



Brandenburgische  
Technische Universität  
Cottbus - Senftenberg

# 12<sup>th</sup> EEEIC

## International Conference on Environment and Electrical Engineering – Student Edition

Wrocław-Ostrava-Cottbus  
20<sup>th</sup> - 25<sup>th</sup> of May 2013

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module at BTU: 11396

**ISBN 978-3-940471-33-8**

organiser / veranstalter

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publisher / verlag

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printing / druck

**Technical University of Cottbus, Reprografie**

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# Offshore Wind Energy

## An Evaluation of Potentials and Profitability in Germany

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**Abstract**—Offshore wind energy is becoming increasingly important in Germany. There is a high potential which yet is hardly exploited. Due to German political objectives to exit nuclear energy and promote renewable energy instead, offshore wind energy is supported by the German Federal Government. This is expressed in the Renewable Energy Act that regulates fixed remunerations for various renewable energies and thus also offshore wind energy. The extremely high potential is especially visible in the maximum load hours which are more than twice as high as those onshore. In addition, the acceptance among the German society is very high. Obstacles, however, are the great investment and operating costs due to different environmental conditions, e.g. water depth, current, salinity. However, trends show that offshore wind farms are becoming increasingly bigger in size and productivity.

**Keywords**—offshore wind farm, Renewable Energy Act, potential wind farm areas, maximum load hours, Alpha Ventus, remuneration of wind energy.

### I. INTRODUCTION

In the framework of the energy concept 2010 the German Federal Government has set out the goal to meet at least 35 % of the electricity demand in Germany by 2020 and at least 80 % by 2050 by using renewable energy sources [1]. Under these preconditions the Renewable Energy Act (EEG) came into effect in 2000 [2].

The EEG regulates to favor renewable energy for supply to the grid. Therefore, all base and initial compensation will be set fix. The aim of the Act is to promote the development of renewable energy and to create financial incentives for investors. Furthermore, it seeks to reduce harmful emissions, conserve resources, reduce dependency on energy imports, increase energy efficiency and create new jobs [1].

Wind energy plays an important role in implementing of the German Federal Government's goals. Since the early 2000s, wind power has expanded widely in Germany. Since 2010, Germany increasingly concentrated on wind energy turbines (WET) in the water. The use of wind power on the water, so called offshore, is exploited very little in Germany and still holds tremendous potential. By 2050, at least 25000 MW of installed capacity shall be available at offshore wind farms (OWF) in Germany [3].

Currently Great Britain is the worldwide leader in OWF with an installed capacity of 1660 MW [4]. In addition to Great Britain, Denmark, the Netherlands and Spain have also installed large OWF [4]. In Germany there are now 3 OWF with a total capacity of 528.3 MW: Alpha Ventus, Bard (both North Sea) and Baltic 1 (Baltic Sea). Furthermore, the construction of 27 OWF has been approved, which will add up to a total capacity of 8.3 GW [4]. In Germany the "Federal Maritime and Hydrographic Agency – Bundesamt für Seeschifffahrt und Hydrographie" (BSH) is responsible for the certification and licensing of OWF [5].

In Germany there is considerable concern to establish OWF near the coastline. On the one hand, there are large protected areas (e.g. National Park Wadden Sea) and on the other hand public acceptance is limited due to "disturbing silhouettes" of the OWF and concerns regarding a potential decline in revenues from tourism [6]. Therefore, most OWF are planned and constructed "behind the horizon" at a distance of 30-120 km from the coastline and at a water depth of 20-45 m [6].

### II. POTENTIALS

There are significant differences between the potentials and conditions of onshore and offshore wind energy. In general, conditions offshore are much better than onshore, because the wind reaches higher speed and even more important, it blows more constantly. It is most efficient, if WET can run permanently and at a steady speed. Therefore, stable wind conditions are much more profitable than high peaks [7].

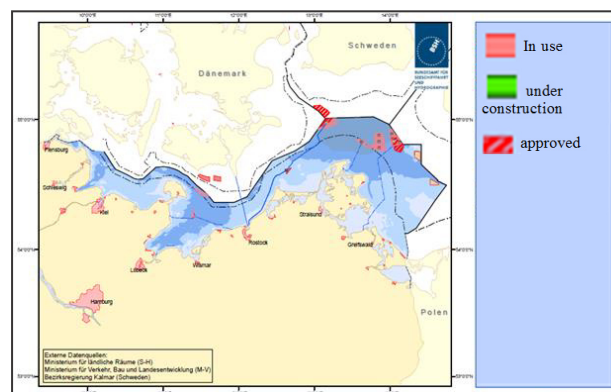


Figure 1. Potential OWF installation areas in the German Baltic Sea (Source: BSH [8])

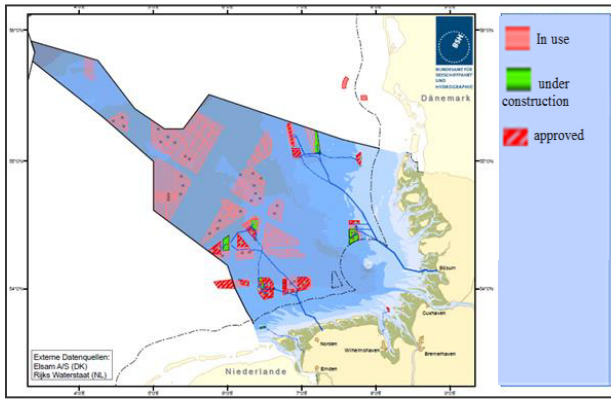


Figure 2. Potential OWF installation areas in the German North Sea (Source: BSH [9])

The “Netzstudie II” released by the German Energy Agency in 2010 proceeds on the assumption that there are about 3000-4500 maximum load hours for WET offshore compared to only 1500-1750 hours onshore [4].

Figure 1 and 2 show the potential areas for OWF installations in the German Baltic Sea and North Sea respectively. These areas are restricted by international borders, the 12 mile zone and the exclusive economic zone. Furthermore, major shipping routes and environmental issues must be taken into account. Furthermore, the characteristics of the sea bottom as well as the potential existence of various plants and wildlife must be accounted for. In addition, air tracks of large bird colonies and existing protected landscapes such as the National Park Wadden Sea must be included in the search for suitable areas [10].

TABLE I. APPROVED OFFSHORE WIND FARMS IN GERMANY (SELECTION)

| North Sea             |                          |                    |                           |
|-----------------------|--------------------------|--------------------|---------------------------|
| Name                  | Maximum Capacity (in MW) | Water Depth (in m) | Distance to Shore (in km) |
| Albatros              | 400                      | 40                 | 105                       |
| Amrumbank West        | 400                      | 20-25              | 36                        |
| Borkum Riffgrund West | 280                      | 29-33              | 50                        |
| DanTysk               | 400                      | 21-33              | 70                        |
| Deutsche Bucht        | 250                      | 40                 | 87                        |
| Hohe See              | 400                      | 26-39              | 90                        |
| MEG Offshore 1        | 400                      | 25-26              | 45                        |
| Sandbank 24           | 576                      | 30                 | 90                        |
| Veja Mate             | 400                      | 39-41              | 89                        |
| Baltic Sea            |                          |                    |                           |
| Arkona Südost         | 400                      | 21-38              | 35                        |
| Baltic II             | 320                      | 20-35              | 31                        |
| Wikinger              | 400                      | 29-41              | 35                        |

(Source: Fraunhofer IWES [4])

Due to difficulties in transportation and logistics, onshore WET have to be smaller and less powerful than offshore. Hence, a significantly higher production per unit is installed offshore than onshore. At the moment there are three completed and connected OWF in Germany with a total capacity of 528.3 MW [10]. As of today, 27 OWF are planned and already approved by the BSH. Table 1 shows a representative selection of planned and approved OWF in both the North Sea and the Baltic Sea. These OWF will have a combined total capacity of 8.3 GW. The BMU presumes that the potential total capacity of OWF in Germany will be as high as 20-30 GW by 2030 [7]. The European Wind Energy Association (EWEA) predicts that by 2030 there will be up to 5000 WET with a total combined installed capacity around 25 GW in the German exclusive economic zone alone. Investments will reach about 220 billion € [6].

### III. ALPHA VENTUS

The first German OWF “Alpha Ventus” was commissioned in 2010. It is a joined project of the energy suppliers E.ON, EWE and Vattenfall. “Alpha Ventus” is located 60 km off shore in a water depth of 30 m. It consists of 12 turbines with a capacity of 5 MW each and a total combined capacity of 60 MW. The average wind speed is 10 m/s and the average height of waves 6-8 m. In 2011, 4450 maximum load hours were reached and 267 GW of electricity were fed into the German grid [13]. “Alpha Ventus” is a pioneer project in the German offshore industry which generated new and highly sought after knowledge and expertise in terms of planning and building OWF.

### IV. PROFITABILITY

The construction of OWF is associated with great investment costs as well as great installation and operating costs.

The installation costs consist of expenses for the turbine and tower as well as the fundament and grid connection [14]. Costs for the grid connection are covered by the OWF operator. Due to high infrastructure and construction costs, most WET are built in OWF containing up to 30 WET with a capacity of 3.5 MW each or more [7]. Costs for the fundament vary with the type of fundament used. This type is determined by numerous physical and economic factors, e.g. the water depth, strength of current, height of waves and size of WET [14].

In general, operating costs are 33-50 % higher offshore than onshore [14]. Another disadvantage is the limited accessibility of the facility for maintenance work. The WET cannot be accessed if waves reach a height of 1.5 m or above [4].

Offshore WET are exposed to more and larger impact factors than those onshore. Due to the high content of salt in the air, corrosion of the tower, gondola and wings is a big threat [4]. Furthermore, large mechanic forces (e.g. current, waves) affect the fundament and tower [15]. As a result of kolk of the surrounding sea bottom the rigidity of the fundament may be reduced. Furthermore, fiber-reinforced composites age

significantly because of high UV radiation and humidity. In addition, WET are being negatively affected by marine fouling [7].

In the EEG, a start remuneration of 15 ct/kWh for offshore energy is being set. After 12 years, a basic remuneration of 3.5 ct/kWh is guaranteed by the Act [2]. Compared to remunerations for onshore energy (start: 9.2 ct/kWh for the first five years; basic: 4.9 ct/kWh) the offshore energy is better supported and more incentives are given to investors [16].

The production costs for offshore WET are much higher compared to those onshore. These costs are measured based on weighted average costs for different power generating technologies, which makes it possible to compare different technologies among each other. Despite the much higher maximum load hours, costs for offshore energy reach 10.5-16.4 ct/kWh produced compared to 6.5-8.1 ct/kWh onshore [14].

Possibilities to lower costs are restricted due to the high costs for installation and maintenance. However, a growing market and more competition will make cheaper production costs achievable in the future.

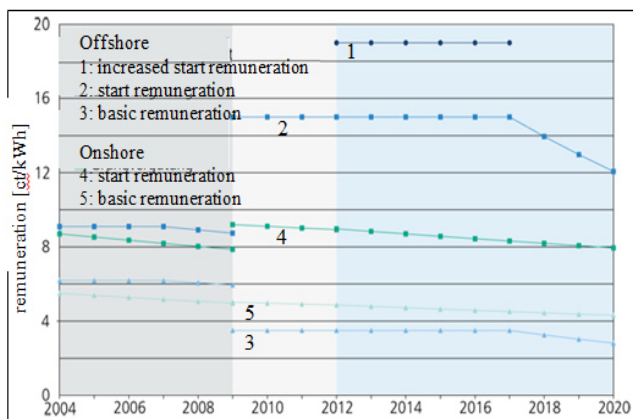


Figure 3. Remuneration for Wind Power in Germany. (Source: [4])

### V. SOCIAL OPINION

According to a recent study conducted by the Mercator Foundation and the University of Stuttgart, offshore wind energy has the greatest popularity among the general population in Germany amongst the various renewable energy sources [17]. In the coastal regions, the acceptance is partially different. There are small associations such as “Gegenwind – für eine Industriefreie Nordsee e.V.” which campaign against OWF [18].

To increase the acceptance among the public, the BMU sponsors an interdisciplinary project named “Akzeptanz der Offshore – Windenergienutzung“ which collects expectations, opinions and experiences before and after the building of OWF to enable policy recommendations for a conflict-free construction of OWF [19].

Before OWF were built in Germany, negative impacts on the tourism industry, were expected. However, contrary to initial expectations no such negative impacts occurred when the OWF “Baltic 1”, which is visible from the coast, was built

and connected to the grid [21]. Furthermore, there are different ideas of how OWF can be involved in the local tourism to help grow the local economy even further [22].

### VI. OUTLOOK

A variety of trends are recognizable in the field of constructing and planning of OWF and those trends are likely to continue during the years to come.

First, the distance from OWF to the coastline is becoming much larger. In 2012, the average distance to shore in Europe increased by 26.4 % from 23.4 km in 2011 to 29 km. In addition, new technologies enable operators to build OWF in greater water depth. Recent plans consider possible OWF areas within a range of 200 km off shore and at a water depth up to 215 m [23].

Second, OWF tend to become larger in size. The average installed capacity per OWF increased from 199 MW in 2011 by 36 % to 271 MW in 2012 [23]. In Germany, 78 % of all planned OWF (21 out of 27) have a maximum total capacity of over 250 MW and 48 % have a maximum total capacity of over 400 MW [4]. This development is a result of the high costs for connecting OWF to the grid. Therefore, large OWF and few power cable connections cut the costs for the operators. Furthermore, WEA are becoming more durable and efficient. In the last two decades, the average capacity of newly installed WET increased continuously. Since 2009 the number increased from 2.6 MW to 4 MW. In 2012, nearly three quarters of all newly developed WET had a maximum capacity of 5 MW or more [23].

In Germany, a combined total capacity of around 2 GW was installed by the end of 2012. In 2013, another 1 GW will be installed and connected to the grid. In addition, 3.5 GW are already planned and only need final investment decisions to go into construction [20]. There are still more OWF, which have already the official approval from the BSH. All of the planned and approved OWF in Germany combined will have a total maximum capacity of 8.3 GW [4].

### VII. SUMMARY

By 2020, the German Federal Government wants to achieve its goal to meet 35 % of the German electricity demands by using renewable energies [1]. At the moment, there are three OWF installed and connected to the grid in Germany: Alpha Ventus, Bard and Baltic 1 reaching a total combined capacity of 528.3 MW. In the next few years, 27 OWF are planned and already approved [4].

As a result of protected coastal areas such as the National Park Wadden Sea, OWF in Germany are being built 30-120 km off shore at a water depth of 20-45 m. In the future, OWF are very likely to grow in size and quantity, as well as being built at greater distance to shore and depth of water [23].

Offshore there is a much higher wind energy potential than onshore. Offshore WET have 3000-4500 maximum load hours compared to those onshore which have only 1500-1750 hours. The BMU predicts a total offshore potential of 20-30 GW for

all German OWF by 2030. Investment costs for 25 GW offshore power will be as high as 220 billion € [6].

In general, OWF are very expensive in planning, constructing and operating. Operating costs are 33-50 % higher offshore than onshore and the grid connection must be paid for by the OWF operator. Because of these high costs, the EEG guarantees fixed remunerations for every 1 kWh produced. These remunerations are as high as 15 ct/kWh for the first 12 years, after that they fall down to a fixed amount of 3.5 ct/kWh [2].

The overall acceptance of offshore wind energy in the German population is very high. This is mainly a reason of the big distance from the shore and therefore the little direct effects OWF have on the people. Other negative impacts, e.g. impacts on marine wildlife or tourism in coastal areas, have not been as high as expected [17].

### VIII. DISCUSSION

We think that offshore wind energy must be seen from two different viewpoints.

A great disadvantage is that it is not profitable now and will probably not be reaching this in the next 10 years. It is linked to large investment costs and needs the financial support of the Federal Government, which causes costs for the tax payers and distorts the energy market. In addition, construction and operating of OWF are likely to have various negative impacts on the environment which are difficultly measurable and detectable.

Despite these negative aspects, offshore wind energy also brings many advantages. Investments in renewable energies are investments in future generations, help secure Germany as an innovative, technological forerunner state and lower the reliability on other countries in the conventional energy sector. In addition, investments in offshore wind energy create knowhow which is indisputably important for a country poor on raw materials, generate new job possibilities and are widely supported by the German population.

The German Federal Government has established the foundations of a change of goals and priorities in the energy sector. The acknowledgement of a global climate change, the German role in the renewable energy sector and the termination of nuclear energy usage in Germany are all factors, which point in the same direction. Supporting offshore wind energy not only serves Germany as an economical advantage, but is also the realization of the idealistic and revolutionary idea of an emission-free future.

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# Effects of the intermittent characteristic of wind turbines

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**Abstract**—This article gives an overview over the different effects of the fluctuating power supply from wind turbine generators (WT). Different WT designs and planning parameters influencing the availability of WT are discussed. As an external option to stabilize the grid and reduce power fluctuation, storage technologies are discussed.

## I. INTRODUCTION

The oldest known wind turbines (WT) were built around 200 BC. The first vertical axis turbine came from Iran and Afghanistan and was used as a windmill [1]. Between 1850 and 1970, the US developed over 6 million small machines used for water supply between. In 1888, the US explored the first wind turbine, of 12kW, producing electrical energy in Cleveland, Ohio. During the 20th century the First and Second World Wars influenced the quick development of this technology. The development made by the army, in the field of mechanical engineering, airplanes and rotors, was a big advantage for the progress and improvement of wind turbines. The oil crisis between 1973 and 1986 was crucial for the US government's decision to build the commercial wind farm applications from 50-600 kW [2]. In 1990, the wind energy in Germany had its renaissance. In 1994, Germany had already installed 500 MW of electrical power from WT [3]. Today the globally most installed WT are in Europe (over 73%, 2006). The global leaders (2006) in wind energy generation are Germany (14609MW), the US (6352MW), Spain (6202MW), Denmark (3115MW) and India (2120MW).

## II. CHARACTERISTICS OF WIND TURBINES

### A. Intermittency of wind

The most important factor for WT is the wind velocity. The wind measurement is particularly significant since the performance of a wind turbine increases with the cube of the wind speed. For this reason measuring an error of 3% in the wind speed will cause an error of 9% in the expected performance calculations. To calculate the potential of a location at least one year data is needed. However, it is recommended to observe three years in order to avoid fluctuations and miscalculations [1]. The variation of the wind velocity influences the produced amount of electrical power. This has an effect on the electric network which needs to be balanced. In case of higher demand and/or lower supply of the wind, conventional power sources have to be used to balance

the grid. One of the principal characteristics of wind energy is its intermittence which is also the biggest problem the wind turbines face to supply energy.

### B. Challenge

The intermittent characteristics of energy supply from WT cause several challenges:

- Storage of the excess energy produced by the WT
- Balance supply and demand at any time
- Improve transmission of electricity to large centers
- Increase the efficiency of WT
- Design WT and wind parks for optimum yield

## III. EXTENSION OF WIND TURBINES

### A. Main types of wind turbines

Since the quick development of wind energy technology started, machines of different types had been designed in all parts of the world. Figure 1 shows the two main types of wind turbines, categorized depending on their rotational axis: horizontal axis (HAWT) and vertical axis (VAWT) [4].

