calculated for each power plant block from several parameters (Table 10):

- Resource price of the respective fuel (annual average and monthly price data);
- allowance price for carbon emissions (annual average and daily price data);
- efficiency value specific to the power plant block (Table 8);
- carbon intensity of the fuel;
- optional: variable costs for operation and maintenance (O&M).

The fuel costs are derived from the resource price (incl. 28.12 EUR/t SKE tax for fuel oil) divided by the efficiency value. For each carbon-based fuel we consider a carbon factor. The emission costs on net generation are calculated using the carbon factor divided by the efficiency value of the specific power plant block and are factored in with the emission allowance price. O&M costs could be considered but are often neglected in electricity market models because of the difficulty to distinguish between fixed and variable components. For power plants fired by hard coal fuel transportation costs are approximated depending on the plant's location (aggregated by DENA zone). The transportation costs are measured in EUR/t SKE and the values used in the fuel cost calculations are illustrated in Figure 13.

Table 10: Annual price data for 2012 and carbon intensity

	Price data		O&M**	Carbon factor
	[EUR/t SKE]	[EUR/MWh_{th}]	[EUR/MWh_{el}]	[t CO_2/MWh]
Uranium (estimate)	-	3.00	8.00	-
Lignite (estimate)	-	4.00	7.00	0.4000
Hard coal	93.00*	11.42	6.00	0.3600
Natural gas	264.00*	32.43	3.00 - 4.00	0.1872
Heavy fuel oil	422.12*	48.40	3.00	0.2664
Emission allowances	7.94 EUR/t CO_2			

Source: *Statistik der Kohlenwirtschaft e.V. (2013), **Schröder et al. (2012).

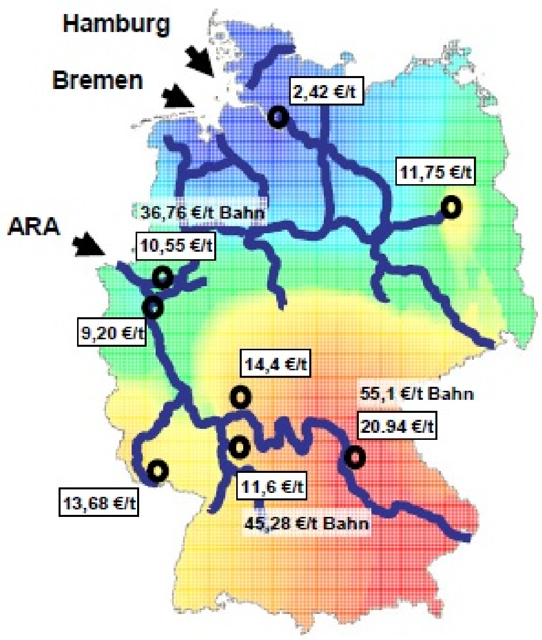
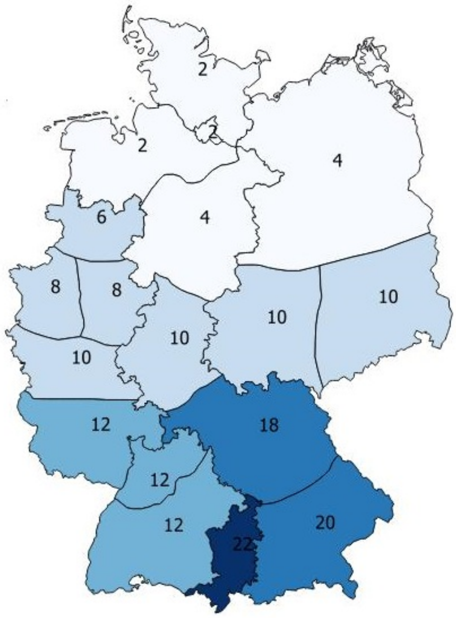
Study	Assumption on DENA zones (EUR/t SKE)
	

Figure 13: Spatial shipping costs for hard coal

Source: Frontier Economics and Consentec (2008).

The resulting merit order is illustrated in Figure 14. It includes all generation capacity of renewables and waste with the assumption of zero marginal costs.

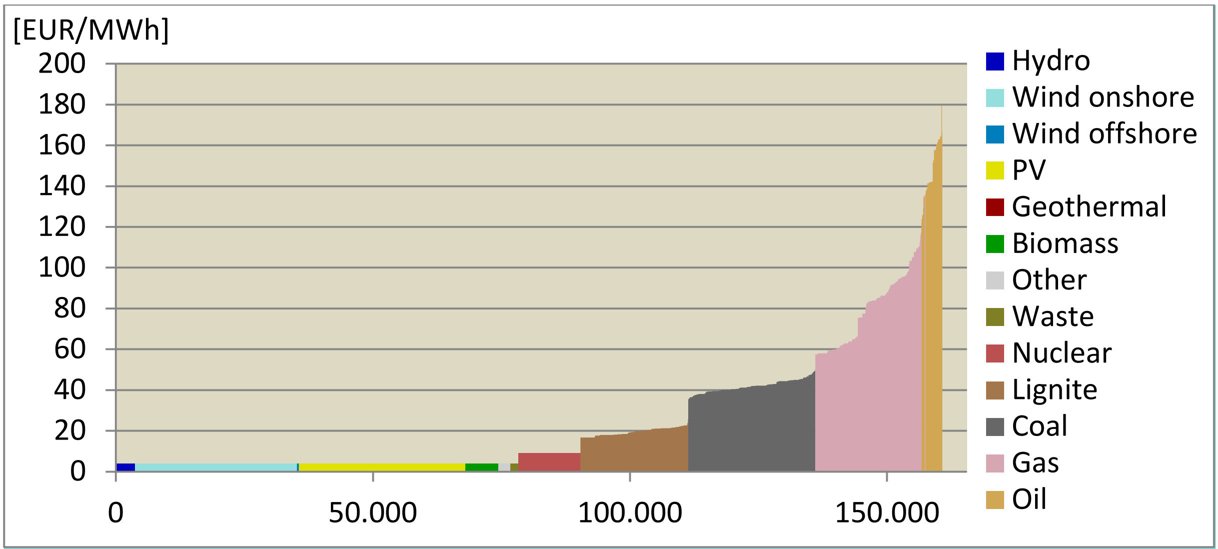


Figure 14: Merit order for the German electricity market with all capacities in 2012

Source: Own illustration.

Monthly data is available for fuel prices on hard coal, natural gas, and fuel oil. Figure 15 illustrates the significant price changes in 2012 between the highest and lowest monthly price of about 15% for hard coal, 5% for natural gas, and 24% for fuel oil. The yearly price assumption for uranium (3.00 EUR/MWh) and lignite (4.00 EUR/MWh) is not further specified, as no publically available data exists. Daily data is included for the allowance price of carbon emissions (Figure 16).

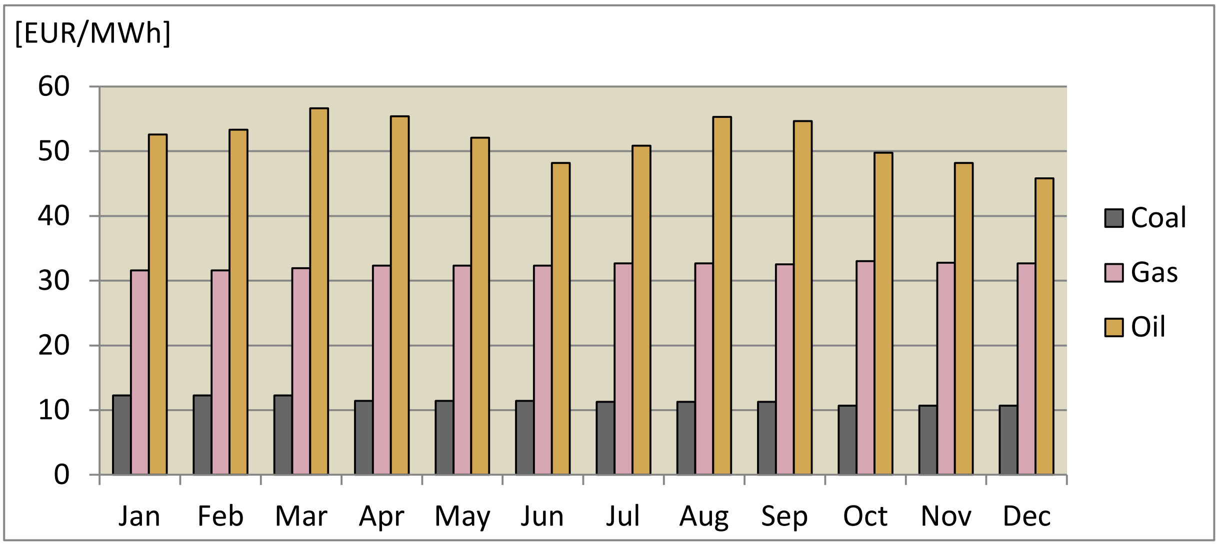


Figure 15: Monthly hard coal, natural gas, and fuel oil prices in 2012

Source: Statistik der Kohlenwirtschaft e.V. (2013), own illustration.

Figure 16: Daily futures price of 2013 emission allowances in 2012

Source: EEX (2013a), own illustration.

2.1.3.2 Cross-border exchange

German TSOs publish cross-border flows to their neighboring countries (50Hertz, 2013b; Amprion, 2013b; TenneT, 2013b; TransnetBW, 2013a).[19] The exchange flows with Sweden on the HVDC interconnector (Baltic cable) are not reported by the TSOs. Here hourly exchange values by ENTSO-E (2013c) are applied. The published exchange data is available for each TSO to the individual neighboring countries. It is therefore more detailed than the national ENTSO-E data but the statistics vary significantly.

The alternative to an exogenous trade parameter is an endogenous representation of the dispatch for the neighboring countries. Yet, modeling several countries at this level of detail would increase the model size and the data requirements significantly.

When fixed exogenously, the cross-border trade has to be included in the energy balance of the respective cross-border node (Table 11) as an additional source of load (export) or supply (import). The allocation is either to the cross-border node in the neighboring country (better network representation as cross-border lines are included, e.g. Laufenburg (CH) and St.Peter (AT)) or to the cross-border node within the German borders (slight reduction of the size of the dataset). Both options allow a realistic representation of physical exchange flows for the reference year 2012.

Further assumptions on the regional allocation of the reported imports and exports by the TSOs might become necessary. In case there is more than one cross-border network node for one TSO and neighboring country, the data does not provide any information on the distribution. The TSO 50Hertz is an exception as it publishes the cross-border flows in separate time series for its four individual cross-border connectors. For the other TSOs the import and export values are allocated to the network nodes according to the capacity of the cross-border lines (Table 11).

The data published by the TSO TenneT misses 642 data points of 15 minutes (160.5 hours) for every neighbor. The remaining data includes some data points with cross-border flows

[19] The financial trade flow results from implicit auctions in a market design with national price zones. To consider realistic physical flows in the nodal topology we have to use the reported physical flows measured for every 15 minutes. They significantly deviate from the financial trade flows.

exceeding the physical line capacity by large amounts. These hours occur only at specific days during the years. Thus we assume metering or reporting errors and limit the maximal flow to the physical line capacity minus a transmission reliability margin. The annual physical exchange flows in the dataset (except Luxemburg, which is endogenous to the model) are illustrated in Figure 17 for each neighboring country and TSO. They sum up to a total in imports of 35.6 TWh and exports of 51.0 TWh, leading to a surplus in exports of 15.4 TWh in 2012.

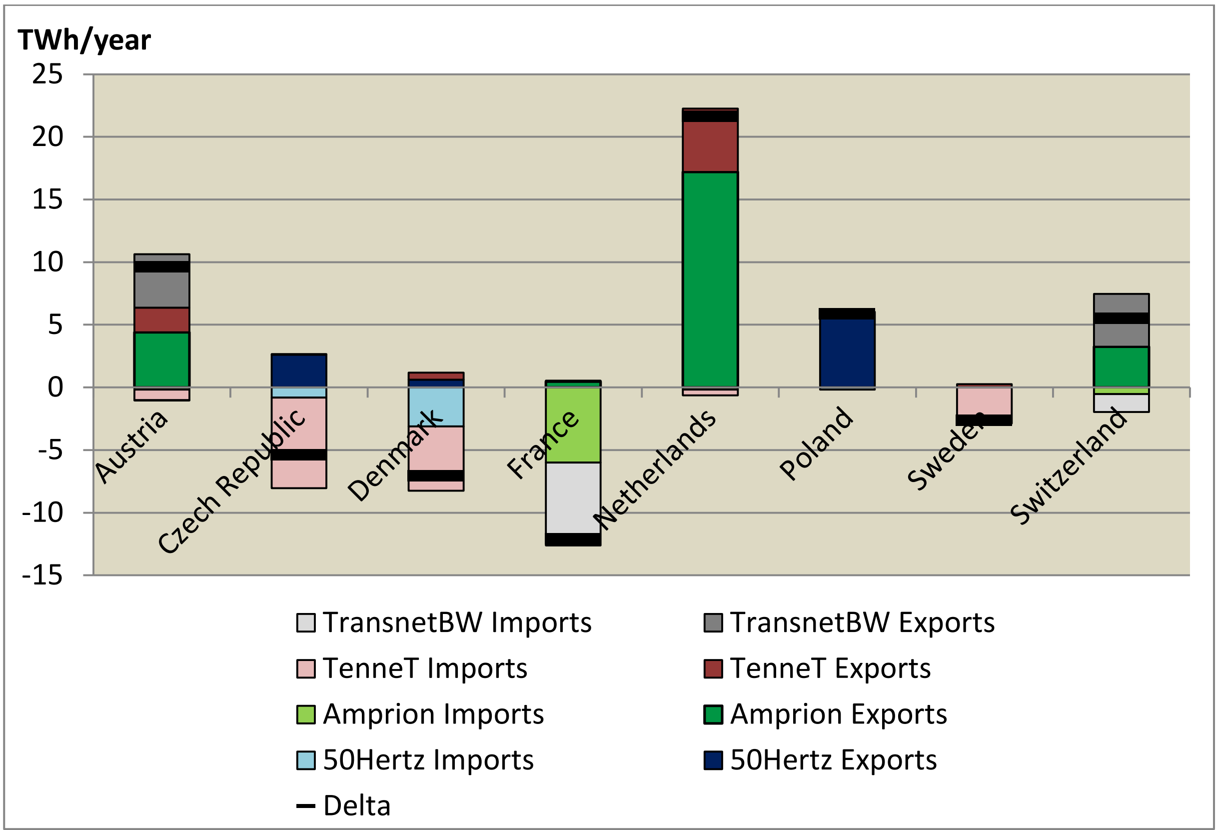


Figure 17: Annual imports (-) and exports (+) toneighboring countries in 2012

Source: 50Hertz (2013b), Amprion (2013b), TenneT (2013b), TransnetBW (2013a), ENTSO-E (2013c).

Table 11: Assumptions on flow allocation on the cross-border connections

TSO	Country	Node Neighbor	Node DE	Type	Capacity [MW]	Share [%]
50Hertz	Denmark	Bjæverskov	Kontek	DC	600	100
	Poland	Krajnik	Vierraden	2x 220 kV	980	100
	Poland	Mikulowa	Hagenwerder	2x 380 kV	3,400	100
	Czech Rep.	Hrader	Röhrsdorf	2x 380 kV	3,400	100
Amprion	Austria	Westtirol	Leupholz	1x 220 kV 1x 380 kV	490 1,700	50
		Bürs	Herbertingen Obermooweiler	1x 220 kV 1x 380 kv	490 1,700	50
	France	St.Avoid	Ensdorf	1x 220 kV	490	13
		Vigy	Ensdorf	2x 380 kV	3,400	87
	Netherlands	Hengolo	Gronau	2x 380 kV	3,400	50
		Maasbracht	Oberzier Siersdorf	1x 380 kV 1x 380 kV	1,700 1,700	50
	Switzerland	Laufenburg	Kühmoss Tiengen	3x 380 kV 1x 380 kV	5,100 1,700	80
		Beznau	Tiengen	1x 380 kV	1,700	20
TenneT	Austria	St. Peter	Pleinting Altheim Simbach Pirach	1x 220 kV 1x 220 kV 1x 220 kV 1x 220 kV	490 490 490 490	60
		Silz	Krün	2x 220 kV	980	40
	Czech Rep.	Hradar	Etzenricht	2x 380 kV	3,400	100
	Denmark	Node 220 kV	Flensburg	2x 220 kV	980	22
		Node 380 kV	Audorf	2x 380 kV	3,400	78
	Netherlands	Meeden	Diele	2x 380 kV	3,400	100
	Sweden	Kruseberg	Herrenwyk	DC	600	100
TransnetBW	Austria	Bürs	Herbertingen Dellmensingen	1x 220 kV 1x 380 kV	490 1,700	100
	France	Muhlbach	Eichstetten	2x 380 kV	3,400	50
		Sierentz	Laufenburg	2x 380 kV	3,400	50
	Switzerland	Asphard	Kühmoos Eichstetten	1x 380 kV 1x 380 kV	1,700 1,700	67
		Laufenburg	Trossingen	1x 380 kV	1,700	33

2.1.3.3 Availability of generation capacity

Unplanned non-availabilities (e.g. outages) and planned downtimes (e.g. revisions) affect the technical availability of conventional power plants. While unplanned outages are stochastic, the timing of revisions is determined by economic rationale, i.e. the seasonality of electricity load and market prices. In the current power system prices are lowest in the summer season. We therefore assume lower availability factors for nuclear and coal fired power stations in the summer and higher factors in the winter season (Figure 18).

The constraint for waste plants is set to a flat 65% availability with zero marginal costs to target the annual generation output. For technologies without specified fuel (e.g. steel works) a must-run constraint at 52.6% of installed capacity (13.6 TWh/year) is imposed.

In the current version we do not discuss the highly relevant interrelation between electricity and heat supply (district heat as well as heat and process steam for industrial consumers). Many of the hard coal and gas-fired power plants operate in combined heat and power (CHP) mode affecting the economic rationale. Yet the data requirements for implementing regional heat markets and pinpointing industrial CHP complexes are high, both at the analyzed spatial and time disaggregation.[20]

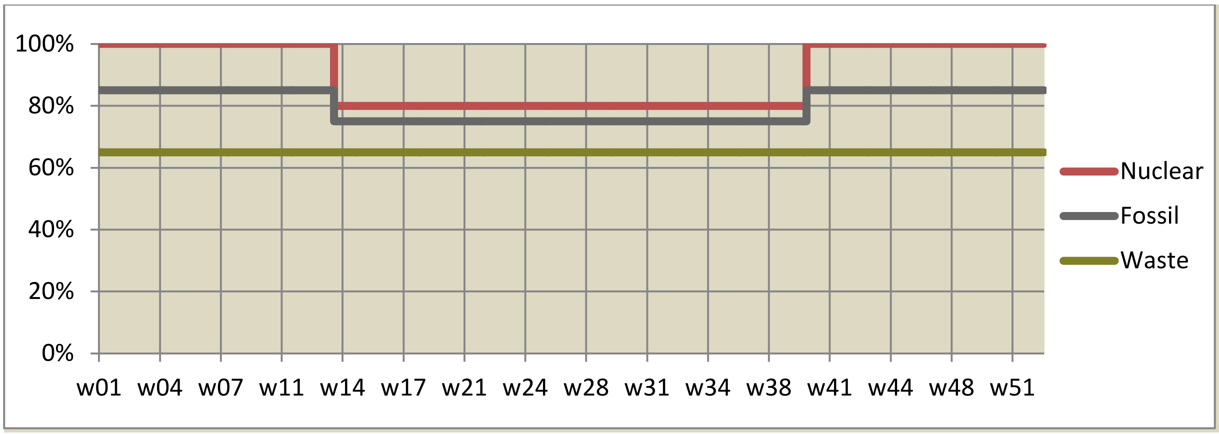


Figure 18: Availability factors for conventional power plants

Source: Own assumption.

[20] In addition, we are not aware of a promising public source which aggregates data, yet still provides sufficient information on a plant level for all of Germany.

For renewable generation technologies, the German TSOs publish time series for solar and wind feed-in on a quarter-hourly basis (Table 12). They can be allocated on a spatial level according to installed generation capacity per technology and node. For PV and wind the monthly capacity additions in 2012 have been considered by a factor on a national level for the calculation of the availability factors.[21]

Compared to the payments in the renewables support scheme (BMUB, 2013), the 2012 data by TSOs is too low for wind (+4.5 TWh) and too high for PV (-1.7 TWh). To adjust the time series for this deviation, we scale the data of wind and PV by a constant factor.

The availability factor for hydropower capacity is set to meet monthly generation levels in 2012 (BDEW, 2013c) putting them in a range between 60-80%. For biomass capacity the availability factor is set to 64.26% (36 TWh in 2012). Though geothermal is almost negligible we include it with a must-run constraint and an annual output of 25.4 GWh.

Table 12: TSO data sources for time series of solar and wind generation

	Wind generation	Photovoltaic generation
50Hertz	Onshore time series (50Hertz, 2013c)	Single time series (50Hertz, 2013d)
Amprion	Onshore time series (Amprion, 2013c)	Single time series (Amprion, 2013d)
TenneT	Onshore / offshore time series (TenneT, 2013c)	Five time series by federal state (TenneT, 2013d)
TransnetBW	Onshore time series (TransnetBW, 2013b)	Single time series (TransnetBW, 2013c)

[21] An alternative to historic feed-in values is the application of weather data, e.g. time series for wind speeds on spatial disaggregation.

2.2 Model Validation – Generation and Transmission in Germany (2012)

2.2.1 Model formulation

The dataset on the German power system of the year 2012 (chapter 2.1) contains all necessary information to run a DC load flow model on a nodal level for all 8,784 hours of this leap year. The applied model is closely related to the ELMOD formulation (Leuthold et al., 2012). An explanation of the equations, parameters, and variables is provided in the following.

Equations and explanatory text for the DC load flow model

$$\min cost = \sum_{p,t}\left(g_{p,t} * VC_{p,t}\right) \qquad \text{(Eq. 1)}$$

$s.t.$

$$g_{p,t} \leq Gmax_p * AvaC_{p,t} \qquad \forall p,t \qquad \text{(Eq. 2)}$$

$$r_{n,t} \leq \sum_s\left(Rmax_{n,s,t} * AvaR_{n,s,t}\right) \qquad \forall n,t \qquad \text{(Eq. 3)}$$

$$pspG_{psp,t} \leq GStor_{psp} \qquad \forall psp,t \qquad \text{(Eq. 4)}$$

$$pspD_{psp,t} \leq GStor_{psp} \qquad \forall psp,t \qquad \text{(Eq. 5)}$$

$$level_{psp,t} \leq LStor_{psp} \qquad \forall psp,t \qquad \text{(Eq. 6)}$$

$$level_{psp,t} - Eff\_PSP * pspD_{psp,t} + pspG_{psp,t} = level_{psp,t-1} \qquad \forall psp,t \qquad \text{(Eq. 7)}$$

$$d_{n,t} + pspD_{psp,t} = g_{p,t} + r_{n,t} + pspG_{psp,t} + netinput_{n,t} \qquad \forall n,t \qquad \text{(Eq. 8)}$$

$$f_{l,t} \geq -Cap_l \qquad \forall l,t \qquad \text{(Eq. 9)}$$

$$f_{l,t} \leq +Cap_l \qquad \forall l,t \qquad \text{(Eq. 10)}$$

$$netinput_{n,t} = \sum_{nn}\left(delta_{nn,t} * B_{n,nn}\right) \qquad \forall n,t \qquad \text{(Eq. 11)}$$

$$f_{l,t} = \sum_n\left(delta_{n,t} * H_{l,n}\right) \qquad \forall l,t \qquad \text{(Eq. 12)}$$

$$slack_n * delta_{n,t} = 0 \qquad \forall n,t \qquad \text{(Eq. 13)}$$

The objective function (Eq. 1) minimizes total variable generation cost (generation (g) times the plant specific variable costs (VC) summed up over all plants blocks (p) and hours (t)).

Power generation is bounded in the generation constraints (Eq. 2/3). Eq. 2 limits the hourly generation of conventional power plant blocks to the installed capacity ($Gmax$) multiplied by an hourly availability factor ($AvaC$). Renewable output (r) is limited (Eq. 3) in each node and hour by the sum over all renewable technologies (s) on their installed capacity at the specific node ($Rmax$) multiplied with their hourly availability factor ($AvaR$).

Pumped storage plants (psp) are described in Eq. 4-7. Their installed capacity ($GStor$) limits the variables for generation and pumping ($pspG$ and $pspD$) in Eq. 4/5. Storage is also constrained (Eq. 6) in its energy content ($level$) by the storage level ($LStor$). Eq. 7 defines the interperiod constraints. The storage level of one hour (t) depends on the usage of the storage, its cycle efficiency (Eff_PSP), and the level in the previous hour ($t-1$).

Network flows (including loop-flows) are implement with the DC load flow simplification (Schweppe et al., 1988). The positive and negative capacity (Cap) constraints (Eq. 9/10) set the lower and upper limits on the free variable line flow (f) for every line (l). The flow is also constrained (Eq. 11) by the sum over all nodes of the free variable flow angle ($delta$) times the network transfer matrix (H). The network transfer matrix reflects the physical network characteristics. To enforce unique solutions for the flow angles, the value for $delta$ is zero for one reference node enforced by a slack parameter not equal to zero (Eq. 13).

The energy balance (Eq. 8) includes generation, demand, and the network in-/outflows which depend (Eq. 12) on the flow angles and the physical network characteristics related to nodes (B).

These additional constraints in the DC load flow approach provide a more restricted solution space than transport models. As the flow allocation on individual lines relies on the entire network, line capacity might not be available in full extent due to constraint on other lines in the network. All variables are defined as positive variables unless stated otherwise.

2.2.2 Model results and comparison to historic data

The aggregation to annual numbers combines the results of 53 model runs in steps of one week. Every week relates to the time span from Saturday 0 a.m. to the following Friday midnight (168 hours per run). Pumped-storage reservoir levels are the only variables with interperiod constraints for the 168 hours of one model run. Storage content is assumed zero in the first and last hour of each run. The transmission reliability margin is set to 20% and quarter-hourly values in the dataset are aggregated to hourly values.

