Renewables Grid Initiative

50Hertz "Energiewende Outlook 2035"

Study Brief

Purpose of Study

The "Energiewende Outlook 2035" study completed by 50Hertz proposes a set of five coherent future scenarios and draws conclusions on what the resulting economically meaningful network investments for 50Hertz would be in the TSO's area of operations (North Eastern Germany). The study specifically looks to reduce the risk of stranded assets due to the uncertain development of the energy transition.

Questions to be answered by the study
Which development paths (scenarios) of the energy transition are conceivable and not unrealistic?
What are the consequences for the power stations, the power plant use and for the power flows in Germany and cross-border which arise from the different development paths?
What are the drivers of the transmission network in the future and what interdependencies arise from the alternative development paths of the energy transition?
How robust are the individual grid expansion measures of 50Hertz? Including what individual measures are needed in different scenarios and which are appropriate to ensure the necessary transport of electricity?

Geographic Scope

In terms of geographic scope, a purely German focused analysis would not be true to what the future interconnected European system is likely to look like. The study therefore modelled market data and transmission networks not only from Germany but also from its immediate neighbours in detail. This included data from the Benelux countries, France, Switzerland Czech Republic, Austria, Poland, Denmark, and Slovakia. The basic profile (electricity production, national import/export etc.) from other countries in Europe was also included in the study but in significantly less detail.

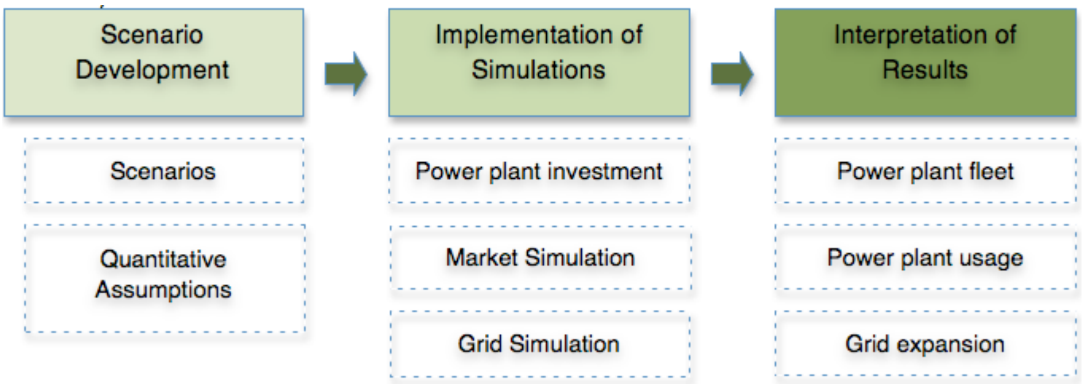
Time Scale

A time scale of 2035 allowed 50Hertz to form a set of realistic scenarios that can be quantified with some degree of accuracy. 2035 also fits between the German governments goals of 40% renewable energy by 2020 and 80-95% by 2050. In terms of grid development, such a middle to long-term perspective also provides enough time for the relatively slow planning, permitting and construction periods that new grid infrastructure developments need.

Methodology Overview

The study itself consisted of three main process stages, the scenario development stage, the simulation phase and the interpretation phase.[1] 50Hertz conducted the study in cooperation with a project team consisting of the consulting firm E-Bridge Consulting GmbH (E-Bridge), Prognos AG, the Institute of Power Systems and Economics at the university RWTH Aachen University and the FGH GmbH.

[1] See Figure 1 "Methodology of the 50Hertz "Energiewende Outlook 2035"" (Source: 50Hertz, Available at http://www.50hertz.com/de/Netzausbau/Wofuer-Netzausbau/50Hertz-Energiewende-Outlook-2035 (German Only).



Scenarios

The scenarios developed were required to be realistic, varied and internally coherent.[2] All of the scenarios made the assumption that electricity supply is at a level where it is sufficient at all times to cover the load in Germany and secure security of supply. The green scenarios in the table represent where German policy objectives have been achieved and the grey those where they have not.