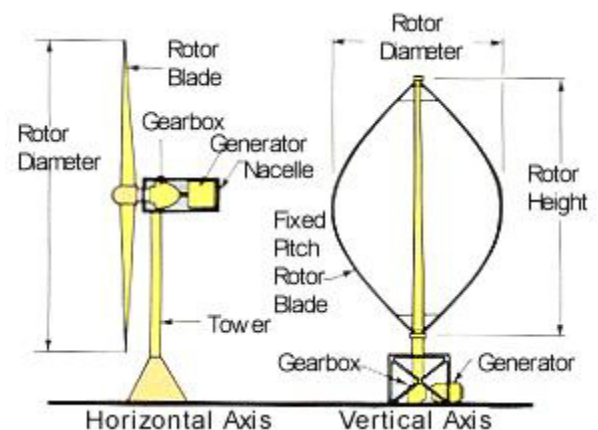


Figure 1. Wind Turbine Configurations [5]

### B. Horizontal axis wind turbines

HAWT are the most commercial WT. Even though, they have some advantages (low cut-in wind speed, the generator and gearbox are placed in tower, which makes the construction



more expensive and complicated) they need tail (yaw devices) to orient the turbine towards the wind. The HAWT are most present with three blades which balance the wind turbine and are more efficient than the turbines with less than three blades. The multi-bladed rotors are high solidity rotors. These rotors can start easily which is important for e.g. water pumping. The optimum between material costs and produced energy makes three blades the most profitable kind of WT [4]. They also can be built higher, with rotors having a bigger diameter to catch more wind and produce more electricity.

#### C. Vertical axis wind turbines

VAWT rotate vertical to the ground. They can receive wind from any direction and do not need yaw devices. The generator can be placed on the ground which makes it more economical and simpler. Another advantage is that the maintenance of the turbines is simpler and can be done on the ground. In this system pitch control is not required which is needed to setup the direction of the blades to the wind in HAWT. The biggest problem and disadvantage of VAWT is that they are usually not self-starting. To move the stopped turbine it is required to push the turbine which makes the process and the regulation more complicated and difficult. Another problem is the possibility of dangerous high blade speed which can cause the destruction of the WT.

#### D. Policy

The local policy has a big influence on the expansion of WT in every country. Germany is an example for the dependency and success of subsidies in the energy sector. Germany wants to reach 35% of renewable energy by 2020, 50% by 2030, 65% by 2040 and 80% by 2050. This should decrease carbon dioxide production. After having experienced the incident in Fukushima, the German government decided to shut down all German nuclear power plants much earlier in 2022 instead of 2040 [6]. Due to these ambitious goals the German WT market is expected to grow further. Electricity from WT in Germany is paid 9.27 cent/kWh (2013) [7]. The drawback of this feed-in tariff is the focus on capacity and not stability provided by WT. With a very high penetration of renewable energy Germany also faces the challenges resulting from intermittent power sources like WT and photovoltaic. The security of supply in a grid with a highly fluctuating power in feed from WT becomes more important. Additional technologies to balance the grid and reduce the variability of supply are necessary.

### IV. MAIN SITE PARAMETERS

The wind velocity is naturally fluctuating. Hence, several parameters have to be used to quantify these fluctuations. Various parameters can be used to evaluate the potential of a location for wind farms. Furthermore, identifying the expected variations in power output will help to identify the necessity for additional technologies to smooth the power supply and stabilize the grid. Detailed analysis of the prevailing conditions is crucial for the selection of adequate WT for each location.

#### A. Prevailing wind speed characteristics

Each location has a prevailing wind regime which has to be evaluated using long term measurements. The measured wind speed is Weibull distributed. This means that very low as well as very high wind speed has low occurrence. The energy content of the wind is proportional to the wind speed to the power of three. Thus the mean wind speed cannot be used to make accurate decisions for wind farm planning.

#### B. Air density

The air density fluctuates with high humidity and temperature. Paper [12] shows that air density variations will impact the extractable energy. The variations between the rated density for the WT and the prevailing conditions have to be taken into account. Especially in tropical climates the air density can vary. The study in Brazil showed a discrepancy of 16% less yield compared to sea level due to the lower air density and the higher altitude of the wind park [12].

#### C. Climate change impact

Article [13] is a recent study about climate change impact on prevailing wind conditions. It is stated that there are changes in wind conditions. Anyway, in [13] the overall global effect is considered as not significantly affecting the use of wind energy as a major future energy source.

### V. MAIN WT PARAMETERS

Numerous different WT are available today. The characteristics of each WT have an influence on the variability of the output. In this section the impact of various WT parameters on the availability and the capacity factor are investigated.

#### A. The capacity factor

The capacity factor  $c_p$  is defined as the average produced power in relation to the rated power:

$$C_p = P_{avg}/P_r \quad (1)$$

Paper [14] shows that the capacity factor of the observed wind farms is about 21% as yearly average. This means that the average annual production of a wind farm is only about 21% of its rated power. Furthermore, the capacity factor visualizes the fluctuating power output with daily capacity factors ranging from 0.3% to 66.5% [14].

#### B. Cut in, rated, cut out wind speed

The characteristic wind speed parameters for WT are shown in figure 2. The cut in wind speed is defined as the lowest operational wind speed. The WT will reach its rated power output at the rated wind speed. The WT will produce the rated power until the cut out wind speed, where it stops to operate in order to protect the equipment from high stresses. In articles [11] and [15] it is shown that the cut in wind speed has the biggest effect on the availability of the WT (figure 3). The effect of the rated wind speed is shown in figure 4 and is lower compared to the cut out wind speed. The occurrence of very high wind speed above the cut out wind speed is rare. Thus, there is nearly no influence of the cut out wind speed and the capacity ratio [15].

The article [11] introduced an index to show the effect of the relation of the prevailing site parameters and the WT. Article [11] shows that comparing the site parameters and the WT parameters will give a strong tool to choose the WT type in order to maximize the power yield. If the wind turbines from different manufactures can be weighted using this index, the output and reliability for a wind site can be maximized. Moreover, research indicated that different WT within a wind park can even contribute to better performance [16].

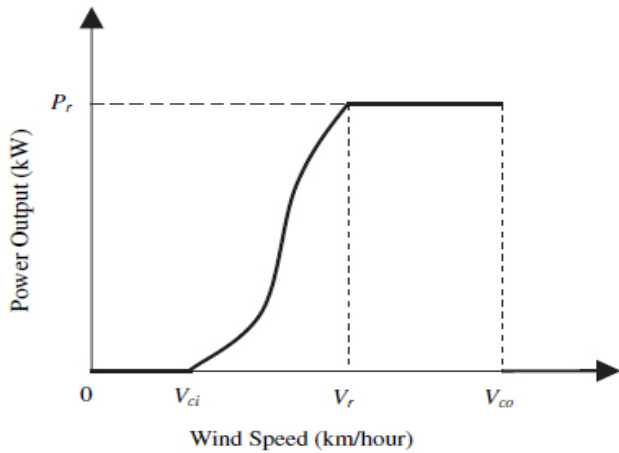


Figure 2, Cut in, rated and cut out wind speed [11]

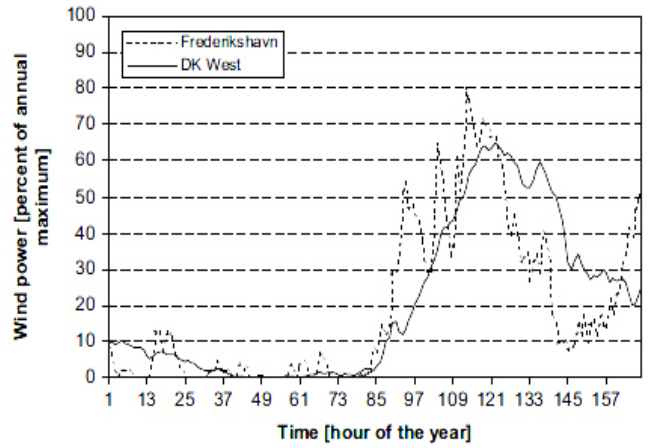


Figure 5, capacity factor for single turbine (Frederikshavn) and interconnected wind parks [17]

Figure 5 shows that the fluctuation of a single WT in Denmark and all Western Danish WT. It is obvious that the variability for a single wind turbine is much higher compared to an interconnected system. The standard deviation for a single turbine is 32% of its maximum while it is 22% for the connected system [17].

However to profit from this effect the grid has to be able to carry the loads. This is mostly the case in rather small and densely populated areas with good grids. Furthermore, the variation of electrical power production from WT can be reduced but still remains on a high level.

#### D. Impact of hub high

The hub height has a big impact on the energy production from WT. The wind speed increases with increasing the hub height of WT [18]. This effect is not limited to higher yields due to higher speed, even the reliability of a WT increases with hub height. In article [11] it is shown that even the minimum production rises and thus, the fluctuations in power supply decrease. Research has indicated that the combination of different hub heights in a wind farm can increase the cost per unit power output of a wind farm [16].

In general, the fluctuation of the power supply from WT can be reduced by taking the characteristics mentioned above into account. Anyway, the fluctuation of power output is still high and additional external technologies have to be applied. These external technologies are especially needed for an energy system with a high penetration of wind power.

## VI. MEETING SUPPLY AND DEMAND

The produced energy needs to be synchronized due to the variation of produced electrical power and the demand of electrical power. Figure 6 shows that the generation and the supply of electricity are changing over time. This process demonstrates that the energy security of WT and renewable energy needs another energy source. The regulation of the electricity supply is connecting renewable energy sources, conventional coal, oil and gas power plants, as well as nuclear

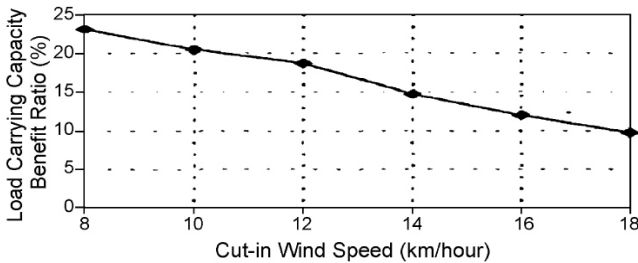


Figure 3, Capacity factor change with cut in speed [15]

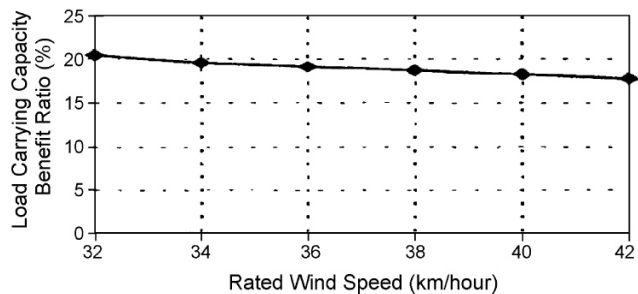


Figure 4 Capacity factor change with rated wind speed [15]

#### C. Geographical distribution of WT

The geographical distribution of wind parks highly impacts the availability of energy from WT. The local variations in wind speed will be partially compensated by connecting multiple regions.

power plants and other storage technologies into the smart grid (Figure 7). This method ensures the supply of electrical energy and is the future of the smart grid [9].

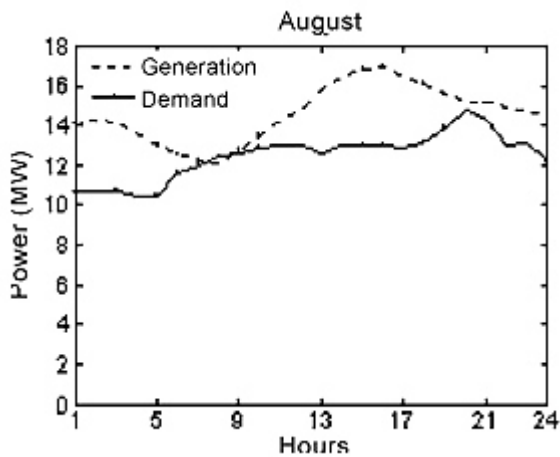


Figure 6, farm power generation and the load demand [8]

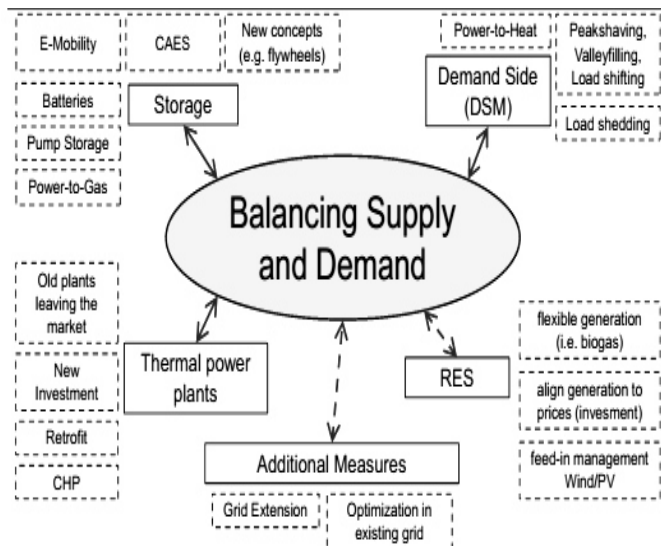


Figure 7 Supply and Demand of electricity [9]

## VII. STORAGE OF ELECTRICITY

The storage of electricity is a good possibility to save the excess supply, when the demand is low compared to the supply. The energy can be used in times when demand is higher than supply. This is one possible solution of the variation problem of renewable energy and demand. There are several methods to balance supply and demand:

- Batteries – the advantage is the storage of electricity, disadvantages are the limited capacity and high costs [10].
- Thermal energy storage – utilizing cheap electricity in the night and store it for heating during the day, only possible for a short period of time [10].
- Compressed air energy storage – excess supply is used to compress air in cavern, the stored energy can be used to drive a gas turbine for electricity during peaks.

- Pump storage – storing pumped water in high reservoir when demand is low. In peak demand its works as a hydroelectric power station with high efficiency about 80%.
- Power-to-Gas – excess electrical power, e.g. from WT, can be used to produce hydrogen which is an excellent energy carrier. Furthermore, the process can be extended to produce methane by converting hydrogen and carbon dioxide.

## VIII. CONCLUSION

This article gives an overview on the parameters of wind turbine generators which influence the variability of power supply due to the intermittent characteristics of wind. Inherent options of WT to reduce the variability by planning and design parameters are presented. Different storage technologies are evaluated as an external option to meet supply and demand in a network with high wind penetration.

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# Energy-efficient home appliances

## on the example of laundry care

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**Abstract**—“ Home appliances are electrical/mechanical machines which accomplish some household functions, such as cooking or cleaning” [1]. “Energy efficiency is the goal to reduce the amount of energy required to provide products and services” [2].

*energy, laundry, european standards, washer, dryer, eco, appliance*

### I. INTRODUCTION

The development of household appliances in the last ten years has increased very rapidly. In addition to new developments towards ergonomic design and user-friendly operation, two other aspects play a very important role nowadays. First, the newly developed devices should be low-priced and secondly, they should be as energy efficient as possible.

### II. EUROPEAN ENERGY STANDARDS

Each household appliance must have an EU certificate so it can be allowed to be sold. This is documented in the form of an energy label, which can be stuck on by either the purchaser or the seller.

#### A. The new energy label for washing machines

Due to the fast development in the sector of energy efficient household appliances, a new energy label was introduced in 2010 (Fig.1). The points below explain the meaning of each label [3]:

1. Name or trademark of manufacturer, classification.
2. Class of energy efficiency.
3. Annual energy consumption in kWh based on 220 standard washing cycles. The actual energy consumption depends on the use of the appliance.
4. Water consumption (liters / year), based on 220 standard washing cycles. The actual energy consumption depends on the use of the appliance.
5. Maximum filling capacity in a standard washing program in 60 ° C or 40 ° C for cotton.
6. Classification of the centrifugal power.
7. Noise level in dB (sound power), while the wash or spin cycle in standard washing program 60 ° C cotton at full load.
8. Name of regulation.

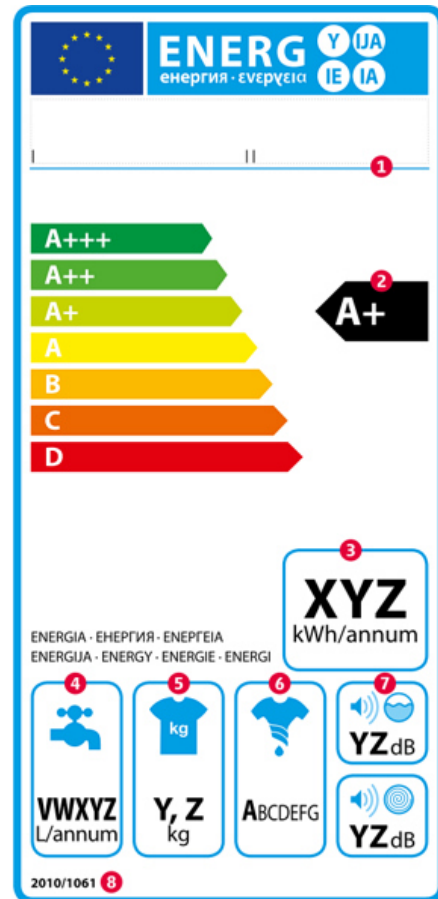


Figure 1. New european energy label [3]

The new label for washing machines no longer contains the classification of the washing effect. The reason is that a minimum washing affectivity is prescribed. This corresponds to today's "A" class (or class "B" for washing machines with a maximum capacity of 3 kg) [3].

#### B. Energy efficiency index and energy efficiency classes

An energy efficiency index also determines the classification in an energy efficiency class. This index takes into account several variables: Energy consumption in 60 ° C wash program at both full load and at part load, the energy consumption in a 40 ° C wash program at partial load as well as the maximum filling capacity in these programs [4].

| Energy efficiency classes | Index of energy efficiency IEE | Average saving compared to efficiency class A |
|---------------------------|--------------------------------|---|
| A+++                      | IEE<46                         | 32%   |
| A++                       | 46<=IEE<52                     | 24%   |
| A+                        | 52<=IEE<59                     |   |
| A                         | 59<=IEE<68                     |   |
| B                         | 68<=IEE<77                     |   |
| C                         | 77<=IEE<87                     |   |
| D                         | 87<=IEE                        |   |

Figure 2. Energy efficiency index and energy efficiency classes [3]

### III. PROCESS ENGINEERING MEASURES TO INCREASE ENERGY EFFICIENCY

The circle in Fig. 3 consists out of four major components:

- time,
- washing mechanics,
- temperatur and
- detergents.

A full circle represents symbolically the clean laundry. To get at the end of the washing process clean laundry, all of these components must include a full circle.

Detergents are in the washes only a small part of what man needs to the laundry to wash clean. The manufacturers of household appliances have no influence on detergents and for the this reason this part of the circle is neglected.

Wshing mechanics means the contact between the laundry and the drum. This very contact means friction, and that friction is in large part responsible for ensuring that the dirt particles are removed from the lands of the clothing material.

The time component is easy to explain. The longer the washes are washed, the cleaner they are.

The temperature component can be explained by physically. It is in the nature that the molecules and particles have a higher kinetic energy at higher temperatures. So the higher the temperature, the faster the dirt particles are transported out of the laundry.

The largest content of this circle is been absorbed by the washing mechanic and the temperature. These are the same two components in the washing process that consume the largest share of the energy. So, in order to reduce energy consumption, the reduction of temperature is required. But for this reason, the time component and washing mechanics parts have to rise because the circuit must remain closed.

If one wants to further reduce the energy consumption, only the washing mechanics parts can be produced. This leads to the fact that the time component enlarges. One can observe the new trend that energy efficient washing machines with low energy consumption take more time to finish the laundry.