2.2.2.1 Generation results

Preliminary statistics on the annual net generation mix for Germany in 2012 (Table 13) have been significantly adjusted in the second half of 2013. Depending on the source the absolute values vary between 576.6 TWh and 591.5 TWh.[22] The feed-in payments of the renewable support scheme (BMUB, 2013) allowed for a more detailed picture on generated quantitities than the preliminary estimates. The final values on wind output are 10% higher (50.5 TWh instead of 46 TWh) while the numbers for PV are actually 6% lower than in the preliminary estimates (26.4 TWh instead of 28.0 TWh). With the preliminary numbers being in range of the data published by the German TSOs, the accuracy of the time series for wind and PV must at least be questioned, because the discrepancies require adjustment of the quarter-(hourly) availability factors to meet annual statistics (chapter 2.1.3.3).

For reasons of consistency we compare the model results to the numbers of the monitoring report 2013 (BNetzA, 2013b) with a generation mix consisting of 437.7 TWh/year in conventional and 138.9 TWh/year (24.1%) in renewable generation output. The discrepancy for renewable generation is negligible for the three final sources with only small differences in hydropower, wind, and PV generation. The higher conventional numbers (BDEW, 2013b) are indicated in the results (Figure 19). The availability factors of renewable generation are adjusted to meet the annual level of the BMUB numbers and we assume lower surpluses in electricity exports of just 15.4 TWh based on the TSO time series.

[22] For the system statistics we compared published data by AG Energiebilanzen e.V. (2013a, 2013b), (BDEW, 2013a), (BDEW, 2013b), (BMUB, 2013), and (BNetzA and Bundeskartellamt, 2013).

Table 13: Net electricity generation by fuel of the German electricity sector in 2012

	Generation in 2012 [TWh]			
Fuel	**BDEW 03/13[1]**	**Final BMUB[2]**	**Final BDEW[3]**	**Final BNetzA[4]**
Nuclear	94.2	-	94.1	94.2
Lignite	146.3	-	148.6	141.5
Hard coal	108.4	-	106.5	108.0
Natural gas	67.9	-	73.4	66.0
Oil	7.9	-	Incl. in other	4.6
Other fuels:	23.8	-	30.8	23.3
- Waste non-Res	* 4.0	-	-	3.7
- Pumped-storage	6.2	-	-	8.9
- Other fuels	* 13.6	-	-	10.7
∑ Conventional	448.5	-	453.4	437.7
- Waste Res	** 4.9	** 4.9	Incl. in biom.	3.7
- Wind	46.0	50.507	50.3	50.6
- Onshore	-	49.785	-	49.9
- Offshore	-	0.722	-	0.7
- Photovoltaic	28.0	26.380	26.6	26.1
- Biomass	* 34.9	** 38.650	40.2	34.7
- Hydropower	21.2	21.793	21.3	21.9
- Geothermal	0.03	0.025	-	-
- Other Res	-	-	-	1.8
∑ Renewables	134.1	138.7	137.7	138.9
∑ Net generation	582.5	-	591.9	576.6

Source: [1]BDEW (2013a), [2]BMUB (2013), [3]BDEW (2013b), [4]BNetzA and Bundeskartellamt (2013), *own assumption, and **gross values.

The model optimizes the operation of power plants towards the minimization of variable generation costs. It considers the spatial distribution of demand, the available generation capacity, as well as its variable generation cost, and the constraints imposed by the transmission network. The aggregated results for the generation quantities (Figure 19) are close to historic values (shaded bars indicate discrepancies in statistics of different sources).

- Other generation: Matches historic value by must-run availability;
- renewable and waste generation: The assumption of zero variable costs gives a strong incentive not to spill the available generation. Still, 19 GWh of renewable generation and 1 GWh of waste generation are spilled due to network constraints;
- nuclear power plants produce at the maximum capacity available. Their location at major nodes close to demand prevents shutdowns due to network constraints;
- lignite plants operate at the maximum of available capacity for most of the time. Yet, in hours with high renewable penetration especially the lignite plants in the eastern parts of Germany see some hours with reduced output (173 GWh);
- Coal, gas, and oil fired generation: In the dataset, the marginal power plant can be found in one of these technologies in the largest share of nodes and hours. Compared to historic levels, the model results exaggerate production fuelled by hard coal and does not use sufficient gas and oil power plants. CCGT (yellow bar in the gas model results) provides most gas generation in the model results.

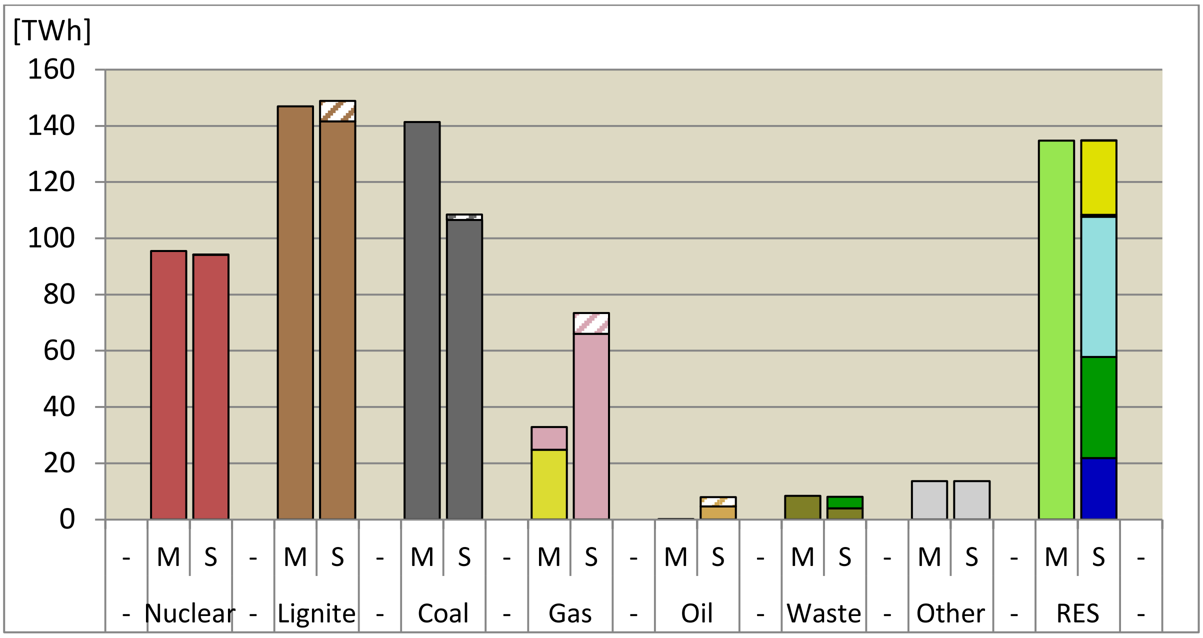


Figure 19: Generation quantities: Model results (M) compared to statistics (S)

2.2.2.2 Price results

With the nodal aggregation of the model application, the assumptions on market design, mainly the auctioning of scarce transmission capacity in the market dispatch, does not reflect the current uniform pricing scheme. In Germany only one common market price exists. The market prices from the day-ahead market are available from EEX and serve as point of reference for the model results.

The average hourly electricity price for Germany is calculated by nodal prices weighted by the hourly nodal demand levels. The comparison to historic spot prices (EEX, 2013b) shows model results with prices above the prices of the German day-ahead market for most hours.

The average price (equal weight per hour) is 58.90 EUR/MWh in the model application compared to 42.59 EUR/MWh in historic prices (Figure 20).

In part, the missing valuation of heat generation causes higher electricity prices as model results than experienced in 2012. Further price-relevant factors not considered are flexibility, uncertainty and the endogenous consideration of imports and exports.

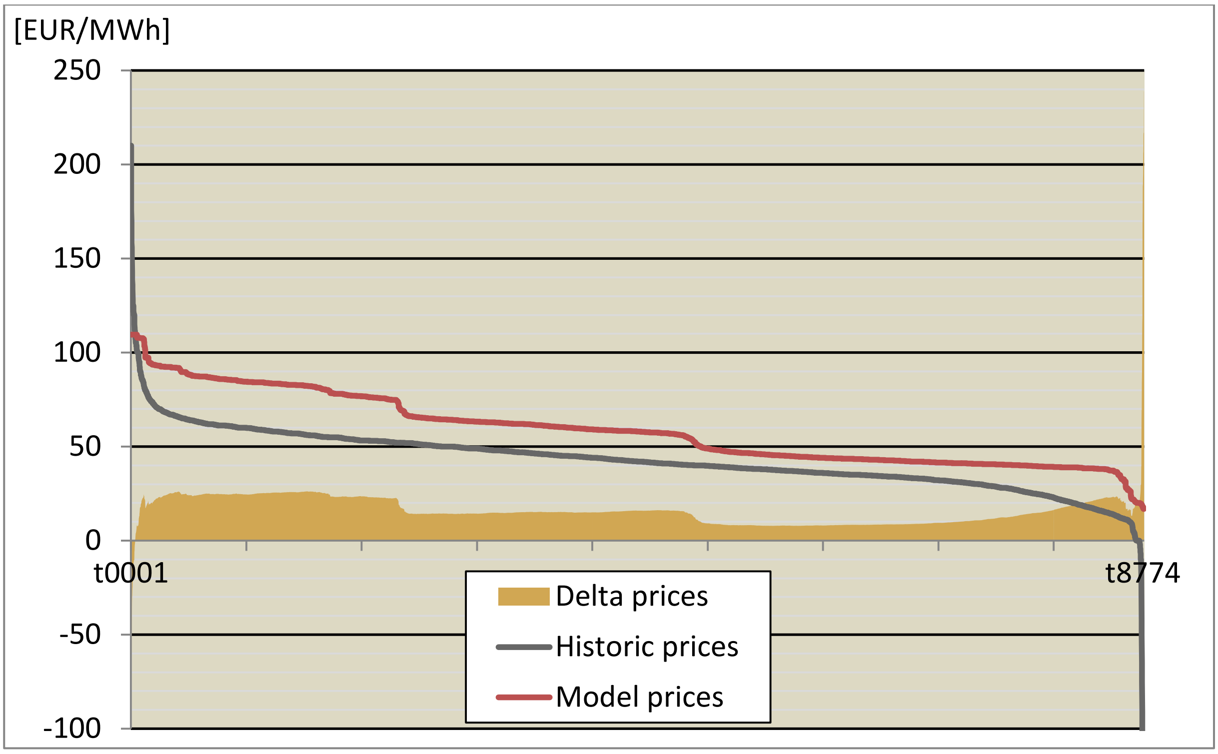


Figure 20: Price-duration curve with model results compared to historic price data

Source: Own depiction based on EEX (2013b) and own calculations.

2.2.2.3 Spatial results

The data on network operation and transmission flows are rare for most regions as the market design integrates internal transmission capacity in the market dispatch. Public data by TSOs is also very limited. BNetzA publishes aggregated information on re-dispatch measures in its annual monitoring report (Figure 21). In addition the open data availability on network flows is good for the TSO 50Hertz area. Historic network flows are available through an online platform (50Hertz, 2013b) for every hour. A detailed comparison of model results for individual transmission lines is not included within this Data Documentation.

The use of the model is not limited to the representation of a nodal pricing scheme. In addition, it can be used for uniform or zonal pricing calculations without a detailed consideration of the transmission network. In those cases an evaluation of the uniform or zonal pricing dispatch using the DC load flow approach shows possible violations of transmission line capacities by physical flows. To reach a feasible solution, the optimal required adjustments of the market result are calculated in a second step (Kunz, 2013; Neuhoff et al., 2013).

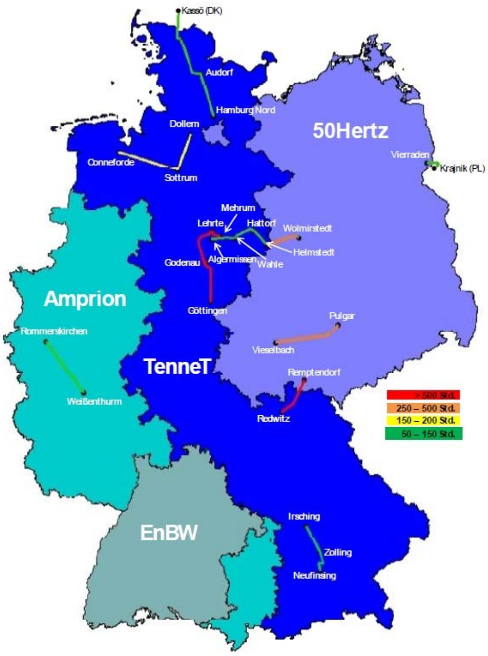


Figure 21: Network elements with more than 50 hours of re-dispatch measures

Source: BNetzA and Bundeskartellamt (2013), p.60.

This Data Documentation is limited to the nodal pricing application. We illustrate the detailed model results on a spatial level for specific hours. Thereby we highlight the nodal balance between supply and demand, the nodal prices, and the utilization of transmission lines (Figure 22). This model provides these results for every hour of the dataset. The specific hours represent the following system states:

- The average results over all hours (Figure 23)**.** This is not an average of input parameters but on the model results;
- The winter hour with the peak load and low renewable generation (Figure 24);
- a winter hour with high load, no PV and high wind generation (Figure 25) and one with low load, no PV and high wind generation (Figure 26);
- summer weekend with low load, very high PV, and low wind generation (Figure 27).

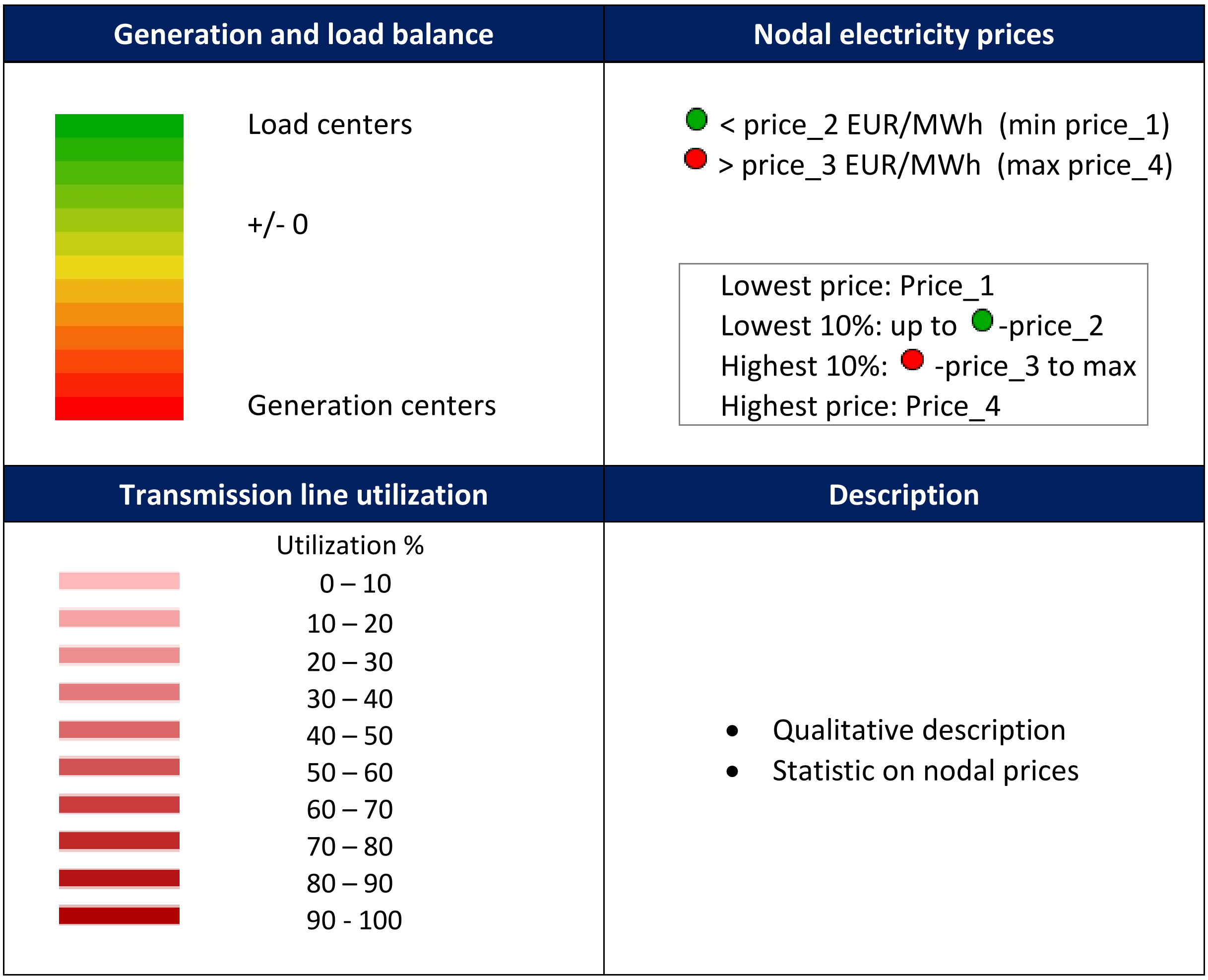


Figure 22: Legend for consecutive figures on spatial results

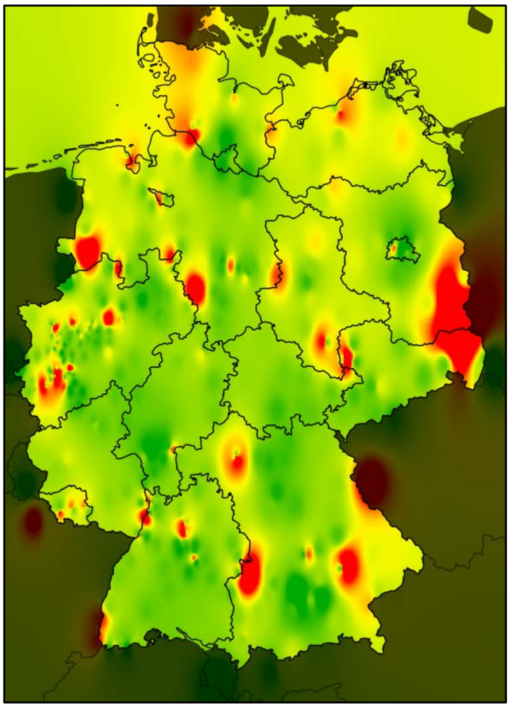
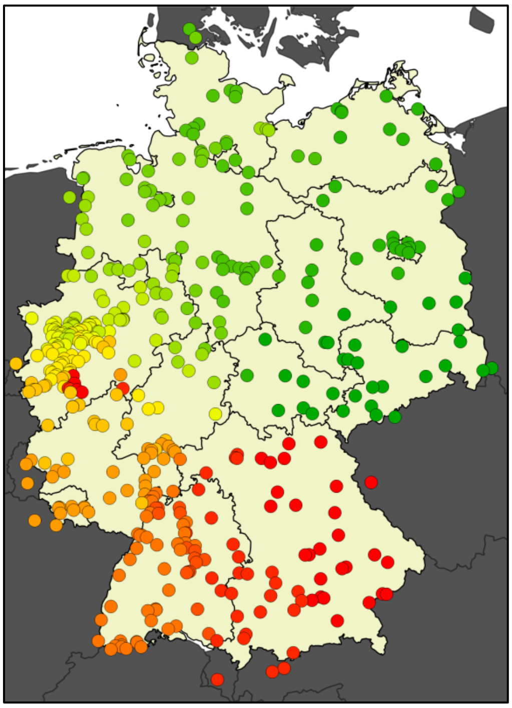
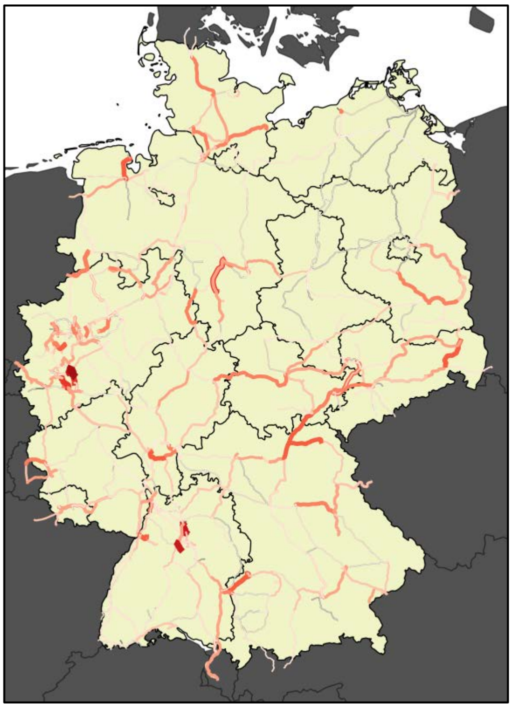
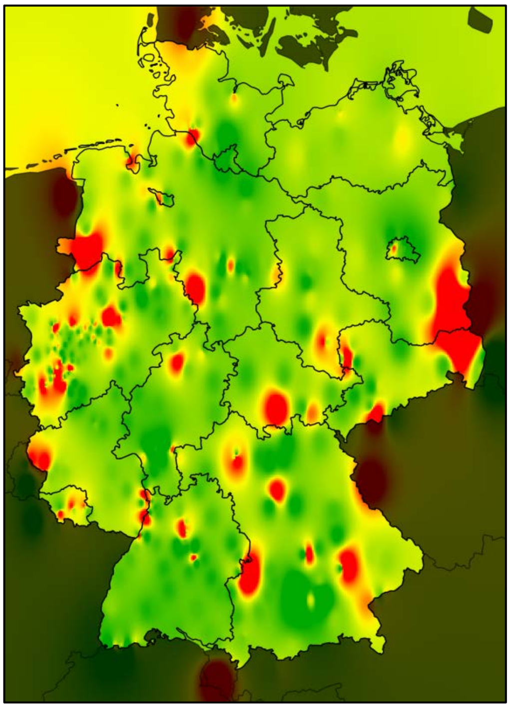
Average over all 8,784 hours	
Generation and load balance 	Nodal electricity prices 
Transmission line utilization 	Description Trade setting: imports from Scandinavia and France; exports to the Netherlands, Switzerland and western Austria; loop-flows from the northern Czech Republic and likely Poland to southern Germany. The average price difference is low. Lowest prices in the east. Highest prices in the south-east. Legend for the electricity price: < 58.08 EUR/MWh (min 57.74) > 59.24 EUR/MWh (max 60.25)

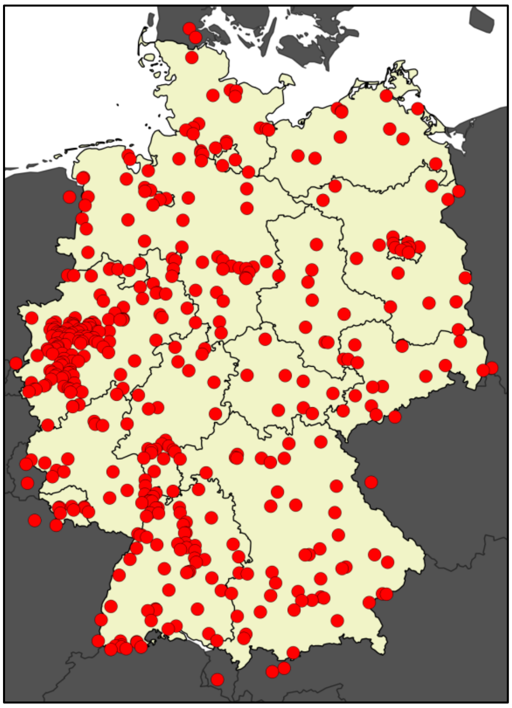
Figure 23: Snap shot of the system in average state of all hours

Peak winter demand and low renewable generation (08.02.2012 at 6 p.m.)

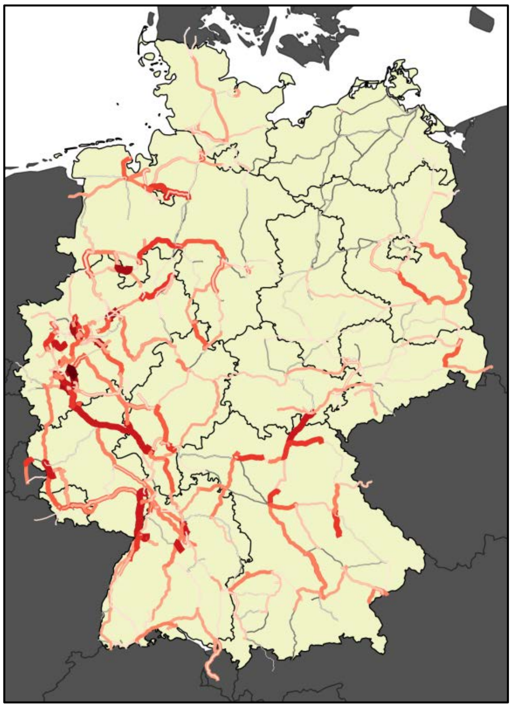
Generation and load balance



Nodal electricity prices



Transmission line utilization



Description

Trade setting: imports from Denmark, the Netherlands, and Western Austria. Exports France, Switzerland and Poland. Transit flows through the Czech Republic.

The generation is concentrated on the large conventional power plants. Network capacity is sufficient to retain one price in Germany, some lines in Southern Germany are well utilized.

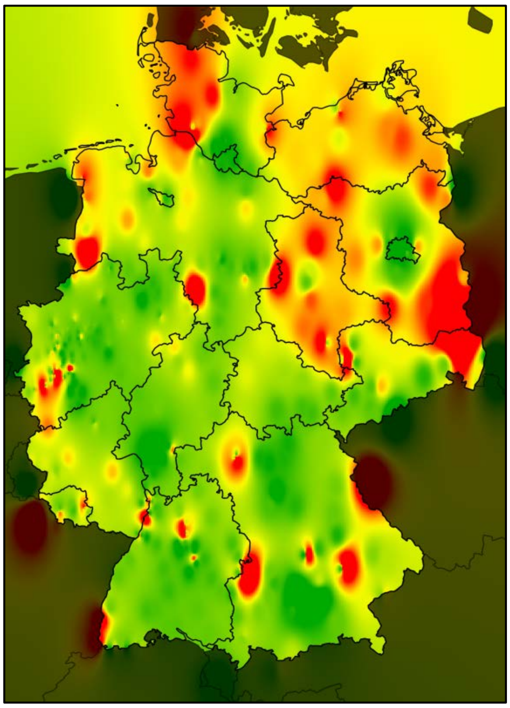
Legend for the electricity price:

● = 110.00 EUR/MWh (for all nodes)

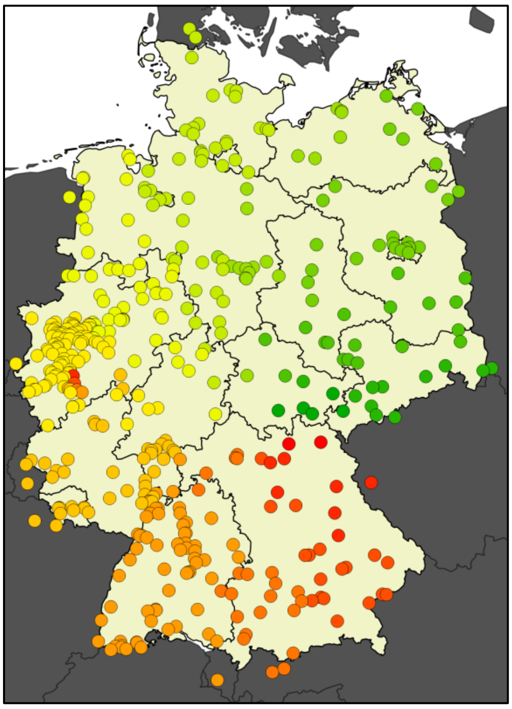
Figure 24: Snap shot of the system with peak load and low renewables

High winter demand, no PV, and high wind (03.01.2012 at 5 p.m.)