Scenarios of 50Hertz "Energiewende Outlook 2035"	
"Prosumer orientated transition"	*- Very high solar PV deployment in Germany - Large PV deployment is married with very high household take-up of independent storage systems. - Active control of household consumption patterns. - Localised production, storage and consumption moderates the role of trade. - Share of electric mobility is particularly strong, increasing load and flexibility.*
"Energy Transition according to the renewable energy act"	*- Continuation along current policy lines. - Growth in large scale onshore and offshore wind and large scale solar PV in productive locations. - Some elements of the prosumer lead transition.*
"Competitive Energy Transition"	*- Large-scale renewable energy grows - Positive but competitive market conditions lead to RES growth in bordering countries - Cross border electricity flows are high. - Prosumer style behaviour plays a very limited role.*
"Delayed Energy Transition"	*- Planned transition that incorporates a range of technology approaches (as seen in the "Energy transition according to the renewable energy act" scenario) is delayed but on-going. - The reason for this may be a lack of acceptance at the local level for new renewable energy deployment.*
"Incomplete Energy Transition"	*- Lack of acceptance associated with the energy transition leads to the energy transition being incomplete.*

[2] For a more detailed breakdown of the scenarios used please see Pg14-17 of the "Energiewende Outlook 2035" (German)

	- The target of 80% by 2050 will not be met and remains stagnant at approximately 50% *- De-commissioning of conventional power plants reduced.*

Quantitative Assumptions[3]

In order to build the required “coherent” future scenarios, a set of consistent assumptions on a range of key factors affecting the electricity system is made. Such assumptions form the parameters of the modelling exercise. Such quantitative assumptions were used by 50Hertz to build the scenarios by using a “sliding scale” metric from Low to High, with differing combinations used to provide data for the agreed upon “story lines” of the scenario. For example, in the Quantitative assumption “Use of Storage”, the assumed number of storage units (measured in MW capacity), their likely geographical location, and their likely use profile are given. The number of units is ranged from High in the ”Prosumer Orientated Transition” (due to the rise in small PV storage combinations), Middle in the “Energy Transition according to the Renewable Energy Act” scenario (due to predicted modest increase in storage) to Low in the “Incomplete Transition Scenario” (due to its unprofitability due to smaller RES share). The intensity and combination of the below assumptions impacts the associated demands on the grid infrastructure of 2035.

Assumption	**Investment Costs**
Detail	Projected cost of deployment of each technology in 2035 (Euro/kW). Investment costs associated with Solar PV fall to differing levels depending on the scenario (biggest drop in the case of prosumer scenario, the energy transition according to the renewable energy act and competitive energy transition scenario), whilst offshore wind drops significantly from the 4000 per kW that it is today to between 2,200-2,700 in 2035, due to increased project efficiencies and new technological solutions. A small drop in investment costs for onshore wind is predicted for all scenarios.
Assumption	**Electricity Prices**
Detail	Projected price of electricity produced by technology (cent/kWh). Prices were formed using the LCOE (Levelised Cost Of Electricity) using the combination of capital costs, operations and maintenance (O&M), performance, and fuel costs. Prices for conventional technologies are considered by 50Hertz to remain stable at the 2015 level for all scenarios. A drop in price is seen in solar PV in the prosumer energy transition, whilst offshore wind benefits from the most on price in the competitive energy transition.
Assumption	**Fuel Prices**
Detail	Projected price of fuel costs (Euro(2012)/MWh). The assumptions for fuel prices are based on the current long-term policy scenario of the World-Energy Outlook Of the International Energy Agency (IEA) 2014. Uranium and Brown coal prices are envisaged to stay stable. With a doubling of Coal and an approx. 40% increase in Gas prices for gas fired power plants.