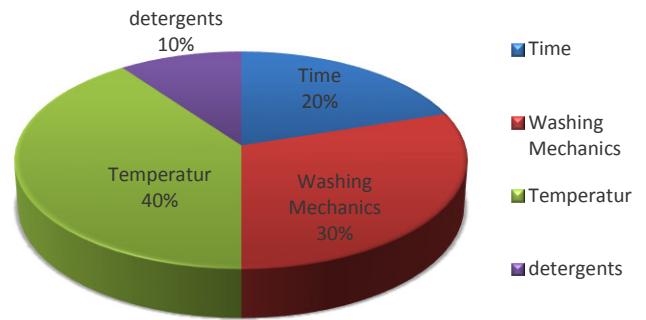


Figure 3. Process engineering in laundry care

### IV. STRUCTURAL ENGINEERING MEASURES TO INCREASE ENERGY EFFICIENCY

#### A. Eco Bubble

The Eco Bubble procedure was first introduced by Samsung and is a patented procedure “Samsung’s eco bubble technology uses a bubble generator to dissolve detergent into the water and inject air, making a rich soapy foam cushion. This means detergent is better dissolved and penetrates clothes faster so cleaning needs less hot water.” According to the manufacturer, the Super Eco Washing mode has very good washing performance at temperatures round 15°C and it saves up to 70% of the energy [5].



Figure 4. Samsung ecobubble technology [5]

#### B. Heat pump technology in dryer appliances

There are condensation dryers that operate on the principle of the heat pump. The hot part of the heat pump heats the incoming air, the moisture condenses on the cold part of the outgoing air. These devices consume much less energy. Compared with conventional appliances of energy efficiency class B, tumble dryer with heat pump technology has more than 50% energy saving potential. Modern condenser dryer with heat pump technology achieve energy efficiency class A, among which are quite economical models with manufacturer instruction up to A-50% (which would correspond to an extended European norm of A++) or even A-60% [6].

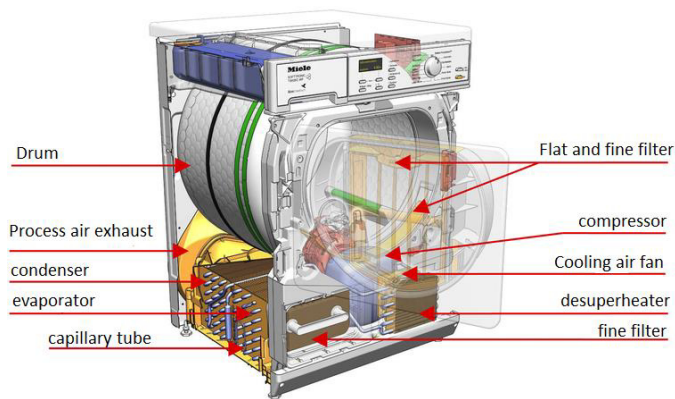


Figure 5. Heat pump technology [7]



Figure 7. Alveolar-like washer drum [10]

### C. Hydroactive+ technology

The Hydro Active + Technology is patented by Panasonic. The Hydro Active + Technology uses “water injecting ring” with a five injection points. The injection points are arranged radially on the Gasket (Fig. 6).

They are used for a uniform distribution of water in the laundry resulting in an increase of the washing performance and eventually to reduce energy consumption [8].



Figure 6. Hydroactive+ technology [8]

### D. Alveolar-like washer drum

By inwardly hexagonal honeycombs produced during rotation of the drum, a water film between the metal and laundering is produced, which significantly results in reducing friction. The water drain holes are located in the cavities between the honeycombs. Their number and their diameter is compared with conventional embodiments has been significantly reduced. Thus the laundry gets caught in the holes less; this procedure also protects the textiles. Thanks to this procedure, the washing is significantly improved, resulting in the reduction of energy consumption [9].

### E. Silver active system

Silver has been popular in ancient times due to its special characteristics, its rarity and its pure brilliance. But far more than its special characteristics, the antibacterial effect of silver contributed positively in household and in medicine a long time ago.

This antibacterial effect of silver is now used with the Samsung Active Silver Technology in the new washing machines. By each stage of the washing program, silver ions are released. These silver particles reach the laundry in order to unfold their antibacterial effect. On the one hand the emergence of a bio film with its unsanitary germs and bacteria is prevented, so that the washing machine and the laundry remain almost sterile. On the other hand, this also protects the environment. Electricity and water are saved [11].



Figure 8. Silver active [11]

## V. SUMMARY

The customers want the Modern washing machines and tumble dryer to be capable to do more washing units and consume less energy. In this work, only selected examples are presented that help in meeting these requirements. There is whole range of small technological solutions that lead to better washing performance and thus improved energy efficiency.

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# Solar Technology in Building Envelopes

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**Abstract**— Public consciousness, dramatic increase of fossil fuels prices and CO<sub>2</sub> production costs, climate change and (to a small extent) government policies and support acts have promoted a movement toward the development of sustainable architecture in the world. In the last decade, great improvements have been made in the energy efficiency and management of buildings. One of the advanced ways of energy generation in buildings is Photovoltaic energy. Photovoltaics (solar electric cells or ‘PVs’) integrated into buildings can help to take building technology to the next step, by generating electricity while enhancing efficiency besides giving a new look to them. At the same time, building integration will improve the economics of photovoltaics and encourage researchers and manufacturers to focus more on this clean source of energy. This trend is so interesting and tempting that architectures around the globe are offering new designs for more efficiency which use solar panels as decorative elements to make even more stylish buildings. It seems that after all, there is something luxurious and useful.

**Keywords**-Solar Energy, Photovoltaic, Building envelope, Building-Integrated Photovoltaic (BIPV)

## I. INTRODUCTION

Photovoltaic conversion is the direct change of sunlight energy into electricity without any heat engine to interfere (1). Since there is no moving parts involved, photovoltaic devices are easy operating and simple in design requiring just a little maintenance and their main advantage, being their construction as stand-alone systems to give outputs from microwatts to megawatts. This ability to work stand-alone demanding no especial routine maintenance makes it the best choice for remote power source, water pumping, far-off buildings, solar home systems, communications, satellites and space vehicles, reverse osmosis plants, and for even megawatt scale power plants. With such a vast range of applications, the demand for photovoltaics is increasing every year (1), (2).

These superior advantages of photovoltaic technology make it one of the main interests of researchers and leader manufacturers of renewable energy resources in today’s world. Nanotechnology is promising a very bright future by offering high efficient PV cells which is going to be more commercial after all (3).

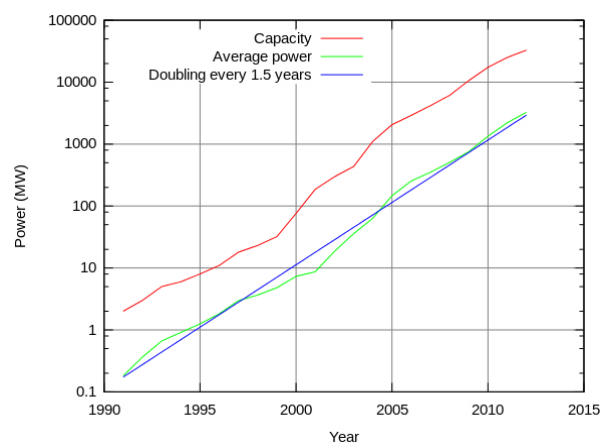


Figure 1: Increase of solar PV in Germany (4)

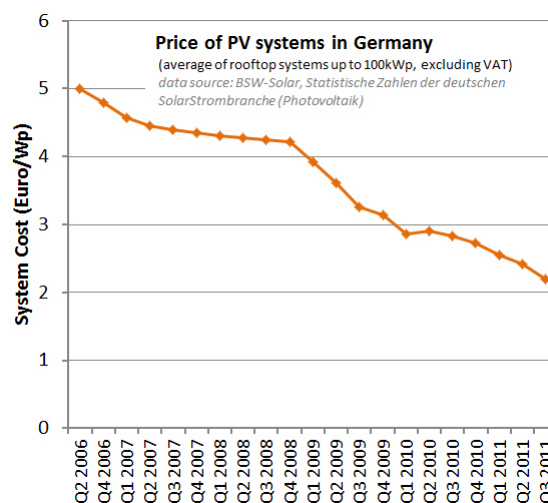


Figure 2: decreasing price of PV systems in Germany (4)

Considering the goals of the new EU Energy Performance of Buildings Directive (EPBD), near-zero-energy and plus-energy buildings will become the demand in new building construction. Moreover, existing buildings have to be improved concerning their energy consumption and emissions in order to achieve the climate protection aims of governments. Therefore, more and more roofs and facades are used as generators of heat and/or electricity. In any case, not only can solar technologies increase a building’s value but also its character. Thus,



integrating solar technologies in building envelopes is a challenge referring to the design (5).

## II. BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV)

### A. Definition of BIPV

Building Integrated Photovoltaics (BIPV) refers to photovoltaic cells and modules which can be integrated into the building envelope as part of the building structure, and therefore can replace conventional building materials, rather than being installed afterwards (6). BIPV elements can be naturally combined into the design of the building. It means that BIPV can be used in any external building surface.

Together with the evolution of the integration of modules in the architecture, the new BIPV products have the ability to fully replace some building components - the construction parts of the building envelope (roofing, facade cladding, glass surfaces), devices, sun protection (sunscreen), architectural elements and accessories "(porches, balconies, railings, etc.) or for instance, elements of visual and acoustic shielding. Within the BIPV definition, also plants integrated in urban and transport structures (independent shelters, shelters for vehicles, sports or play, bus stops, etc.) are considered (6).

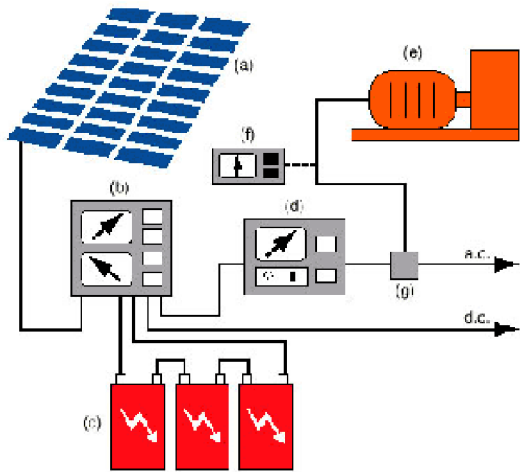


Figure 3: A BIPV system diagram including (a): PV panel, (b): converter and controller, (c): batteries, (d): inverter, (e): local motor loads, (f): meters, (g): junction box (7)

### B. BIPV as a multifunctional building element

BIPV is a multipurpose technology. Besides of being a source of electricity, several other functions can be achieved by installing photovoltaics, such as weather protection, thermal insulation, noise protection or modulation of daylight. For instance, they can be used to regulate the intake of daylight to a building by powering an automatic sun-blind, operate an engine driven ventilation opening or even as emergency lighting (8).

Studies also prove that PV integration on the roof and buildings envelopes effects on heat transfer from both sides in different seasons. Experimental cases and researches prove that

photovoltaic panels in cold seasons increase the building efficiency. Besides, by reflecting and absorbing sunlight, and acting like an insulator, photovoltaic panels play a very remarkable role in the warm seasons to higher the efficiency of building (9), (10).

Furthermore, they perform a very courageous role as a public demonstration of a building owner's green ecological and future-oriented image. The following is an exclusive list of the functions that PV modules can deliver besides production of electricity (6):

- Noise protection (up to 25 db sound dumping is possible)
- Thermal insulation (heating as well as cooling), improving the efficiency of cells by cooling through rear ventilation, isolation function is possible as well.
- Visual cover/ refraction (one-way mirroring visual cover)
- Electromagnetic shielding (can be used as Faraday cage but also as repeating antennas)
- Aesthetic quality (integration in buildings as a design element)
- Safety (safety glass function is possible)
- Weatherproof (waterproof and windproof façade or roof of a building)
- Sun protection/ shadowing (degree of shadowing is eligible through positioning and degree of transparency)

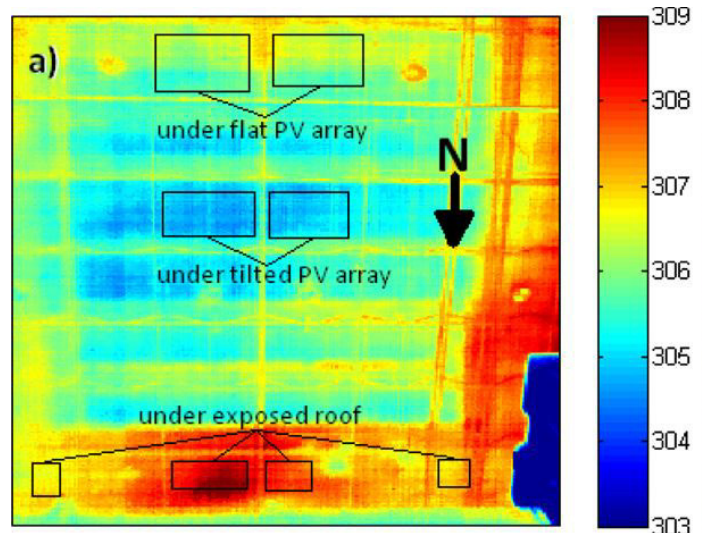


Figure 4: Thermal IR camera image of ceiling at 1710 PST on April 19, 2009. The color bar denotes temperature in K. Horizontal and vertical lines through the image result from steel trusses that are below the ceiling at a different temperature. The footprint of the tilted PV array is visible as a cool area in the center. Pixels within black rectangles were chosen as representative of the ceiling underneath each roof type and were used to obtain its average temperature (9)

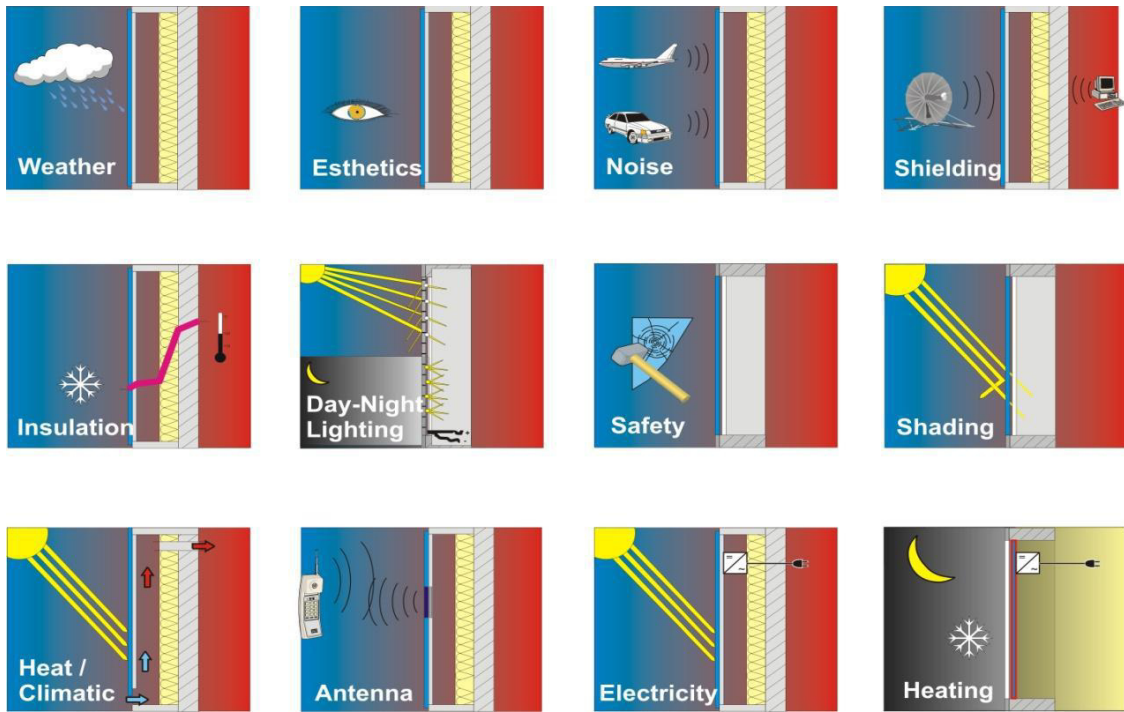


Figure 5: Multiple functions of PV modules (11)

### III. BIPV AS A MULTIASPECT STUDY

Like all products and designs, BIPV has also different aspects to study, specialize and implement. Numerous standard organizations and companies are offering specific designs, standards and ways for the integration regarding types of PV cells, costs, sunlight availability and angle of irradiation, and architectural facets. National Renewable Energy Laboratory (NREL) is one of the leading organizations which is offering several documents concerning all types of buildings including commercials, residential and industrial constructions. For more detailed information on this matter, you can refer to free documents of NREL (8), (12), (13).

### IV. INTEGRATION OF PHOTOVOLTAIK MODULES IN ARCHITECTURE

PV always remains an element that is added to the surfaces of buildings. However, there are different strategies for the integration of PV modules in building envelopes.

#### A. PV modules are applied invisibly

The PV system is applied invisibly and thus do not disturb the architectural appearance.

#### B. PV modules are added to the design

The PV system is added to the design. In this case the PV system is not really integrated to the buildings envelope. But this does not necessarily lead to a lack of architectural integrations.

#### C. PV system contributes to the architectural image

The PV system is integrated well into the entire design of the building and does not change the external appearance.

#### D. PV system determines the architectural image

The PV system is well integrated into the design of the building and is a significant characteristic for the image of the building.

#### E. PV system leads to new architectural concepts

The use of PV modules in combination with other solar technologies leads to designs and architectural concepts (14), (15).

### V. DESIGN POSSIBILITIES FOR PHOTOVOLTAIC

There is more variety in respect of the design for PV modules than for solar thermal energy. Not only color nuances of polycrystalline or thin-film cells but also the transparency and reflection properties of the module covers can be designed differently (3).

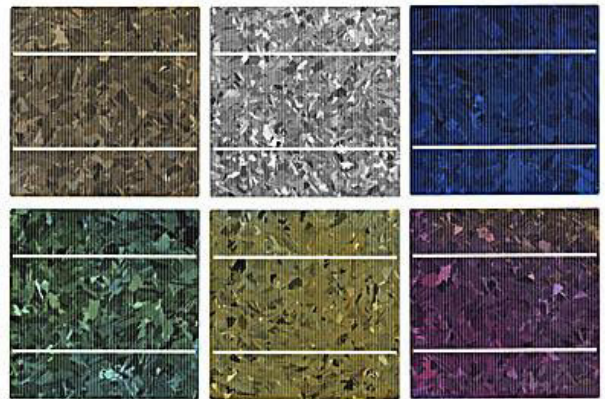


Figure 6: PV color variety (16)

## VI. CRITERIA FOR WELL-INTEGRATED SYSTEMS

The IEA PVPS (PV Power Systems) program defined the requirements that are necessary in order to achieve successful PV integration. According to the group of experts the following criteria are significant for evaluating the aesthetic quality of buildings with PV systems (14), (15):

- natural integration of the PV system
- designs that are architecturally pleasing
- good composition of colors and materials
- dimensions that fit the grid, harmony and composition
- PV systems that match the context of the building
- well-engineered design
- use of innovative design

## VII. EXAMPLES FOR WELL-INTEGRATED SOLAR TECHNOLOGIES IN BUILDINGS ENVELOPES

### A. Solar collectors

The deltaZERO building Lugano (2009) created by De Angelis Mazza Architetti shows the use of flat-plate collectors in facades. The apartment complex has a steel and glass facade and is designed as a zero-energy building. Depending on their orientation and requirements its elements (3,20 x 2,70 m) have different structures. They have different glass lamination to optimally combine daylight use and thermal insulation. Storey-high solar collectors are integrated in the south facade for supporting the heating system and the heating water (3).