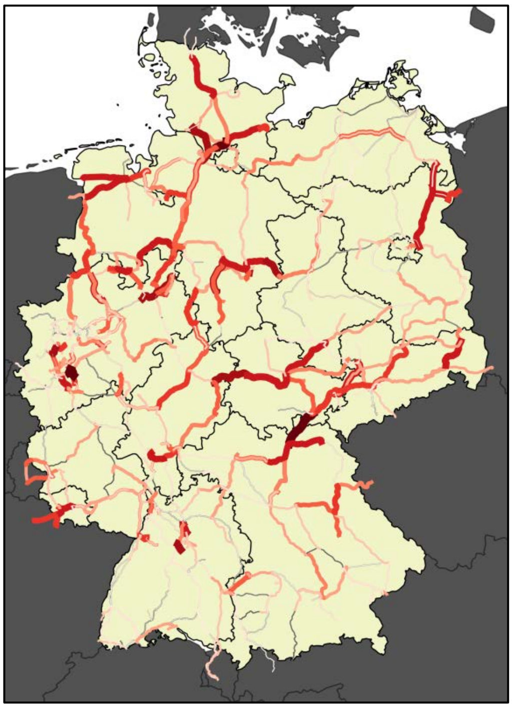
Generation and load balance



Nodal electricity prices



Transmission line utilization



Description

Trade setting: imports from Scandinavia and France; exports to the Netherlands, Switzerland and western Austria; loop-flows from the northern Czech Republic to southern Germany.

Surplus generation (mainly lignite) in the East causes bottlenecks towards Bavaria and a certain price spread between Western, Eastern, and Southern Germany.

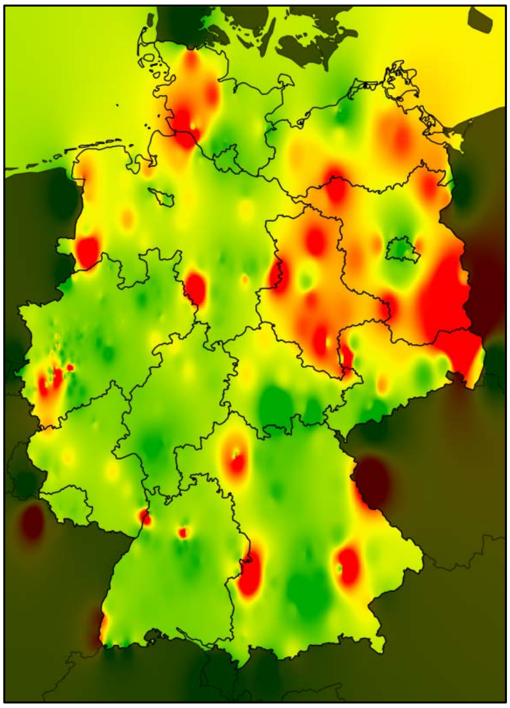
Legend for the electricity price:

- < 18.23 EUR/MWh (min 14.63)
- > 61.45 EUR/MWh (max 65.05)

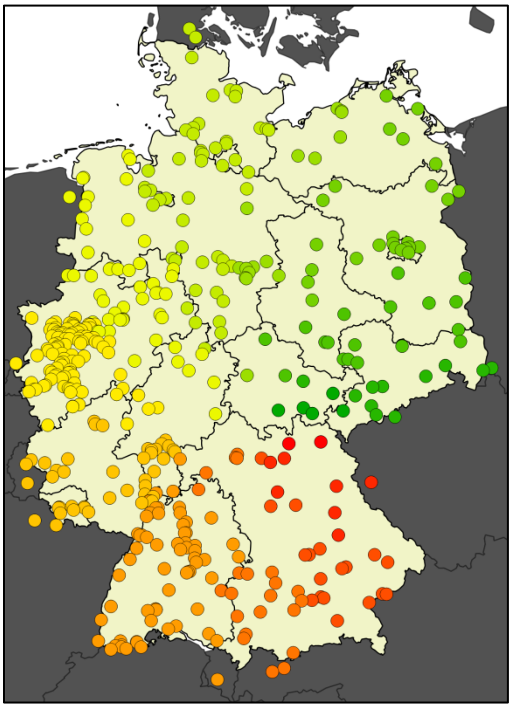
Figure 25: Snap shot of the system with high winter load and high wind generation

Low winter demand, no PV, and high wind (06.01.2012 at 2 a.m.)

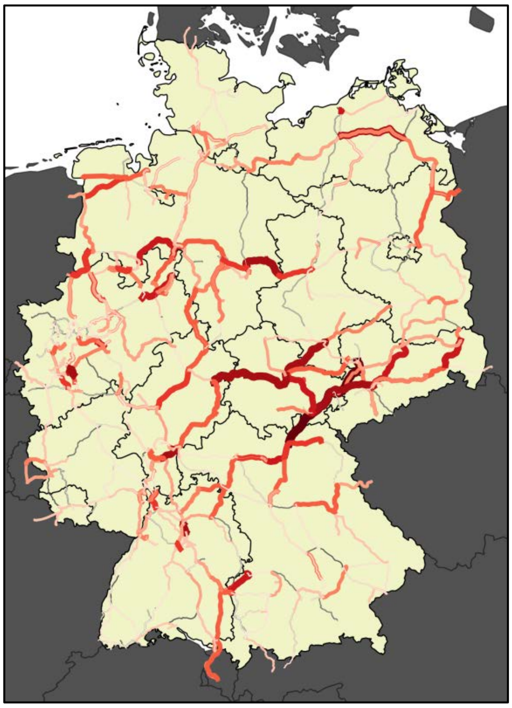
Generation and load balance



Nodal electricity prices



Transmission line utilization



Description

Trade setting: Exports to all countries exept France (imports) and loop-flows through the Czech Republic to southern Germany.

Surplus generation (mainly lignite) in the East causes bottlenecks towards Bavaria and a certain price spread between Western, Eastern, and Southern Germany.

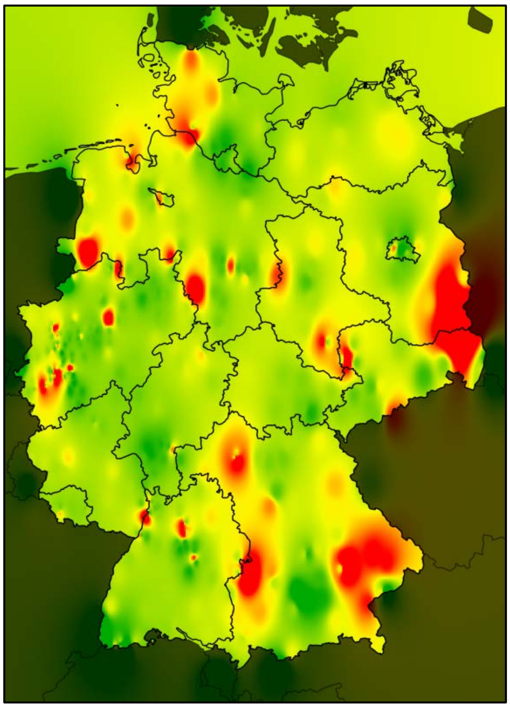
Legend for the electricity price:

- < 15.36 EUR/MWh (min 17.69)
- > 45.61 EUR/MWh (max 47.94)

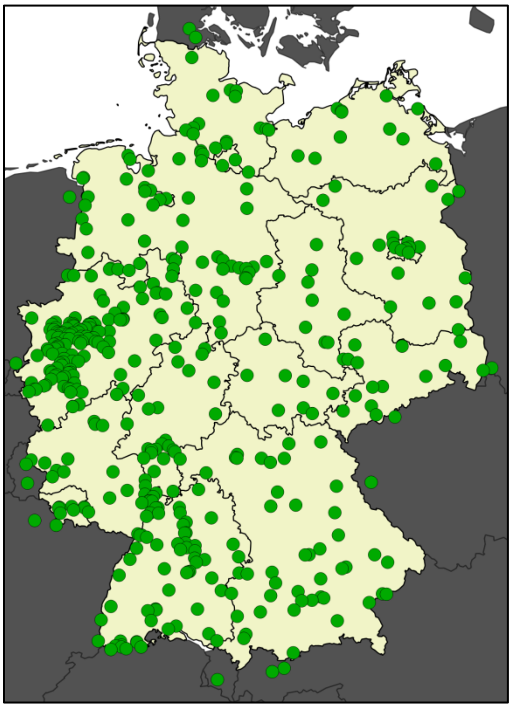
Figure 26: Snap shot of the system with low winter load and high wind generation

Low summer demand, high PV, and low wind (Sunday 12.08.2012 at 1 p.m.)

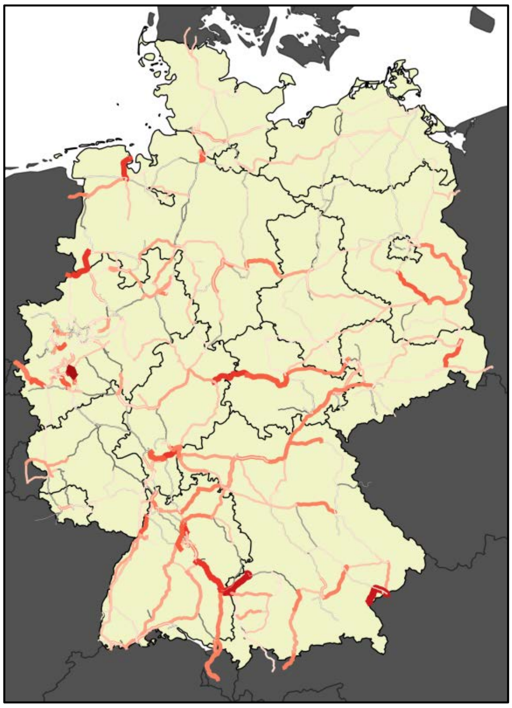
Generation and load balance



Nodal electricity prices



Transmission line utilization



Description

Trade setting: exports on almost all cross-border lines to neighboring countries except transit flows north to south through the Czech Republic.

The generation is more balanced with the availability of large PV capacities in the south. No bottlenecks occur in Germany and the nodal price is equal for the entire system.

Legend for the electricity price:

● = 40.67 EUR/MWh (for all nodes)

Figure 27: Snap shot of the system with low summer load and very high PV

2.2.3 Model limitations

On the network side, the DC load flow approach naturally only reflects approximated flows compared to the real AC flows. Also transformer blocks and the possibility of TSOs to switch transmission lines and thereby affect the network topology are not included. The n-1 criterion is only approximated by the transmission reliability margin. On the generation side, the linear character of the model does not allow to integrate on- and off-conditions for power plants, as no binary variables are available. Yet, technical limitations as the minimum generation level, ramping constraints and costs, and downtime requirements demand for this type of binary constraint. Regarding heat and power generation, additional heat output changes the economic rationale of the operational planning. Not considering CHP capacity certainly explains large shares in the discrepancy of the results. The heat sector has however locally specific constraints which are difficult to implement on a national scale with their spatial character.

2.3 Summary

This section has laid down the current availability of open data for the German power sector. It further describes the application within a techno-economic optimization model that has both a high spatial and a high temporal resolution. While some information (e.g. power plant data) has partly improved, information on network topology and technical characteristics of the system (on demand, transmission, and generation) is still kept private. Considering the public interest in the discussion related to the transformation of the electricity system and the related expansion of the transmission network this is surprising.

3 Europe

3.1 Electricity Data

3.1.1 Data sources

The dataset for the European electricity system is mainly based on the sources listed in Table 14. A particular challenge for the European system lies in the consistency: most data can be found on a European level (e.g. EUROSTAT) as well as on a national level which are not always consistent in their specification. Therefore, the current dataset concentrates on sources which cover most of the considered European countries. Beside the generation capacities which are provided by Platts and The Wind Power, all other data is publicly available.

Table 14: Data sources for the European electricity system

Institution	Type of data
ENTSO-E	- Transmission network map - Annual generation capacities - Time series on • Demand data (hourly) • Aggregated generation
European TSOs	- Transmission network maps
European Commission	- Annual fuel price data; in particular natural gas
EUROSTAT	- Annual generation - Regional statistical indicators
Energy exchanges (e.g. EEX)	- Price data e.g. on: • Natural gas, hard coal, oil • Emission allowances • Day-ahead market prices for electricity
PLATTS WEPP	- Generation capacities - Generation technologies - Rough locational information
The Wind Power	- Wind generation capacities - Locational information
Aerial Imagery	- Geographic information

3.1.2 Spatial electricity infrastructure data

3.1.2.1 High-voltage transmission network

The transmission network of the electricity market model covers the interconnected European network system. It includes continental European countries, the British Islands, Scandinavia, and the Baltic countries (including Estonia, Latvia, and Lithuania). For each of the countries, our network comprises the transmission network with a voltage of 220, 300, and 380 kV. For the case of Denmark, the 150 kV level is explicitly considered. Furthermore, direct current (DC) connections are included beside the alternating current (AC) network.

Generally, the transmission network is modeled by nodes and links. Nodes represent substations with generation and/or load connected to it. Links replicate transmission lines which connect different nodes to form a network. Links are characterized by the technology (AC or DC), voltage level, number of circuits mounted on the towers, length of the line, as well as their starting and ending nodes.

The topology of the European transmission network is derived from the ENTSO-E grid map (ENTSO-E, 2013a). However, the grid map gives a rather rough picture of the transmission network and does not provide sufficient information on the course of individual transmission circuits or connection of lines to substations in case of lines with different voltages. Therefore the dataset is updated to include more detailed data (e.g. SEPS (2013)). The final transmission network is depicted in Figure 28. This transmission network covers 3,216 nodes with either load or generation, or both connected to it. The nodes are connected via the AC transmission network through 4,987 transmission lines with a total of 6,610 transmission circuits covering four voltage levels. Additionally, 13 HVDC lines provide the possibility for interregional exchange, with the major parts of the lines being installed overseas.

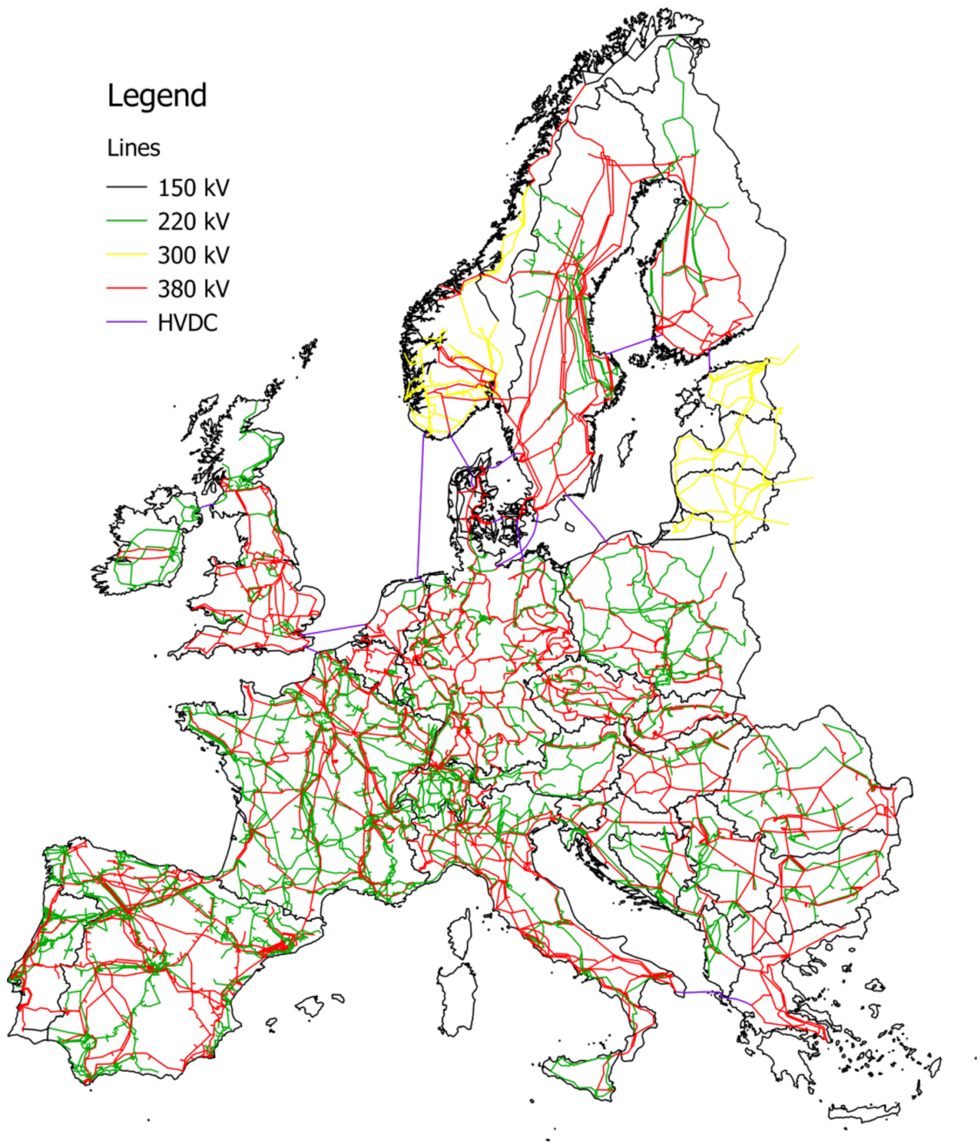


Figure 28: European transmission network

Source: Own depiction based on ENTSO-E (2013a) and own research.

In order to calculate the load flow on a transmission line, the electrical characteristics like resistance, reactance, and transmission capacity need to be specified. Generally, these parameters are specific to each transmission line. However, as there is no specific data available on a public domain, an approximation is applied for the resistance and reactance using specific electrical parameter from Kießling et al. (2001) and the length of the line. The same applies for the transmission capacity which depends on the voltage of the transmission line and the number of circuits. The technical parameters are depicted in Table 15.

Table 15: Technical line characteristics

Voltage [kV]	Specific resistance [Ohm/km]	Specific reactance [Ohm/km]	Thermal transmission limit [MVA]
150	0.176	0.41	140
220	0.075	0.40	490
300/380	0.029	0.33	1,700

3.1.2.2 Generation capacities

Generation capacities for the European network model are firstly distinguished between conventional and renewable sources. For conventional generation capacities power plants are considered individually, whereas for renewable sources regional aggregated generation capacities are defined without an explicit consideration of individual generators. The generation technologies used in the European version of the dataset are characterized by their primary fuel as well as the specifics of the generation process. Currently 20 generation technologies are specified (Table 16):

Table 16: Definition of generation technologies

Technology	Primary Fuel	Description
Nuclear	Uranium	Nuclear steam power plant
Lignite	Lignite	Steam power plant fired with lignite or subbituminous coal
Coal	Hard Coal	Steam power plant fired with anthrazite or bituminous coal
CCGT	Gas	Gas-fired combined cycle plant consisting of gas turbine(s) and steam turbine(s)
OCGT	Gas	Open cycle gas-fired plant consisting of gas turbine(s)
GasSteam	Gas	Steam power plant fired with gas
CCOT	Oil	Oil-fired combined cycle plant consisting of gas turbine(s) and steam turbine(s)
OCOT	Oil	Open cycle oil-fired plant consisting of gas turbine(s)
OilSteam	Oil	Steam power plant fired with oil
Reservoir	Hydro	Hydro storage or reservoir plant with natural inflows with storage potential

PSP	Hydro	Pump hydro storage plant without natural inflows
RoR	Hydro	Run-of-river power plant with natural inflows and negligible storage potential
Waste	Waste	Power plant fired with waste
Biomass	Biomass	Power plant fired with any kind of biomass/bioliquids/biogas
Tidal	Hydro	Tidal hydro power plant
Geothermal	Heat	Power plant using geothermal energy
Wind Onshore	Wind	Onshore wind turbine
Wind Offshore	Wind	Offshore wind turbine
Solar	Sun	Solar power plant mainly photovoltaic
CSP	Sun	Concentrated solar power plant

Conventional generation capacities

The database for conventional generation capacities is based on the World Electric Power Plant Database (WEPP) (Platts, 2013). The database contains 48,937 generation units in 28,512 power plants with detailed information on operating status, electricity type, generation type, fuels, ownership, etc. Due to the detailed information on power plants and their generation technology, an aggregation of generation units has been done to reduce the number of generation units entering the model, and to match the information on generation types with generation technologies considered in the dataset.

WEPP lists the generation technologies with a high level of detail by specifying the technology type, the main input fuel, and the type of fuel. In the current version of WEPP, 323 combinations of these three characteristics are used. In order to match the 323 generation technologies specified in WEPP with the 20 generation technologies, a mapping has been defined for each of the generation technologies. The aggregated generation capacity figures fit well with real capacity figures of ENTSO-E in 2011 (ENTSO-E, 2013d). Out of the 323 generation technologies, 10 could not be appropriately assigned. A problem in WEPP is the missing further classification of hydro generation technology into sub technologies as WEPP only differentiates between hydro and pumped-hydro storage.

In order to specify the location of power plants, WEPP only provides information on the city, state, and country, but no explicit GIS data. The geographical information of individual power plants is required to assign the power plants to the network nodes. Therefore, three steps are undertaken to get this information:

- the website CARMA.org (CARMA, 2013) provides information on geographical information for power plants. Using the name of the power plant a matching is conducted to receive additional information on the location for each plant and particularly the geographical coordinates. The CARMA website specifies that 12% of the worldwide listed power plants have accurate data and 70% have approximate data on geographical coordinates. Unfortunately, it is not directly possible to receive the information, whether location information is accurate or approximate;
- if no information on geographical information could be provided, approximate coordinates are taken from Google Earth using the name of the plant as well as locational information as input;
- in a last step, geographical information is achieved by a manual search process if either no information on the location could be found in the previous steps or if current geo information is obviously inaccurate.

Based on the previous steps of matching technologies and assigning geographical coordinates to generation plants, the final power plant list is constructed comprising generation units with a minimum generation capacity of 10 MW and assigned to the nearest network node using shortest distance as selection criterion. In the following model calibration, the location of plants is adjusted if serious local congestion arises. The finalized regional distribution of conventional generation capacities is depicted in Figure 29.

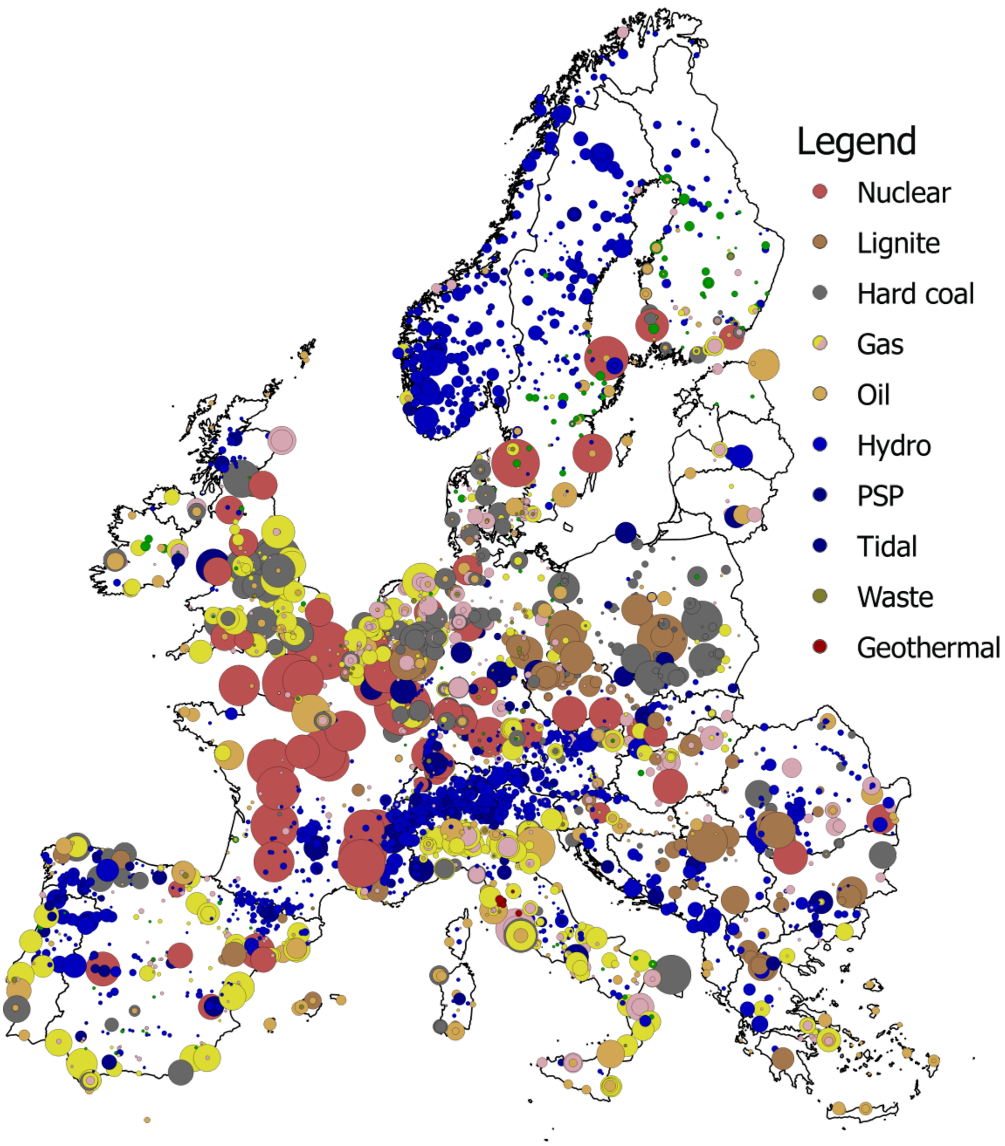


Figure 29: Regional distribution of generation capacities

The final power plant list consists of 4,724 power plants and an aggregated capacity of 760 GW, of which 732 GW are conventional, nuclear, and hydro-based generation technologies. ENTSO-E reports a total net generating capacity for their countries for the selected generation technologies of 765 GW (ENTSO-E, 2013d). Thus, comparing the total figure with the according capacity values of ENTSO-E indicates a representativeness of the dataset of 96%.[23]

[23] The ENTSO-E data does not represent the entire generation capacities for Germany and UK.

