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Evaluation and Implementation of Energy Systems based on Wind Resources in Germany

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Abstract. The rising concerns over global warming, environmental pollution and energy security have increased interest in developing renewable and environmentally friendly energy sources such as wind, as the replacements for fossil fuels. Wing energy conversion systems have become the main point in the research of renewable energy sources. The Government of Germany has made a serious commitment to include wind energy in its future energy policy. The aim for the present work is to analyse the wind energy in Germany under a technical point of view. The results show the current situation and future perspectives of these sources by energy systems.

Key words. Energy systems, Wind Energy, Germany.

1. Introduction

Wind energy represents a mainstream energy source of renewable generation and an important player in the world's energy market. The kinetic energy in the wind is a promising source with high potential in many parts of the world as renewable energy. This type of energy that can be captured by energy systems (i.e. wind turbines) is highly dependent on wind speed. Areas that normally show the most attractive potential are located near coast on inland areas with open terrain.

Wind is a highly intermittent energy source for causing overall fluctuation in power generation. Electricity generated from wind turbines strongly depends on the weather and geographic conditions. Although the wind power industry appears to be booming in recent years worldwide, achieving continuous cost reduction in wind power generation continues to be a challenge and a key focus for the wind industry in Germany.

The European Union is clean-energy, zero-emissions oriented and their support to the efficiency measures, energy savings and renewable energy proliferation are clear [1], [2], [3]. The European Energy Policies have a three-side approach: (i) Security Supply, (ii) Competitiveness and (iii) Environmental sustainability, developed by different Directives (Directive 2009/28/EC for the 2020 targets or the Renewable Energy Directive 2018/2001/EC), so the aim for a Renewable-based energy model is one of the relevant solutions available [4].

Europe installed 11.3 GW of new wind energy during 2018 (9 GW onshore, 2.7 GW offshore and 0.4 GW decommissioned) and has a total installed capacity of 189 GW (Figure 1). Wind energy is the second largest form of power generation capacity and it is likely to overtake natural gas installations during 2019. Germany installed the most wind power capacity (3.3 GW) and remains the European country with the largest installed wind power capacity (59.3 GW) followed by Spain (23.5 GW), UK (21 GW) and France (15.3 GW) [5].

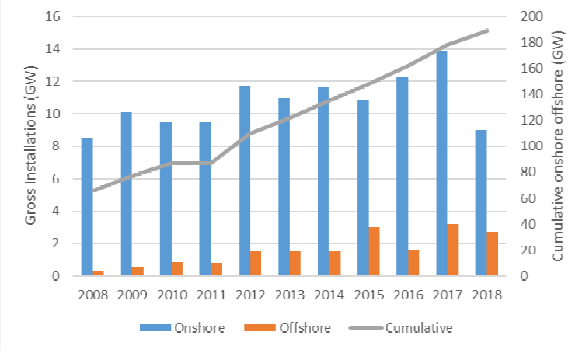

Figure 1 Gross Annual Onshore and Offshore Wind Installations and Total Cumulative Capacity in Europe (GW) (Source: Wind Europe)

Although Figure 1 shows a sustained increase in power installed, there is a significant volatility in the sector going throughout Europe [4]. Particularly serious is the Spanish situation, where the investments in Renewable Energy Sources (RES) have dropped to almost zero since 2013 due to the destabilization of the legislative framework, the economic crisis and the austerity measures implemented.

On the other hand, it is important to stress-out the unexpected consequences the feed-in-tariff (FIT: constant payment per unit of electricity generated) are having across de European Union, not only for the uncontrolled growth of certain renewable sources, but also for the increased expenses that this means for the countries [6].

This problem is being addressed by some countries in the form of changes in regulatory frameworks and mechanisms such as auctions/tenders [7].