Figure 7: DeltaZERO, in Lugano, DeAngelis Mazza Architetti (17)

Another approach was taken by Herzog+Partner for the Oskar von Miller Forum (2009) in Munich. In this connection the outside facade of the south building is uncouple from the primary construction by a steel structure. This construction with protruded beams forms a platform for vacuum-tube collectors, which are arranged in five rows. On the south side they also are used as protection against the weather and sun. The whole steel construction and the high-performance solar system optimize each other to form an energy roof which affords 20 % of the thermal energy needs from the building and covers 16 % of the cooling energy requirements in combination with absorption cooling machine (3).



Figure 8: Miller Forum, in Munich, Herzog + Partner (18)

### B. Photovoltaic systems

In Saint-Étienne, France, in a former industrial complex the architects Finn Geipel + Giulia Andi designed a new construction project, the Cité du Design (2009). The single-storey elongated building has a multi-functional, adaptive envelope and is characterized by a triangular grate. This envelope consists of 14,000 panels with ten different layer structures. The entire building is assured not only formally but also with reference to its technical and urban-planning qualities (3).

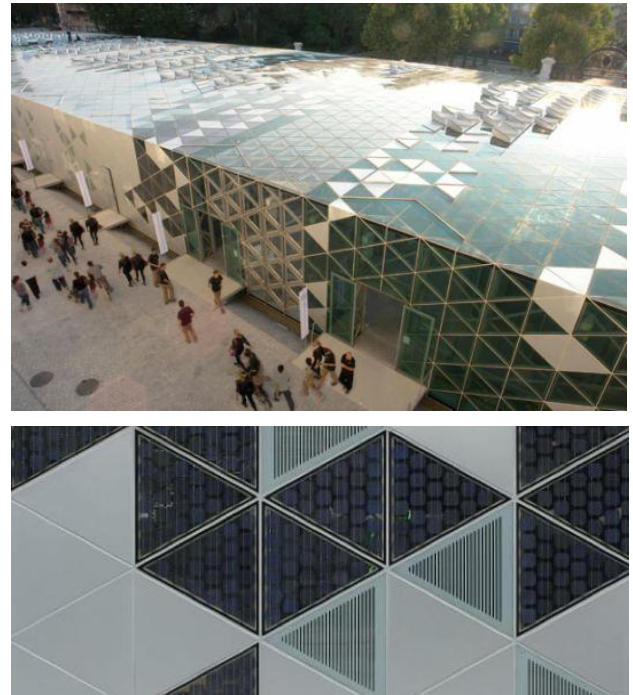


Figure 9: Cité du Design, in Saint-Étienne, Finn Geipel + Giulia Andi (19)

The building from Simone Giostra & Partners Architects, Greenpix - Zero Energy Media Wall in Beijing has an impressive facade. It applies sustainable and digital media technology to the curtain. It is the largest LED display worldwide and it has the first PV system which is integrated into a glass curtain wall. The building performs as a self-sufficient organic system. The wall / display (60 x 35 m)

extracts solar energy by day that is used to illuminate the screen by night.



Figure 10: Greenpix, in Beijing, Simone Giostra & Partners Architects (20)

### VIII. CONCLUSIONS

To sum up, the examples of buildings emphasize that solar energy systems are a relevant factor of superior and innovative building concepts. Although there is some variety for designs the solutions for well-integrated PV systems are limited due to the functional and technical components. However, there is potential for further progress. In addition, when integrating solar technologies in buildings envelopes, the criteria from the IEA PVPS programme should be considered in order to achieve an advanced overall concept concerning function, construction, design as well as ecology. Besides, architecturally pleasing and well-integrated systems will increase market acceptance.

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# The 3. Interconnector

## Grid extension in Germany/Poland

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*Abstract*— **With renewable energy rapidly increasing its market share in Germany, the German grid desperately needs expansion. Even today, some renewable energy technologies are not used to optimal capacity and some renewable power plants have even had to be shut down as a consequence of the Energy Act (EnWG) § 13.2. The expansion of the network is overdue and has been delayed too often already. Transmission system providers are presently facing a major challenge in trying to ensure a stable and well-functioning power grid for the future.**

*Interconnector 3; grid extension; PSE-O; 50Hertz*

### I. THE CURRENT SITUATION IN GERMANY

Climate change has led to a rethinking of German energy policy. This has created incentives to expand the production of electricity from renewable energy resources. The realisation in Germany has been financially subsidized through regulations, such as the EEG-act [5]. (Erneuerbare Energien Gesetz). The largest part of renewable energy comes from wind power, hydropower and photovoltaic systems, the latter receiving the highest subsidies. The market share of renewable energy in Germany comes to 17 per cent, according to BMU in 2010. The problem of renewable powers is that a large part falls back on heavily fluctuating supply, which means an expansion especially in high voltage networks is becoming increasingly important if a stable power grid and reliability in supply are to be guaranteed [1].

### II. PROSPECTS

The goal of the energy policy is a market share of 39 per cent of renewable energy sources by 2020. This ambitious scheme represents a major challenge for energy utilities. Therefore, the German Energy Agency [1] has commissioned two grid studies. The impact of this project on the supply system is discussed and analysed in detail in the Dena Grid Study 2 [1]. According to the study a massive grid extension has to take place soon. The purpose is to preserve and optimize the following features:

Stable networks in order to guarantee a high level of supply reliability

100 per cent integration of renewable energy, to allow the full utilization and acceptance of renewable electricity. In other words, adapting the use of conventional power plants to temporary fluctuations in availability of renewable energy so that conventional energy is not used when unnecessary.

Facilitating an open competition for electricity trading in Europe by good connection of the countries through interconnectors (European Priority Project).

### III. GRID EXTENSION IN GERMANY

The Dena 2 calls for approximately 3,600 km ([1] p. 28) of power lines expandable to the 380 kV transmission grid in order to achieve the above mentioned goals. The track construction must be done without further deferment in order to preserve the security of the energy supply network. Delays in the project are:

- citizen participation in the form of citizens' initiatives
- landowners' concerns about the value of their land holdings due visual impairment
- repeatedly demanded discussion hearings
- problems for approval bodies and TSOs
- transnational disagreements such as insufficient cooperation between authorities and transmission system operators
- missing legal grounds, no definitive laws, modification of permission proceedings in the course of proceedings

Legislation to accelerate construction has been passed in order to allow fast implementation of grid extension, because otherwise it is not possible to integrate renewable energy sources. The Law on development of energy networks (Power Grid Expansion Act - EnLAG) notes that for the instalment of new power plants and an avoidance of structural bottlenecks in the transmission grid (EnLAG [2] § 1), the development and expansion of the network is absolutely necessary [2].

### IV. USING THE TEMPLATE

The 3rd Interconnector is a European priority project, that is about constructing a 380 kV power transmission line. This connection will be built between the electrical substations Eisenhüttenstadt via Frankfurt-Oder to the substation

Plewiska. The following values and figures refer only to the German section. Furthermore, the network connection of the substation Eisenhüttenstadt is to be amplified. At this German-Polish project the transmission system operators, 50 Hertz on the German side and the PSE-O on the Polish side, are involved. Currently the planning and zoning process in which the optimal routing is sought is already in progress. As you can see on the schedule in Figure 1, the Material Requirements Planning (MPR) has been completed.



Figure 1. Time schedule 50Hertz

The European Union and the countries have codified the project in the said legal act. In addition there has been a general agreement between PSE-O and 50 Hertz. The next step is the regional planning process, which is currently in full swing. In the course of it the alternative routings are presented to the public and are being discussed. Once the planning is completed (scheduled for 2014) zoning follows. The routing is fixed and land is purchased, pre-construction commences, construction follows and finally, in 2017, the new power line is to be commissioned. [4]

## V. TECHNICAL IMPLEMENTATION

The sub-project of the grid amplification line is itself subdivided into two sections. First, the phase of construction associated with the bundling of an existing 380kV overhead transmission line on the section from the UW Eisenhüttenstadt to Preilack. Second, the construction phase in free line routing from point Rießen to point Schernsdorf ([3] p. 62).

Image 2: „Donau-Mastbild with typical dimensions ([6] P.13)

The second part of the project, the expansion of the substation, aims at the optimized use of the transmission capacity of the primary technical resource. These measures mainly concern the following resources [6]:

1. conductor cables
2. high voltage terminals

3. power circuit and disconnecting switch
4. line traps (TFH-Gates)

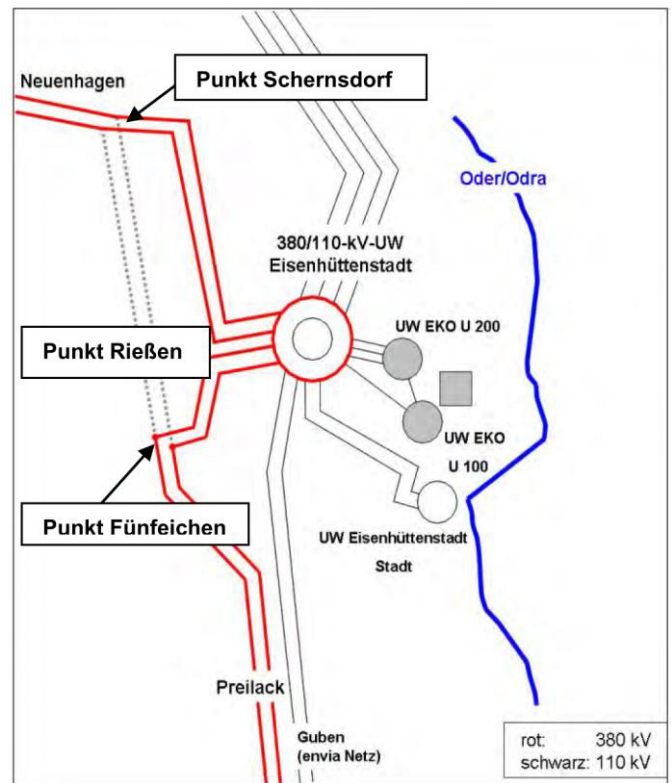


Figure 2. Regional Planning Procedure

The expansion of international interconnectors is a declared objective of the European Union. This is laid down in various treaties and laws. These include, for example, the Treaty of Lisbon (Article 147). In Germany, the political and the legal need to strengthen the transmission grid is manifested in the Power Grid Expansion Act [2].

There is a number of protective goods pertaining to the necessary regional planning procedure. These include the human, flora / fauna, landscape, as well as the ground. The interferences can be classified in three categories:

- temporary / during construction phase:
  - construction machines
  - environmental pollution
- permanent / after construction phase:
  - permanent landscape strain
- periodical / during the entire operational phase:
  - visual impairment
  - electromagnetic field

In the course of regional planning for the transmission route five variations have been developed by the planning office “Förster” in cooperation with the City of Eisenhüttenstadt. [3]

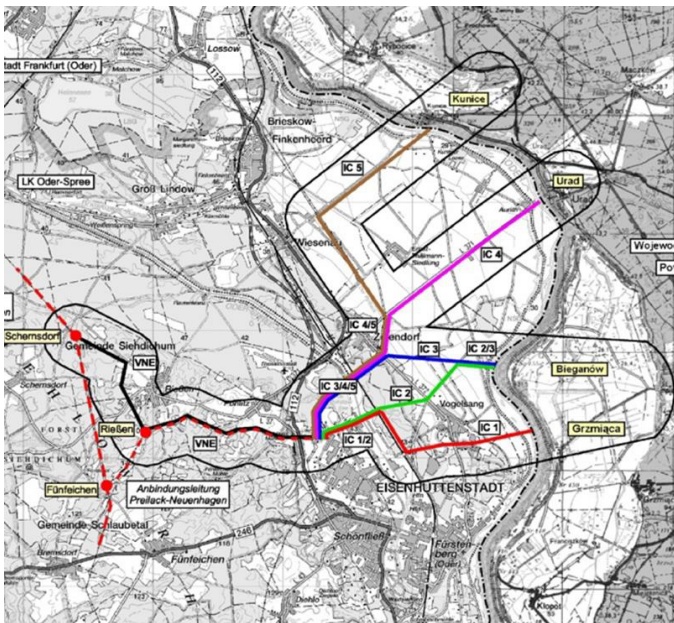


Figure 3. Track routing

All five alternatives were examined and evaluated with regard to different aspects. These include among others the settlement area, vacation and tourism, economy, agriculture, traffic, disaster management and so forth. The pipe routing version 2 had the least potential for conflicts over all aspects and is therefore a preferred option. It has a total length of 6.4 km to its transfer point to Polish network operator PSE-O in Bieganów (see Fig. 3 course green line).

Potential conflicts for this course are due to:

- 0.5 km strain of landscape
- at 2.4 km crossing of high-quality, agriculturally important regions
- imbrication of significant touristic areas
- fragmentation of forest areas and thus occupation of approximately 21 ha.

The affected parts of corridor 2 through the network extension of the UW Eisenhüttenstadt are inevitable. The additional impairments can at best be minimized [4].

## VI. CONCLUSION

The example of the third interconnector is to show that a grid expansion is not easy to implement and requires a great deal of time ahead of project start. This is due to the multitude of factors involved in grid extension and its approval process. And even if the project is approved there are still many delays. The reasons are public decisions or slow action of the authorities as well as discrepancies between the TSOs. These problems can cause multiple delays in project realization and,

if bad comes to worse, may even lead to the termination of the entire project. No exception, the interconnector, too, has already been delayed, which was caused by the Polish transmission system operator, while the most sensitive issue, the regional planning process, had not even been opened at that point. Despite the status of a priority project, the process has been dragging on for over 10 years, and each delay leads to a slower extension of the transmission grid. This problem exists not only at the Interconnector, but in almost every grid expansion project in Germany. This also has a negative impact on the development of renewable energies, because without an expanded grid, more and more renewable energy can be fed into the grid only insufficiently if at all. Now the question arises how to speed up the approval process and thereby network expansion itself.

The main focus is on the planning processes, which must be shortened. This can be achieved through faster implementation of swifter political processes. Another possibility would be to accelerate the process of regional planning. But a quick decision could adversely affect the country and the people and increase the probability of flawed planning. This shows, grid extension is a huge challenge for the TSO's, which must be solved to guarantee a stable grid in the future.

## ACKNOWLEDGMENT

Special thanks to Arno Zucknick.

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# Photovoltaic

## The recent struggle of the solar energy market

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**Abstract** — Photovoltaic is considered as one of the most important next generation energy technologies. Although technical improvements in the past have shown that photovoltaic holds a big potential for future developments recent rivalry between global competitors prevents the European solar energy sector from ongoing success.

**Keywords** - photovoltaic; Germany; China; sustainable; oversupply; import duty; trade war

### I. INTRODUCTION

The worldwide need for energy is rising every day. But the amount of global fossil fuel resources is not only limited, but also comes with numerous negative environmental and social impacts. Logically there is a need for a more balanced handling of energy production. Energy produced by sustainable technologies is a key element to ensure societies an enhancing standard of living.

Speaking of sustainable energy production, photovoltaic technology (PV) has a broad field of application and is considered as one of the most important next generation energy technologies. Significant technical advances in the past have shown that photovoltaic holds a big potential for future developments and is on the right path to play a major role in future energy supply [1]. This paper will show how the global Solar Power Industry developed technically and economically using the example of Germany and the People's Republic of China.

### II. GERMANY'S SOLAR POWER INDUSTRY

#### A. Development in Germany

As many as 1.3 million photovoltaic power stations are installed in Germany, more than any other type of power station. Photovoltaic delivers 5.3% of the entire German power consumption. As an important part of the German

energy transition the photovoltaic technology is extensively supported by the renewable energy act [2]. The renewable energy act was originally released in 2000 with the goal to at least double the percentage of renewable energy in the collective German power consumption [3]. It went through several changes until today, but the main idea remained.

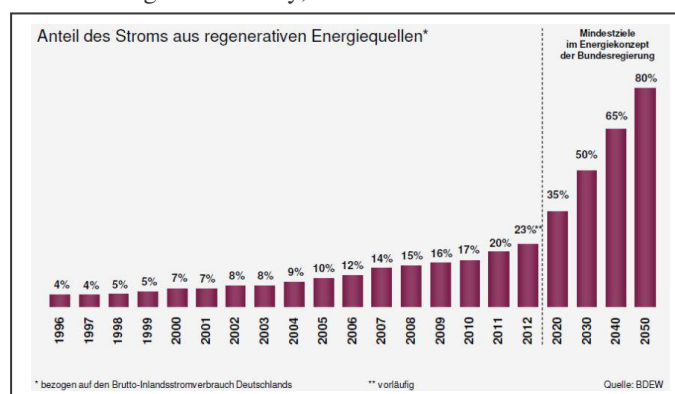


Figure 1: Percentage of renewable energy sources in Germany (H. Wirth, "Aktuelle Fakten zur Photovoltaik in Deutschland", Fraunhofer Institut für solare Energiesysteme, pp. 6, April 2013.)

Resulting advantages of this act are a cheaper access to capital, reduction of costs of electricity generation and guaranteed feed-in for renewable energy. Because of this implied warranty, secure economical investments are warranted and investors can be attracted. In addition to this advancing technology and further development in production, operation and maintenance is constantly reducing investment costs, which are the largest costs for electricity generated by photovoltaic. A cost reduction of 15% per year has been achieved and is considered as reasonable figure for the next years. In consequence of this trend the main point of criticism, which is high investment costs in comparison to nuclear or fossil technology, is increasingly invalid. As a matter of fact, operation costs for photovoltaic stations are the lowest of all power stations [2].



This positive development in photovoltaic as technology seems to conflict with the highly competitive photovoltaic market, which is widely characterized by governmental subsidies and rivalry between not only companies but countries. Fall in the price of solar cells and supplier components found its peaks in a situation where corporations sold their products below manufacturing costs resulting in major losses especially devastating for smaller competitors, often resulting in bankruptcy [4].

### B. Oversupply and Dumping Prices

In 2007 German solar energy companies were top ranked among all global players in photovoltaic technology [6]. Germany was highly regarded as one of the leading countries in renewable energy, not only developing sustainable technologies, but also to install and use them in great numbers. Early assistance measures (renewable energy act) for those new technologies paid off and secured Germany's position as strongest and fastest growing solar energy market worldwide [6]. In 2011 the global market share of German photovoltaic suppliers was 46% and 87% of the supply technology was exported. This upward trend found its peak in 2010 and 2011 where it also became clear that China's fast growing, governmental supported solar panel production is a serious competition for German manufacturers. As a consequence of this companies were forced to reduce their production capacities or even to close their factories in high numbers. Figure 2 shows the heavy effect on employment in the solar energy sector 2012, because of the heavy downswing in this year.

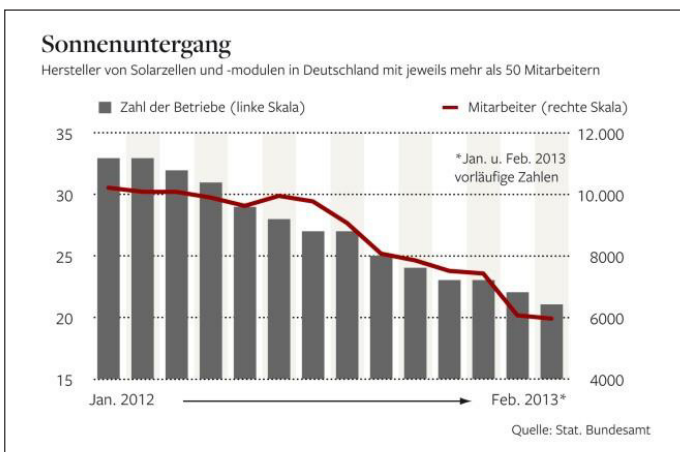


Figure 2: Sunset ([www.welt.de/wirtschaft/article115455341](http://www.welt.de/wirtschaft/article115455341))

The reasons for these actions are found at the ongoing developing industrial policy of China. With generous support of the government the Chinese companies produced solar goods until the market was oversupplied. The export led to a fall in prices in Europe, which afflicted a lot of damage to the

resident companies [7]. As a result former market leader "Solarworld" from Germany is indebted with about 1 Billion Euro [8]. The USA early protected themselves against the flood of products from Asia via import duties. Although some Chinese traders were able to avoid this interference by selling their products from Taiwan many European companies argue the case for enforcing these import duties here as well to restore a regulated competition and prevent themselves of becoming insolvent. Therefore they founded the joint initiative "EU ProSun", which demands a forceful procedure against the dumping prices caused of the oversupply of the EU-Commission - with success: In the very same year new laws will be adopted, that Chinese products can only be imported with extra duties by an average of 47% [9].