Table 17: Comparison of the generation capacities

Technology	Net capacity	ENTSO-E Net capacity	Representativeness
Hydro	169 GW	193 GW	88%
Nuclear	127 GW	127 GW	100%
Conventional	436 GW	441 GW	99%
Total	**732 GW**	**765 GW**	**96%**

Table 18: Generation capacities of European countries

[GW]	AL	AT	BA	BE	BG	CH	CZ	DE	DK	EE	ES	FI	FR	GR	HR	HU	IE	IT	LT	LU	LV	ME	MK	NL	NO	PL	PT	RO	RS	SE	SI	SK	UK	Sum
Nuclear	0	0	0	5,738	1,900	3,175	3,707	12,055	0	0	7,344	2,698	62,586	0	0	1,900	0	0	0	0	0	0	0	475	0	0	0	1,368	0	9,148	691	1,852	11,979	**126,616**
Lignite	0	0	1,332	0	3,672	0	6,884	20,222	0	0	2,455	55	2,262	3,925	0	1,010	0	0	0	0	0	207	736	0	0	8,884	0	5,314	5,197	0	447	513	0	**63,115**
Coal	0	1,248	133	1,544	1,727	0	1,299	26,205	4,247	0	7,423	3,056	4,558	0	312	0	851	9,538	0	0	0	0	0	3,884	0	20,722	1,747	1,845	95	274	115	154	26,429	**117,404**
CCGT	0	2,561	0	4,276	48	98	226	11,886	387	0	24,256	1,479	2,773	3,433	378	2,083	2,947	37,591	88	370	588	0	0	9,826	672	712	3,871	240	0	742	24	778	29,101	**141,435**
OCGT	0	663	0	1,137	104	139	522	4,574	585	0	2,065	1,010	2,841	305	60	857	615	6,757	22	27	12	0	0	2,531	529	38	215	15	94	253	312	153	2,425	**28,860**
GasSteam	0	788	0	883	446	19	12	9,128	1,435	193	383	438	1,125	548	71	1,907	750	7,288	1,426	29	235	0	41	3,197	0	17	11	3,452	141	204	12	211	2,131	**36,520**
CCOT	96	0	0	88	0	0	0	214	0	0	0	0	0	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	66	0	0	**720**
OCOT	0	21	0	175	0	38	63	2,120	453	0	450	529	1,775	112	92	220	312	219	0	0	0	0	0	83	131	0	555	52	0	1,373	62	13	1,668	**10,515**
OilSteam	199	992	49	603	90	34	12	2,257	571	2,712	3,466	702	5,854	576	984	21	710	10,706	778	0	0	0	202	20	11	532	1,186	1,476	287	1,594	21	0	3,355	**39,998**
Hydro	1,439	9,199	1,431	50	1,671	11,707	827	2,800	0	0	10,899	2,668	17,758	2,303	1,798	42	200	13,122	101	0	1,512	667	587	26	26,992	599	5,318	5,821	2,127	15,374	909	1,526	1,448	**140,924**
PSP	0	2,003	441	1,205	1,014	1,408	1,145	6,470	0	0	4,005	0	4512	615	276	0	292	5,693	800	1,100	0	0	0	0	818	1,466	972	0	614	430	185	854	2,950	**39,268**
Tidal	0	0	0	0	0	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**240**
Waste	0	52	0	181	0	259	0	1,381	179	0	146	0	519	0	0	24	0	421	0	15	0	0	0	433	32	0	77	0	0	186	0	17	380	**4,303**
Biomass	0	233	0	353	0	23	12	712	452	49	393	2,840	144	35	0	134	394	673	0	0	0	0	0	128	0	37	136	0	0	1,883	0	0	324	**8,952**
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	845	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**845**
Sum	**1,734**	**17,760**	**3,387**	**16,234**	**10,673**	**16,899**	**14,708**	**100,024**	**8,309**	**2,953**	**63,284**	**15,475**	**106,946**	**11,852**	**3,970**	**8,199**	**7,072**	**93,108**	**3,214**	**1,541**	**2,346**	**874**	**1,566**	**20,603**	**29,186**	**33,007**	**14,087**	**19,583**	**8,555**	**31,460**	**2,845**	**6,072**	**82,189**	**759,715**

Renewable generation capacities

Non-dispatchable renewable generation sources, of which wind and solar power are of particular interest, are included in the model. These technologies are considered separately as they are not explicitly included in the detailed power plant list due to their small-scale and diversified character. Thus, the methodology on deriving regionally distributed generation capacities is explained subsequently for wind and solar capacities. Biomass capacities are currently only considered if they are included in the power plant list. Therefore, any kind of distributed small-scale biomass generation is neglected in the model.

Wind generation

The data on wind generation required for modeling comprises two elements: first, the geographical distribution of wind generation capacities and second, the nationally installed capacity for a specified year.

In order to derive the geographical distribution, we use data obtained from The Wind Power (2011). This data includes information on the location of individual wind farms as well as their installed capacity. Using the locational information, we can assign individual wind power turbines to the nodes of the transmission network using the shortest-distance method. This gives us a share of wind generation capacitiy located at each node within the European transmission network. However, as the total national reported capacity for wind generation diverges from the wind farm dataset, we only extract the relative share in order to obtain the regional distribution for each European country. With regard to the aforementioned divergence, national wind generation capacities for 2011 are obtained from yearly statistics (EWEA, 2012). Table 19 lists the wind generation capacities for the considered countries. The regional distribution of wind generation is depicted in Figure 30. As can be seen, the largest amounts of wind capacities are located in Germany, Spain, Denmark, and the United Kingdom.

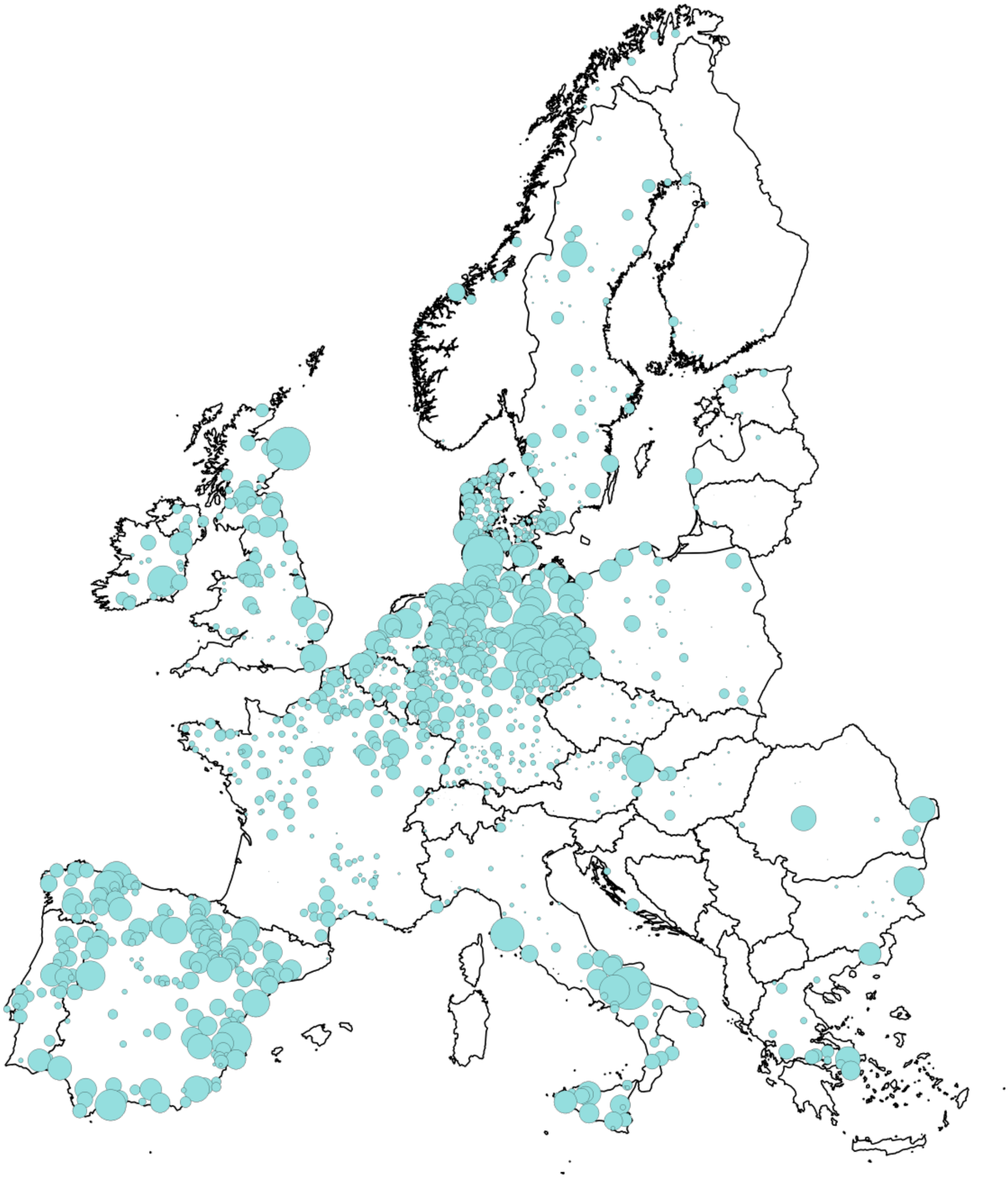


Figure 30: Regional distribution of wind generation capacities

Solar generation

For solar generation capacities, a modified approach is applied. Firstly, a geographical distribution is specified and secondly the relative distribution shares are accounted with national solar generation capacities to derive regional solar capacities.

As information on solar capacities on a regional European level is not available, an alternative approach is chosen to proxy the regional distribution of capacities: it is assumed that the share of solar generation depends on the geographical size of the regional area valued with the solar potential on a NUTS2-level (ESPON, 2010). The following formula approximates the regional solar share that is installed at each node n in the network.

$$Solarshare_n = \frac{\left(\frac{Potential_{NUTS2(n)}}{AvgPotential_{Country(NUTS2(n))}}\right)^2 Size_{NUTS2(n)}}{Size_{Country(NUTS2(n))} * \sum_{nn \in NUTS2(n)} nn}$$

The solar share is then adjusted by an additional weight to ensure that the sum of all shares per country equals 1 (the current approach represents a first approximation, and a verification of the described proxy is necessary).

Given the regional distribution of solar generation capacities, national solar capacities for 2011 are based on reported values from EPIA (2013). Table 19 lists the solar generation capacities for the considered countries. The regional distribution is depicted in Figure 31. As can be seen, Germany and Italy show the highest installed capacities among the European countries.

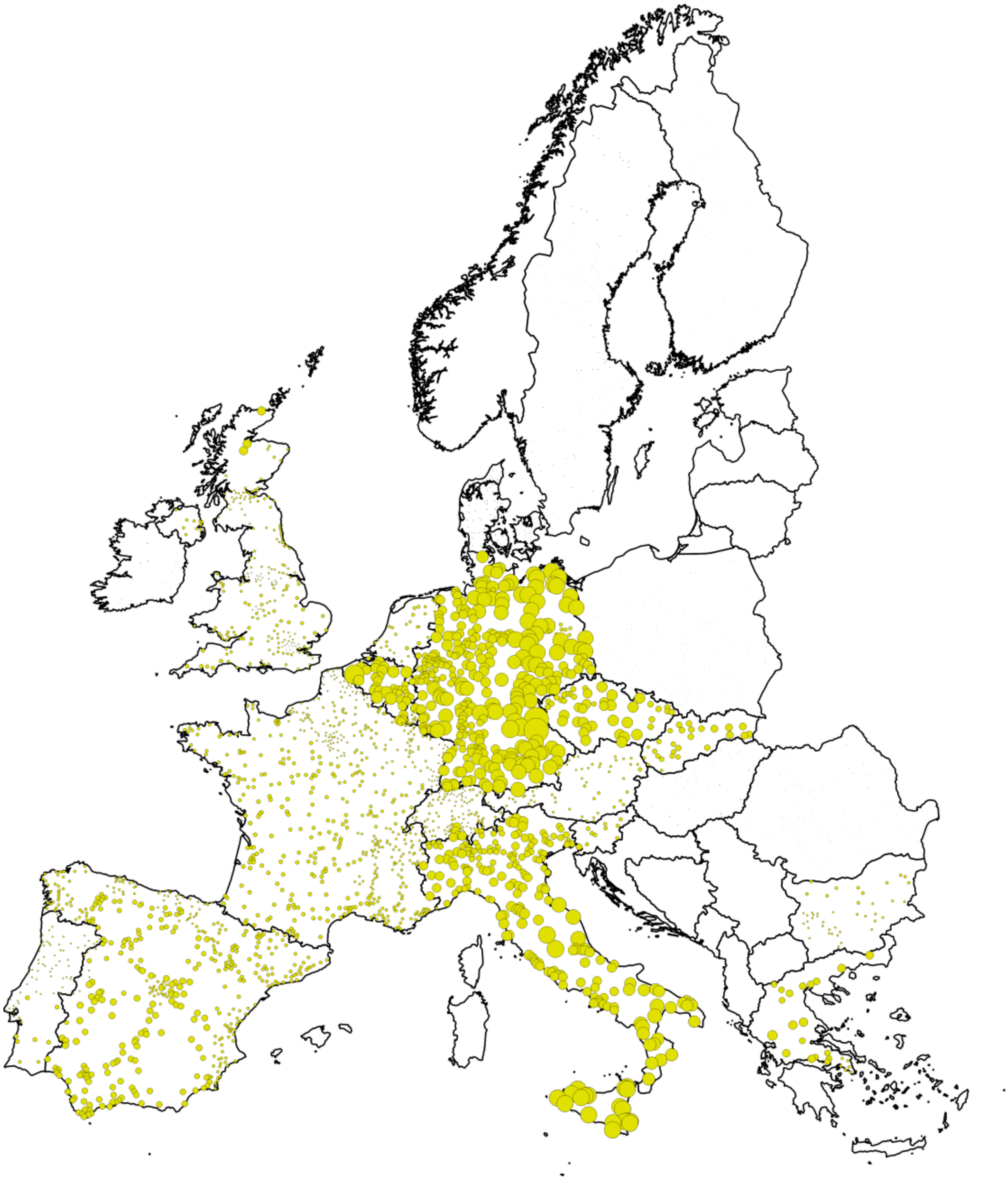


Figure 31: Regional distribution of solar generation capacities

3.1.2.3 Electrical load

Electrical load represents the demand for electricity by industry, services, and households. Publicly available data on electrical load comprises national annual values on consumed electrical energy for the different demand types and hourly load values on a national, but not on a regional or nodal level. Thus, further information and adjustments are required to proxy regional hourly values for electrical load.

In order to define nodal electrical load two parameters are required for our modeling purpose. First, the hourly load as provided by ENTSO-E (2013b) is given on a national basis. Therefore, a further regional distribution of the national electricity load is necessary.

The share of electrical load at each network node is determined using regional statistical data on gross domestic product (GDP) and population. While the GDP is used as a proxy for industrial demand weighted with a share of 60%, the regional statistical population data proxies the residential demand weighted with a share of 40% of total nodal load. Due to the size of the European model the NUTS-2 regional classification is taken as a regional detail level representation, instead of the more detailed NUTS-3 classification. Statistical data for European regions are taken from EUROSTAT and include the regional GDP (Eurostat, 2013a) and population (Eurostat, 2013b). In case of a country not being listed in the European dataset, statistical data is derived from national statistical offices. This applies particularly to Switzerland. For smaller countries without information on regional characteristics, like Albania, Serbia, Montenegro, and Bosnia-Herzegovina, an equal distribution of nodal loads among all nodes within the country is assumed.

Given the nodal distribution of the load, national load values are taken from ENTSO-E (2012). If a country is not listed, like Albania, data from the national statistical office is used. Table 19 lists the average hourly load for the countries considered. Figure 32 visualizes the regional distribution of the electrical load.

In our modeling approach, electrical load can be considered either as price-elastic or price-inelastic. The latter approach assumes a fixed demand which has to be served by generation in each hour, whereas the first approach allows for adjustments of electrical load assuming a linear relation between price and quantity. The approach described in Leuthold et al. (2012)

is adopted to define the linear nodal load function. While the previously determined nodal load serves as a reference load, annual average spot prices of European countries determine the reference price. When national spot prices are not available, the available average spot price of other European countries is applied. Additionally, a point demand elasticity of -0.25 is assumed.

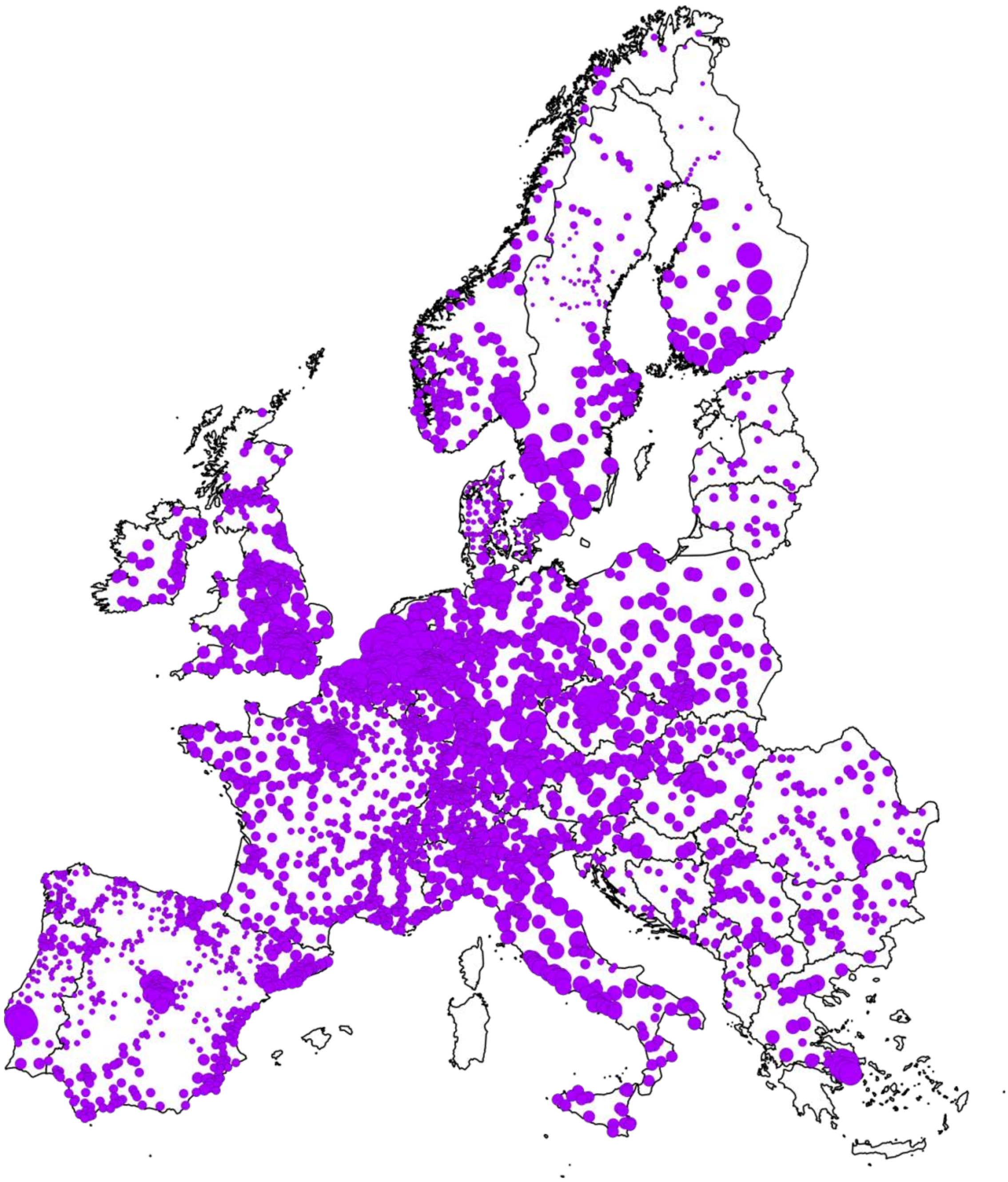


Figure 32: Regional distribution of electrical load

Table 19: National average load and renewable capacities

Country	Average hourly load [MW]	Wind capacity [MW]	Solar capacity [MW]
AL	574	0	0
AT	7,827	1,084	188
BA	1,391	0	0
BE	9,879	1,078	2,051
BG	3,794	612	141
CH	7,356	46	216
CZ	7,196	217	1,959
DE	62,131	29,060	24,807
DK	3,934	3,871	16
EE	893	184	0
ES	29,108	21,674	4,889
FI	9,617	197	1
FR	54,708	6,800	2,924
GR	6,041	1,629	624
HR	1,997	131	0
HU	4,582	329	4
IE	2,982	1,631	3
IT	38,201	6,747	12,923
LT	1,183	31	0
LU	749	44	30
LV	829	179	0
ME	478	0	0
MK	1,026	0	0
NL	13,452	2,328	141
NO	13,929	520	0
PL	16,635	1,616	3
PT	5,765	4,083	195
RO	6,269	982	4
RS	4,586	0	0
SE	15,893	2,907	11
SI	1,434	0	81
SK	3,057	3	508
UA	0	0	0
UK	38,599	6,540	904

3.1.3 Time dependent electricity data

3.1.3.1 Generation fuel cost

In order to apply an economic modeling framework the specification of generation costs for the different generation technologies is required based on fuel and emission prices. Hence, only conventional generation sources face generation costs whereas renewable generation is accounted with zero generation cost. Generation costs describe the short-term variable costs of producing one megawatt hour of electricity and hence comprise fuel as well as carbon emission costs. Operation and maintenance costs as well as unit commitment costs are not considered. A review of these cost components can be found in Schröder et al. (2013).

The input fuel costs for hard coal, natural gas, and oil reflect average prices for 2011 for all countries. For other input fuels own assumptions need to be made. For carbon emissions an average price from EEX is used. The assumed fuel prices are depicted in Table 20. As energy fuel prices vary between European countries due to different import sources (e.g. natural gas) or transportation costs (e.g. hard coal) a regional differentiation of these prices is required. However, the regional differentiation can currently be applied to natural gas as transparent information is available for this matter, based on EC (2012).

Table 20: Fuel prices in 2011

Fuel	Price in 2011 [EUR/MWh_{th}, EUR/t(CO_2)]	Source
Uran	3	Own assumption
Lignite	4	Own assumption
Hard coal	13.14	(Statistik der Kohlenwirtschaft e.V., 2013)
Natural gas	25.72	(EC, 2012)
Oil	43.60	(Statistik der Kohlenwirtschaft e.V., 2013)
Biomass	7	Own assumption
Waste	7	Own assumption
Carbon emission	12.94	EEX

3.1.3.2 Generation efficiency

Based on the fuel costs generation costs can be calculated using the efficiency of generation units. In order to capture technological progress and thus the increase in efficiency in the dataset, efficiencies are determined based on the commissioning year of the power plant. The general approach is based on Schröter (2004) and depicted in Table 21.

Table 21: Efficiency of conventional generation technologies

[%]	Nuclear	Lignite	Coal	CCGT and CCOT	GasSteam and OilSteam	OCGT and OCOT
1950	33.0	29.0	29.6	20.0	30.6	24.7
1960	33.0	32.0	32.8	26.7	33.8	27.3
1970	33.0	35.0	35.9	33.3	36.9	29.9
1980	33.0	38.0	39.1	40.0	40.1	32.5
1990	33.0	41.0	42.3	46.7	43.3	35.1
2000	33.0	44.0	45.5	53.3	46.5	37.7
2010	33.0	47.0	48.7	60.0	49.7	40.3

3.1.3.3 Availability of generation capacity

To account for non-availability of generation sources due to maintenance, outages, or variability of wind and solar radiation, an availability factor is specified to cover these effects. The availability factor reduces the installed capacity to an available generation capacity.

For conventional generation sources, aside from nuclear and hydro generation, average annual availability is specified mainly based on Schröder et al. (2013) (Table 22). For nuclear and hydro generation, availability factors are differentiated by country using annual generation data for 2011 provided by ENTSO-E (2013c).

Table 22: Availability of conventional generation technologies

Technology	Availability factor [%]	Source
Nuclear	71-96	Own calculation based on data from ENTSO-E (2013c)
Hydro	11-48	
Lignite	85	(Schröder et al., 2013)
Hard coal	84	
CCGT / CCOT	89	
OCGT / OCOT	86	
Gas / Oil steam	87	

For the renewable sources wind and solar, the availability factor reflects the average utilization of installed generation capacities in 2011 differentiated by country. The determination of the regional availability factor takes into account the amount of energy produced by the renewable technology (Eurostat, 2013c) and the installed capacity (EPIA, 2013; EWEA, 2012) at the end of the considered year 2011. For wind generation the regional availability factor ranges from 17% in South Central to 29% in North Western Europe. For solar generation the average utilization is highest in south Western Europe with 18% and lowest in north Western Europe with only 3%. It is important to note, that the average utilization assumes an average hour of the year 2011. In the future, the aim is to have a more detailed representation of the hourly wind and solar generation.

3.2 Model Validation - Electricity Prices, Generation, and Cross-border Flows (2011)

Within the application of the described data, the dataset has been continuously checked for inconsistencies using a welfare-maximizing modeling approach with a price-elastic demand. Inconsistencies result from incorrect power plant placing, NUTS classification, and network topology. The ELMOD model specification aims at welfare maximization of the European power system for an average hour of the year 2011. Thus the model optimizes generation dispatch and load. For electrical load, the average load as reported in ENTSO-E (2012) and the 2011 power exchange prices are taken to determine the linear demand curve (Leuthold et al., 2012); a point elasticity of -0.25 is assumed. Furthermore, intertemporal restrictions like unit commitment are neglected.

The comparison of an average hour with average historic data is complicated and can only give first indications on the consistency of the dataset. A more detailed modeling approach would indeed be helpful, but is limited mostly by missing data. This holds especially true for renewable time series. Furthermore, the modeling approach assumes an integrated optimization of generation as well as network constraints, which deviates significantly from the current European market design, which is based on commercial transfer restrictions in the day-ahead electricity markets, followed by a mostly nationally oriented congestion management.