2. Energy Outlook in Germany

In the European context, Germany has compromised for 2020 that the 18% of the gross final energy consumption as a whole, including transport, will come from RES and a 30% for 2030 due to the large investment expected in renewable electric and thermal energy. According to Eurostat (Figure 2), that percentage was 15.5% at the end of 2017, quite in line with the National Renewable Energy Action Plan (NREAP) values estimated for that year. Given this trend, Germany should not have any problems to achieve this goal, however, it should not be forgotten that they are facing a transition from the current power mix to achieve a share of renewable energies in power consumption of 80% by 2050 [8].

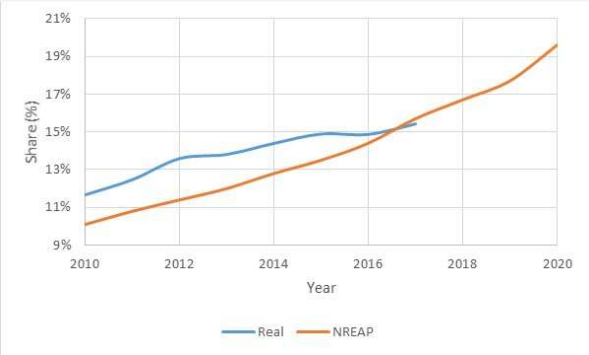

Figure 2 RES in Gross Final Energy Consumption (Source: German NREAP, Eurostat)

Another mark in the German NREAP is a share of 38.6% of renewable energies in the electricity market by 2020. Although it is not yet achieved, the trend shown in Figure 3 shows a positive result by that year.

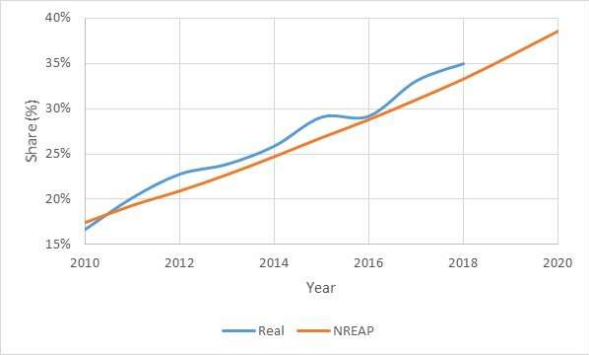

Figure 3 RES in Electricity Demand (Source: German NREAP, AGEB)

Germany electricity production (Figure 4) has suffered important variations during the last years. It can be seen how, in 2009, the electricity demand fell a 5.4% with regard to 2008 values. In 2010 the demand went back to the usual values but the following years have shown a continuous decrease until 2014. Since then, the demand is stuck under 600 TWh.

The electricity demand is covered with a power generation mix of about 206 GW conforming an energy mix in which the presence of renewable energies is increased every year (Figure 5). In 2018, renewable energies covered almost 35% of the electricity generation and Nuclear energy still provides 12% of the electricity generation (27.1% in 2004) and it is likely to be zero by 2022. On the other hand, the coal and lignite production has remained almost constant over the last decade [9].

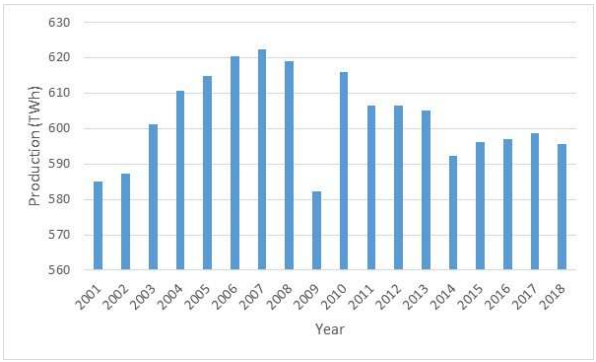

Figure 4 Germany - Net Electricity Production in TWh (Source: AGEB)