### III. CONCLUSION

The photovoltaic industry is, despite the unsatisfying development for European companies, still one of the most important next generation technologies of the power supply industry with a huge market size. In the past years Asian companies outran their European rivals with the help of governmental subsidies and have a lot of benefits compared to the European companies, who are not able to compete them without aid. But is the plan of the European Committee to put a high import duty on solar products from Asia really the right way to regulate the competition?

This is highly questionable. On the one hand import duties will most likely have a bad influence on the demand for solar products in Europe with all its undesirable side effects. On the other hand China will not deedlessly accept this action as the second most important trading partner of Europe.

Chinese representatives only just warned the European Union to realize their plans that could lead to a trade war, which would harm both sides, because not only solar products but other commodities from China are scheduled to get import duties. Furthermore it is likely that this action is arranged too late. Even though there is the possibility to save some European companies from insolvency they are way too small to have an influence on the global market, which is dominated by Chinese and American companies. It will also be almost impossible for them to expand their business.

Even if it comes to an economic revival of the solar market in the near future, which is predicted by some market observers, the European companies would not be able to satisfy the new demands of the market in adequate numbers, in contrast to the Asian companies. Import duties will not change this fact.

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# Shale gas and hydraulic fracturing

Is it a blessing or is it a curse?

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*Abstract* — As new technologies have made it commercial to extract natural gas out of shale reservoirs, a true gas boom is taking place in the USA. This so-called “Shale Gas Revolution” also affects the rest of the world. Other countries all over the world would like to participate in that boom and discuss how to handle a certain technology, hydraulic fracturing, which is necessary to extract the gas out of the impermeable shale. This paper provides an overview of the situation in the USA and explains the technological background of shale gas and its production. Furthermore, the risks and advantages of shale gas and hydraulic fracturing are exposed and the situations in European countries, especially Germany, are presented.

*Keywords* - shale gas, hydraulic fracturing, fracking

## I. INTRODUCTION

*“The natural gas boom has led to cleaner power and greater energy independence. We need to encourage that.”*  
- Barack Obama [1]

The “Shale Gas Revolution” in the USA is recognized and emphasized by the president. Since 2007 the shale gas production in the USA has increased enormously due to the exploitation of shale gas fields and with the help of hydraulic fracturing, also known as fracking.

Supporters from industry, politics, science and the financial sector praise it as a technology of the future, which will change the US energy and industry structure from scratch. It nurtures the hope for thousands of new jobs, energy independence and the revitalization of the American industry.

The shale gas production of the USA rose remarkably in six years from 1% to over 25%. Experts estimate an increase of around 50% until 2035 [2].

The main advantage is the growing independence from natural gas imports. As of today there are no more imports of Liquid Natural Gas (LNG) from the Arabic Emirates into the USA. Additionally, the low energy costs make the USA an attractive industrial base, especially for firms from energy-intensive industries, such as the chemical industry or the steel industry. One firm that has already taken action is BASF, which launched a new chemical plant in Texas in 2011 [3].

However, the shale gas boom also implicates risks and problems. Apart from potential risks for the environment, the

IEA also revises the estimates from its first report regarding the sources dimensions and availability of the resource [3]. The insecurity of available data made many firms overestimate the potential of shale gas reservoirs. Chesapeake, for example, is one of the pioneers in the shale gas extraction, and almost went bankrupt in 2012 because the market price for natural gas was too low to cover the expenses of the shale gas production [3].

Resulting in the situation in the USA, there is now a controversial debate about shale gas and hydraulic fracturing in Europe as well. Economic factors and the aspect of energy independence seem very seductive, but public opposition also points out for the environmental danger that comes along with shale gas production.

## II. TECHNOLOGICAL BACKGROUND

### A. Natural gas

Natural gas that we use today mainly consists of methane and was created over a period of millions of years from organic matter on the ground of the sea. During the course of time, this matter became buried in the ground, where rising heat and pressure transformed it into petroleum or natural gas. The newly formed gas could then either stay trapped in between the surrounding rock or migrate upwards where it concentrated under an impermeable layer of soil or dissipated in the atmosphere [4].

Depending on what kind of reservoir it is produced from, natural gas can be classified into two groups: Conventional and unconventional natural gas. Conventional gas on the one hand is concentrated in reservoirs under impermeable seal layers. In general, it is relatively easy and cheap to extract. Unconventional gas on the other hand is trapped inside impermeable soil and rock formations. It can be separated into tight gas, coalbed methane and shale gas. Its production often requires special technologies and is associated with high expenses and a certain risk of environmental damage [5].

### B. Shale gas production

Shale is a rich-in-clay rock formation, which is characterized by thin breaks along its parallel layers. In some cases it contains natural gas, which is called shale gas. Gas-bearing shale exists in various depths, beginning from near the

surface to several thousand meters underground. Its thickness can vary from just a few to several hundred meters [5].

Different from conventional gas reservoirs, shale has an extremely low porosity, which means that generally less than 10% of the total volume is storing gas. Additionally, shale is highly impermeable, so gas can't escape easily. Therefore several bore wells and further specific technologies are necessary to gain access to a commercial amount of gas [5].



Fig. 1 Areal view of shale gas development sites in Louisiana (Source: Journal of Gas Science and Engineering [6])

Shale gas drilling operations can take anything from just a few weeks to several months, depending on the encountered rock and the depth of the reservoir [5]. In the beginning they start like conventional ones, though. A drill bit bores vertically through the rock, while a lubricating drilling fluid, the so-called mud, is circulating through the wellbore to regulate the pressure inside the well and to remove rock cuttings that were created by the drilling bit. Back on the surface, the mud has to be stored safely in special mobile containers or in open, impermeable pits that are dug into the ground and lined with impermeable material. Afterwards, it has to be recycled or disposed of safely, in order to prevent it from harming the environment [5].

As soon as the vertical bore well reaches the gas-bearing shale, it can be upgraded by horizontal wells to expand its radius and gain access to a higher amount of gas [5].

When the drilling is finished successfully, the bore well has to be sealed from the surrounding soil layers to prevent gas and toxic liquids to be set free to the outside. Therefore, a combination of steel casing and cement forms a stable barrier, which has to be designed to withstand even the most stressful moments without suffering any damages. From the point where the bore well reaches into the reservoir, the casing has to be perforated to let gas and liquids flow through [5].

In fact, gas production could start now, but due to the shale's low permeability, vertical and horizontal wells alone are not enough to extract a commercial amount of gas out of the rock. Therefore, a special technique, hydraulic fracturing, is used. In this process, a water-based fracturing fluid is pumped at high pressure through the well into the target rock to create fractures that can extend tens or even hundreds of meters away

from the bore well. As a result, the trapped gas can escape along those fractures in the well and towards the surface [5].

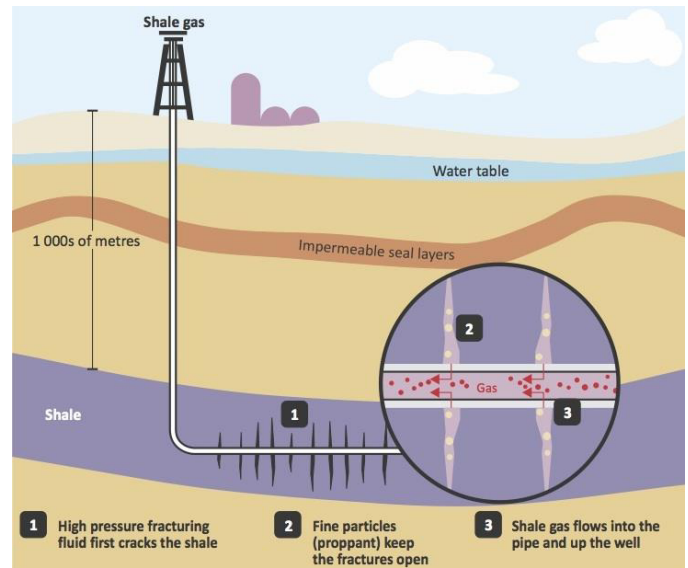


Fig. 2 Shale gas production techniques (Source: IEA [5])

Although hydraulic fracturing in general has been practiced for decades, in order to expand the life cycle of conventional gas and oil field, it is more risky and controversial in the case of shale gas. Often multi-stage fracturing is used, a technique that has played a key role unlocking shale gas reservoirs for commercial production. Hereby, the fractures are created not all at once, but in set intervals around every hundred meters along the horizontal wellbore [5]. The amount of fracturing fluid and the pressure in the well, which are required for this procedure, are much higher than in a regular conventional gas or crude oil case [7].

To give the fracturing fluid certain properties that are needed for successful fracturing, it contains a number of additives. The so-called proppant, which can be sand or small ceramic particles, is pumped into the open fractures to prevent them from closing after the pressure in the well is released. As a result, gas is released and can escape through the well. Water and proppant together make up over 99% of a general fracturing fluid [5]. The rest is a mix of several chemical additives, which can vary, depending on the geological circumstances. Their typical tasks are to support the transport of the proppant into the fractures evenly and to assist the gas escaping along the fractures into the well. Furthermore they can avoid corrosion, annihilate bacteria and other microbiological vegetation and decrease fraction inside the well in order to make the whole process more energy-efficient [5,8].

After the pressure in the well is released, gas can escape through the well. It is accompanied by parts of the fracturing fluid, called the flow-back, which also flows back towards the surface. Around 60% of the total flow-back volume returns to the surface during the first 4 days [8]. While it constantly decreases, the gas content of the produced stream increases. Back on the surface, the flow-back material has to be separated from the gas and stored safely in a similar way as the mud during the drilling phase to prevent harmful influences to the

environment. Later on, it can be recycled or disposed in empty gas or oil reservoirs in the ground [5].

### III. RISKS AND ADVANTAGES

Even if the potential and promise of energy independence are very seductive to many people the critical voices are increasing, especially in Germany. One of the most pressing problems is uncertain data network, which is attributed to the diversity of the potential fracking locations and to the diversity of their geological characteristics. Up until recently there has been a sparse amount of citable data about the impact of fracking to the environment.

In November 2012, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany published a report about the environmental consequences of fracking. This report describes the actual situation in Germany, the surrounding conditions, a risk evaluation and it gives some recommendation for the prospective handling of fracking. This report is one of the first serious handlings of the environmental impact of shale gas production and hydraulic fracturing [9].

Unconventional natural gas sources are one part of bigger ecosystems, which differ in geology and hydrology. These differences make local and specialized explorations and strategies necessary [9].

In the following figure, the potential exposure pathways that result from the investigation and the exploitation of natural gas with the help of fracking are illustrated [9].

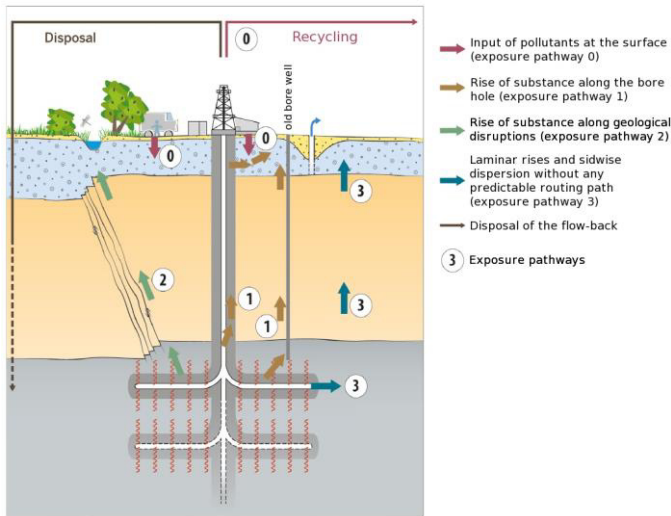


Fig. 3 Potential exposure pathways (Source: BMU [9])

The path 0 describes the input of pollutants directly at the surface of the earth. This happens particularly during the handling of the fracturing fluids and during the disposal of the flow-back. Here, in the phase of the fracking process it can come to defined pollution at the surface of the earth because of accidents, interruptions and improper handling [9].

Path 1 describes the potential rise of substance alongside the drilled hole. At these drill-holes it could come to leakages and defects in tightness, which will cause the unintentional

emersion of the fracturing fluids. Simultaneously due to the fractures in the rock, it could come to a hydraulic attachment to older drill-holes in the surrounding area. This means the natural gas will not effuse the desired way through the new drill-hole but in the direction of the older drills [9].

Path 2 comprises all the effects along geological disruptions. Here the opportunity of control and monitoring of the crack formation plays an important role because it could directly come to an attachment to disruptions because of the fractures [9].

Path 3 describes laminar rises of fluids and gases, or rather their sidewise dispersion through the geological beds without any predictable routing path. These exposure pathways depend on the geological and the hydro-geological conditions [9].

As many flow processes in the deep subsoil drain very slowly the long-term effects also have to be evaluated. Therefore extensive knowledge of the geological and hydro-geological conditions of the deep subsoil is essential. However, this data is in the minority of cases available [9].

Besides the direct environmental impacts like noise, land consumption, material emissions etc., all these exposure pathways contain potential risks. For example, the rise of gases and fluids could cause a contamination of the groundwater [9].

Another large risk is the unregulated crack formation. Apart from simulations of the crack formation in the forefront of a fracking procedure, there is no possibility to forecast the crack growth. Therefore, the exposure pathways 1 to 3 cannot be precisely localized [9].

Additionally, the used fracturing fluids pose another risk. The attached additives are largely declared as harmful, hazardous, or even poisonous to the environment. Another problem is that not all of the additional substances have been investigated, least of all their interaction with other substances. Hence, it is not completely clarified what will happen if these additives are pumped into the soil and which reactions will follow in these processes. For our primarily subterranean water and our drinking water this could be quite malignant. The Federal Environment Ministry came to the conclusion that the selected fracturing fluids have high or rather medium to high human-ecological-toxicological risk potential [9].

Another risk is posed to the flow-back. The flow-back consists in a variable mixing ratio of fracturing fluids and native water. Due to the poisonous additives in the fracturing fluids, the flow-back is toxic waste and has to be disposed of cost-intensively. Highly alarming is that only about 8% of the injected fracturing fluids are extracted back to the surface. The rest remains in the ground and poses a great risk to the shallow groundwater [9].

In addition to all these risks there are also some profound advantages.

One aspect, which is paramount for the industry and politics, is the energy independence.

A further positive aspect affects the climate protection. Gas-fired power plants are a very important pillar on the way to the energy transition. As it is very easy and quick to turn on

or off gas-fired power plants they are advantageous to balance the fluctuation of renewable power stations. Furthermore gas-fired power plants have very low carbon dioxide emissions [10]. Thus, there would be a large advantage if Germany could extract their required natural gas for the energy revolution from its own sources.

Another advantage is that through the own extraction supply rises and the price would fall. As the energy costs play an important role in the choice of industrial location this would also have a positive impact on the industry. This could possibly lead to a higher competitive advantage of Germany as an industrial base [3].

#### IV. SITUATION IN EUROPE

Excited by the recent US gas boom, also the second largest gas market in the world, Europe, is discussing the possibility of domestic shale gas development. In the European Union, the precautionary principle, which is part of the Lisbon Treaty, sets the rules for the implementation of a new technology, such as hydraulic fracturing. Due to high potential risks, there have so far just been exploration and test drillings and most member states are configuring their law, in order to set rules for the shale gas case. For example, France has legally forbidden hydraulic fracturing while in other countries, such as Poland, point out the potential benefits and support domestic shale gas development [11].

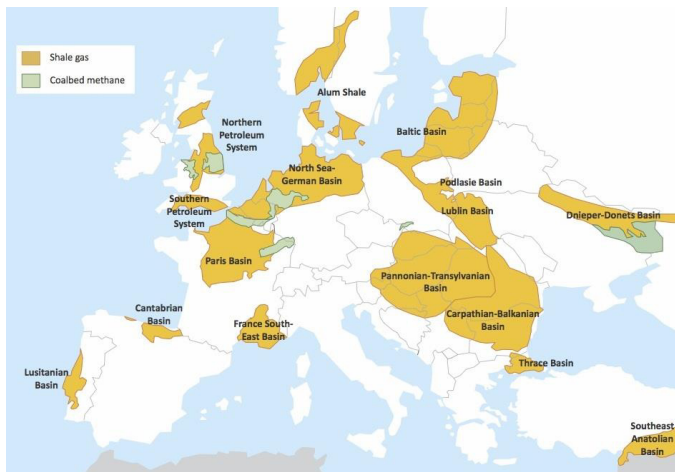


Fig. 4 Shale gas reservoirs in Europe (Source: IEA [5])

Poland has the largest European shale gas reservoirs. In 2011, the US Energy Information Agency estimated that technologically recoverable resources are likely 5 300 billion cubic meters (bcm), which is around 900 times the amount of the 2010 total Polish consumption. An Assessment of the Polish Geological Institute, which was published one year later in 2012, is significantly more modest, but still estimates 1 920 bcm of shale gas, of which 350 to 570 bcm are technologically recoverable. Considering a yearly consumption of around 14 bcm, that amount would still sustain for a few decades and could make Poland more energy-independent from its main gas provider Russia [11]. Polish politicians therefore are very open-minded towards shale gas and hydraulic fracturing and have issued over 100 exploration licenses to a high number of international companies [5]. Nonetheless, the Polish shale gas

dream is in danger since exploration drillings could not achieve commercial flow-rates. As a result, major companies such as ExxonMobil, Talisman Energy and Marathon decided to end shale gas tests in Poland [12].

France’s resources are estimated to be almost as large as those in Poland. During the beginning of the shale gas discussion, the government had issued three licenses for exploration drilling, but due to safety concerns and upcoming public opposition, it announced a moratorium on the use of hydraulic fracturing and prohibited it by law shortly afterwards [5].

Germany has had a considerable amount of shale gas resources and so far there have been exploration drillings in Lower Saxony and North Rhine-Westphalia. As reported by the Federal Institute for Geosciences and Natural Resources, the amount of gas that is technically recoverable is about 700 to 2 300 bcm. Conforming to the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, that amount could guarantee gas supply for about 13 years [9]. That means that Germany would be much more independent from gas imports from Russia and the security of supply would be higher. Especially since natural gas plays a key role in the German energy transition, this aspect appears even more substantial. Despite this fact, opposition and public concerns are growing. Due to the high number of insecurities regarding the impact of fracking on the environment, organizations like Greenpeace or NABU demand a general ban of fracking until all uncertainties are clarified. Additionally, the NGO Campact, that stands for direct democracy and public participation, started a campaign named “Fracking stoppen: Keine Chemie ins Grundwasser!” to force politics to forbid hydraulic fracturing in Germany by law. The campaign was started in March 2013 and has already been signed by 159 000 skeptical citizens so far [13]. Facing the economic advantages, the government is currently discussing a new legal draft regarding that topic. It is assumed that it will not declare a general prohibition of fracking, but due to the high environmental risk, fracking will only be permitted under very strict regulations [9].