The results of the model are firstly checked with historical power prices of selected countries, secondly with the average generation as reported by ENTSO-E, and thirdly with the exchange statistics of selected countries with data from ENTSO-E.

3.2.1 Price results

The average power price at the spot markets is the first indicator used for model validation. As can be seen in Figure 33, prices of the model mainly resemble real prices considering a price level of about 50 EUR/MWh. Also, the price pattern is consistent for most countries. However, some differences occur in south central Europe (Italy and Slovenia) and the Iberian

Peninsula, where optimized prices are below observed ones. Especially Italy should have higher prices in the range of 72 EUR/MWh.

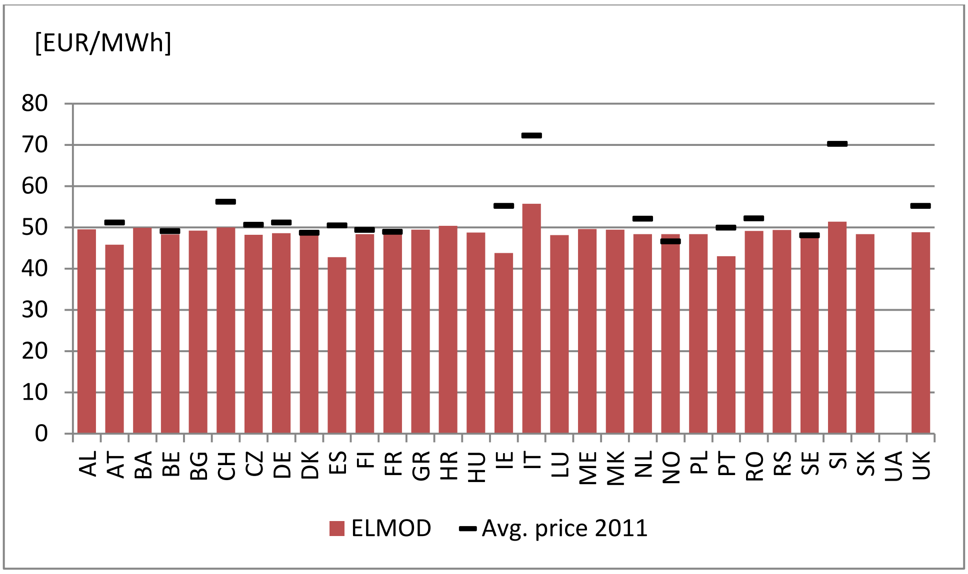


Figure 33: Comparison of modeled prices with historic prices in 2011

3.2.2 Generation results

In this section, the generation determined in the model run is compared to the average generation as reported by ENTSO-E for 2011. Figure 34 and Figure 35 illustrate the reported and modeled generation on a country-specific basis. The technological classification does not allow for a more detailed differentiation for conventional generation technologies as the reported historic generation is aggregated for all fossil fuels. Comparison on the total scale indicates that the total generation in the model is higher by approximately 5 GWh but the share of generation types is comparable. The reason for the higher generation in the model is based on the welfare maximization approach and the assumption of a linear demand curve. As the model shows lower prices e.g. in Italy the demand is higher than the average demand reported by ENTSO-E.

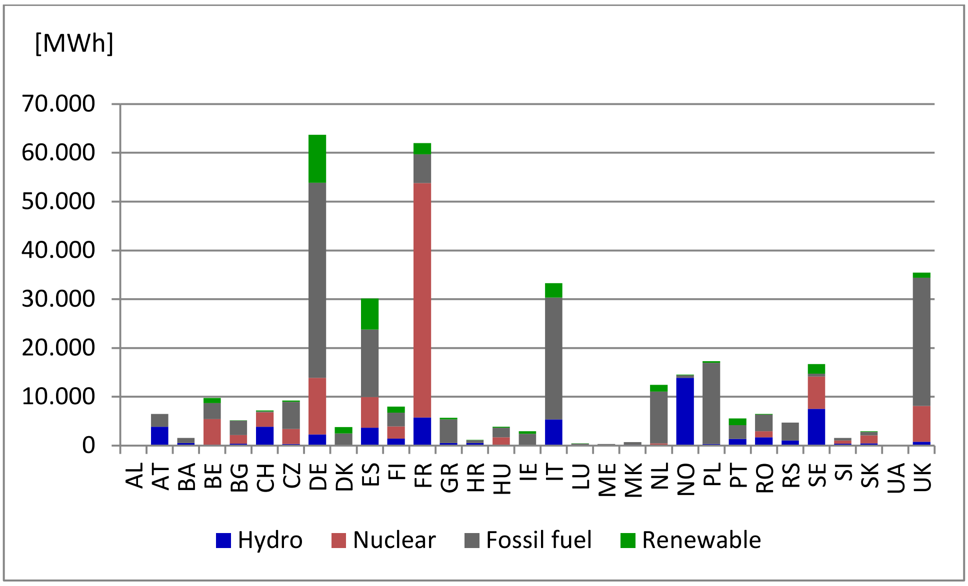


Figure 34: Average generation in 2011 based on ENTSO-E

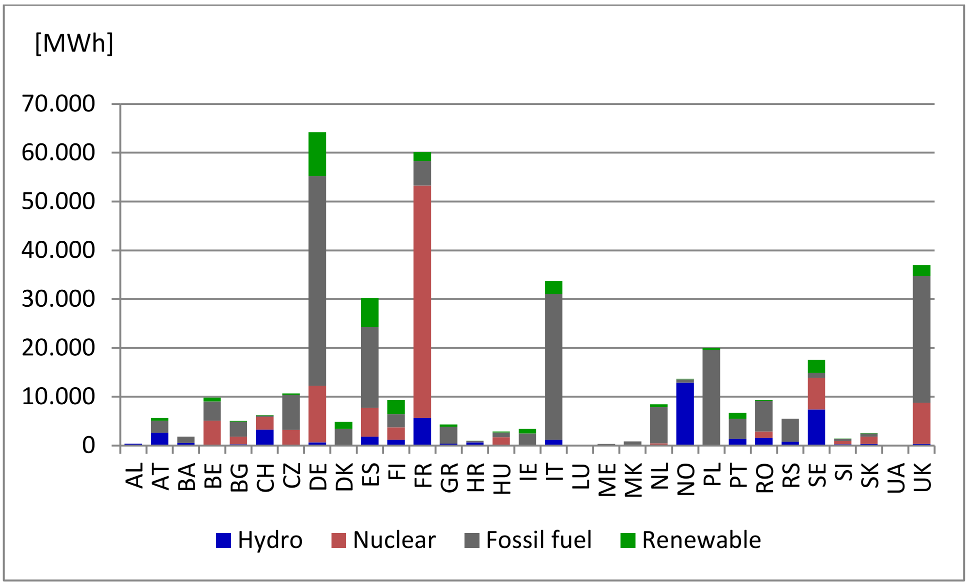


Figure 35: Generation results

A look at specific countries provides additional insights on the differences in the generation pattern. In most countries (e.g. Spain and Germany), the total amount of generation is relatively close to the reported data. However, some differences are observed in other countries like the Czech Republic, France, the Netherlands, Poland, and Romania. France and the Netherlands show lower generation in the model run than experienced in 2011. Other countries show higher generation. The differences are mainly caused by the dispatch of conventional generation as other generation technologies are either bounded like nuclear and hydro or fixed like renewable generation. Additionally, the limitations and assumptions of the modeling approach may also lead to higher generation in particular countries. This can be traced back to commercial transfer limits as well as complex generation constraints like unit commitment or restrictions due to cogeneration of heat, which are not taken into account.

3.2.3 Exchange results

Considering exchange results, the national balances are compared to the data reported by ENTSOE for 2011. It can be seen from the following figure that for most countries, the pattern of the exchange saldo is close to real numbers. However, the level differs among countries like the Netherlands, Poland, the United Kingdom, Germany, and Norway showing the highest differences between model results und experienced exchanges. In particular the Netherlands show higher imports than experienced in 2011 which also conforms to the presented generation figures. On the other hand eastern European countries like Poland and Romania show higher export as they are characterized by less costly generation technologies as e.g. in the Netherlands. Additionally, cogeneration restrictions which may be important in the Netherlands are currently not implemented due to inconsistent data sources. Such restrictions may lead to higher domestic generation instead of relying on imports from other countries. However, it can finally be noted, that the general pattern is comparable.

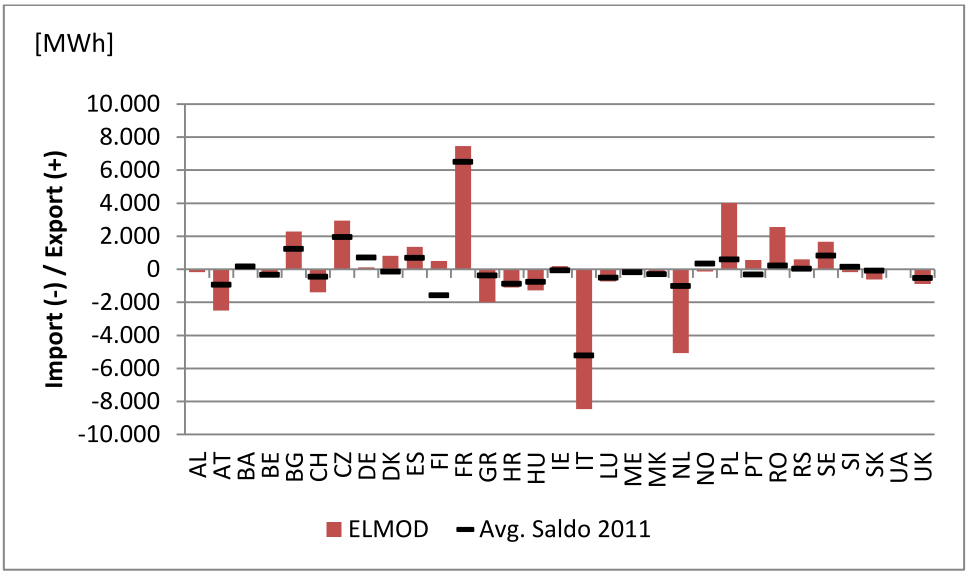


Figure 36: Average exchange saldo of European countries

Looking at individual borders of selected countries and the exchanges within the AC grid (Figure 37 to Figure 39), the pattern but not the absolute level resembles realistic numbers. In particular, the exchanges with the central eastern part of Europe (Poland, the Czech Republic), which was discussed earlier, are higher than in reality. On the other hand, exports to the Netherlands are higher than experienced in 2011.

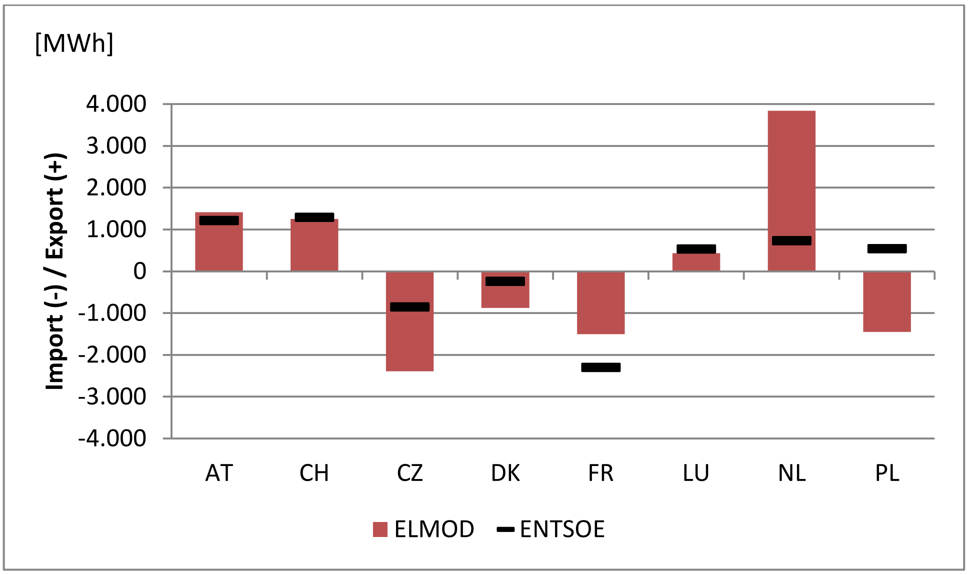


Figure 37: Cross-border flows from (+) and to (-) Germany

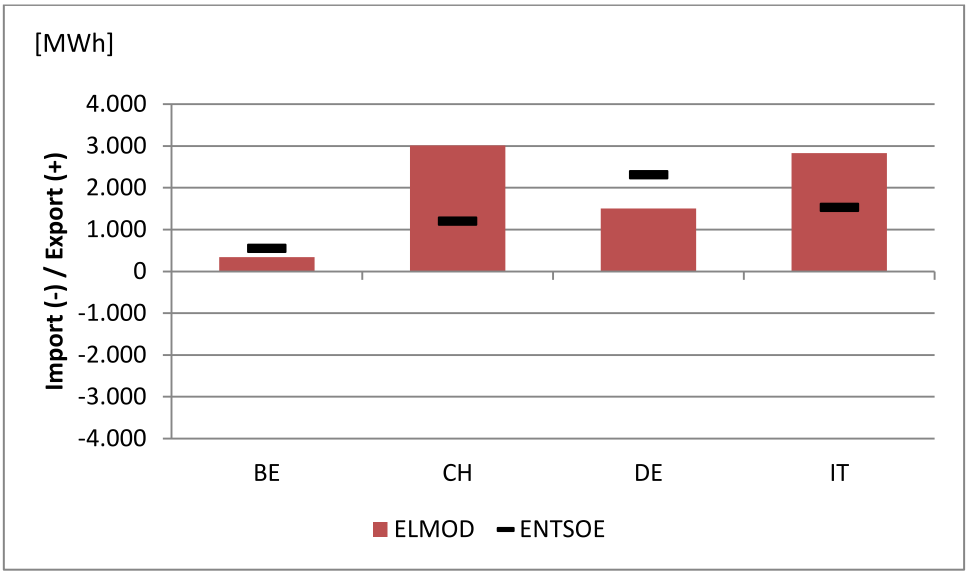


Figure 38: Cross-border flows from (+) and to (-) France

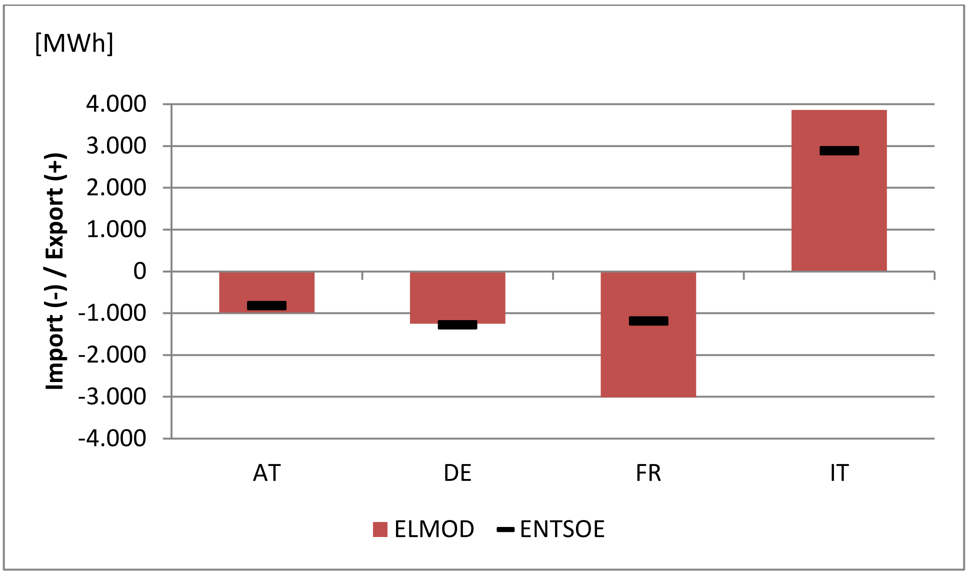


Figure 39: Cross-border flows from (+) and to (-) Switzerland

3.3 Summary

The dataset for the European electricity system needs a variety of data to cover the relevant characteristics of the industry. The more general data on aggregated generation capacities, historic generation, and consumption can be found with a consistent data specification for most European countries in databases like EUROSTAT. On the other hand, more detailed data like generation capacities for conventional and renewable sources are usually not publicly available, sometimes not even on a national basis, and henceforth appropriate assumptions or commercial databases are required to retrieve the necessary information. Due to the already mentioned issue with regard to available information, setting up a consistent dataset for the European electricity system is more difficult in comparison to the German electricity system, where mostly consistent data is publicly available. Similar projects on a European level could be helpful for a consistent dataset.

Having set up a dataset for Europe, the model application shows that the general tendencies on regional generation and import/export pattern can be captured. However, differences are obvious in particular regions where the model shows different results than the historic values which may be based either on the rough modeling approach or on an insufficient data supply.

To that end, the presented dataset and model application are a continuous process, and further steps are required to improve the data quality as well as the modeling. Among others, the implementation of cogeneration restrictions, improvement of renewable generation and their distribution, and an intertemporal model calibration are potential improvements for the future.

4 Conclusions

4.1 A Neglected Issue

Data availability and transparency are an important element of numerical models and the acceptance of the respective results, but they have often been neglected in the policy making process. Having followed this process for a decade now, we observe a striking discrepancy: while the numerical models used for electricity sector analysis have become more and more sophisticated, neither the quality nor the transparency of data have followed suit. It is surprising that in times of the internet and the IT-revolution, so little attention has been given to data issues, and that very important decisions for the entire economy, such as energy system planning and infrastructure development, are not transparently presented to the public.

In this Data Documentation, we have set out the methodological underpinnings and the necessity for data policies in any modeling context, be it academic or policy- and business-oriented. We have provided the approach to assembling the necessary data to model electricity generation, transmission, and demand activities, both at the German and the European level. This Data Documentation connects several (mostly open) data sources to form two consistent datasets, one at the national level for Germany, and one at the European level. They allow developing techno-economic models for the electricity system, with a high spatial accuracy. Applications of these data use the ELMOD modeling framework. The results indicate a high quality of both, the data and the model, since the calculations obtain results close to the observed reality.

Future work using these and other data and models need to confirm these results, and open the way to a broader discussion of data quality and transparency issues. In this conclusion, we sketch out two streams that merit particular attention: i) possible model and data improvements; and ii) work on the institutional implementation of the modeling work into the policy arena.

4.2 Potential Data and Modeling Improvements

Some obstacles remain on the pathway towards better modeling of national and European electricity sector reform, and, thus, for higher acceptance of some of the measures proposed. The electricity market model ELMOD, built on the DC load flow approach, applies the available open data together with some additional assumptions. Given the simplifications, the resulting statistical aggregations provide a surprisingly good match with the observed quantities in 2012. Yet, the linear character of the optimization model simplifies certain technical system constraints and neglects uncertainty and strategic behavior.

While data on electricity generation is generally available and accurate, data on transmission networks and demand characteristics is sparse. Although significant efforts have been made at national and European level to foster the collection and publication of data, progress "on the ground" has been relatively slow, both at the European level and the national level. A notable exception for this role is the internet publication of all relevant network data in Great Britain.

This work also applies the datasets to linear techno-economic optimization models based on the DC load flow approach and presents their results. There is a certain trade-off between the availability of public and transparent data, and the complexity of the models used. Some important technical aspects, e.g. combined heat and power and inflexibility of power plants, would require additional technical parameters on the individual power plant blocks. Still, the model results provide good insights in the regional distribution of electricity generation, network flows, and bottlenecks related to the infrastructure.

Concluding on the experienced difficulties in the data collection, the current availability of open data provided by public and private stakeholders is often insufficient. A major issue is open data on the transmission network where precise geo-referenced and topology information are not available. Also, many data sources are only reported at the national level. Thus, the European dataset does not include hourly system information, uses rather crude allocation approaches for wind and PV capacity, and has to rely on a commercial dataset for conventional power plants.

Future work includes further details on the data side, focusing notably on network and demand data. Also, additional model runs are required, both with ELMOD and other models, to broaden the insight into the functioning of the national and European electricity market, and future reform needs, including network planning.

4.3 Establishing Routines for Modeling Policy Interaction

Even more challenging, though, is the translation of modeling results for use in the policy arena, and the establishment of clarity and consistency that provide real value to the business community and policymakers alike. To that end, the pressure on the electricity industry itself and the public policymakers to release data and secure higher transparency of sector planning needs to be maintained, both in the interest of producers and consumers in the sector, and of public acceptance. More work needs to be done to integrate the modeling world and the policy world, and to establish routines for interaction between the two levels.

The Data Documentation, and the application to real-world phenomena, highlights a trade-off between the complexity of the model, and the ability to convey model results to the larger arena of business and policy. More model features do not imply better decision support, often the contrary is the case. Routines need to be established to structure the modeling-policy interface and to allow for sufficient feedback by well-informed policy makers (or advisors). The management of knowledge of this process is at least as important as the data and modeling work itself.

4.4 The Next Steps

With models being about insights instead of absolute numbers, it is important that model results are transparent and replicable. Thus, the transparent character of this Data Documentation and the discussion of model results is one step in that direction. Next steps can include i) comparative work with similar approaches in the national and/or the European context ("model comparison"); and ii) pilot projects to test different interface routines, and make us of implicit and explicit knowledge of the stakeholders involved.

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Appendix

Table 23: Conventional power plant blocks of specific size by voltage level

		Nuclear	Lignite	Coal	Gas				Oil			Waste	Other
[kV]	[MW]	ST	ST	ST	CC	CB	ST	GT	CB	ST	GT	ST	-
220 & 380	<50	-	-	-	-	-	-	1	-	-	-	-	-
	<100	-	-	-	-	-	-	1	-	-	4	-	-
	<500	-	21	27	3	3	-	3	-	3	1	-	2
	>500	9	15	15	4	-	-	-	-	-	-	-	-
<220	<10	-	-	-	-	-	2	21	-	-	1	11	2
	<50	-	13	17	-	1	9	102	-	-	21	59	15
	<100	-	10	17	1	4	3	35	2	-	13	2	10
	<500	-	3	25	9	3	7	18	-	-	5	-	5
	>500	-	-	-	1	-	-	-	-	-	-	-	-
	Sum	9	62	101	18	11	21	181	2	3	45	72	34

Table 24: Conventional generation capacity for each DENA zone

[MW]	Nuclear	Lignite	Coal	Gas				Oil			Waste	Other	Hydro
State	ST	ST	ST	CC	CB	ST	GT	CB	ST	GT	ST		PSP
21	1,410	-	470	-	-	-	20	-	-	435	-	77	-
22	-	-	1,631	-	-	1	682	-	-	144	56	260	-
23	1,360	352	2,371	324	-	65	210	-	-	-	75	299	220
24	-	34	1,136	-	-	34	488	-	-	25	87	48	623
25	1,275	-	42	-	-	823	478	-	-	-	127	-	291
26	1,410	-	801	1,932	-	202	241	-	772	158	42	-	99
41	2,712	-	1,774	353	41	35	189	-	-	206	10	-	-
42	-	-	921	-	50	-	394	162	262	70	44	-	1,873
71	1,329	-	794	876	710	224	-	-	-	-	-	-	-
72	-	2,648	7,315	586	-	30	1,944	-	-	146	262	1,483	153
73	-	-	2,124	838	165	53	943	-	-	206	61	-	138
74	-	7,847	-	1,213	-	55	254	-	-	146	114	-	-
75	-	-	3,553	398	1,117	-	391	-	-	-	160	141	-
76	2,572	-	-	-	-	-	121	-	-	57	10	6	-
81	-	184	1,285	604	-	354	1,267	-	-	661	246	14	-
82	-	-	454	127	-	-	16	-	-	139	40	-	119
83	-	998	-	-	-	-	812	-	-	213	54	29	1,589
84	-	8,928	-	250	-	-	490	-	-	32	64	119	1,085

Table 25: Conventional generation capacity for each federal state

[MW]	Nuclear	Lignite	Coal	Gas				Oil			Waste	Other	Hydro
State	ST	ST	ST	CC	CB	ST	GT	CB	ST	GT	ST		PSP
BW	2,712	-	4,012	353	91	35	583	162	262	276	98	-	1,873
BY	5,257	-	843	1,932	-	1,025	828	-	772	215	180	6	390
BE	-	164	777	444	-	288	230	-	-	327	36	-	-
BB	-	4,409	-	160	-	-	686	-	-	334	99	119	-
HB	-	-	874	-	-	-	14	-	-	88	56	260	-
HH	-	-	194	127	-	-	16	-	-	38	24	-	-
HE	-	34	1,002	-	112	-	698	-	-	25	98	48	623
MV	-	-	508	-	-	-	287	-	-	-	17	-	-
NI	2,689	352	2,150	1,200	710	224	905	-	-	56	75	299	220
NW	-	10,495	11,411	2,637	165	203	3,129	-	-	499	437	1,483	291
RP	-	-	13	398	880	-	147	-	-	-	78	56	-
SL	-	-	2,156	-	125	-	39	-	-	-	27	85	-
SN	-	4,325	-	250	-	-	332	-	-	17	15	-	1,085
ST	-	1,152	-	-	-	66	635	-	-	227	185	43	80
SH	1,410	-	730	-	-	-	20	-	-	536	16	77	119
TH	-	60	-	-	-	34	390	-	-	-	11	-	1,509

Table 26: Renewable generation capacity for each DENA zone

[MW] DENA Zones	Hydro RoR	Biomass ST	Wind Onshore	Wind Offshore	Solar PV	Geothermal	Sum
21	4	318	3,587	0	1,118	0	5,027
22	21	549	4,062	340	1,518	0	6,491
23	66	441	2,861	0	1,011	0	4,379
24	68	190	950	0	1,380	0	2,589
25	185	401	674	0	3,264	0	4,523
26	1,299	396	60	0	4,006	11	5,772
41	89	215	207	0	1,283	6	1,801
42	580	455	350	0	3,105	0	4,490
71	1	246	1,077	0	1,033	0	2,358
72	42	420	531	0	1,411	0	2,405
73	65	268	1,318	0	1,263	0	2,915
74	156	136	1,261	0	1,081	0	2,,634
75	179	290	1,582	0	1,753	2	3,806
76	430	290	98	0	2,098	0	2,916
81	9	915	7,165	48	2,680	0	10,818
82	0	119	379	0	188	0	687
83	60	342	2,424	0	1,653	0	4,480
84	97	388	2,851	0	2,464	0	5,801
Sum	3,352	6,381	31,439	388	32,311	19	73,890