[3] For more detail on the assumptions contained in this list please see Pg15-39 of the “Energiewende Outlook 2035” (German)

Assumption	**CO2 Prices**
Detail	Projected price of CO2 in (Euro/t). Assumptions relating to the price of CO2 are divided into three groups. All scenarios in which the energy transition is achieved assumes that the price of CO2 has risen significantly in line with the goals of reducing emissions by 80% below 1990 levels. In the scenarios with a delayed or incomplete energy transition the CO2 experiences a significantly smaller rise as no ambitious climate protection policies are pursued.
Assumption	**Development of Load**
Detail	Electricity demand in Germany is currently decreasing; in the energy transition scenarios (green) this decrease is envisaged by 50Hertz to be reversed in the near future by increased take-up of electrification of mobility and heating. This will happen as “traditional” load is continuing to decrease, partly due to increased energy efficiency measures. The annual peak load envisaged for the transition scenarios was 97.5 GW in 2035, this is contrasted with 88.7 GW for the incomplete energy transition scenarios. Forecasting where this additional load will be geographically located was also taken into account by the study. A continued reduction in load in rural areas especially in the east of the country was assumed, largely due to further population decline. This is coupled with increased load in the cities where additional load from transport and heating will likely be concentrated.
Assumption	**Development of Storage**
Detail	With regards to storage, a significant growth was envisaged for small-scale storage unit take-up in the prosumer scenario and, to a lesser extent, the energy transition according to the renewable energy act scenario, with 4000MW capacity in Germany for the former and 2000MW for the later. Such a take up will be driven by a projected reduction of approximately 75% in battery storage prices coupled with a dramatic reduction of PV module prices. The development of storage also took into account potential sector coupling with electric vehicles, and geographic distribution of these new units, with wealthier urban areas seeing the highest increase.
Assumption	**Renewable electricity development**
Detail	In all five scenarios that 50Hertz formulated, significant additional construction of renewable energy plants in Germany was expected. That being said, each scenario presented different technology features and regional distributions of this new generating capacity. For the three scenarios achieving a successful energy transition, onshore wind turbine installed capacity ranged between 68GW for the prosumer lead scenario and 92 GW for a competitive transition. Values for offshore wind are also the highest in the competitive energy transition at 18GW. As mentioned previously, declining world market prices for PV modules leads to growth in PV deployment in all scenarios. The highest of these occurring in the prosumer lead scenario with 87 GW of installed capacity. Despite the differences in the technological composition of RES systems in the presented successful energy transition scenarios (Prosumer, Energy transition according EEG path, competitive) almost the same amount of power produced by renewable energy plants (amounting to 180 GW in 2035) is foreseen to reach German green energy policy objectives. Geographical distribution of this new generating capacity was also taken

	into account, with the most profitable areas for RES developments hosting the new generation units. This means that most of the wind energy is located in the North of the country, whilst most new PV generation is located in the South where yields are higher.
Assumption	**Development of conventional power stations**
Detail	The energy transition, by definition, means the increasing dominance of renewable energies and marginalization of conventional power plants. Partly due to the declining hours of full load, the installed capacity of hard coal and lignite power plants were assumed to reduce significantly in all scenarios. This reduction is considerably less in the incomplete energy transition scenario as CO2 prices remain low. Such capacity is largely replaced by the growth in natural gas plants, which also compensate for the loss of nuclear capacity (currently 12.1GW) after the German governments current policy of its complete abolition. In the transition scenarios, due to the higher peak load from heat pumps and electric vehicles, overall capacity from conventional power plants is higher than in the delayed and incomplete energy transitions. Capacity is also necessarily high in the transition scenarios, as enough capacity needs to remain online to cover peak load. In the competitive energy transition scenario, security of supply can be more guaranteed by cross border interconnectors covering peak load. This means that the expected installed capacity for this scenario will be slightly lower than the other transition scenarios. As in the renewable energy development assumptions, new conventional generating sites were distributed spatially across Germany in order to properly understand their subsequent impact on the German grid. The distribution of these (mainly gas) was largely focused near the large cities and the Ruhr valley, with several other large plants located in Lower Saxony and at the North Sea coastline.
Assumption	**Cross border flow assumptions**
Detail	Understanding cross border flow relationships means that the study had to build a set of scenarios for countries bordering Germany, trying to provide some assumptions on how different countries energy sectors would behave under the same scenario conditions. All scenarios except for the competitive energy transitions show an overall deficit in cross border flows meaning imports to Germany outweigh the exports. These range from –22,3 TWh/a in the delayed energy transition to –2,5 TWh/a in the energy transition according to the renewable energy act. The competitive energy transition shows a predicted surplus of +3,5 TWh/a. In all the scenarios imports across the northern and southern borders were seen, while the Benelux countries Czech Republic and Poland were generally net importers of German electricity. With regards to the Germany/France cross border flows, net imports of between +2.3 TWh/a in the “according to the renewable energy act” scenario and +12,7 TWh/a in the incomplete energy transition scenario, most of this electricity being base load from French nuclear plants. The prosumer scenario was the only scenario where exports to France totalled higher than imports due to the assumed phasing out of Nuclear in France.