#### V. CONCLUSION

This paper has provided an overview over the different aspects of shale gas and hydraulic fracturing, beginning with the “Shale Gas Revolution” in the USA, technological background information, the advantages and risks and the current situation in Europe. In conclusion, it can be said that shale gas indeed brings along a number of benefits. However, there is yet a lack of secure scientific insight and a relevant risk for the environment, as previously stated. Furthermore, the situation in the USA is not very comparable to the situation in Europe, especially in Germany, so the US shale gas boom cannot be expected to bloom the same way in other countries as well. For example is the population density per capita in Germany much higher than in some regions of the USA where shale gas is currently produced. In a country such as Germany, where some complain about green energy plants like wind turbines, it is hard to imagine that shale gas production and hydraulic fracturing could take place without huge public opposition. Furthermore, natural gas in fact is a relatively clean fossil

energy resource and will be used as a transition technology in course of the transition to a more sustainable energy supply. Nevertheless, one should keep in mind that it is better to support and invest directly in green energies than to set full focus on the transition technology.

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# Risks and Chances of Nuclear Power

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**Abstract—This abstract gives an overview about nuclear power and the chances and the risks of this technology. The physical basics will be and the structure and function of a nuclear plant will be discussed. Furthermore the chances and risks of Nuclear power will be argued.**

## I. INTRODUCTION

In 1896 Henri Becquerel has discovered radiation. Later on in 1898 Marie Curie detected the decay of radium. In 1942 Enrico Fermi has designed and constructed the first nuclear reactor, in which the first controlled chain reaction has been executed [1].

## II. PHYSICAL BASICS

### A. Atom model

The name atom has a Greek heritage and comes from the Greek word atomos, that means indivisible. The atom is a basic unit of matter which consists of an electron cloud and a central nucleus, which is surrounded by the electron cloud. There are at least three models, which were developed in the history of the atom. In the beginning was the “Plum pudding model”, discovered in 1897 by J.J.Thomson, which described the atom as a composition of electrons, he called them “corpuscles”, and a “soup” of positive charge to balance the electrons. He compared the model with negatively charged plums surrounded by a pudding with positive charge.

Later on, in 1909, the model was disproved by the so called “Geiger-Marsden experiment”, under the direction of Ernest Rutherford. The idea of this experiment was to fire alpha particles (helium nuclei with a positive charge) at a very thin sheet of gold foil. A few years later, in 1911, Rutherford released the “Rutherford model”. The main idea was that much of the positive charge of an atom is concentrated at the center of the atom, the so called nucleus. Furthermore Rutherford said, that the nucleus is surrounded by an electron cloud, which does not influence the alpha particle scattering. In Addition the electrons do orbital movements like planets do in the planetary model. But the problem with Rutherford’s model is, if the electrons shall fulfill the laws of the classical mechanics, they have to emit electromagnetic radiation. Because of that, the electrons would lose energy and after a certain time, they would

fall into the nucleus making the atom unstable [2]. And last but not least, there is the Bohr model from 1913. In that model, Niels Bohr describes the atom as a positively charged nucleus, which is small. In addition this nucleus is surrounded by electrons which travel in circular orbits around it without emitting radiation. Bohr suggested that electrons would only be able to do certain motions while fulfilling the laws of classical mechanics and that means the motions are limited. Besides the electrons can only orbit at a defined set of distances. These orbits are related to energy shells the so called “energy levels”. The nucleus has a volume of about  $10^{-5}$  of the atom [2]. Furthermore the atom is able to absorb and emit photons with definite amounts of energy which are proportional the frequency  $\nu$ , according to the equation :  $E = h \nu$ , where  $h$  is the planck constant.

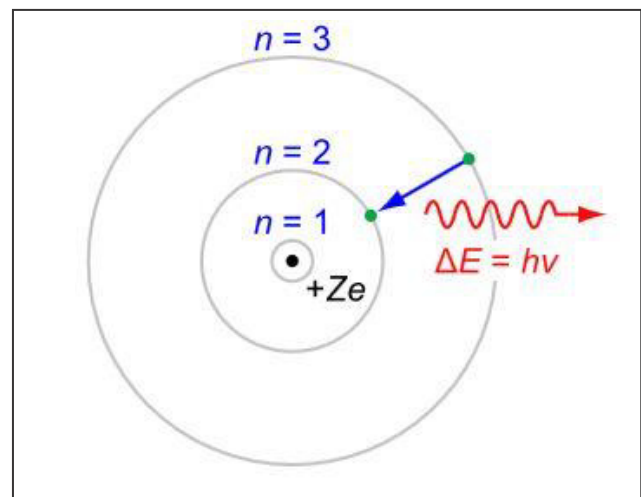


Figure 1. Bohr model[3]

### B. Mass defect and binding energy

The amount of force with that the core nuclei stick together can be calculated. For example an helium atom, that is composed of two protons and two neutrons. However the mass of an helium atom is less than the mass of two neutrons and two protons. This, so called mass change, results of the fact, that while the combination of protons and neutrons, a little ratio of their mass is converted to energy. Furthermore the energy will be emitted as Gamma radiation [4]. The amount of



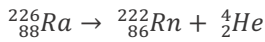
binding energy depends on the amount of energy of the converted mass during this process, the higher the emitted energy the higher binding [4].

$$m_{2p+2n} = 6,69510 \cdot 10^{-27} \text{ kg}$$

$$m_{\text{He}} = 6,644656 \cdot 10^{-27} \text{ kg}$$

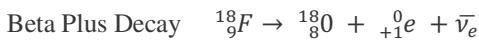
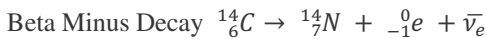
### C. Alpha radiation

During a radioactive decay helium nuclei (2 protons, 2 neutrons) are going to be emitted with a kinetic energy of 5 MeV, but a low range. This can be described with the following equation : [4]



### D. Beta radiation

There are two kinds of Beta decay, Beta Plus Decay and Beta Minus Decay. During Beta Plus Decay, a proton of the atomic nucleus is transmuted into a neutron with the emission of an positron and an anti-neutrino. In contrast to during a Beta Minus Decay, a neutron is transmuted into a proton with the emission of an electron and an anti-neutrino [4].



### E. Gamma Radiation

During Gamma radiation, a stimulated, metastable atomic nucleus emits gamma rays. Because of that, the nucleus has afterwards less energy and is more stable [4]

### F. Nuclear fission

For all atomic nuclides fission is possible. The advantage of the fission of uranium – and plutoniumisotopes is that the fission is especially easy and that the resulting heat is higher than the energy needed for the reaction. (exothermic reaction) Besides in nature there are 3 uranium isotopes : U-234, U-235 and U-238. Futhermore all of them are Alpha-radiators with a different half-life. In addition all three isotopes are fulfilling fission spontaneous, because of the repulsion between the protons is as high as the core forces, which keeps the nucleons together. The U-238 isotope is about 99,275 % of the uranium 's deposit, U-235 is about 0,72 % and U-234 is about 0,005%. However when a slow (thermic) neutron hits the nucleus of U-235 it will be absorbed. This leads to an highly animated atomic nucleus of the isotope U-236, with an duration of life of  $10^{-14}$  seconds. In 6 of 7 cases this state of the nuclid causes fission and in 1 case the nucleus just emits Gamma-rays and transmutes to the stable isotope U-236. The fission of U-235 leads to various fission nuclei. In addition the sum of the charge numbers of the fission nuclides has to be equal with the charge number of U-235. The sum of the set free energy of the fission is 210MeV. Nevertheless just 90 % of this energy per fished nuclide can be used, because nearly 10 % will be lost because of absorbtation. This means round about  $1,9 \cdot 10^8$  eV can be used [4].

### G. Chain reaction

After each fission in U-235 there are two free neutrons that means theoretically the number of nuclear fissions from one neutron generation to the next is doubled and this kind of a

lawine. As a result of this there is very much energy set free [4].

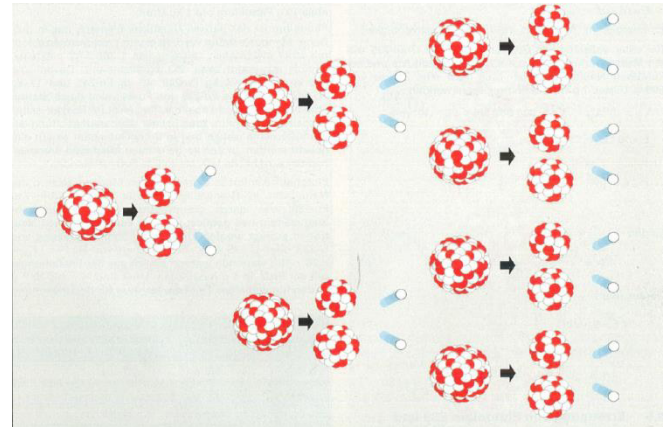


Figure 2 Chain reaction[4]

## III. NUCLEAR PLANTS

### A. Nuclear reactors

A nuclear reactor is able to realize a controlled chain reaction. It is commonly composed of 5 elements : sufficient mass of fissile material, material to slow down the neutrons (moderators), excepted the breeder reactor, a device to catch the neutrons (control rods), a medium to take away the heat, barriers to protect against radiation and to keep back the nuclear material. Besides Nuclear reactors can be divided in the purpose of use. There are research reactors, which are used for scientific research and teaching, focussing on neutron radiation, and power reactors which are used for the generation of electric potential energy. Furthermore the most common types of reactors are breeder reactors and light water reactors, like boiling water reactors and pressurized water reactors [4].

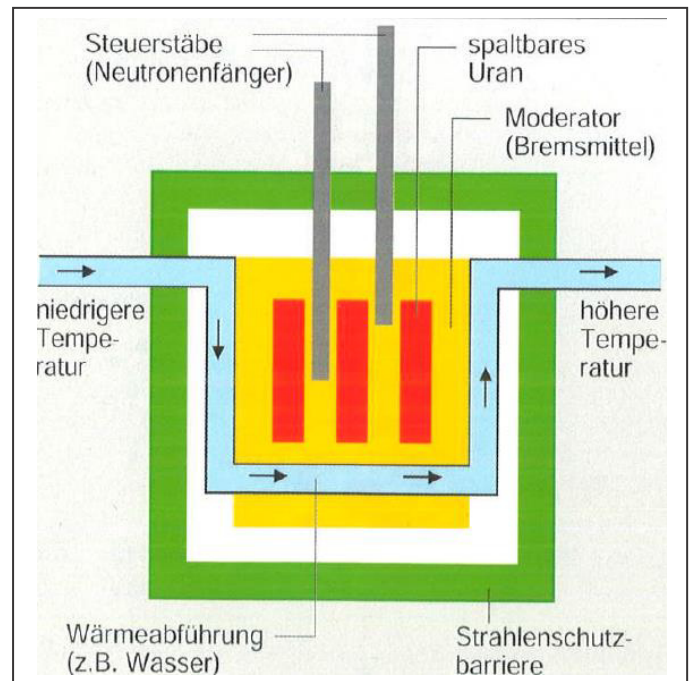


Figure 3 Basic structure of a reactor [4]

The moderators in nuclear reactors are used to slow down the fast neutrons, resulting from nuclear fission, because slow neutrons will cause a nuclear fission in U-235 with a much higher probability. Besides good moderators have to fulfill two conditions : slow down the fast neutrons and a low tendency to capture neutrons, because they can't be used for further nuclear fission. There are three common moderators :heavy water (D<sub>2</sub>O) , light water (H<sub>2</sub>O) and graphite. Deuterium, a hydrogen isotope with one neutron; is the best moderator considering the problem of neutron capture, but its quite expensive. Another possible moderator is graphite, which has positive attributes considering mechanic and thermodynamic, but for use it has to be pure and. However, hydrogen slows down the neutrons very good, is cheap, but it has a high tendency to capture neutrons. That means light water has also the advantage, that it can be used for cooling. According to this the proportion of the U-235 in the fissile uranium has to be raised from 0,7 % up to between 2 % and 4 %, to run a light water reactor. The resulting fissile material is called enriched uranium. In boiling reactors (light water reactors), water is used for cooling and for moderating. When the number of nuclear fissions increases, the proportion of steam bubbles in the water increases, which decreases the number of absorbed neutrons, because steam contains less molecules per volume than water. As a result the water will be diluted and from this point, its moderating effect is has a greater influence than the absorbating effect. This is why the number of nuclear fission is decreasing automatically. This is called a negative Steam Bubble Coefficient of the moderator and means that the process stabilises itself. This fact was the main reason for choosing the boiling reactor type in the Federal Republic of Germany in the 1950's [4].

#### B. Control of the chain reaction

The chain reaction in a nuclear reactor is going to be controlled with the use of control rods. The material for these rods is chosen by the ability to absorb neutrons. During the start of the reactor the control rods will be moved out of the section/area between the fuel rods. When the chain reaction shall be stopped, the control rods have to be moved into this section/area [3].

#### C. Process for the enrichment of U-235

In general, for the enrichment of U-235 the uraniumhexafluorid (UF<sub>6</sub>) is needed. One common process to enrich the U-235 in natural uranium from 0,7% up to 2% to 4%, which is needed for light water reactors, is the gas centrifuge process. Within this process, the heavy molecules are moved at the outer wall, because of the centrifugal force, while the lighter molecules stay near the axis of the rotor. In the following, the enriched U-235 will be converted to UO<sub>2</sub> which will be pressed in pellet forms afterwards [4].

#### D. Nuclear plants : Nuclear plant with pressurized water reactor (example : Nuclear Plant in Brokdorf; Germany)

The resulting heat in the reactor, generated by the fuel rods will be absorbed by the cooling water. In the main cooling cycle there is a pressure of 15,2 MPa, which prevents the water from boiling. The cooling water enters the reactor with a

temperature of 291°C and leaves it with a temperature of 326° and loses its heat by conduction in 4 steam generators to the water of the secondary cycle. The water in the secondary cycle heats up and because of the lower pressure it begins to boil. As a result of that steam is generated. According to this the steam enters the high pressure part of the turbine and the turbine starts to rotate. The turbine is running in a single shaft system with a Synchron-Generator, which transforms the kinetic energy into electric potential energy. However the advantage of such a two cycle system is that the radioactive material in the cooling water is limited to the primary cooling cycle, so it can't enter the turbine or the condenser [4].

### IV. PRESENT DISCUSSION ABOUT NUCLEAR POWER

#### A. Developments on the energy market of the world

Energy Mix : Worldwide there are various energy carriers in use. The Energy Mix in Europe from 2009, is the following : 34,7 % oil, 25,1 % gas, 16,1 % coal, 14,1 % nuclear power and 9,9 % Renewable energy. In the USA the energy market is divided into : 34 % oil, 24,7 % gas, 22,4 % coal, 10 % nuclear power and 5,7 % renewable energy. As a contrast to this the energy market of china is strongly focused on coal with 67,1 % while the other carriers are : 16,9 % oil, 3,4 % gas, just 0,8 % nuclear power and 11,8 % of renewable energy. However the Chinese proportional demand of worlds supply with primary energy (not converted or transformed energy form) is about 18,7 % [5] The outlooks on Chinese need for electric potential energy recognize an increase, for example from about 4.693 TWh up to 10.166 TWh and a change to produce more electricity with the renewable energy sources and also with nuclear plants [6]. As a result of that the proportion of producing electricity with coal is decreasing from 67 % to 51 % [6]. As a matter of fact there is happening a modification of the energy market in China with the aim of reducing CO<sub>2</sub> and limiting the pollution of the air. Furthermore a study of the oil company British Petroleum expects that the world's demand for energy will increase until 2030 up to 39 %, mainly influenced by the BRICS-states (Brazil, Russia, India, China and South Africa). In contrast to China, India will possibly focus on coal for fulfilling the demands of economy and society [7]. According to the rising demand for energy, the process of reducing the production of electricity with fossile fuel, can be easier realised by rising the proportion of renewable energy in combination with rising that of nuclear power. However producing electricity with using the energy of wind and sun is depends on the weather. So when the source of renewable energy is reduced or missing, there will be a lack of energy. As a result the economy of a country can be handicapped, but to prevent such a case there is a need for more reliable sources of energy, this could be nuclear power, particularly if focus lies on the base load supply of electricity.

#### B. Costs of nuclear power

The storage of radioactive waste is a further very important aspect for generating nuclear power. The search for an adequate geological repository is a very difficult and expensive project. Besides the transport of nuclear waste is also quite complex. As a matter of fact nuclear waste is emitting radioactive radiation for several million years [8], for which reason repositories have to guarantee that for this period a just

very low amount of radiation will be possibly set free [9]. Indeed this will cause expensive investments for securing a deposit for radioactive waste, but that is almost unavoidable. Nevertheless the storage of radioactive waste is an important cost factor of nuclear power, which has to be considered. The resulting costs of generating electricity by using nuclear plants consist of high costs for building the nuclear plant, costs for processing and operation, costs for the storage of radioactive waste and high costs for decommissioning a plant. In addition the investments for building the nuclear plant have been subsidized by many national governments around the globe. Of course there also subsidies have been given to produce electricity with fossil-fuel power stations, particularly coal-fired power stations [10]. An article, that described the calculation of the price for electricity, mentioned that the resulting costs of electricity, generated by nuclear plants, are much higher for the society, than the costs of the other fuel sources. Their calculation considered the so called "external costs", which are composed of the costs for deconstruction of a nuclear plant, the disposal of nuclear waste and the financial risks caused by nuclear accidents. So the resulting costs per kWh for nuclear power is situated between 16,4 € Ct/kWh and 42,2 € Ct/kWh in contrast to 14,8 € Ct/kWh for black coal, 9,0 € Ct/kWh for gas, 8,1 € Ct/kWh for wind power and 7,6 € Ct/kWh for water power [10]. So there is doubtless a need for financial help given by governments to reduce the external costs and therefore to afford a profitable generation of electricity with nuclear power.

### C. Risks of nuclear power

Despite of the long period nuclear power has been supplying the demand for electricity in lots of countries, there are several risks that have to be considered. Since its development, nuclear power also serves national political interests. During the period of the cold war the western allied forces particularly the superpower USA and the forces of the Soviet Union threatened each other with their nuclear weapons. Besides this weapons have also a high deterrence potential. There were several cases in this period, in which nuclear weapons have almost been launched causing horrible damage to our planet. Despite of that, countries which are beginning to develop the requirements for a civil use of nuclear power (producing electricity) often also have a military use in mind. However also geological and climate issues influence a secure use of nuclear power. High temperatures lead to problems for supplying the nuclear plant with cooling water, which is gained out of rivers. Natural disasters also have to be considered, e.g. volcano eruption, tsunami and earth quakes, A further risk for nuclear power is the limitation of fuel matter.

### D. Chances of nuclear power

One of the most important factors for prosperity of the economy of a nation is electricity. Considering the increasing demand for electricity within the next 20 years, all possible technologies should play a role. Besides the decrease of pollution of air, particularly greenhouse gas is an international aim, written down in Kyoto Protocol [11]. That means producing electricity, while emitting less greenhouse gas, is a strong argument for focusing on nuclear power.