Table 27: Renewable generation capacity for each federal state

[MW] Federal States	Hydro RoR	Biomass ST	Wind Onshore	Wind Offshore	Solar PV	Geothermal	Sum
BB	3	475	4,874	0	2,080	0	7,432
BE	1	82	318	0	261	0	662
BW	705	682	710	0	4,586	6	6,689
BY	1,893	1,103	710	0	9,303	11	13,020
HB	0	22	176	0	53	0	251
HE	63	181	758	0	1,284	0	2,286
HH	0	70	152	0	64	0	286
MV	3	347	1,896	48	746	0	3,040
NI	85	1,067	7,159	340	2,925	0	11,576
NW	149	960	3,362	0	4,032	0	8,503
RP	259	217	1,974	0	1,676	2	4,128
SH	4	347	3,753	0	1,186	0	5,290
SL	27	85	244	0	403	0	759
SN	99	276	1,488	0	1,808	0	3,671
ST	17	249	2,958	0	1,072	0	4,296
TH	44	216	906	0	831	0	1,997
Sum	3,352	6,379	31,438	388	32,310	19	73,886

Table 28: Conventional plants feeding directly into the 220 kV and 380 kV systems [24]

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
Baden Wurttemberg	BNA0019	Heizkraftwerk Altbach/Deizisau	ALT HKW 2 (DT Solobetrieb)	Coal	ST	336.0	1997	Altbach	
	BNA0020	Heizkraftwerk Altbach/Deizisau	ALT HKW 1	Coal	ST	433.0	1985	Altbach	
	BNA0434	Heizkraftwerk Heilbronn	HLB 7	Coal	ST	778.0	1985	Großgartach	
	BNA0518	Rheinhafen-Dampfkraftwerk	RDK 7	Coal	ST	505.0	1985	Daxlanden	
	BNA0643	GKM	Block 4	Coal	ST	202.5	1970	Mannheim West*	Allocated evenly west/east
	BNA0644	GKM	Block 6	Coal	ST	255.0	2005	Mannheim East*	Allocated evenly west/east
	BNA0645	GKM	Block 7	Coal	ST	425.0	1982	Mannheim East*	Allocated evenly west/east
	BNA0646	GKM	Block 8	Coal	ST	435.0	1993	Mannheim West*	Allocated evenly west/east
	BNA0514	Rheinhafen-Dampfkraftwerk	RDK 4S	Gas	CC	353.0	1998	Daxlanden	
	BNA0686	Gemeinschaftskernkraftwerk Neckarwestheim II	GKN II	Nuclear	ST	1,310.0	1989	Neckarwestheim	
	BNA0802	Kernkraftwerk Philippsburg 2	KKP 2	Nuclear	ST	1,402.0	1985	Philippsburg	
	BNA0649	Dampfkraftwerk Marbach am Neckar	MAR III DT	Oil	ST	262.0	1975	Hoheneck*	Closest node
Bavaria	BNA0969	Nord 2	2	Coal	ST	333.0	1991	Föhring*	Closest node
	BNA1093	Zolling	Zolling Block 5	Coal	ST	468.0	1986	Zolling*	Closest node
	BNA0994	Gemeinschaftskraftwerk Irsching	5	Gas	CC	846.0	2010	Irsching	
	BNA0995	Ulrich Hartmann	4	Gas	CC	545.0	2011	Irsching	
	BNA0263	Isar 2	KKI 2	Nuclear	ST	1,410.0	1988	Isar	
	BNA0355	Grafenrheinfeld	KKG	Nuclear	ST	1,275.0	1982	Grafenrheinfeld	
	BNA0381	Gundremmingen	B	Nuclear	ST	1,284.0	1984	Gundelfingen	
	BNA0382	Gundremmingen	C	Nuclear	ST	1,288.0	1984	Gundelfingen	
	BNA0378	Ingolstadt	3	Oil	ST	386.0	1973	Ingolstadt	
	BNA0379	Ingolstadt	4	Oil	ST	386.0	1974	Ingolstadt	
Berlin	BNA0086	Reuter West	Reuter West D	Coal	ST	282.0	1987	Reuter	
	BNA0087	Reuter West	Reuter West E	Coal	ST	282.0	1988	Reuter	
Brandenburg	BNA0785	KW Jänschwalde	A	Lignite	ST	465.0	1981	Preilack	
	BNA0786	KW Jänschwalde	B	Lignite	ST	465.0	1982	Preilack	
	BNA0787	KW Jänschwalde	C	Lignite	ST	465.0	1984	Preilack	
	BNA0788	KW Jänschwalde	D	Lignite	ST	465.0	1985	Preilack	
	BNA0789	KW Jänschwalde	E	Lignite	ST	465.0	1987	Preilack	
	BNA0790	KW Jänschwalde	F	Lignite	ST	465.0	1989	Preilack	
	BNA0914	Schwarze Pumpe	A	Lignite	ST	750.0	1997	Graustein	
	BNA0915	Schwarze Pumpe	B	Lignite	ST	750.0	1998	Graustein	
Bremen	BNA0147	Farge	Farge	Coal	ST	350.0	1969	Farge	
Hessen	BNA0375	Staudinger	1	Coal	ST	249.0	1965	Großkrotzenburg	
	BNA0377	Staudinger	5	Coal	ST	510.0	1992	Großkrotzenburg	
Mecklenburg-West Pomera-nia	BNA0849	KNG Kraftwerk Rostock	Rostock	Coal	ST	508.0	1994	Kontek*	Node Kontek is equal to the Bentwisch 380kV node

[24] Data is based on the power plant dataset by (BNetzA, 2013a) published on 16.10.2013 and adjusted for 2012. Every * indicates data with additional sources not listed or own assumptions.

State	Number BNetzA	Name of power plant	Block name	Fuel	Tech-nology*	Net capacity in MW	Year	High-voltage node	Comments
Lower Saxony	BNA0464	KWM	Block3	Coal	ST	690.0	1979	Mehrum	
	BNA1061	Wilhelmshaven	1	Coal	ST	757.0	1976	Maade	
	BNA0239	Huntorf		Gas	GT	321.0	1978	Huntorf	
	BNA0245a	Emden Gas		Gas	GT	50.0	1973	Emden	
	BNA0604	Emsland	B2	Gas	CB	355.0	1973	Hanekenfähr	
	BNA0605	Emsland	C2	Gas	CB	355.0	1974	Hanekenfähr	
	BNA0606	Emsland	D	Gas	CC	876.0	2010	Hanekenfähr	
	BNA0918	Dow Stade	Kraftwärmekopplungsanlage	Gas	GT	190.0	1972	Stade*	Closest node
	BNA1437	KWK AOS GmbH	GT 1/2	Gas	GT	30.7	2012	Abbenfleth	
	BNA0439	Buschhaus	D	Lignite	ST	352.0	1985	Helmstedt	
	BNA0251	Grohnde	KWG	Nuclear	ST	1,360.0	1985	Grohnde	
	BNA0607	Emsland	KKE	Nuclear	ST	1,329.0	1988	Hanekenfähr	
North Rhine Westphalia	BNA0067	Bergkamen	A	Coal	ST	717.0	1981	Gersteinwerk	
	BNA0203	Knepper	C	Coal	ST	345.0	1971	Pöppinghausen	
	BNA0216	KW Walsum	Walsum 9	Coal	ST	370.0	1988	Walsum	
	BNA0331	Scholven	C	Coal	ST	345.0	1969	Bellendorf*	Assumption
	BNA0332	Scholven	B	Coal	ST	345.0	1968	Polsum*	Assumption
	BNA0333	Scholven	D	Coal	ST	345.0	1970	Polsum*	Assumption
	BNA0334	Scholven	E	Coal	ST	345.0	1971	Polsum*	Assumption
	BNA0335	Scholven	F	Coal	ST	676.0	1979	Polsum*	Assumption
	BNA0449	KW Herne	Herne 3	Coal	ST	280.0	1966	Eiberg	
	BNA0450	KW Herne	Herne 4	Coal	ST	449.0	1989	Bochum	
	BNA0493	Ibbenbüren	B	Coal	ST	794.0	1985	Westerkappeln	
	BNA0619	KW Lünen	Lünen 7	Coal	ST	324.0	1969	Elmenhorst	
	BNA0793	Heyden	4	Coal	ST	875.0	1987	Ovenstädt	
	BNA0813	Kraftwerk Veltheim	3	Coal	ST	303.0	1970	Veltheim	
	BNA0989	KW West	West 2	Coal	ST	318.0	1971	Voerde*	Different node name
	BNA0990	KW West	West 1	Coal	ST	322.0	1971	Voerde*	Different node name
	BNA0991	KW Voerde	Block A	Coal	ST	695.0	1982	Voerde*	Different node name
	BNA0992	KW Voerde	Block B	Coal	ST	695.0	1985	Voerde*	Different node name
	BNA1037	Kraftwerk Werdohl-Elverlingsen	E4	Coal	ST	310.0	1982	Elverlingsen	
	BNA1046a	Gersteinwerk	K2	Coal	ST	607.5	1984	Gersteinwerk	
	BNA0410	Trianel Gaskraftwerk	Block 10	Gas	CC	417.1	2007	Geithe	
	BNA0411	Trianel Gaskraftwerk	Block 20	Gas	CC	420.9	2007	Geithe	
	BNA0548	Knapsack Gas		Gas	CC	800.0	2006	Knapsack*	
	BNA1045	Gersteinwerk	G2	Gas	CB	355.0	1973	Gersteinwerk	
	BNA0313	Frimmersdorf	P	Lignite	ST	284.0	1966	Gohrpunkt	
	BNA0314	Frimmersdorf	Q	Lignite	ST	278.0	1970	Norf	
	BNA0696	Neurath	A	Lignite	ST	277.0	1972	Osterath	
	BNA0697	Neurath	B	Lignite	ST	288.0	1972	Opladen	
	BNA0698	Neurath	C	Lignite	ST	292.0	1973	Opladen	
	BNA0699	Neurath	D	Lignite	ST	607.0	1975	Opladen	
	BNA0700	Neurath	E	Lignite	ST	604.0	1976	Rommerskirchen	
	BNA0705	Niederaußem	D	Lignite	ST	297.0	1968	Brauweiler	
	BNA0706	Niederaußem	F	Lignite	ST	299.0	1971	Opladen	
	BNA0707	Niederaußem	H	Lignite	ST	648.0	1974	Rommerskirchen	

State	Number BNetzA	Name of power plant	Block name	Fuel	Tech-nology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0708	Niederaußem	G	Lignite	ST	653.0	1974	Rommerskirchen	
	BNA0709	Niederaußem	K	Lignite	ST	944.0	2002	Rommerskirchen	
	BNA0712	Niederaußem	C	Lignite	ST	294.0	1965	Brauweiler	
	BNA0713	Niederaußem	E	Lignite	ST	295.0	1970	Opladen	
	BNA1026	Weisweiler	F	Lignite	ST	304.0	1967	Oberzier	
	BNA1027	Weisweiler	G	Lignite	ST	590.0	1974	Oberzier	
	BNA1028	Weisweiler	H	Lignite	ST	592.0	1975	Oberzier	
	BNA1401a	BoA 2	Neurath F	Lignite	ST	1,050.0	2012	Rommerskirchen	
	BNA1401b	BoA 3	Neurath G	Lignite	ST	1,050.0	2012	Rommerskirchen	
	BNA1036	Kraftwerk Werdohl-Elverlingsen	E 1/2	Oil	GT	206.0	1975	Elverlingsen	
	BNA0485	Huckingen	A	Other	ST	303.0	1975	Mündelheim	
	BNA0486	Huckingen	B	Other	ST	303.0	1976	Mündelheim	
Rhineland Palatinate	BNA0614b	Kraftwerk Mitte	GUD A 800 GT 11, GT 12, DT 10	Gas	CB	490.0	2005	BASF*	Different name
Saarland	BNA0093	Kraftwerk Bexbach	BEX	Coal	ST	721.0	1983	Mittelbexbach	
	BNA0253	Kraftwerk Ensdorf	Block 1	Coal	ST	106.0	1963	Ensdorf	
	BNA0820	Weiher	Weiher III	Coal	ST	655.6	1976	Uchtelfangen	
Saxony	BNA0115	Lippendorf	R	Lignite	ST	875.0	2000	Pulgar	
	BNA0116	Braunkohlekraftwerk Lippendorf	LIP S	Lignite	ST	875.0	1999	Pulgar	
	BNA0122	Boxberg	N	Lignite	ST	465.0	1979	Bärwalde	
	BNA0123	Boxberg	P	Lignite	ST	465.0	1980	Bärwalde	
	BNA0124	Boxberg	Q	Lignite	ST	857.0	2000	Bärwalde	
	BNA1404	Boxberg	R	Lignite	ST	640.0	2012	Bärwalde	
Saxony Anhalt	BNA0878	Schkopau	A	Lignite	ST	450.0	1996	Lauchstädt	
	BNA0879	Schkopau	B	Lignite	ST	450.0	1996	Lauchstädt	
Schleswig-Holstein	BNA0526	Gemeinschafts-KW Kiel		Coal	ST	323.0	1970	Kiel-Süd*	Connected to station Kiel but missing 110kV
	BNA0157	Brokdorf	KBR	Nuclear	ST	1,410.0	1986	Brokdorf	
	BNA0161	Brunsbüttel	GT A	Oil	GT	63.5	1973	Brunsbüttel	
	BNA0162	Brunsbüttel	GT B	Oil	GT	63.5	1973	Brunsbüttel	
	BNA0163	Brunsbüttel	GT C	Oil	GT	63.5	1973	Brunsbüttel	
	BNA0164	Brunsbüttel	GT D	Oil	GT	63.5	1973	Brunsbüttel	

Table 29: Conventional plants not directly feeding into the 220 kV and 380 kV systems [25]

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
Baden Wurttemberg	BNA1006	Kraftwerk Walheim	WAL 2	Coal	ST	148.0	1967	GKN	
	BNA0432	Heizkraftwerk Heilbronn	HLB 5	Coal	ST	110.0	1965	Heilbronn	
	BNA0433	Heizkraftwerk Heilbronn	HLB 6	Coal	ST	110.0	1966	Heilbronn	
	BNA1005	Kraftwerk Walheim	WAL 1	Coal	ST	96.0	1964	GKN	
	BNA0935	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN DT12	Coal	ST	45.0	1982	Mühlhausen	
	BNA0936	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN DT15	Coal	ST	45.0	1984	Mühlhausen	
	BNA0801	Heizkraftwerk Pforzheim GmbH	Wirbelschichtblock	Coal	ST	26.9	1990	Birkenfeld	
	BNA0934	Heizkraftwerk Stuttgart-Gaisburg	GAI DT 14 neu	Coal	ST	22.6	2009	Mühlhausen	
	BNA1405a	Heizkraftwerk Magirusstraße		Coal	ST	20.7	1978	Dellmensingen	
	BNA1467			Coal	ST	18.5	1995	Weier	no year (assumption 1995)
	BNA0016	Heizkraftwerk Altbach/Deizisau	ALT GT A (Solo)	Gas	CB	50.0	1971	Altbach	
	BNA0800	Heizkraftwerk Pforzheim GmbH	Kombiblock/GuD	Gas	CB	41.2	1980	Birkenfeld	
	BNA0018	Heizkraftwerk Altbach/Deizisau	ALT GT C	Gas	GT	81.0	1975	Altbach	
	BNA0015	Heizkraftwerk Altbach/Deizisau	ALT GT E (solo)	Gas	GT	65.0	1997	Altbach	
	BNA1260	Heizkraftwerk Sindelfingen	Sammelschienen-HKW	Gas	GT	65.0	1980	Stuttgart-Weilimdorf	
	BNA0293	GuD Anlage WVK	GuD Anlage	Gas	GT	60.1	1998	Eichstetten	
	BNA0017	Heizkraftwerk Altbach/Deizisau	ALT GT B	Gas	GT	57.0	1973	Altbach	
	BNA0361	Kraftwerk Grenzach-Wyhlen		Gas	GT	40.0	2004	Schwörstadt	
	BNA0515	Heizkraftwerk West	T3	Gas	GT	40.0	1984	Karlsruhe-West	
	BNA1275	Kraftwerk Freudenberg Weinheim	2	Gas	GT	21.0	2005	Weinheim	
	BNA1276	Kraftwerk Freudenberg Weinheim	1	Gas	GT	21.0	1982	Weinheim	
	BNA1292b	IHKW Heidenheim	BHKW-Anlage	Gas	GT	19.3	2000	Rotensohl	
	BNA1315	HKW	HKW	Gas	GT	18	1995	Eichstetten	no year (assumption 1995)
	BNA1200	GuD-Kraftwerk		Gas	CB	17.5	2006	BASF	
	BNA1408	Heizkraftwerk Evonik Rheinfelden		Gas	GT	16.0	1980	Schwörstadt	
	BNA1151	KWKK Heidelberg		Gas	GT	13.5	2002	Heidelberg-Süd	
	BNA0957	BHKW Obere Viehweide	-	Gas	GT	12.5	2000	Metzingen	
	BNA0799	Heizkraftwerk Pforzheim GmbH	Gaskesselanlage	Gas	GT	11.3	1969	Birkenfeld	
	BNA1292a	IHKW Heidenheim	Kessel-Turbine	Gas	GT	11.0	1983	Rotensohl	
	BNA0832	BHKW-Hauffstraße	Motorenanlage	Gas	GT	9.8	2011	Metzingen	
	BNA0232c	Werkskraftwerk Sappi Ehingen		Gas	GT	4.0	1976	Dellmensingen	
	BNA1333a	HKW Pfaffenwald	Anlage 40	Gas	ST	12.1	1988	Stuttgart-Weilimdorf	
	BNA1333c	HKW Pfaffenwald	Block 60	Gas	ST	11.5	1968	Stuttgart-Weilimdorf	
	BNA1333b	HKW Pfaffenwald	Block 50	Gas	ST	11.3	1969	Stuttgart-Weilimdorf	
	BNA0648	Dampfkraftwerk Marbach am Neckar	Marbach III GT (solo)	Oil	CB	85.0	1975	Hoheneck	
	BNA0647	Dampfkraftwerk Marbach am Neckar	Marbach II GT	Oil	CB	77.4	1971	Hoheneck	
	BNA1004	Kraftwerk Walheim	WAL GT D	Oil	GT	136.0	1981	GKN	

[25] Data is based on the power plant dataset by (BNetzA, 2013a) published on 16.10.2013 and adjusted for 2012. Every * indicates data with additional sources not listed or own assumptions.