Simulation phases

The simulation phase of the study runs the quantitative assumptions for the scenarios through a set of simulations to derive the results. These simulations were completed sequentially, with the results from the first simulation feeding information into the subsequent simulation. This phase included:

Power plant investment simulation: Assumptions about technology prices, the load development and the development of renewable energy plants allows the simulation to calculate the conventional power plants that are still required by examining the "business case" for these conventional power plants under various conditions.

Market Simulation: Simulates the market behaviour of the foreseen conventional and renewable energy fleet for every hour of the day, taking account of the merit order to assign dispatch to generating units. This also simulates the trade flows for every individual day in 2035 and the assumed cross border trade flows.

Grid Simulation: Hourly values of feed-in from renewable energy sources, power plant feed-in, load and transmission capacities are inserted into a simplified model of the European transmission network. From this the future network loads are determined and the resulting need for network expansion determined. The need for grid extension measures for all scenarios are determined and go through an additional sensitivity analysis process.

Results and Conclusions

From the above simulation phases the below results and conclusions were drawn by 50Hertz.[4]

Results of market modelling show that in 2035 the total German surplus for export will be considerably reduced. The export of electricity from the 50Hertz control area however continues to increase.

The German surplus for export that can be observed at present will drop substantially. In four out of five scenarios, Germany will often be a net importer of electrical energy. In contrast to this trend, the 50Hertz control area clearly remains a net exporter of electricity in all energy transition scenarios. This is because market modelling shows that if the current objectives of the federal government are implemented, eastern Germany will have high capacities of RES installations in 2035 thanks to the available space for higher solar and wind deployment.

The need for grid extension measures was analysed extensively, the grid extension measures planned by 50Hertz for the coming years are necessary and robust.

The results clearly indicate that by the year 2035, regardless of the further development of the energy transition, the grid extension projects 50Hertz is currently realising or has planned for the coming years are necessary and therefore robust. Furthermore, sensitivity calculations were used to study the most important on-going social discussions, including a possible nationwide increase in small storage units, a regionally diversified installation of gas power plants as well as an early phase-out of lignite power plants. Even in the event of a strong reduction in the installed capacity of lignite power plants by 2035, the grid extension projects planned by 50Hertz for the coming years are still necessary.

The main driver for the need for grid development is wind power. The regional

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[4] For a full breakdown of the possible future grid planning methodology and results see Pg40-50 of the "Energiewende Outlook 2035" (German)

installation of new gas power plants is not determinant for further grid extension.

Wind power is the decisive driver for the need for grid development within the 50Hertz transmission system. The allocation of gas power plants, on the other hand, is not very relevant for further grid extension. As a result, the locations for the new gas power plants should be chosen according to a secure and favourable gas supply as well as grid-support aspects (incl. providing ancillary services).

There is also a high transmission demand if the energy transition is achieved by strengthening the role of prosumers.