Besides the technology has been developed further, within the last years. An example for the third generation of pressurized water reactor power plants is the, still not finished, Olkiluoto 3 in Finland, with a net electric output of 1600 MWe [12]. The most important improvements are: security improvements, e.g. four independent emergency cooling systems and a more efficient and flexible utilization of the fuel [13]. However to solve the problem with the decrease of world's deposit of uranium, highly-enriched uranium, which is used for nuclear weapons, can be converted to low-enriched uranium for generating electricity. There was a project, running until 2013, called: "Megatons to Megawatts" [14]. This was a program between USA and Russia which was ran for the last 20 years and there have been generated hundreds of millions of pounds of natural uranium. Unfortunately this program hasn't been extended, but it allows an extended use of nuclear power. However nuclear power is an interesting opportunity to increase the offer of technologies, which are able to fulfill the increasing demand for electrical energy, because of the less emission of greenhouse gases. Nevertheless this technology has to be developed further to increase its security and efficiency and therefore the financial support of governments is needed. As a result of that the support of nuclear power in society has to be improved, particularly in democracies.

In conclusion nuclear power should play a role in the future, but it needs to be regarded as a bridging technology, which supports the change to the generation of electrical energy by using exclusively renewable energy.

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# Potential of Small Wind Turbines

## Market, Techniques and Profitability

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**Abstract** –The importance of wind power increased dramatically in the last years by several factors. One major fact was the innovation driven by the subsidies in many countries. On account of that reason, small wind turbines were also advanced as large turbines. The following paper will show potentials and different techniques and a profitability calculation for the small wind turbine market.

**Keywords** – renewables, decentral generation, energy turnaround, downstream technology, potential, small wind turbine, profitability, classification

### I. INTRODUCTION

Wind turbines are systems for the production of electrical energy by the use of slow or fast wind speed and strong or less wind power. So they can be divided into several classes, which are small and large wind turbines. In contrast to the normal or large Wind turbines, small wind turbines are capable of less nominal capacity (maximum 100 kW) and rotor diameters of 1-16 meters. Comparison: large wind turbines have a nominal capacity of more than 100 kW up to 6 MW. Most of the megawatt classes are wide spread over the world and have overcome their initial problems. Against that, the market of small wind turbines is just at its beginning. An analysis shows that they are not just a small version of the large wind turbine, they differ significantly from the large ones in technical and economic aspects. The following article will show potentials in a market for small wind turbines and some technical issues. Afterwards it will be shown that a simple small wind turbine can partly cover electricity costs and generate a benefit after time of amortization [1].

### II. POTENTIALS OF SMALL WIND POWER

#### A. Development of the German Market

The theoretical global potential of wind power is estimated by about 1.3 million terawatt-hours (TWh), which takes an enormous part in the potential of renewable energies. Even in

Germany, which has a total potential of 4100 TWh, it would mean that it could cover their electrical consumption by about 7.5 times only with wind power. It is clear, that these numbers are only theoretical potentials, which are not possibly reachable, but with a look on the past years and recent trends, figure 1 shows a significant increase of wind power output (on- and offshore) in Germany [2].

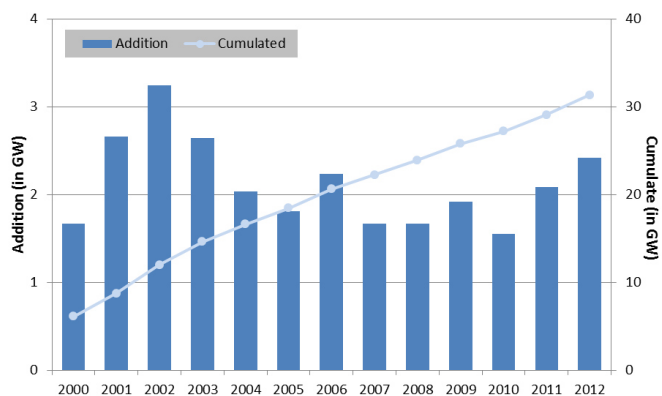


Figure 1: installed capacity in germany [3]

Figure 1 shows the installed wind capacity for every year from 2000 till 2012 and the cumulative results. In 2012 the installed capacity claimed the level of 30 GW [3].

Instead of that figure 2 shows a very good development of produced electrical power of wind turbines in Germany from 1993 up to 2011. The main increase of electrical production is set up after the year 2000. In the years 2008, 2009 and 2010 the production decreases although the installed capacity increased in these years by about 3000 MW. The cause for this can be found in weather details. In these years and also in 2005 and 1997 the average wind speed was rather low, so wind turbines could not generate electrical energy on a high output level [4].

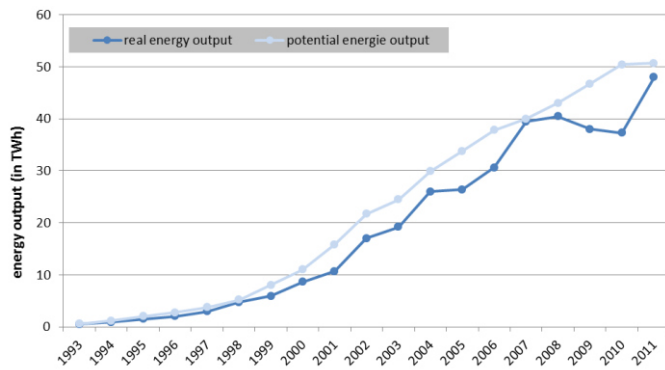


Figure 2: Wind Energy Output of Germany [4]

It is remarkable that Germany tripled the value of installed capacity in almost ten years. This could happen because of a broad based subsidization, named feed-in tariff. In Germany, wind power and other renewable energies were funded by the renewable energy act (RSA). This is also the consequence for a strong push of innovations for the renewable energies. Especially technologies for wind power benefited from the RES, because it reduced the costs of production and maintenance, increased the power output and minimized failures. But instead of stopping the funding, the government has to improve and optimize or reform the RES, to guarantee the success. The funding of wind power has to be continued, so that an innovation-driven technology, which is not only in competition with other renewables sources, but also with conventional technologies, has a chance in the energy markets. This support, as an example of Germany is currently displayed, can be for individual components (development of rotor blades, innovative towers, new lighter and stronger materials, etc.) or for the entire system or the net integrity (automation, quality assurance, plant dismantling, maintenance, optimization and management, etc.) [5].

### B. Theoretical Potential of Wind Power Generation

According to a study of the BWE [3], Germany has the capability to use approximately 2% of their whole surface for wind power generation. Possible areas might not be in or near forests or dependencies, industry, living or settlement areas and difficult terrain. These facts limit the possible installation areas. In case of Germany that means that the whole practicable potential for wind onshore is by about 200 GW installable capacity. Through the adjustment that there are more possible small areas, which are not reflected in the study and can be used to generate electrical power, the total potential for wind onshore raises by about 20%. But most of them will not be economically reasonable. Which region is useful or not, will be discussed in the next section. It is also comprehensible, that many places are not reachable or already built. Furthermore private people want to have their own electrical energy source to participate as an investor, reduce electricity costs or be independent from distributors. One solution for that is to build small wind power turbines. So on the top of that the technical aspects are also an additional relevant point [6].

### C. Technology Development of Small Wind Turbines

Small wind turbines can be divided into several parts and different techniques. First of all they can be classified towards their size. After the definition norm IEC 61400-2 small wind turbines have to be a rotor diameter up to 16 m. Because of that, a classification of 4 classes is suggested by the Bundesverband Kleinwindanlagen [1]:

- Micro-Windturbinen (max. 1,5 kW)
- Wind turbines on roofs or combined directly with the building
- Small wind turbines for self supply up to 6 kW
- Small wind turbines until max. 200 m<sup>2</sup> of wind attack area

Another classification is made by the American Wind Energy Association (AWEA). They divided the small wind turbines into different capacity sizes [1]:

- Class 0: up to 0,9 kW (Micro wind power)
- Class 1: from 1 kW to 10 kW (residential)
- Class 11: from 11 kW to 20 kW (commercial)
- Class 21: from 21 to 100 kW (upper commercial)

Besides the classification of small wind turbines, there are also different techniques to generate electricity from wind. The typically design is the propeller turbine, which is a horizontal turbine. This is used most often, because cost-revenue-relation is the highest of all types. But nearly to that, there are meanwhile other technologies which are competitive enough to the propeller design. The main ones are following [1]:

- Darrieus-Rotor
- Savonius-Rotor
- H-Rotor

All these rotor design are vertical turbines. They have an increasing importance and potential, because they have many positive aspects in contrast to horizontal turbines. One of the main facts is that vertical rotors are more suitable for using turbulent winds than horizontal turbines. They are also easier to construct and have a lower shadow flicker. But they are not that much efficient as horizontal turbine designs. Never the less vertical turbines have also a very high potential, because of high innovation and new techniques and development. They are also useful for places, where horizontal turbine concept cannot be realized [7].

Another point is, that Small wind turbines can be installed even in large quantity and large areas. This is possible, because they have an easy handling and simple influencing factors to integrate them in the electricity net. To integrate wind power and other renewable energies, it is necessary to extend the electricity network and improve an intelligent control for the distribution network [5].

### III. ECONOMICAL REFLECTION OF SMALL WIND TURBINES

When comparing renewables, costs and economies of a certain technology are one of the key aspects in that discussion.

#### A. Influencing Factors

Four factors can mainly be identified concerning the profitability:

##### 1.) Capacity of the system:

In principle, with an increase of capacity of a wind turbine, the efficiency increases as the investment costs per installed capacity decrease. [2] Generally said, a 10 kW system is rather cost-efficient than a 2.5 kW system, but every individual situation must be assessed. A small plant in a windy location may be very well economically.

##### 2.) Height of mast/rotors

The greater the distance to the bottom of the small wind turbine, the greater tends to be the annual wind speed. However, with the rise of the mast height, the costs for the rise as well. Code requirements and approval procedures must also be considered.

##### 3.) Maintenance and repair

Wind turbines usually experience a high mechanical load. Accordingly, costs of maintenance and repair of the system can be high. These operating costs can be contained by a maintenance contract with the manufacturer or a machinery insurance.

##### 4.) High own-consumption of electricity

Due to the existing situation for the promotion of small wind turbines in Germany, the operation is worthwhile especially when the electricity is own-consumed. The personal revenues equal the amount that the consumer would have paid to the utility company which is approximately 25 cents per kWh. [10]

Especially for industrial or agricultural enterprises with a high constant power consumption for machinery or cooling systems may therefore be worthwhile investing in a small wind turbine. [12]

Households should have their own consumption in view. In the design of a small wind system it may be useful to cover the electricity consumption that arises constantly only. This can lead to the fact, that the system is covering only 20 to 30% of annual electricity consumption. But if the small wind turbine produces electricity, this electricity will be consumed as own-consumption. [10]

In order to evaluate the profitability of a small wind turbine it is necessary to take a closer look on two sides: the costs of the system and the electrical output which can either be consumed or fed into the grid. These costs consist of fixed and variable costs.

#### Fixed costs:

- investment costs,
- capital costs,
- connection costs,
- installation costs,
- mast costs.

#### Variable costs:

- maintenance costs,
- measuring costs,
- insurance costs,
- repair costs.

#### B. Exemplary Calculation of Profitability

According to a study of the University of Kassel Germany and Fraunhofer Institute of Wind Energy and Energy System Technology [14] the average technical specification of a small wind power system are the following:

- 70 per cent of the systems are horizontal
- rotor blades: 3
- rotor diameter: 5 meters
- permanent magnet
- nominal capacity: 6.6 kW

| Model  | Sky Stream 3.7 |
|--|----------------|
| Price  | 8,700 Euro     |
| Operation height                               | 10 meters      |
| Nominal capacity                               | 2.4 kW         |
| System losses                                  | 10 %           |
| Wind speed                                     |                |
| - location 1, area around Berlin               | 3.6 m/s        |
| - location 2, costal area of Mecklemburg-Vorp. | 5.0 m/s        |
| Rotor blades                                   | 3              |
| Type of system                                 | horizontal     |

Table 1: Key facts model SkyStream 3.7

other data:

- feed-in tariff wind power, on-shore, Germany, 2013: **0.0893 ct/kWh** (2013), [13]
- average price for 1 kWh, Germany, 2013, grid-supply: **25 ct/kWh**
- annual increase of price for 1 kWh: **3.8 %**

Net-power-output; location 1 (according to [9]): 1175 kwh/a

This output can conclude a 100 per cent own-consumption if a total consume of a four-persons-household is estimated at

4500 kWh per year so that there is no need to feed the generated electricity into the grid.

$$(1) 1175 \text{ kWh/a} * 0.25 \text{ ct/kWh} = 293.75 \text{ Euro/a}$$

Net-power-output; location 2 (according [9]): 3632 kWh/a

The electricity which will be generated equals the total consumption of a four-persons-household, but a supply-demand-equalation of the produced energy can not be assumed. The consequence is that the residual supply could be fed into the grid according to the feed-in tariffs about 0,893 cent per kWh. Assuming a 60 per cent own-consumption and a 40 per cent feed-in. The savings for locations are the following:

*location 1:*

$$(2) 0.60 * 1175 \text{ kWh/a} * 0.25 + 0.40 * 1175 * 0,0893 = 218.22 \text{ Euro}$$

*location 2:*

$$(3) 0.60 * 3625 \text{ kWh/a} * 0.25 + 0.40 * 3625 * 0,0893 = 673.24 \text{ Euro}$$

In case 1 the annual wind speed is lower than at location 2 so that the output is 3.08 times higher than at location 1. A calculation of amortization is necessary.

In case 2 a solution for maximizing the saving for the given example is the sharing of the small wind power system for two households, e.g. a duplex house. A 100 per cent own-consumption can be assumed.

Amortization:

$$(4) PV(A) = PMT \cdot \frac{1 - \frac{1}{(1+i)^n}}{i}$$

i = interest

n = years

PV = present value

PMT = payment

*location 1: PV (1) = 20.9 years*

*location 2: PV (2) = 7.8 years*

As shown in the example the key driver for the profitability is the wind speed as well as the ratio of own-consumption.

#### IV. CONCLUSIONS

The Energy Turnaround in Germany requires the share of renewable energies to grow within the next years. This trend leads to more wind, solar and hydro power plants, making it harder to predict future energy yields. With the electrical power grid already running at its limits and high local discrepancy between power generation and demand, it is necessary to regulate excess energy.

Potentials for small wind turbines are given on different levels: on technical aspects such as downstream technologies from large wind turbines to small ones. Adjustable and flexible generation systems will become more and more important as the Energy Turnaround in Germany goes on. Small wind turbines can contribute a lot to this cause.

As electricity prices are constantly increasing, small wind turbines will become more profitable within the next years. Hence, this technology will become more important in case of own-consumption.

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# *The sustainability of the capacity market in the energy sector*

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**This paper is supposed to analyse the possibility of the creation of a capacity market for the German electrical power supply.**

*capacity market, strategic reserve, security-of-supply contracts, energy-only market*

## I. INTRODUCTION

Since the beginning of the integration of renewable energies the German energy grid has been confronted with steadily growing problems. Because of the aim of the federal government to cover 80% of the gross electrical power consumption till 2050 with renewable energies, it is necessary to activate a transformation of the German power supply system. Due to abandoning nuclear energy the problem is additionally laboured. This issue has an influence on every range of the German electrical power supply, for example on the transmission grid, distribution grid, demand side management or on the condition of the electricity market itself [1].

The current electricity market is called “energy-only market”. Exclusively the amount of energy which is given off into the electric supply grid is remunerated. The fact that renewable energies have to be preferentially fed in is regulated by the “EEG” and presents operators of conventional power plants with financing problems. Furthermore, renewable energies have less marginal costs and put the conventional electricity generation out of the market [1].

This fact is complicating the guarantee of the security of energy supplies since an accurate prediction of fed in, renewable energies cannot be given. Therefore, a sufficient amount of conventional power capacities has to be provided to compensate a possible failure of renewable energies at all times. Consequently, conventional power plants need start-ups and shutdowns more frequently which causes raising costs and increasing wear on the machinery [1].

The current level of the electricity rate combined with previously mentioned new challenges already raises doubts among some stakeholders whether the existing energy-only market can provide enough incentives to make investments in preservation of existing power plants and their reconstruction. Therefore, there is a high risk of not guaranteeing a safe electrical power supply. This is calling for immediate action. According to a current study by Ecofys (2012) there is neither an empirical nor a theoretical market failure in the medium term to expect, although this cannot be excluded in the long

term [2]. On this matter is certainly no agreement among experts. For example other expert opinions say that there already is a market failure because it is currently uneconomic to build new conventional power plants [6].

However, that there is no necessity for new power plants can also be seen as an efficient mechanism of the current market [2].

As a solution of the problem is an introduction of a capacity market possible. Until now there are two variations of the condition of the capacity market which are seriously discussed. One of them is the establishment of a strategic reserve and the other one is the introduction of contracts for a security of energy supplies. Both variations not only vary in their conditions, but also in their purposes which are regulated by the politics. As an example, one of the crucial questions is whether to pursue a national autarky or a Europe-wide energy supply which is within the limits of the Single European Market for electricity [2].

In what follows the two variations shall be explained in more detail.

## II. CAPACITY MARKET

### A. Strategic reserve

The strategic reserve can be build up rapidly out of a certain number of gas-fired or coal-fired power plants which can be new or about to be decommissioned. Those will not take part in the energy-only-market, but will be used if the energy requirement cannot be covered by already on the market operating power plants anymore [2].

The strategic reserve should be chosen when the energy-only market is basically functioning but a remaining risk of an extreme situation cannot be eliminated. Furthermore, the strategic reserve serves as a temporary solution to broader capacity markets, ensures a national autarky and does not affect the efficiency of the electrical market. [2].

The costs for the consumers are considered to be moderate and are estimated at 0.1 cents per kWh.

If the strategic reserve is to be used it should be done at very high prices. So that price signals are set to ensure the efficiency and innovativeness of the market. This should incite



actors to make investments in new technologies. That would mean that the probability of recurrence of extreme situations is reduced [2].

In addition, a reserve can be used to ensure the power supply in southern Germany for so long, until the expansion of the grid has reached a sufficient level. Possible uncertainties of supply are a result of the omissions of recently operating nuclear power plants [1].

The amount of the necessary capacity is determined administratively and is reversible [2].

### B. Security-of-supply contracts

Using this alternative, a comprehensive capacity market is created which exists in addition to the energy-only market. It is likely, however, that the establishment of such a market requires seven to ten years. This variant should be selected if it is assumed that the energy-only market does not provide the desired incentives to invest or does not provide sufficient capacities to ensure national security. Due to this newly created market power plant operators receive remuneration for the provided power plant capacity. The proceeds from the Energy-only market remain [2].

This provided capacity gets used in the event of excess demand to ensure sufficient power supply in order to meet the demand. Five to seven years in advance a central instance asks for the amount of the estimated peak load. These capacities are then sold at auction. He who has awarded the contract also agrees to provide the required performance. If this requirement is not complied with fines may be imposed. To be admitted to the auction, the suppliers have to meet certain reliability requirements [2].

The nature of this capacity market is not yet defined in detail. But there are discussed various ways. For example there could be performed multiple auctions for the same reference year. This is to ensure that demand is able to adjust over the time. Thereby it is able to open the market for participants who are unable to provide secure capacity for the required lead time. The capacities that are not in demand, must be shut down [2].

As consideration for secured supply the customer shall bear the costs of the auction. The auction's costs are estimated at 4.5 to 5.8 billion € per year [2].

Now that both variants have been described these are to be compared in the following. This is done under consideration of the following factors effectiveness, efficiency and regulatory assessment, regulatory risks, distributional effects and distortions of competition.

## III. COMPARISON BETWEEN STRATEGIC RESERVE AND SECURITY-OF-SUPPLY CONTRACTS

Both approaches show advantages and disadvantages in terms of their feasibility. In the following, the comparison is

made under the assumption of a functioning energy-only market [2].