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0516	MiRO	Kesselhaus Werk 1	Oil	GT	45.0	1995	Daxlanden	
	BNA0517	MiRO	Kesselhaus Werk 2	Oil	GT	25.0	1995	Daxlanden	no year (assumption 1995)
	BNA0937	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN GT16	Oil	GT	23.3	1974	Mühlhausen	
	BNA0938	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN GT17	Oil	GT	23.3	1974	Mühlhausen	
	BNA0939b	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN GT18	Oil	GT	23.3	1974	Mühlhausen	
	BNA0641a	HKW Mannheim	Turbine 60	Waste	ST	22.1	2009	BASF	
	BNA0939a	Restmüll-Heizkraftwerk Stuttgart-Münster	MÜN DT19 neu	Waste	ST	19.5	2009	Mühlhausen	
	BNA1139	TREA Breisgau		Waste	ST	13.6	2005	Eichstetten	
	BNA1144	EEW Göppingen	Turb. Neu	Waste	ST	11.0	2009	Bünzwangen	
	BNA1110	Restmüllheizkraftwerk Böblingen	Müllverbrennung	Waste	ST	9.5	1999	Stuttgart-Weilimdorf	
	BNA0640	HKW Mannheim	Turbine 3	Waste	ST	8.7	2005	BASF	
	BNA0641b	HKW Mannheim	Turbine D.0	Waste	ST	8.1	2012	BASF	
	BNA0641c	HKW Mannheim	Turbine E.0	Waste	ST	5.8	2012	BASF	
Bavaria	BNA0926b	Heizkraftwerk der Sappi Stockstadt GmbH		Coal	ST	24.8	1969	Aschaffenburg	
	BNA0261b	HKW Erlangen	K6 DT2	Coal	ST	17.4	1980	Kriegenbrunn	
	BNA0683a	Süd DT1	1	Gas	CC	275.5	1980	Föhring	Aggregation BNA0683b/BNA0683c (CCGT)
	BNA0684a	Süd GT 60	2	Gas	CC	265.0	2004	Föhring	Aggregation BNA0684b/BNA0684c (CCGT)
	BNA0805	Kraftwerk Plattling		Gas	GT	97.9	2010	Plattling	
	BNA0742	HKW Sandreuth	GuD 1	Gas	GT	75.0	2005	Kriegenbrunn	
	BNA0743	HKW Sandreuth	GuD 2	Gas	GT	75.0	2005	Kriegenbrunn	
	BNA0755b	Obernburg	1	Gas	GT	64.0	1995	Aschaffenburg	
	BNA0243	HKW Eltmann		Gas	GT	54.0	2008	Eltmann	
	BNA0174	Industriepark Werk Gendorf		Gas	GT	49.0	2002	Pirach	
	BNA1248	UPM Schongau	Dampfkraftwerk	Gas	GT	45.0	1969	Irsingen	
	BNA1088	Heizkraftwerke an der Friedensbrücke	GTI	Gas	GT	44.5	2005	Bergrheinfeld	
	BNA0755a	Obernburg	2	Gas	GT	36.0	1920	Aschaffenburg	
	BNA1087	Heizkraftwerke an der Friedensbrücke	GTII	Gas	GT	29.5	2009	Bergrheinfeld	
	BNA1103	UPM Augsburg	Dampfturbine 3	Gas	GT	29.0	1966	Lechhausen	
	BNA0033	Gasturbine	GT	Gas	GT	28.8	2004	Lechhausen	
	BNA0702	Cogeneration		Gas	GT	25.4	1996	Sittling	
	BNA1086	Heizkraftwerke an der Friedensbrücke	TSII	Gas	GT	25.0	1993	Bergrheinfeld	
	BNA1085	Heizkraftwerke an der Friedensbrücke	TSIII	Gas	GT	23.0	1971	Bergrheinfeld	
	BNA0261a	HKW Erlangen	GuD I	Gas	GT	21.6	2005	Kriegenbrunn	
	BNA1104	Heizkraftwerk	T2	Gas	GT	18.0	1976	Lechhausen	
	BNA1238	Kraftwerk Meggle		Gas	GT	12.6	2000	Marienberg	
	BNA1327a	Energiezentrale 1992	AGG1 - AGG7	Gas	GT	11.06	1992	Zolling	
	BNA0842a	Gasmotore	Gasmotore 1-3	Gas	GT	9.8	2011	Marienberg	
	BNA1327b	Erweiterung Energiezentrale 2003	AGG8 - AGG9	Gas	GT	7.44	2003	Zolling	
	BNA1127	GHD	GT1	Gas	GT	6.7	1998	Isar	
	BNA1128	GHD	GT2	Gas	GT	6.7	1998	Isar	
	BNA1225	PWG	MHKW 2	Gas	GT	5.3	1989	Oberbrunn	
	BNA1226	PWG	MHKW 1	Gas	GT	5.3	1987	Oberbrunn	
	BNA1444c	GT3		Gas	GT	5.1	1994	Ludersheim	
	BNA1444d	GT4		Gas	GT	5.1	1995	Ludersheim	
	BNA0843	Gasmotor 5	Gasmotor 5	Gas	GT	4.3	2012	Marienberg	
	BNA1444a	GT1		Gas	GT	4.2	1993	Ludersheim	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA1444b	GT2		Gas	GT	4.2	1993	Ludersheim	
	BNA0745	Franken 1	2	Gas	ST	440.0	1976	Kriegenbrunn	
	BNA0744	Franken 1	1	Gas	ST	383.0	1973	Kriegenbrunn	
	BNA0172	Dampfkraftwerk BGH - O1		Gas	ST	178.0	2001	Pirach	Year (1977) / 2001
	BNA1328	HBB	GUD	Gas	ST	24.0	2000	Marienberg	
	BNA0683b	Süd GT3	1	Gas			1980		in BNA0683a
	BNA0683c	Süd GT2	1	Gas			1980		in BNA0683a
	BNA0684b	Süd GT 62	2	Gas			2004		in BNA0684a
	BNA0684c	Süd DT60	2	Gas			2004		in BNA0684a
	BNA1092	Zolling	GT1 & GT2	Oil	GT	46.0	1976	Zolling	
	BNA1007a	SKW Gasturbine	SKW Gasturbine	Oil	GT	24.0	1988	Kempten-Au	
	BNA0427	Kraftwerk Hausham	GT 1	Oil	GT	23.2	1982	Marienberg	
	BNA0428	Kraftwerk Hausham	GT 2	Oil	GT	23.2	1982	Marienberg	
	BNA0429	Kraftwerk Hausham	GT 3	Oil	GT	23.2	1982	Marienberg	
	BNA0430	Kraftwerk Hausham	GT 4	Oil	GT	23.2	1982	Marienberg	
	BNA1338	Spitzenkraftwerk	MLD	Oil	GT	19.0	1995	Plattling	no year (assumption 1995)
	BNA1212	DKW Nord		Oil	GT	11.4	1995	Irsingen	no year (assumption 1995)
	BNA1227	DKW Leinau		Oil	GT	11.4	1995	Irsingen	no year (assumption 1995)
	BNA1007b	SKW Diesel	SKW Diesel	Oil	GT	10.5	1978	Kempten-Au	
	BNA1249	UPM Schongau	Heizkraftwerk 2	Other	ST	6.0	1995	Irsingen	no year (assumption 1995)
	BNA1254	Müllkraftwerk Schwandorf		Waste	ST	54.0	1982	Schwandorf	
	BNA0746	HKW Sandreuth		Waste	ST	25.0	1992	Kriegenbrunn	
	BNA0895	GKS	entfällt	Waste	ST	24.4	1994	Schweinfurt	
	BNA1449b	Turbosatz 2		Waste	ST	24.0	1998	Bergrheinfeld	
	BNA1161	MVA Ingolstadt	Müllheizkraftwerk	Waste	ST	21.4	1984	Ingolstadt	
	BNA1119	MHKW Burgkirchen		Waste	ST	12.0	1994	Pirach	
	BNA1295	AVA GmbH	AHKW	Waste	ST	10.0	1993	Lechhausen	
	BNA0845	MHKW	T1a/b, T2	Waste	ST	9.0	1988	Marienberg	
	BNA1449a	Turbosatz 1		Waste	ST		1984	Bergrheinfeld	no capacity
Berlin	BNA0082	Reuter	Reuter C	Coal	ST	124.0	1969	Reuter	
	BNA0085a	Moabit	Moabit A	Coal	ST	89.0	1990	Mitte	
	BNA0073	Mitte	GuD Mitte	Gas	CC	444.0	1996	Friedrichshain	
	BNA0074	Charlottenburg	Charlottenburg	Gas	GT	211.0	1975	Mitte	
	BNA0070	HKW Adlershof	NEZ	Gas	GT	7.9	2010	Wuhlheide	
	BNA0072	HKW Adlershof	KWC	Gas	GT	6.6	2002	Wuhlheide	
	BNA0071	HKW Adlershof	GT	Gas	GT	4.9	1996	Wuhlheide	
	BNA0075	Lichterfelde	Lichterfelde 1	Gas	ST	144.0	1972	Mitte	
	BNA0076	Lichterfelde	Lichterfelde 3	Gas	ST	144.0	1974	Mitte	
	BNA0081	Klingenberg	Klingenberg	Lignite	ST	164.0	1981	Wuhlheide	
	BNA0083	Wilmersdorf	Wilmersdorf	Oil	GT	276.0	1977	Mitte	
	BNA0085b	Moabit	Moabit GT	Oil	GT	51.0	1971	Mitte	
	BNA0084	Reuter	Reuter M	Waste	ST	36.0	1998	Reuter	
Brandenburg	BNA0130	Kirchmöser		Gas	CC	160.0	1994	Brandenburg-West	
	BNA0893	GuD Schwarzheide		Gas	CC	122.0	1994	Ragow	
	BNA0814	HKW Potsdam-Süd	Gesamtanlage	Gas	GT	81.8	1996	Reuter	
	BNA0005	Ahrensfelde	GT A	Gas	GT	37.5	1990	Marzahn	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0006	Ahrensfelde	GT B	Gas	GT	37.5	1990	Marzahn	
	BNA0007	Ahrensfelde	GT C	Gas	GT	37.5	1990	Marzahn	
	BNA0008	Ahrensfelde	GT D	Gas	GT	37.5	1990	Marzahn	
	BNA0734	Thyrow	GT E	Gas	GT	37.5	1989	Thyrow	
	BNA0735	Thyrow	GT F	Gas	GT	37.5	1989	Thyrow	
	BNA0736	Thyrow	GT G	Gas	GT	37.5	1989	Thyrow	
	BNA0737	Thyrow	GT H	Gas	GT	37.5	1989	Thyrow	
	BNA0738	Thyrow	GT A	Gas	GT	36.5	1987	Thyrow	
	BNA0739	Thyrow	GT B	Gas	GT	36.5	1987	Thyrow	
	BNA0740	Thyrow	GT C	Gas	GT	36.5	1987	Thyrow	
	BNA0741	Thyrow	GT D	Gas	GT	36.5	1987	Thyrow	
	BNA0129	HKW		Gas	GT	36.0	1997	Ragow	
	BNA0183	HKW Cottbus	1	Lignite	ST	74.0	1999	Preilack	
	BNA0284	Heizkraftwerk FFO	Block1-GuD-EK	Lignite	ST	45.0	1997	Eisenhüttenstadt	
	BNA0894c	IKS PCK Schwedt	Block 1 SE 1	Oil	GT	106.0	1998	Vierraden	
	BNA0894d	IKS PCK Schwedt	Block 2 SE 2	Oil	GT	106.0	1998	Vierraden	
	BNA0894e	IKS PCK Schwedt	SE 4	Oil	GT	59.0	2011	Vierraden	
	BNA0894b	IKS PCK Schwedt	Block 6 SE 6	Oil	GT	34.5	1994	Vierraden	
	BNA0894a	IKS PCK Schwedt	Block 5 SE 5	Oil	GT	28.0	1972	Vierraden	
	BNA0238	IKW		Other	GT	95.0	1953	Eisenhüttenstadt	
	BNA0237	EBS-Heizkraftwerk		Other	ST	23.5	2011	Eisenhüttenstadt	
	BNA0855	IKW Rüdersdorf		Waste	ST	30.0	2009	Neuenhagen	
	BNA1255	Kraftwerk Schwedt GmbH & Co.KG		Waste	ST	28.9	2011	Vierraden	
	BNA0380	EEW Großräschen		Waste	ST	23.3	2008	Ragow	
	BNA1233	EVE	EVE	Waste	ST	14.5	2009	Brandenburg-West	
	BNA1232	ZWSF	ZWSF	Waste	ST	2.5	2002	Brandenburg-West	
Bremen	BNA0146	KW Hafen	Block 6	Coal	ST	278.0	1979	Niedervieland	
	BNA0145	KW Hafen	Block 5	Coal	ST	127.0	1968	Niedervieland	
	BNA0144	KW Hastedt	Block 15	Coal	ST	119.0	1989	Blockland	
	BNA1334b	KWK-Anlage	GT 2	Gas	GT	4.8	2002	Niedervieland	
	BNA1334c	KWK-Anlage	GT 3	Gas	GT	4.8	2002	Niedervieland	
	BNA1334a	KWK-Anlage	GT 1	Gas	GT	4.6	1993	Niedervieland	
	BNA1334d	KWK-Anlage	DT	Gas	ST	0.4	2002	Niedervieland	
	BNA0141	KW Mittelsbüren	GT 3	Oil	GT	88.0	1974	Niedervieland	
	BNA0142	KW Mittelsbüren	Block 4	Other	GT	150.0	1975	Niedervieland	
	BNA0143	KW Mittelsbüren	Block 3	Other		110.0	1974	Niedervieland	
	BNA0139	KW Hafen	MKK	Waste	ST	29.3	2009	Niedervieland	
	BNA1116	BEG		Waste	ST	14.0	1976	Unterweser	
	BNA1114	MHKW	MHKW	Waste	ST	12.2	1969	Blockland	
Hamburg	BNA0402	Tiefstack	Tiefstack	Coal	ST	194.0	1993	Hamburg-Ost	
	BNA0400	GuD Tiefstack	GuD Tiefstack	Gas	CC	127.0	2009	Hamburg-Ost	
	BNA0401	Heizkraftwerk	HKW	Gas	GT	16.3	1992	Hamburg-Süd	
	BNA1294	EEV	EEV	Oil	GT	38	1993	Hamburg-Süd	
	BNA0398	MVR Müllverwertung Rugenberger Damm		Waste	ST	24.0	1999	Hamburg-Süd	
Hessen	BNA0498	Heizkraftwerk	Block B	Coal	ST	66.0	1989	Höchst-Süd	
	BNA0289b	HKW West	Block 2	Coal	ST	61.5	1989	Frankfurt-Südwest	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0290	HKW West	Block 3	Coal	ST	61.5	1989	Frankfurt-Südwest	
	BNA0758	Heizkraftwerk Offenbach		Coal	ST	54.0	1990	Frankfurt-Nord	
	BNA0857	GuD-Anlage Rüsselsheim	M120	Gas	CC	112.1	1999	Bischofsheim	
	BNA0444	Wintershall	Wintershall	Gas	GT	109.5	1967	Mecklar	
	BNA0286	HKW West	Block 4	Gas	GT	99.0	1994	Frankfurt-Südwest	
	BNA0497	ADS-Anlage		Gas	GT	96.5	2012	Höchst-Süd	
	BNA0499	Heizkraftwerk	Block A	Gas	GT	86.0	2003	Höchst-Süd	
	BNA0285	HKW Niederrad	Block 1	Gas	GT	70.0	2005	Frankfurt-Südwest	
	BNA0288	HKW Niederrad	Block 2	Gas	GT	56.0	1973	Frankfurt-Südwest	
	BNA0521	Kombi-HKW		Gas	GT	52.9	1987	Bergshausen	
	BNA0804a	Hattorf	Hattorf	Gas	GT	35.0	1962	Mecklar	
	BNA1492a	Kraftwerk 3		Gas	GT	26.2	1990	Dipperz	
	BNA1056	Wi-Biebrich	Block 1	Gas	GT	25.0	2006	Bischofsheim	Year (2003) / 2006
	BNA0059a	HKW Kassel	Turbine 1	Gas	GT	12.2	1961	Bergshausen	
	BNA1117	Industriekraftwerk Breuberg		Gas	GT	11.4	1999	Aschaffenburg	
	BNA1125	Heizkraftwerk	GT	Gas	GT	10.0	1999	Pfungstadt	
	BNA1492b	Kraftwerk 2		Gas	GT	8.0	1995	Dipperz	no year (assumption 1995)
	BNA0523	FKK		Lignite	ST	33.5	1988	Bergshausen	
	BNA0318	ÜWAG Kraftwerk Fulda		Oil	GT	24.8	2011	Dipperz	
	BNA0289a	HKW West	M4	Other	GT	19.7	1954	Frankfurt-Südwest	
	BNA1465	EBS-Kraftwerk Witzenhausen		Other	ST	28.0	2009	Göttingen	
	BNA0287b	MHKW Frankfurt	T 7	Waste	ST	46.5	2006	Frankfurt-Südwest	
	BNA0287a	MHKW Frankfurt	T 3	Waste	ST	26.0	1998	Frankfurt-Südwest	
	BNA1168	Müllheizkraftwerk		Waste	ST	14.7	1985	Bergshausen	
	BNA1222	Müllheizkraftwerk Offenbach		Waste	ST	10.4	1972	Urberach	
Lower Saxony	BNA1076a	HKW West	Block 1	Coal	ST	138.5	1985	Bergshausen	
	BNA1076b	HKW West	Block 2	Coal	ST	138.5	1985	Hattorf	
	BNA0420	GKH	Block1	Coal	ST	130.0	1989	Hannover-West	
	BNA0421	GKH	Block2	Coal	ST	130.0	1989	Hannover-West	
	BNA1075a	HKW Nord	Generator A	Coal	ST	61.5	2000	Bergshausen	
	BNA1075b	HKW Nord	Generator B	Coal	ST	61.5	2000	Hattorf	
	BNA0138	HKW-Mitte	Block 1	Coal	ST	43.3	1984	Braunschweig-Nord	
	BNA0418	GKL	GKL	Gas	CC	250.0	1998	Lahe	Year 1998 / (2013)
	BNA0136	HKW-Mitte	GuD	Gas	CC	74.0	2010	Braunschweig-Nord	
	BNA0419	KWH	B	Gas	GT	102.0	1975	Lahe	
	BNA1335a	PKV Kraftwerk	KWK-Blöcke	Gas	GT	58.1	1989	Conneforde	
	BNA0137	HKW-Nord	GT	Gas	GT	25.0	1965	Braunschweig-Nord	
	BNA0012b	Werkskraftwerk Sappi Alfeld	Gaskraftwerk	Gas	GT	20.0	1947	Godenau	
	BNA0135	HKW-Mitte	Block 12	Gas	GT	20.0	1971	Braunschweig-Nord	
	BNA1463			Gas	GT	19.5	1978	Wolkramshausen	
	BNA1285	Sigmundshall	Sigmundshall	Gas	GT	19.0	1974	Hannover-West	
	BNA0354	HKW Göttingen		Gas	GT	18.8	1998	Göttingen	
	BNA1402	Heizkraftwerk zur Papierfabrik		Gas	GT	18.1	1995	Cloppenburg	no year (assumption 1995)
	BNA1450	GUD-Anlage DREWSEN		Gas	CC	13.0	2000	Klein Ilsede	
	BNA0602	Emsland	C1	Gas	ST	112.0	2011	Hanekenfähr	
	BNA0603	Emsland	B1	Gas	ST	112.0	2011	Hanekenfähr	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA1335b	PKV Kraftwerk	Kondensationsturbine	Gas	ST	0.48	1968	Conneforde	
	BNA1060	Wilhelmshaven	GT	Oil	GT	56.0	1973	Maade	
	BNA0865a	Gichtgas HO A	Gichtgas HO A	Other	GT	10.0	1995	Hallendorf	no year (assumption 1995)
	BNA0864	Kraftwerk Salzgitter	Block 1	Other	ST	97.0	2010	Hallendorf	
	BNA0865b	Kraftwerk Salzgitter	Block 2	Other	ST	97.0	2010	Hallendorf	
	BNA0863	Kraftwerk Salzgitter	AB	Other	ST	94.5	1939	Hallendorf	
	BNA0438	TRV Buschhaus	Linie 1-3	Waste	ST	37.5	1998	Helmstedt	
	BNA0417	E.ON Energy from Waste Hannover GmbH	Hannover	Waste	ST	22.5	2005	Lahe	
	BNA0407	Enertec Hameln	Linien 1,3,4	Waste	ST	14.7	1912	Grohnde	
Mecklenburg-West Pomerania	BNA0848	GuD Marienehe		Gas	CB	108.0	1996	Rostock	
	BNA0688	GuD-HKW Neubrandenburg		Gas	CB	75.0	1997	Windpark Iven	
	BNA0896	HKW Schwerin Süd		Gas	GT	52.0	1994	Görries	
	BNA0897	HKW Schwerin Lankow		Gas	GT	23.0	1994	Görries	
	BNA0025	Kesselhaus Zuckerfabrik		Gas	GT	15.1	1993	Lubmin	
	BNA0360	HKW "Helmshäger Berg"	Gasturbine	Gas	GT	13.8	1996	Lubmin	
	BNA1243	EBS-HKW Rostock		Waste	ST	17.0	2009	Rostock	
North Rhine Westphalia	BNA0413	Westfalen	C	Coal	ST	284.0	1969	Uentrop West	
	BNA1035	Kraftwerk Werdohl-Elverlingsen	E3	Coal	ST	186.0	1971	Elverlingsen	
	BNA0618	KW Lünen	Lünen 6	Coal	ST	149.0	1962	Elmenhorst	
	BNA0662b	Kraftwerk I	Dampfwirtschaft	Coal	ST	133.5	1995	Kusenhorst	no year (assumption 1995)
	BNA0448	Shamrock		Coal	ST	132.0	1957	Herne	
	BNA0189	Datteln	3	Coal	ST	113.0	1969	Ruhr-Zink	
	BNA0557b	Kraftwerk N 230		Coal	ST	110.0	1971	Uerdingen	
	BNA0600b	G-Kraftwerk		Coal	ST	103.0	1962	Uerdingen	
	BNA0187	Datteln	1	Coal	ST	95.0	1964	Ruhr-Zink	
	BNA0188	Datteln	2	Coal	ST	95.0	1964	Ruhr-Zink	
	BNA0211	HKW I	ZAWSF	Coal	ST	95.0	1985	Ruhrort	
	BNA1084	HKW Elberfeld	Block 3	Coal	ST	85.0	1989	Halfeshof	
	BNA0834	Industrie-Kraftwerk		Coal	ST	79.0	1975	Ossenberg	
	BNA0336	FWK Buer		Coal	ST	70.0	1985	Bellendorf	
	BNA0661	Kraftwerk II	Block 3	Coal	ST	60.4	1966	Kusenhorst	
	BNA0662a	Kraftwerk I	Block 5	Coal	ST	60.2	1983	Kusenhorst	
	BNA0660	Kraftwerk I	Block 4	Coal	ST	55.3	1971	Kusenhorst	
	BNA0557a	Kraftwerk L 57		Coal	ST	26.0	1957	Uerdingen	
	BNA1331	Reno De Medici	HD - Kraftwerk	Coal	ST	19.1	1956	Arpe	Year (1923) / 1956
	BNA1039	Gersteinwerk	F1	Gas	GT	55.0	1973	Gersteinwerk	
	BNA1040	Gersteinwerk	G1	Gas	CB	55.0	1973	Gersteinwerk	
	BNA1042	Gersteinwerk	I1	Gas	GT	55.0	1973	Gersteinwerk	
	BNA0199	Dormagen	GuD	Gas	CC	585.5	2000	St. Peter	
	BNA0545	HKW Niehl 2	GuD	Gas	CC	413.0	2005	Dünnwald	
	BNA0442	Cuno Heizkraftwerk Herdecke	H6	Gas	GT	417.0	2007	Kruckel	Not closest node
	BNA0221c	Gasblock	Block E	Gas	CB	293.0	1976	Norf	
	BNA0214	HKW III/B	HKW III/B	Gas	GT	234.0	2005	Rheinhausen	
	BNA0389	Heizkraftwerk Hagen-Kabel	H4/5	Gas	GT	230.0	1980	Garenfeld	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0531	KW Kirchlengern		Gas	GT	201.5	1980	Eickum	
	BNA1046b	Gersteinwerk	K1	Gas	CB	112.0	1984	Gersteinwerk	
	BNA0546	HKW Merkenich	GuD	Gas	GT	108.0	2004	Bayer Y35	
	BNA0685	Heizkraftwerk Hafen	GuD	Gas	GT	100.2	2005	Amelsbüren	
	BNA0220	GuD	AGuD	Gas	CC	100.0	2000	Norf	
	BNA1336	Holthausen		Gas	GT	84	1948	Reisholz	
	BNA1082	HKW Barmen	Block 1	Gas	GT	82.0	2005	Linde	
	BNA0659	Kraftwerk III	Block 312	Gas	GT	77.6	1974	Kusenhorst	
	BNA0221b	GT	Block E GTE1	Gas	CB	66.7	1974	Norf	
	BNA0221a	GT	Block E GTE2	Gas	CB	64.7	1974	Norf	
	BNA0658	Kraftwerk III	Block 311	Gas	GT	61.1	1973	Kusenhorst	
	BNA1041	Gersteinwerk	H1	Gas	GT	55.0	1973	Gersteinwerk	
	BNA1279	Gasturbine	D290	Gas	GT	51.9	1995	Bollenacker	
	BNA0213	HKW III/A	HKW III/A	Gas	GT	40.0	2002	Rheinhausen	
	BNA0100	GuD Kraftwerk Hillegossen	GuD	Gas	CC	37.5	2005	Eickum	
	BNA0544	HKW Südstadt	GuD	Gas	GT	35.0	1994	Bollenacker	
	BNA0556a	KWK-Anlage Krefeld DT	Dampfturbine	Gas	GT	25.8	2004	Edelstahl	
	BNA0753	HKW 2	HKW 2	Gas	GT	24.5	1995	Thyssen	
	BNA0098	HKW Schildescher Straße		Gas	GT	23.5	1978	Eickum	
	BNA0752	HKW 1	HKW 1	Gas	GT	23.1	1972	Thyssen	
	BNA1332	Sasol Kraftwerk	TG7/8	Gas	GT	22.3	1995	Utfort	
	BNA0386	Energiezentrum Mohn Media		Gas	GT	22.0	1994	Gütersloh	
	BNA0110	Bochum	KBO	Gas	GT	20.7	2004	Bochum	
	BNA1406	FS-Karton		Gas	GT	18.9	1992	Osterath	
	BNA1183	HKW Merheim	GuD	Gas	GT	15.8	2001	Gremberghoven	
	BNA1182	HKW Merkenich	Block 4	Gas	GT	15.5	1965	Bayer Y35	
	BNA1094	Gaskraftwerk	GKW	Gas	GT	15.1	1966	Hambach	
	BNA0556b	KWK-Anlage Krefeld VM	Gasmotor	Gas	GT	14.0	2004	Gellep	
	BNA0156b	Egger Kraftwerk Brilon	Gasturbinen - KWK	Gas	GT	13.5	1996	Nehden	
	BNA1193	HKW-West		Gas	GT	12.8	2002	Lage	
	BNA0202	Dortmund	KDO	Gas	GT	12.0	2004	Ratsbusch	
	BNA1165	P&L Werk Appeldorn	Lentjes-Kessel	Gas	GT	11.4	2004	Pfalzdorf	
	BNA1120	Energiezentrale	Gasturbine	Gas	GT	10.2	1991	Pöppinghausen	
	BNA1138	BHKW an Klinkerweg	Module 1, 2 und 3	Gas	GT	10.2	2000	Mettmann	
	BNA1187	P&L Werk Lage	Kessel 1/2/3	Gas	GT	10.2	1980	Lage	
	BNA1121	Energiezentrale	Energiecenter	Gas	GT	0.9	2005	Pöppinghausen	
	BNA0810	Kraftwerk Veltheim	4 GT	Gas	ST	65.0	1974	Veltheim	
	BNA0101	HKW Schildescher Straße		Gas	ST	53.0	1966	Eickum	
	BNA0111	HKW Hiltrop		Gas	ST	30.3	1975	Laer	
	BNA0600a	X-Kraftwerk		Gas	ST	29.0	1981	Bayer Y35	
	BNA1131	MT, Düren		Gas	ST	14.0	2011	Oberzier	
	BNA0117	Heizkraftwerk Karlstraße	Heizkraftwerk Karlstraße	Gas	ST	12.0	1991	Stockem	
	BNA1025	Weisweiler	E	Lignite	ST	312.0	1965	Weisweiler	
	BNA0292	Frechen/Wachtberg	Frechen/Wachtberg	Lignite	ST	118.0	1959	Knapsack	
	BNA0490	Goldenberg	F	Lignite	ST	85.0	1993	Knapsack	
	BNA0543	HKW Merkenich	Block 6	Lignite	ST	75.3	2010	Bayer Y35	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0489	Goldenberg	E	Lignite	ST	66.0	1992	Knapsack	
	BNA0714	Fortuna Nord	Fortuna Nord	Lignite	ST	54.0	1995	Niederaußem	no year (assumption 1995)
	BNA0491	Ville/Berrenrath	Ville/Berrenrath	Lignite	ST	52.0	1995	Knapsack	no year (assumption 1995)
	BNA1451	HKW Sachtleben		Lignite	ST	27.5	1995	Ruhrort	no year (assumption 1995)
	BNA1164	P&L Werk Jülich	Kessel 5	Lignite	ST	24.6	2004	Oberzier	
	BNA1097	Kohlekraftwerk	K06	Lignite	ST	14.4	2010	Hambach	
	BNA1141	P&L Werk Euskirchen	Kessel 4 / 6	Lignite	ST	10.0	1995	Meckenheim	no year (assumption 1995)
	BNA1293b	Kraftwerk	K2/TG2	Lignite	ST	10.0	1995	Niederaußem	
	BNA0222	GT	GTKW	Oil	GT	86.2	1977	Eller	
	BNA0547	Raffineriekraftwerk Köln Godorf		Oil	GT	80.0	2004	Bollenacker	
	BNA1280	Kraftwerk	D210	Oil	GT	66.3	1962	Bollenacker	
	BNA1083	Spitzenlastanlage Barmen	Block 2	Oil	GT	60.0	2008	Linde	
	BNA0219	Duisburg Ruhrort 4	Block 4	Other	GT	165.0	1968	Beeck	Not closest node
	BNA0396	Duisburg Hamborn 4	Block 4	Other	GT	100.0	1976	Beeck	
	BNA0218	Duisburg Ruhrort 3	Block 3	Other	GT	90.0	1963	Ruhrort	
	BNA0217	Duisburg Ruhrort 2	Block 2	Other	GT	60.0	1955	Ruhrort	
	BNA0395	Duisburg Hamborn 3	Block 3	Other	GT	60.0	1958	Beeck	
	BNA0397	Duisburg Hamborn 5	Block 5	Other	ST	225.0	2003	Beeck	Not closest node
	BNA1399	Oxea GmbH		Other		38.0	1995	Handbach	no year (assumption 1995)
	BNA1397e	O10	T31	Other		30.0	1967	St. Peter	
	BNA1409	DK Kraftwerk		Other		21.0	2010	Rheinhausen	
	BNA1397a	O10	T21	Other		20.5	1963	St. Peter	
	BNA1397b	O10	T22	Other		20.5	1963	St. Peter	
	BNA1397c	O10	T23	Other		20.5	1963	St. Peter	
	BNA1488			Other		16.0	1989	Wambel	Year (1984) / 1989
	BNA1397d	O10	T24	Other		10.0	1966	St. Peter	
	BNA0223b	DT	Flingern T1	Waste	ST	53.7	2000	Eller	
	BNA1184	RMVA Köln	RMVA Köln	Waste	ST	45.1	1997	Frühlingen	
	BNA0750	GMVA Niederrhein	Turbine 2	Waste	ST	40.4	1990	Handbach	
	BNA0519	Karnap	B	Waste	ST	38.0	1987	Karnap	
	BNA0097	MVA Bielefeld	Linien 1 - 3	Waste	ST	34.0	1981	Bielefeld-Ost	
	BNA1490	EBKW Knapsack		Waste	ST	33.4	2008	Knapsack	
	BNA1316	Müllheizkraftwerk		Waste	ST	30	1976	Halfeshof	
	BNA1020	MVA Weisweiler	MVA	Waste	ST	24.0	1996	Weisweiler	
	BNA0751	GMVA Niederrhein	Turbine 1	Waste	ST	21.1	2006	Handbach	
	BNA1155	RZR Herten II	RZR II	Waste	ST	17.1	2009	Herne	
	BNA1167	Abfallentsorgungszentrum Asdonkshof	MVA	Waste	ST	16.0	1997	Ossenberg	
	BNA1148	MVA Hamm		Waste	ST	14.6	1985	Gersteinwerk	
	BNA1186b	MKVA Krefeld	Turbine 4	Waste	ST	13.8	1995	Uerdingen	no year (assumption 1995)
	BNA1186a	MKVA Krefeld	Turbine 3	Waste	ST	13.5	1995	Uerdingen	no year (assumption 1995)
	BNA1289	AMK - Abfallentsorgungsgesellschaft des Märkischen Kreises mbH		Waste	ST	12.6	1981	Bixterheide	
	BNA1154	RZR Herten I	RZR I	Waste	ST	12.5	1982	Herne	
	BNA0599	AVEA MHKW Leverkusen GmbH & Co. KG	entfällt	Waste	ST	11.6	2011	Bayer Y35	
	BNA1186d	MKVA Krefeld	Turbine 5	Waste	ST	2.8	1995	Uerdingen	no year (assumption 1995)
	BNA1186c	MKVA Krefeld	Turbine 2	Waste	ST	1.5	1995	Uerdingen	no year (assumption 1995)