Even in case of a prosumer-oriented energy transition with a high number of small storage units (assumption for 2035: 2.1 million small storage units) combined with PV installations, the demand for transmission grid extension will be substantially high. The projects 50Hertz has planned the coming years are necessary in every analysed scenario. However, it is worth noting that the need for further grid extension in the prosumer-oriented energy transition model is much smaller when compared to other scenarios from the 50Hertz Energiewende Outlook 2035. Interestingly, this scenario's total cost for investments in power plants and transmission grids and for fuel for conventional power stations is comparable to other energy transition models.

Grid development at 50Hertz is almost exclusively limited to existing routes, with a few exceptions for the planned HVDC10 transmission line.

In all scenarios, the majority of grid development measures, either through grid reinforcement or through new constructions, can use the existing routes. However, for the new HVDC transmission line from Wolmirstedt to Isar and from Güstrow to Wolmirstedt, a new route is needed. The current length of the 50Hertz transmission system only increases slightly, from the current 10,000 kilometres to between 10,300 and 10,500 kilometres in 2035. (see Fig 1).

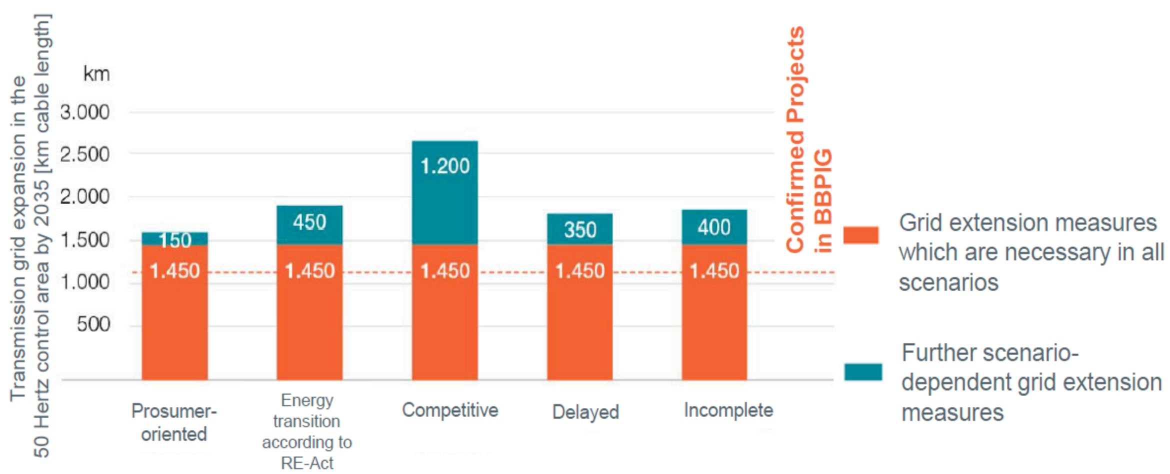

Figure 1: Forecast required transmission grid expansion in the 50Hertz Control area by 2035 (Source: 50Hertz Pg 41"Energiewende Outlook 2035")

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Final conclusions

- **In almost all cases, grid development at 50Hertz can use the existing routes through grid reinforcement or new constructions.**
- **The current grid development planning for the 50Hertz transmission system is robust for a wide range of scenarios.**
- **In many scenarios, there is also a long-term need for additional grid extension measures. This applies to the least extent in a prosumer-oriented energy transition.**
- **In order to make a prosumer-oriented energy transition more likely, significant cost digression is required for PV installations and small storage units. Furthermore, the resulting investments that need to be made in the distribution systems should be further studied.**
- **By comparison, the scenario with the greatest need for the construction of new transmission lines is that of a competitive energy transition with a high capacity of wind turbine installations.**
- **All scenarios determine a similar need for transmission system development in the years to come.**

Important Links

"50Hertz "Energiewende Outlook 2035" Report *(German with English Executive Summary)*

Presentation to policy makers *(German)*

Collected data on assumptions