### A. Effectiveness

The objective of security of supply is achieved by two mechanisms, the security-of-supply contracts approach achieves an increase of supply in Germany, but no increase in Europe, compared to the Energy-only market. This effect could occur if a security-of-supply contracts market is set up only in Germany, but no capacity markets in other European countries. This would lead to a transfer of capacity to Germany as a result [2].

An strategic reserve would be effective both in Germany and in Europe, however, the capacity requirement would tend to rise in national perspective. This effect, however, counts for both mechanisms. European coordination of supply tends to lead to a reduced need for guaranteed capacity in comparison to the national security of supply [2].

To maintain the security of supply incentives for both demand and supply must be created. Both mechanisms are generally capable of providing this if a suitable design is given. The strategic reserve refers here the whole market, as long as the exercise price is set high enough. In contrast to it the level of incorporation of the demand-side at the security-of-supply contracts approach depends on the specific configuration parameters and depends on the design of the market [2].

### B. Efficiency

Efficiency losses of the strategic reserve tend to be higher at a national perspective than from a European perspective, as potentially a higher power plant performance for the strategic reserve is required. This is due to the goal of national self-sufficiency, for whose maintenance a higher strategic reserve is required if applicable [2].

In the security-of-supply contracts approach, there are significant risks of inefficiency, as some options are excluded by long pre-qualification and auction periods. In addition, price spikes are reduced, thereby incentives to expand the elasticity of demand could be reduced. In addition, the security-of-supply contracts approach is regulation intensive which could result in inefficiencies. As with the strategic reserve, the efficiency losses from a national point of view are higher than the European approach to the security-of-supply contracts [2].

The security-of-supply contracts solution has higher total economic costs in comparison to the strategic reserve and for the end user. Also the additional capacity payments are not cost effective [2].

### C. Regulatory assessment, regulatory risks, distributional effects and distortions of competition

For the highest possible efficiency of the security-of-supply contracts approach long-term stable policy frameworks

are needed. In addition, there is no adequate data on such complex mechanisms and the economic capacity of significant capacity payments could place distributional aspects in the foreground, in respect to effectiveness and efficiency aspects [2].

The strategic reserve, however, can without change the market design be introduced and expanded at a European mechanism without problems. However, difficulties arise in maintaining a high exercise price, when a high current price is applied, while unused capacity of the strategic reserve could produce cheap electricity. Therefore, it is crucial to signal policy credibility to ensure the functioning of the energy-only market [2].

Finally, a consideration of national and European security must be taken because a European coordination would bring significant efficiency gains. The strategic reserve is basically in line with the EU's internal market and can easily be coordinated and implemented in national unilateralism [4].

After introduction the strategic reserve can be reversed, if there is no demand for it or the functionality is insufficient. In contrast to it a basic property of the security-of-supply approach is that it is applied durable and on a long-term. A return to an energy-only market would most likely not be possible [2].

#### IV. ANALYSIS OF THE ENERGY-ONLY MARKET

Now that an explanation of possible shapes of a capacity market has been given, we will go back to the energy-only market. We will now discuss the question of whether a capacity market in this country is actually needed. This is necessary for a better understanding which variety of capacity markets is better suited to solve possible problems.

To answer this question, it must be examined whether the design of the energy-only market is likely to ensure security of supply. This is not the case when there are insufficient investment incentives to fund a sufficient number of new buildings of conventional power plants, which form the basis for an efficient supply [5].

To decide this, it is necessary to understand the functioning of the current energy-only market. For this reason, now follows an economic excursus on price formation in electricity markets [5].

The starting point is a perfect competition market. Here, demand and supply curves meet at an intersection point and thus form the market price. This provides the participating

companies efficient incentives for investment and production decisions. In perfect competition, the supply curve shows the offer price. This corresponds to the marginal cost of production. Marginal cost means that the price is at the level of the cost of an additional unit produced. The demand curve shows the willingness to pay of consumers and their corresponding marginal utility. The marginal benefit is the benefit that would result from an additional unit [5].

Both curves are elastic. This means that the quantity demanded and offered adjust to the price and any required height can be met as it is shown in Fig. 1.

In the electricity market, this is no longer the case above a certain amount. The quantity supplied may not be adapted, as only a certain number of power plants are present or due to technical restrictions cannot be arbitrarily switched on and off [5].

The quantity demanded depends on the day, week and year. This means that the marginal utility varies continuously. Similar to the supply curve also the demand is inelastic in the short run. The reason is that it is not possible for some of the consumers to respond to price signals in the short term. Furthermore, it is not possible to store electrical energy in an appreciable extent. It follows that the demand from falling below a certain amount is perfectly inelastic [5].

In the electricity market the power plant sets the electricity rate, which has the highest variable costs to meet demand. This results in the power plant operation for two distinctive situations that are important for financing [5].

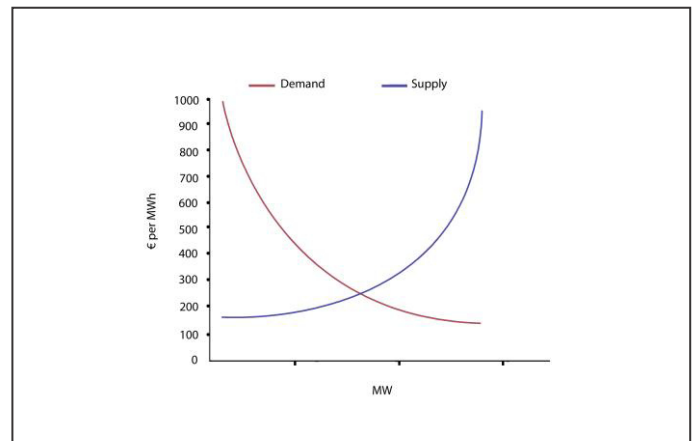


Figure 1. Example of a perfect competition market

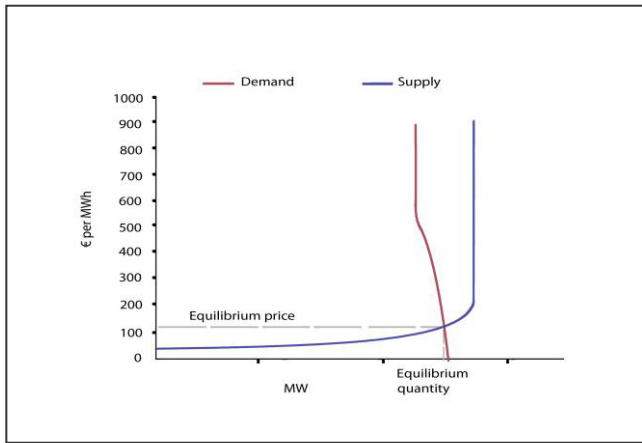


Figure 2. Example of the first situation

The first situation may result in a price at which the marginal cost of supply corresponds to the marginal utility of demand. In this case, all power plants whose marginal cost is below the market price, to cover its total costs. However, the price-setting power plant cannot do this, as it is shown in Fig. 2. The desired effect of this is that the required electrical energy is provided efficiently and at minimum cost [5].

In the second situation, a price develops that is above the marginal cost of all the power plants on the market and is only determined by the marginal utility of the demand which arises. In this case all power plants can cover their costs [5].

The result of both variants is that it can adapt supply to demand. If the contribution margin of the power plants is too low, power plants are shut down and the supply curve shifts to the left, causing prices to rise. But if too few capacities are provided, the price rises so high that it is worthwhile to provide new capacities. In that case the supply curve shifts to the right [5].

In theory, the energy-only market is thus able to provide enough incentives to provide sufficient capacity for a secure supply [5].

In practice, however, there may be differences that may affect the theoretical efficiency. This will be examined in the following [5].

The first variable to be examined is the price elasticity of demand. Consumers generally react only slightly to changes in price. This is partially explained by the fact that part of the customer is not able to recognize the current prices. However, using smart meters, smart grids and electric mobility is to be tried in the future, to strengthen the demand side management. Another explanation is that the low elasticity of customers' preferences is reflected. The customers who account for 60% of consumption in Germany, because of stipulations know the exact cost of energy production and are therefore willing to pay high prices. Under this aspect, it can be assumed that the mechanism to set price signals for the construction of new facilities, works [5].

In the following it is to be examined how attempts to regulate affect the efficiency of the market [5].

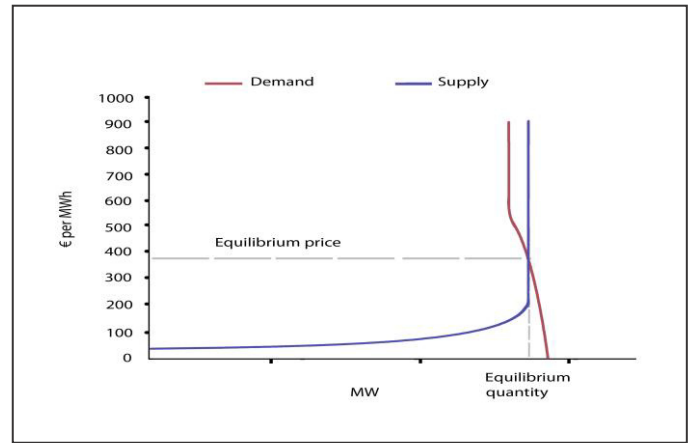


Figure 3. Example of the second situation

Markets can fail not only due to a faulty construction but also by faulty policy interventions. As already explained market prices, which are above the short-term marginal costs are necessary to secure the financing of all power plants. However, these price spikes lead the policy to act regulatory. The consequence of this is that no efficient investments are made and consumers do not respond to price spikes. Thus optimal average costs are prevented [5].

This regulatory failure is one of the main causes of market failure. This creates the need for the policy to understand the mechanisms of the market and to only intervene if inefficiencies reach a critical level [5].

The result shows that the energy-only market may be able to ensure security of supply efficiently. It is a prerequisite to identify and eliminate confounding factors. In this case especially regulatory failure and demand side management has to be mentioned that holds many opportunities for improvement [5].

There is, however, even after this generally positive assessment still to proof that the energy-only market is also in the long term capable to ensure security of supply, "So far there is no evidence that the market is able to ensure supply. However, I admit that there is on the other side also no evidence that it is able to do so in the long term." [6]

## V. RECOMMENDATION TO PROCEED

At the end of this paper a short recommendation to proceed is given as follows.

The different approaches of creating a capacity market could ensure a security of supply in event of a failing energy-only market [2].

Short to medium term, the strategic reserve could provide such a solution. It is easy to build, inexpensive and reversible. Furthermore, after implementation the strategic reserve is developable in case of a collapsing energy-only market [2].

The approach of the security-of-supply contracts, however, possesses great risks and is uneasy to reverse. Additionally, integration requires a long lead time of seven to ten years

The consequences on the European internal market should be investigated thoroughly and in any case its basic rules for the introduction of capacity markets should be worked out [3]

The energy-only market should be preserved as long as possible. If, however, the market is threatened by collapsing the elimination of the causes by, for instance, increasing the elasticity of demand would be more reasonable than fighting symptoms [2].

Finally, you can say that the strategic reserve could be an appropriate interim solution to ensure security of supply in Germany and the whole continent [2].

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# Wind power

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**Abstract** *The use of wind power by humans has its origin in the late past and was developed since there. The progression of the windmill and its increasing relevance show that expensive technologies for power generating can depend on cheaper alternatives. In Europe, especially Germany electricity has a high relevance and good possibilities to expand.*

## **I. Introduction**

Wind energy belongs to the renewable energies and it is gaining more and more importance throughout the world. It also contributes to the environment by reducing carbon dioxide emission. For example five countries – Germany, USA, Denmark, India and Spain – concentrate more than 83% of worldwide wind energy capacity in their countries. Due to the decreasing amount of raw materials worldwide renewable energies are getting more development.

Wind energy or wind power describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for different fields.

Winds are caused by the heating of the atmosphere by the sun, the irregularities of the earth's surface and rotation of the earth.

The current of air are modified by the earth's terrain, bodies of water, and vegetative cover. The wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

## **II. History**

The use of wind as an energy source is very old. Vertical axis windmills for grinding grain were for example reported in Persia in the tenth century. It was also a major source of energy for transportation (sailboats) and pumping water.

Windmills and with their water mills, were the largest power sources before invention of the steam engine. Dutch windmills are very famous and one of the oldest country with windmills. They have nearly about 9000 windmills. The first windmills were created in the Orient around 1700 B.C. They were basically used for watering. Also the mechanism how they were working was different from the actual principal. Historical windmills had horizontal axis of rotation, so they gained the energy due to the resistance. This mechanism can extract 12% of the energy from the wind. The first windmills with a horizontal axis of rotation were invented in the 12<sup>th</sup> century in France. From this point the windmill spread over Europe.

Apart from the technical aspect, the development of windmills was dependent from ecological problems and other energy sources. In 1759 John Smeaton has enlarged the efficiency of windmills by specific experiments. That was a massive boost for expansion and improvement. In 19<sup>th</sup> century the first windmill that generated electrical power was built by Paul LaCour. But the windmill couldn't displace the more effective steam machine. After the Westernmill was invented, the era of new windmills started. Until today this type is built in USA, Australia and Argentina. The Westernmill could already be called a "modern" windmill. This Type had a yaw control and storm insurance, which was a major step in research. Historical windmills had always been supervised by a miller.

## **III. Operation of Wind Turbines**

Wind turbines can be compared with aircraft propeller blades. They turn the moving air and power an electric generator that supplies an electric current. A wind turbine is the opposite of a fan. Instead of using electricity to make

wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, connects to a generator and makes electricity.

There are two basic turbine groups. The horizontal axis windmill (Fig.1) which is like the traditional farm windmill.

And the vertical-axis windmill (Fig.2), like the eggbeater-style Darrieus model, named after its French inventor. Most used windmills are the



Fig.1. horizontal axis windmill



Fig.2. vertical axis windmill

horizontal-axis turbines.

#### IV. Modern wind energy

After the First World War the windmill experienced recovery. The military and civil aircraft evolve new propeller. Another point, which still is in application today, is Betz' law. In 1920 Albert Betz described the actuator disc theory. He has concluded that wind can be extracted 59% of his energy<sup>1</sup>. 1926 Betz connected his theory with the law of conservation of energy and the conservation of momentum. That theory creates simple rules for blade geometry. On this background novel turbines were developed. The brake-out of the Second World War freezes the research and also the interest in wind energy, just the USA held on the wind energy and built the first net feeding plant.

Due to the dwindling coal inventories the demand on wind energy rises and experts from the OEEC came together for an exchange of experience. Johannes Jul had a simple concept for net feeding plants. In this point the most important move would had been the advancement of these ideas.

But the upcoming cheap oil from the Orient displaces the interests in expensive wind-generated power. The oil price shock in 1973 and 1978 results in a reflection about energy supply. Thus the wind energy came back to talk. Up from the 1980's the wind power plant put foot in Europe. The pin wheel had a diameter of 12 to 15m. Those windmills develop from this time on consistently. The diameter has today around 80 to 100m (Fig.3).

In contrast to the historical windmill the modern windmill is mainly used for generating electrical energy. Although there 're still a lot of other possibilities for the use of windmills, e.g. direct mechanical use or conversion into hydraulic energy for water pumps. But any other application needs special constructions.

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<sup>1</sup> Gasch, R. & Twele, J. (2011): Windkraftanlagen-Grundlagen, Entwurf, Planung und Betrieb

The basic structure of modern wind turbines for the conversion into electrical energy is relatively consistently. A wind turbine has three rotor blades. Besides the less noise exposure, the three

rotor blades lead to a uniform distribution of burden.

The coarse operation for generating electrical Energy is quiet simple. The Rotor is driven by the wind. With the Transmission the speed can be translated. The electrical power is generated through a generator. After this step the power can be net feed.

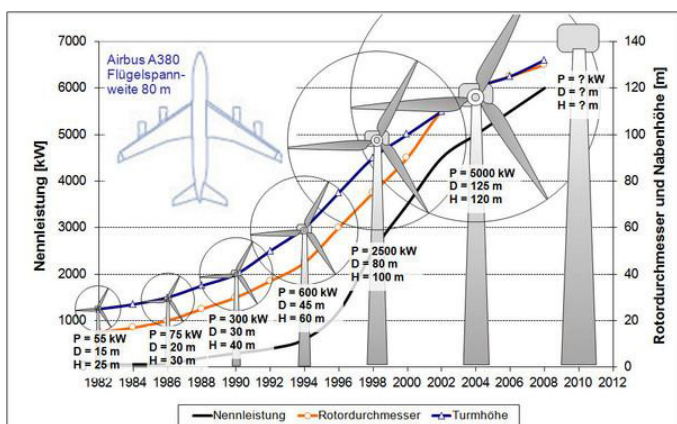


Fig.3. development of modern windmills from 1980 Black line: performance; orange line: rotor diameter; blue line: height

## V. Wind power in Germany

The romans were the first to use wind power in ancient Germany to run farm machines to reap grain in the 13<sup>th</sup> century.

Later on the Germans built wind mills on their own. In the 18<sup>th</sup> century the whole country was covered with the structures. 1769 James Watt invented the steam engine, which replaced the mills during the industrial revolution.

After the German reunion, in the year 1990 the government initialized a new wind power program that included the use of wind turbines to generate electricity. In the beginning the electricity wind turbines generated only counted 160 kW. Three years Later the amount of produced energy could be doubled and until today Germany steady increased the capacity. Nowadays the performance is many times more

effective than in 1990.

Due to the nuclear disaster in Japan in 2011 and its feared consequences the use of wind power gained a new relevance in Europe. The German government decided to concentrate more on renewable energies, especially on offshore wind farms.

The capacity in this year could be increased to 29075 megawatts, which is 30 percent more than in 2010. Recent wind power generates more than 8 percent of Germany's total electricity.

Especially in middle and south Germany the potential to grow is optimal. The sinking prices for buildable vacant lots and progressing technologies simplify the expansion.

The German institution for renewable energies predicts 55000 megawatts wind power performance for 2020.

Germany's main problem that still couldn't be solved is the transport of energy turbines in the north and East Sea generate, to the industrial consumers in Germany's southern part. Most of Germany's energy is produced in the north, where the wind blows strongest.

## VI. Wind Power and its problems

The main problem is the unreliability and the inconstancy of the wind strength, it can vary from wind stillness to great storms or tornados.

That means that the amount of electricity turbines produce is unpredictable. Long Periods of wind stillness can even cut off the supply of wind electricity, because turbines doesn't work without wind. Responsibilities can't just relay on wind power, another energy source for emergency cases is required.

In areas where the wind strength is too low to generate energy with turbines, the use of solar and geothermal power is a good alternative.

Another disadvantage is the pollution of contaminants into the natural environment the production of wind generating machines cause, due to the use of steel, aluminum and concrete. In Addition to that the machines require fossil fuel to run.

Many claim that wind energy is cheaper than other types of power generation. The over average high production costs of the turbines and the fact that in the United States the price for a kilowatt hour is similar to coal and natural gas can prove them wrong.

Compared with other energy sources the

generation of wind power isn't even that effective. The most powerful turbine worldwide, the *Fuhrländer Wind Turbine Laasow* in Germany can produce electricity for only 475 average homes, if it works on full capacity. The supply of a whole city would need a huge turbine farm that requires a lot of money for the production and much place for the large structures.

Furthermore wind machines are very loud and noisy. The caused noise pollution can be compared to small jet engines. Already mentioned Wind farms disturb especially nearby humans and wildlife. Besides many people share the opinion the nature should be untouched by such big buildings, because they disfigure the landscape and its beauty.

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