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA1186e	MKVA Krefeld	Turbine 1	Waste	ST	1.5	1995	Uerdingen	no year (assumption 1995)
Rhineland Palatinate	BNA0510b	HKW Karcherstr.	20	Coal	ST	13.4	1996	Otterbach	
	BNA0615	Kraftwerk Süd	GUD C200 GT1, GT2, DT 1	Gas	CB	390.0	1997	BASF	
	BNA0626	Kraftwerk Mainz	KW3	Gas	CC	398.0	2001	Bischofsheim	
	BNA1078	HKW Wörth		Gas	GT	59.0	2008	Karlsruhe RDK	
	BNA1458			Gas	GT	28.0	1995	Otterbach	no year (assumption 1995)
	BNA1196a	BHKW Ludwigshafen		Gas	GT	12.5	2008	Mannheim West	
	BNA1291	IHKW Andernach		Gas	GT	12.4	2009	Bandstahl	
	BNA1196b	Industriekraftwerk Ludwigshafen		Gas	GT	12.0	2003	Mannheim West	
	BNA0510a	HKW Karcherstr.	10	Gas	GT	11.6	1989	Otterbach	
	BNA1284	Co-Generation	-	Gas	GT	11.5	1991	Bürstadt	
	BNA0616b	Kraftwerk Nord	S300, VT 1, VT 2, NT 7	Other	GT	56.0	1964	Mannheim West	
	BNA1197	FHKW Ludwigshafen	FHKW	Waste	ST	28.7	1954	BASF	
	BNA1199	MHKW Mainz		Waste	ST	15.6	2009	Bischofsheim	
	BNA1229	MHKW Pirmasens		Waste	ST	15.0	1999	Homburg	
	BNA1447a		G2	Waste	ST	11.9	1990	Bürstadt	
	BNA1447b		G3/Kontu	Waste	ST	6.9	2011	Bürstadt	
Saarland	BNA0252	Kraftwerk Ensdorf	Block 3	Coal	ST	283.0	1971	Ensdorf	
	BNA0999	Heizkraftwerk	HKV	Coal	ST	211.0	1989	Ensdorf	
	BNA0998	Modellkraftwerk	MKV	Coal	ST	179.0	1982	Ensdorf	
	BNA0861	Römerbrücke	HKW Römerbrücke	Gas	CB	125.0	2005	Weiher	
	BNA1464	Gas- u. Dampfturbinenanlage Südraum		Gas	GT	38.6	2012	Weiher	
	BNA1115	Gichtgaskraftwerk Dillingen		Other	GT	85.0	2010	Dillinger Hütte	
	BNA1244	AVA Velsen		Waste	ST	15.5	1997	Ensdorf	
	BNA1448	AHKW Neunkirchen	Linie 3 + 4	Waste	ST	11.6	1999	Mittelbexbach	
Saxony	BNA0207	HKW Dresden-Nossener Brücke	3 GT + 1 DT	Gas	CC	250.0	1995	Dresden-Süd	
	BNA0588	Heizkraftwerk Leipzig-Nord		Gas	GT	167.0	1996	Taucha	
	BNA0178	HKW Chemnitz Nord II	Block A	Gas	GT	57.2	1986	Niederwiesa	
	BNA0233	Kombikraftwerk		Gas	GT	46.6	1993	Taucha	
	BNA1396	EVC / GLOBALFOUNDRIES	EVC I	Gas	GT	34.7	1998	Dresden-Süd	
	BNA1407	STW		Gas	GT	13.5	2007	Niederwiesa	
	BNA1329	K&N PFK AG EV	GT / GDT	Gas	GT	12.75	1993	Niederwiesa	
	BNA0179	HKW Chemnitz Nord II	Block C	Lignite	ST	90.8	1990	Niederwiesa	
	BNA0177	HKW Chemnitz Nord II	Block B	Lignite	ST	56.8	1988	Niederwiesa	
	BNA0369	Spitzenlastkraftwerk Sermuth		Oil	GT	17.0	1995	Eula	
	BNA1190	Thermische Abfallbehandlung Lauta GmbH		Waste	ST	15.0	2004	Schmölln	
Saxony Anhalt	BNA0922	GuD-Ikw Staßfurt		Gas	CC	132.0	1996	Förderstedt	
	BNA0105	GuD Bitterfeld		Gas	GT	106.0	2000	Marke	
	BNA0392a	HKW Halle Trotha	Block A und B	Gas	GT	97.0	2005	Schkopau	
	BNA0592	GuD Leuna		Gas	CB	52.0	1998	Schkopau	
	BNA1089	Zielitz	Zielitz	Gas	GT	52.0	1996	Wolmirstedt	
	BNA1074	Spitzenlastkraftwerk Wolfen		Gas	GT	40.0	1997	Marke	
	BNA0595	ILK-GuD	GT3	Gas	GT	37.0	1994	Schkopau	
	BNA0593	ILK-GuD	GT1	Gas	GT	35.0	1994	Schkopau	
	BNA0594	ILK-GuD	GT2	Gas	GT	35.0	1994	Schkopau	
	BNA1489	Heizkraftwerk Stendal		Gas	GT	22.0	1994	Stendal-West	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0051	KWK-Anlage Barby	-	Gas	GT	16.0	1993	Förderstedt	
	BNA1403	Steinitz	GUD	Gas	GT	11.4	1995	Hattorf	
	BNA0088b	Industriekraftwerk Bernburg (IKB)		Gas	ST	66.0	1994	Förderstedt	
	BNA0196	Deuben		Lignite	ST	67.0	1936	Großdalzig	
	BNA0194	Kraftwerk Dessau		Lignite	ST	49.0	1996	Marke	
	BNA1486	Grubenheizkraftwerk		Lignite	ST	49.0	1979	Lauchstädt	
	BNA1002	Wählitz		Lignite	ST	31.0	1994	Großdalzig	
	BNA1185	P&L Werk Könnern	Kessel 1 und 2	Lignite	ST	20.3	1995	Förderstedt	no year (assumption 1995)
	BNA1400a	EZ1	WSK	Lignite	ST	18.5	1993	Großdalzig	
	BNA1461			Lignite	ST	17.5	2005	Großdalzig	
	BNA0373	Spitzenlastkraftwerk Großkayna		Oil	GT	120.0	1994	Schkopau	
	BNA0596	Raffineriekraftwerk		Oil	GT	92.5	1997	Schkopau	
	BNA1400b	EZ1	DTI	Oil	GT	14.5	1993	Großdalzig	
	BNA0598b	ILK-GuD	KT1	Other	ST	20.0	2010	Schkopau	
	BNA0598a	ILK-EKT	EKT	Other	ST	14.0	2000	Förderstedt	
	BNA0597	ILK-GuD	DT1	Other	ST	8.7	1994	Schkopau	
	BNA0088a	Dampfturbinenanlage der EBS-Kessel		Waste	ST	35.0	2010	Förderstedt	
	BNA0622	MHKW Rothensee	Block 1	Waste	ST	29.2	2005	Wolmirstedt	
	BNA0623	MHKW Rothensee	Block 2	Waste	ST	29.2	2006	Wolmirstedt	
	BNA1198	SITA Abfallverwertung GmbH		Waste	ST	25.4	2005	Großdalzig	
	BNA1262	EVZA Energie- und Verwertungszentrale		Waste	ST	24.0	2008	Förderstedt	
	BNA0590	TREA Leuna	Linie 1	Waste	ST	16.3	2005	Schkopau	
	BNA0591	TREA Leuna	Linie 2	Waste	ST	16.3	2007	Schkopau	
	BNA1108	PD energy GmbH		Waste	ST	9.9	2010	Marke	
Schleswig-Holstein	BNA0404	Wedel	Wedel 1	Coal	ST	137.0	1961	Kummerfeld	
	BNA0403	Wedel	Wedel 2	Coal	ST	123.0	1962	Kummerfeld	
	BNA0273	Heizkraftwerk FL	Block 8	Coal	ST	35.0	1982	Flensburg	
	BNA0272	Heizkraftwerk FL	Block 9	Coal	ST	33.0	1985	Flensburg	
	BNA0271	Heizkraftwerk FL	Block 10	Coal	ST	29.0	1988	Flensburg	
	BNA0270	Heizkraftwerk FL	Block 11	Coal	ST	27.0	1992	Flensburg	
	BNA0274	Heizkraftwerk FL	Block 7	Coal	ST	23.0	1978	Flensburg	
	BNA0527	HKW Humboldtstr.	GT 5/6; DT1	Gas	GT	20.0	1970	Kiel	
	BNA0759	Itzehoe		Oil	GT	88.0	1972	Itzehoe	
	BNA0766	Audorf		Oil	GT	87.0	1973	Audorf	
	BNA1015	Wedel	GT A	Oil	GT	50.5	1972	Kummerfeld	
	BNA1016	Wedel	GT B	Oil	GT	50.5	1972	Kummerfeld	
	BNA0693c	Heizkraftwerk NMS	Diesel 3	Oil	GT	5.5	1982	Kiel-Süd	
	BNA0693a	Heizkraftwerk NMS	Turbine 2,3,4,5	Other	ST	60.0	1982	Kiel-Süd	
	BNA1330	Steinbeis Energie		Other	ST	17	2010	Brokdorf	
	BNA1261	EEW Stapelfeld GmbH		Waste	ST	16.4	1978	Hamburg-Ost	
Thuringia	BNA0504	HKW Jena	HKW Jena	Gas	GT	182.0	1996	Großschwabhausen	
	BNA0256	HKW Erfurt-Ost		Gas	GT	78.5	2000	Vieselbach	
	BNA0343	Heizkraftwerk Gera-Nord		Gas	GT	74.0	1997	Weida	
	BNA0856	HKW Schwarza		Gas	GT	21.1	2008	Hohenwarte	Year (1936) / 2008
	BNA1264	HKW Bohrhügel		Gas	GT	13.5	1995	Altenfeld	
	BNA0255	HKW Iderhoffstraße		Gas	GT	11.0	1996	Vieselbach	

Table 30: Pumped storage power plants[26]

State	Number BNetzA	Name of power plant	Block name	Net capacity in MW	Storage size* in MWh	High-voltage node	Comments
Baden Wurttemberg	BNA0426	Häusern	Häusern	100.0	463	Tiengen	Node Tiengen / (Gurtweil)
	BNA1003	Kraftwerk Waldshut	Waldshut	150.0	402	Gurtweil	
	BNA0669	Pumpspeicherkraftwerk Glems	Pumpspeicherkraftwerk Glems	90.0	560	Metzingen	
	BNA0279	Rudolf-Fettweis-Werk	Pumpspeicherkraftwerk Schwarzenbachwerk	43.0	301	Bühl*	Closest node
	BNA0046	Säckingen	Säckingen	360.0	2520	Kühmoos	
	BNA1019	Wehr	Wehr	910.0	6370	Kühmoos	
	BNA1071	Witznau	Witznau	220.0	636	Tiengen*	Node Tiengen / (Gurtweil)
Bavaria	BNA0946a	Kraftwerksgruppe Pfreimd	PSKW Tanzmühle	28.0	88	Etzenricht*	Closest node
	BNA0953	Kraftwerksgruppe Pfreimd	PSKW Reisach	99.0	312	Etzenricht*	Closest node
	BNA0972	Leitzach 1	1	49.0	250	Marienberg*	Closest node
	BNA0973	Leitzach 2	2	49.8	300	Marienberg*	Closest node
	BNA0337	PSW Langenprozelten	entfällt	164.0	1148	Aschaffenburg*	Closest node
Hessen	BNA0229	Waldeck 2	Waldeck 2	480.0	3360	Waldeck	
	BNA0228	Waldeck1/Bringhausen	Waldeck1/Bringhausen	143.0	1001	Waldeck	
Lower Saxony	BNA0558	Erzhausen		220.0	940	Erzhausen	
North Rhine Westphalia	BNA0443	Koepchenwerk	Koepchenwerk	153.0	590	Garenfeld	
	BNA0268	Pumpspeicherwerk Rönkhausen	PSW	138.0	690	Elverlingsen	Closest node in 110kV grid
Saxony	BNA0652	Markersbach	PSS A	1,045.2	4020	Markersbach	Node Markersbach
	BNA0653	Markersbach	PSS B				
	BNA0654	Markersbach	PSS C				
	BNA0655	Markersbach	PSS D				
	BNA0656	Markersbach	PSS E				
	BNA0657	Markersbach	PSS F				
	BNA0721	Niederwartha	PSS C	39.8	790	Dresden-Süd*	Closest node
	BNA0722	Niederwartha	PSS D				
Saxony Anhalt	BNA1031	Wendefurth	PSS A	79.7	522	Wolkramshau-sen*	Closest node
	BNA1032	Wendefurth	PSS B				
Schleswig-Holstein	BNA0327	Geesthacht	PSS A	119.1	534	Krümmel*	Closest node
	BNA0328	Geesthacht	PSS B				
	BNA0329	Geesthacht	PSS C				
Thuringia	BNA0882	Bleiloch	PSS A	79.8	800	Remptendorf	
	BNA0883	Bleiloch	PSS B				
	BNA0350	Goldisthal	PSS A	1,052.0	8500	Altenfeld	
	BNA0351	Goldisthal	PSS B				
	BNA0352	Goldisthal	PSS C				
	BNA0353	Goldisthal	PSS D				

[26] Data is based on the power plant dataset by (BNetzA, 2013a) published on 16.10.2013 and adjusted for 2012. Every * indicates data with additional sources not listed or own assumptions. Additional information not provided in the BNetzA data set is the pumping capacity which deviates from the generation capacity for most pumped storage power plants.

State	Number BNetzA	Name of power plant	Block name	Net capacity in MW	Storage size* in MWh	High-voltage node	Comments
	BNA0465	Hohenwarte 1	PSS A	59.8	600	Remptendorf	
	BNA0466	Hohenwarte 1	PSS B				
	BNA0467	Hohenwarte 2	PSS A	317.8	2088	Remptendorf	
	BNA0468	Hohenwarte 2	PSS B				
	BNA0469	Hohenwarte 2	PSS C				
	BNA0470	Hohenwarte 2	PSS D				
	BNA0471	Hohenwarte 2	PSS E				
	BNA0472	Hohenwarte 2	PSS F				
	BNA0473	Hohenwarte 2	PSS G				
	BNA0474	Hohenwarte 2	PSS H				

Table 31: Renewable power plants outside the EEG scheme[27]

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
Baden Wurttemberg	BNA0232b	Werkskraftwerk Sappi Ehingen		Biomass	ST	8.0	1961	Dellmensingen	
	BNA0520	Stora Enso Maxau		Biomass	ST	78.0	2010	Daxlanden	
	BNA0010a	RADAG		Hydro	RoR	79.5	1933	Gurtweil	
	BNA0045	Rheinkraftwerk Säckingen	Säckingen	Hydro	RoR	27.6	1959	Schwörstadt	
	BNA0278	Rudolf-Fettweis-Werk	Forb/ Murgwerk	Hydro	RoR	22.0	1918	Kuppenheim	
	BNA0362	KW Wyhlen	KW Wyhlen	Hydro	RoR	37.9	1912	Schwörstadt	
	BNA0494	Rheinkraftwerk Iffezheim	Iffezheim M1-M4	Hydro	RoR	54.6	1978	Kuppenheim	
	BNA0825	Rheinkraftwerk Reckingen	Reckingen	Hydro	RoR	19.0	1938	Gurtweil	
	BNA0859	Rheinkraftwerk Ryburg-Schwörstadt	Ryburg-Schwörstadt	Hydro	RoR	30.0	1931	Schwörstadt	
	BNA1126	Dettingen	Dettingen	Hydro	RoR	11.0		Dellmensingen	
	BNA1175	Unteropfingen	Unteropfingen	Hydro	RoR	14.2		Dellmensingen	
	BNA1265	Tannheim	Tannheim	Hydro	RoR	12.3		Dellmensingen	
Bavaria	BNA0540	Walchensee	Walchensee	Hydro	RES	72.0	1924	Krün	
	BNA0847	Roßhaupten	Roßhaupten	Hydro	RES	45.5	1954	Leupolz	
	BNA0042	Egglfing	Egglfing	Hydro	RoR	40.4	1944	AT St. Peter	
	BNA0065	Bergheim	entfällt	Hydro	RoR	23.7	1970	Ingolstadt	
	BNA0173	Alzwerke GmbH	Alzwerk	Hydro	RoR	45.0	1922	Pirach	
	BNA0259	Ering	Ering	Hydro	RoR	36.5	1942	AT St. Peter	
	BNA0324	Gars		Hydro	RoR	25.0	1938	Marienberg	
	BNA0529	Braunau-Simbach	Braunau-Simbach	Hydro	RoR	50.0	1953	Simbach	
	BNA0689	Bittenbrunn	entfällt	Hydro	RoR	20.2	1969	Ingolstadt	
	BNA0695	Neuötting		Hydro	RoR	26.1	1951	Pirach	
	BNA0747	Nußdorf	Nußdorf	Hydro	RoR	36.6	1992	Marienberg	
	BNA0748	Oberaudorf-Ebbs	Oberaudorf-Ebbs	Hydro	RoR	30.0	1992	Marienberg	
	BNA0782	Kachlet	Kachlet	Hydro	RoR	53.7	1927	Pleinting	

[27] Data is based on the power plant dataset by (BNetzA, 2013a) published on 16.10.2013 and adjusted for 2012. Every * indicates data with additional sources not listed or own assumptions.

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
	BNA0784	Passau-Ingling	Passau-Ingling	Hydro	RoR	43.2	1965	Pleinting	
	BNA0792	Perach		Hydro	RoR	19.4	1977	Pirach	
	BNA0795	Geisling	Geisling	Hydro	RoR	25.0	1985	Regensburg	
	BNA0839	Rosenheim		Hydro	RoR	35.1	1960	Marienberg	
	BNA0854	Feldkirchen		Hydro	RoR	38.2	1970	Marienberg	
	BNA0912	Teufelsbruck		Hydro	RoR	25.0	1938	Marienberg	
	BNA0921	Stammham		Hydro	RoR	23.2	1955	Simbach	
	BNA0929	Straubing	Straubing	Hydro	RoR	21.5	1994	Plattling	
	BNA0950	Töging		Hydro	RoR	85.3	1924	Pirach	
	BNA0996	Vohburg	entfällt	Hydro	RoR	23.3	1992	Irsching	
	BNA1008	Uppenborn 1	1	Hydro	RoR	25.0	1930	Föhring	
	BNA1013	Wasserburg		Hydro	RoR	24.1	1938	Marienberg	
	BNA1118	Dessau	Dessau	Hydro	RoR	10.3	1967	Leupolz	
	BNA1129	Dingolfing	Dingolfing	Hydro	RoR	15.0	1957	Isar	
	BNA1134	Eitting D	Eitting D	Hydro	RoR	18.0	1925	Neufinsing	
	BNA1136	Ellgau		Hydro	RoR	9.7	1952	Meitingen	
	BNA1157	Höchstädt		Hydro	RoR	9.7	1982	Gundelfingen	
	BNA1160	Ingolstadt	entfällt	Hydro	RoR	19.8	1971	Ingolstadt	
	BNA1169	Kaufering	Kaufering	Hydro	RoR	16.7	1975	Oberottmarshausen	
	BNA1189	Faimingen	entfällt	Hydro	RoR	10.1	1965	Gundelfingen	
	BNA1191	Urspring	Urspring	Hydro	RoR	10.1	1966	Leupolz	
	BNA1192	Prem	Prem	Hydro	RoR	19.2	1971	Leupolz	
	BNA1209	Meitingen		Hydro	RoR	11.3	1922	Meitingen	
	BNA1210	Merching	Merching	Hydro	RoR	12.0	1978	Oberottmarshausen	
	BNA1213	Pfrombach D	Pfrombach D	Hydro	RoR	14.0	1929	Altheim	
	BNA1217	Niederaichbach	Niederaichbach	Hydro	RoR	16.2	1951	Isar	
	BNA1219	Gummering	Gummering	Hydro	RoR	14.8	1957	Isar	
	BNA1220	Aufkirchen D	Aufkirchen D	Hydro	RoR	19.0	1924	Neufinsing	
	BNA1221	Oberpeiching		Hydro	RoR	11.9	1954	Meitingen	
	BNA1228	Landau	Landau	Hydro	RoR	12.6	1984	Plattling	
	BNA1230	Pielweichs	Pielweichs	Hydro	RoR	12.6	1994	Plattling	
	BNA1234	Prittriching	Prittriching	Hydro	RoR	12.1	1984	Oberottmarshausen	
	BNA1235	Rain		Hydro	RoR	10.9	1955	Meitingen	
	BNA1239	Bertoldsheim	entfällt	Hydro	RoR	18.9	1967	Meitingen	
	BNA1245	Schwabstadl	Schwabstadl	Hydro	RoR	12.0	1981	Oberottmarshausen	
	BNA1246	Scheuring	Scheuring	Hydro	RoR	12.2	1980	Oberottmarshausen	
	BNA1247	Unterbergen	Unterbergen	Hydro	RoR	12.4	1983	Oberottmarshausen	
	BNA1251	Dornau	Dornau	Hydro	RoR	16.6	1960	Leupolz	
	BNA1263	Mühltal	Mühltal	Hydro	RoR	11.2	1924	Oberbrunn	
	BNA1267	Uppenborn 2	2	Hydro	RoR	18.0	1951	Föhring	
	BNA1273	Obernach	Obernach	Hydro	RoR	12.8	1955	Krün	
	BNA1274	Ettling	Ettling	Hydro	RoR	12.6	1988	Plattling	
	BNA1466	Kraftwerk 3		Hydro	RoR	18.5	1920	Pirach	
	BNA0364	Jochenstein	Jochenstein	Hydro	RoR	66.0	1955	AT St. Peter	220kV line to Jochenstein not in topology
	BNA1140	Altheim	Altheim	Hydro	RoR	17.8	1951	Altheim	BNetzA data wrong ZIP code
Brandenburg	BNA1256	UPM Schwedt	Dampfturbine	Biomass	ST	13.3	2009	Vierraden	
Hessen	BNA0230	Hemfurth	Hemfurth	Hydro	RES	20.0	1915	Waldeck	

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology*	Net capacity in MW	Year	High-voltage node	Comments
North Rhine Westphalia	BNA1102	Bigge		Hydro	RES	15.0	1965	Altenkleusheim	
	BNA1152	Schwammenauel		Hydro	RoR	14.0	1938	Dahlem	
	BNA1153	Heimbach		Hydro	RoR	16.0	1905	Dahlem	
Rhineland Palatinate	BNA0715	Lehmen		Hydro	RoR	20.0	1962	Weißenthurm	
	BNA0880	Detzem		Hydro	RoR	24.0	1962	Osburg	
	BNA1066	Wintrich		Hydro	RoR	20.0	1965	Wengerohr	
	BNA1135	Fankel		Hydro	RoR	16.4	1963	Wengerohr	
	BNA1137	Enkirch		Hydro	RoR	18.4	1966	Wengerohr	
	BNA1143	Serrig		Hydro	RoR	12.1	1985	Saarwellingen	
	BNA1181	Koblenz		Hydro	RoR	16.0	1951	Weißenthurm	
	BNA1214	Müden		Hydro	RoR	16.4	1965	Weißenthurm	
	BNA1216	Neef		Hydro	RoR	16.4	1966	Wengerohr	
	BNA1269	Trier		Hydro	RoR	18.8	1961	Weißenthurm	
	BNA1287	Zeltingen		Hydro	RoR	13.6	1964	Wengerohr	

Table 32: Cross-border plants[28]

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology	Net capacity in MW	Storage [MWh]	Year	High-Voltage node	Comments
Austria	BNA0567a	KW Kühtai	Kühtai Ma1	Hydro	PSP	144.5		1981		in Austria
	BNA0567b	KW Kühtai	Kühtai Ma 2	Hydro	PSP	144.5		1981		in Austria
	BNA0777	Kopswerk I	Masch. 1 bis 3	Hydro	PSP	247.0	1,729	1968	Bürs	**Included** at node Bürs
	BNA0778	Kopswerk II	Masch. 1 bis 3	Hydro	PSP	525.0	3,675	2008	Bürs	**Included** at node Bürs
	BNA0954	Lünerseewerk	Masch. 1 bis 5	Hydro	PSP	238.0	1,666	1957	Bürs	**Included** at node Bürs
	BNA0974	Rodundwerk I	Masch. 1 bis 4	Hydro	PSP	198.0	1,386	1943	Bürs	**Included** at node Bürs
	BNA0975	Rodundwerk II	Masch. 1	Hydro	PSP	295.0	2,065	2012	Bürs	**Included** at node Bürs
	BNA0505	KW Jenbach	Jenbach	Hydro	Res	79.0		1926		in Austria
	BNA0779	Obervermuntwerk	Masch. 1 u. 2	Hydro	Res	29.0		1968	Bürs	**Included** at node Bürs
	BNA0780	Vermuntwerk	Masch. 1 bis 5	Hydro	Res	158.0		1930	Bürs	**Included** at node Bürs
	BNA0816	KW Kaunertal	Prutz	Hydro	Res	392.0		1964		in Austria
	BNA0906	KW Silz	Silz	Hydro	Res	500.0		1981		in Austria
	BNA0024	KW Amlach	Amlach	Hydro	RoR	60.0		1989		in Austria
	BNA0496	KW Imst	Imsterberg	Hydro	RoR	89.0		1956		in Austria
	BNA0917	Schärding-Neuhaus	Schärding-Neuhaus	Hydro	RoR	48.0		1963		in Austria (St.Peter)
France	BNA1158	Rheinkraftwerk Gambsheim	Gambsheim	Hydro	RoR	48.0		1974		in France
Luxemburg	BNA0982	PSW Vianden	Maschine 1	Hydro	PSP	500.0	2,407	1962	Bauler	**Included:** Feeding into the German grid: Aggregation to Bauler
	BNA0983	PSW Vianden	Maschine 2	Hydro	PSP			1962	Bauler	
	BNA0984	PSW Vianden	Maschine 3	Hydro	PSP			1963	Bauler	
	BNA0985	PSW Vianden	Maschine 4	Hydro	PSP			1963	Bauler	

[28] Data is based on the power plant dataset by (BNetzA, 2013a) published on 16.10.2013 and adjusted for 2012. Every * indicates data with additional sources not listed or own assumptions.

State	Number BNetzA	Name of power plant	Block name	Fuel	Technology	Net capacity in MW	Storage [MWh]	Year	High-Voltage node	Comments
	BNA0986	PSW Vianden	Maschine 5	Hydro	PSP			1963	Bauler	
	BNA0978	PSW Vianden	Maschine 6	Hydro	PSP	596.0	2,218	1964	Niederstedem	**Included:** Feeding into the German grid: Aggregation to Niederstedem
	BNA0979	PSW Vianden	Maschine 7	Hydro	PSP			1964	Niederstedem	
	BNA0980	PSW Vianden	Maschine 8	Hydro	PSP			1963	Niederstedem	
	BNA0981	PSW Vianden	Maschine 9	Hydro	PSP			1964	Niederstedem	
	BNA0987	PSW Vianden	Maschine 10	Hydro	PSP			1975	Niederstedem	
Switzerland	BNA0583	Laufenburg	KW Laufenburg	Hydro	RoR	104.4		1914		in Switzerland