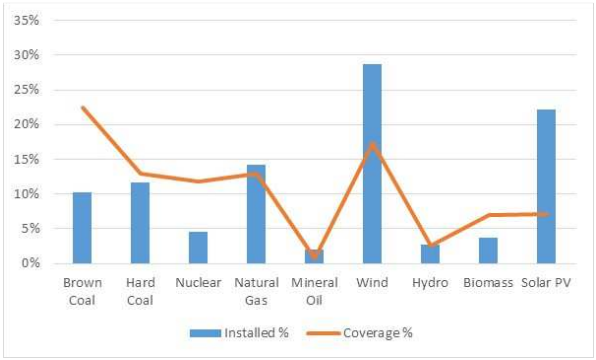

Figure 5 Installed Power and Demand Coverage (%) (Source: AGEB)

Despite efforts to improve energy security, energy imports still account for 64% of total primary energy supply (Figure 6) but the problem is that from 2015 to 2016 it has increased by 1.6%, starting a trend that should be observed during the next years.

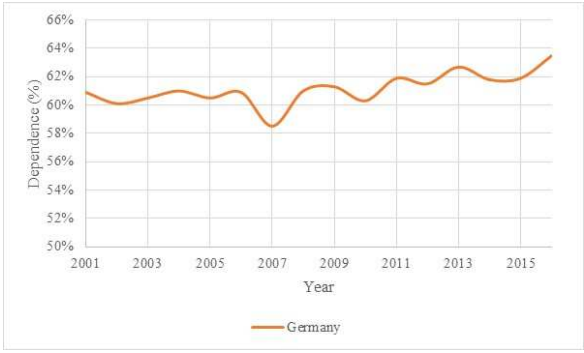

Figure 6 Energy Dependence (Source: Eurostat)

A. Wind energy

From 1990 to 2018, the share of the renewable energies in electricity generation has raised from 3% to 35%. This percentage depends, not only on the power installed increase, but also on the climatic conditions during the

year, as the renewable energies have priority in the pool market [10]. The evolution of the Germany onshore wind park is smooth (Figure 7), without abrupt changes. A more stable and favorable regulatory framework might be the reason behind that.

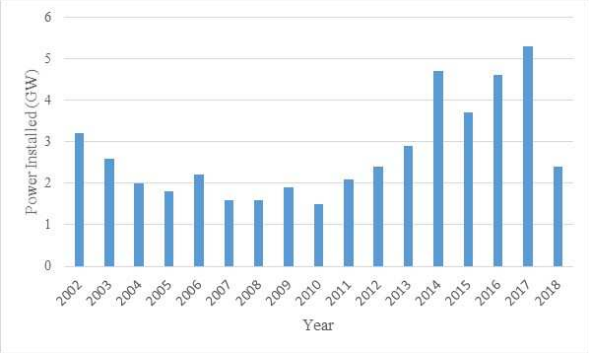

Figure 7 Wind Annual Power Installed Onshore in GW (Source: BWE)

According to BWE [11], Germany installed in 2018 2.4 GW of onshore wind power but also decommissioned a combined capacity of 249 MW. A portion of these were replaced by new wind turbines for a total of 363 MW. The onshore cumulative capacity was 53 GW in that year. In offshore, 0.9 GW were added for a total of 6.4 GW.

B. Regulatory Framework – Evolution and Current Situation

Germany has been using the FIT scheme since 1991 when the *Stromeinspeisungsgesetz* (*StromEinspG* – Grid Feed-In Law) [12] came into force. In 2000, the *StromEispG* was abolished by the *Erneuerbare Energien Gesetz* (EEG – Energy Renewable Resources Act) [13] which established support schemes for the investors to introduce the new technologies into the market. The prices were fixed by the Government and were market-independent, although they have some influence on it, and they were applied during the installation lifetime (estimated in 20 years) [14]. Looking for the cost reduction through research and development, the tariff is reduced for new installations in a percentage depending on the amount of new power installed [15].

The EEG has suffered several changes throughout the years, but none of them has had a significant impact on the development of the renewable park. The first important change came in 2004, when retributions for the less-developed technologies were re-adjusted to make them more attractive [16].

Subsequently, a new modification was made in 2009 for a better adaptation to the market evolution [17]. Due to the fast implementation of photovoltaic power plants, a tariff reduction for this generation source was made in 2010. This would happen again in 2012 [18].

An important modification to the EEG was introduced on the 2012 revision: the investors were offered the opportunity to sell their production directly to the market via a market premium scheme. This premium was the difference between de average pool price and the FIT established by the EEG. Although the number of installations that chose this option was greater than expected, authors like Gawel and Purkus [19] conclude that this is not the best way to incorporate renewable energies to the system.

One of the latest EEG revisions [20] took place in 2014 and was partially influenced by the Fukushima events. With those changes, Germany was moving towards a new energy model, a transition called *Energiewende* (Energy Turnaround), in which the renewable sources would be the main actors. It came into force in August 2014 and the objectives established were: (i) to facilitate the sustainable development of energy supply; (ii) to reduce the cost of energy supply to the country; (iii) to conserve fossil fuels and (iv) to promote further development of technologies for generation of electricity from Renewable Energy Sources.

According to that path, a 40% - 45% of the final electricity consumption should come from Renewable Sources by 2025. This percentage is increased to 60% on 2035 and to 80% on 2050. Achieving those goals would require the annual installation of 2,500 MW of wind energy, 2,500 MW of photovoltaic and 100 MW of biomass. Another remarkable change on the EEG is that almost all new installations are obliged to sell directly to market, but under a new payment framework which grants them the feasibility up to a certain point.

The last EEG reform took place on July 2016, being the bid process the main change. This new procedure for the new installed capacity is based on a bid process instead of the regulated prices. German Government will call for public tenders in relation to the power planned to be installed through the year. 2,800 MW of wind energy and 600 MW of photovoltaic were bided this way during 2016, and, apart from those two technologies, only the offshore and the biomass will have the option to apply for new power installed. With this reform, the Government aims to install new renewable power at lower costs. During 2017, an auction for the offshore wind energy took place. 1,490 MW were allocated and the mean price was set at 4.4 €/MWh.

The German Government is currently planning its strategies for the 2012-2030 period. The draft of the Integrated National Energy and Climate Plan (INECP) aims for a share of the renewable energy in the electricity generation of around 65% in 2030, with a power installed between 74 and 86 GW of onshore wind energy and between 17 and 20 GW of offshore. Likewise, the Plan foresees that in the year 2030, the presence of renewables in final energy use will be 30% from todays 16%. This positive result will be a consequence of the high penetration of the electric and thermal renewables in all sectors of the economy and the progress obtained in savings and efficiency in the sectors as a whole.

3. Future Perspectives and conclusions

Fukushima disaster in 2011 had a great impact on Germany's energy policy since the Government closed the seven oldest nuclear power plants in the country after the incident. The rest of them will stop producing energy by 2022. Their energy transition aims to create a nuclear power-free park with lower CO_2 emissions and this implies closing fossil fuel-based technologies.

The consequences those changes might have, will be seen in the following years, but changes in the electricity price are expected along with an increase in the coal consumption to compensate this lack of power. CO_2 emissions are expected to grow too, contradicting, at least partially, one of the main objectives.

Yet another interesting point is the reason behind the colossal decline in power installed in 2018 (from 6.7 GW in 2017 to 3.4 GW in 2018, including onshore and offshore wind parks) [11]. This could jeopardize the achievement of the targets set in the new INECP if it is not effectively addressed. It has to be taken into account that the *Energiewende* is calling for a complete transformation of the generation mix so the nuclear and coal based power have to be replaced by another renewable sources in the midterm. This will require a complete transformation of the German electricity sector to meet the future needs, [21] and great investments in off-shore [22], repowering and R&D [23], [24]. Wind power in Germany is a growing industry with high potential in the future years based on European technology and policies.

So, even when Germany has also suffered the consequences of the FIT schemes and it is showing a positive trend for the achievement of the 2020 goals, the following years will be of outmost importance to see if the *Energiewende* is "turning around" effectively their energy model.

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