Wrocław University of Technology

Brandenburgische Technische Universität Cottbus - Senftenberg

18th EEEIC

International Conference on Environment and Electrical Engineering – Student Edition

Cottbus

Ostrava-Wrocław

11th – 14th of June 2019

Harald Schwarz, Przemysław Janik,
Radomir Gono, Dirk Lehmann

module at BTU: 11396

Presented by

Wrocław University of Technology
Department of Electrical Engineering
pl. Grundwaldzki 13
PL 50 – 377 Wrocław

Technical University of Cottbus
Department of Power Distribution and High Voltage Technology
Walther-Pauer-Straße 5
D – 03046 Cottbus

VŠB - Technical University of Ostrava
Department of Electrical Power Engineering
17. Listopadu
CZ - 15 Ostrava - Poruba

Publisher
Brandenburg University of Technology Cottbus - Senftenberg
Information, Communication and Media Center
University Library

Impressum
Brandenburgische Technische Universität
Cottbus-Senftenberg
IKMZ - Universitätsbibliothek
2018

10.26127/BTUOpen-5714

Table of contents

Renewable Energy and Techniques to Improve Efficiency of Solar Cells	1
The Challenge of Storing Energy	5
Is the Paris Agreement on the way to transnational climate protection	11
German and Indonesian Policy on Renewable Energy	14
Possibilities and perspectives of diagnosis and condition monitoring of power transformers and switchgear assemblies	18
Optimistic vs. pessimistic view regarding the scarcity of oil	21
Advantages and disadvantages of the usage of renewable power-plants	23
Clean Air by Siemens	26
Wind Power	28

Renewable Energy and Techniques to Improve Efficiency of Solar Cells

Pei-Chi, Wang
Kaohsiung, Taiwan
Power Engineering
Brandenburg Univerity of Technology
wangpeic@b-tu.de

Yu-Hung, Lee
Tainan, Taiwan
Power Engineering
Brandenburg Univerity of Technology
leeyuhun@b-tu.de

Zohaib Shoaib
Jhelum, Pakistan
Power Engineering
Brandenburg Univerity of Technology
zohaib.shoaib@b-tu.de

***Abstract*—Renewable energy sources are clean sources of generating power and optimal use of these resources minimize the impacts to our environment, electrical power from Renewable resources produce minimum waste and are sustainable based on current and future energy requirements. This paper presents the environmental impacts of traditional sources of energy generation and presents data which signifies the importance and need of renewable energy especially in terms of environmental impacts and human wellbeing. Latest techniques to increase the share of renewable energy from solar by increasing efficiency of solar cell is also presented.**

Keywords—renewable energy, environment protection, solar energy, plasmonic nanostructures.

I. Introduction

The theme of the paper is to present the importance of renewable energy using logic and statistics in comparison with the traditional sources of generating power with an aim to protect the environment from further deterioration and to identify means to increase the share of solar energy production by using latest techniques known as light trapping via plasmonic nanostructures embedded in solar cell structure.

II. Renewable Energy

Renewable energy (RE) refers to energy that is not depleted when utilized but it is naturally replenished e.g. solar energy and wind energy. Renewable energy is just beginning to be developed or utilized and it is actively researched, and needs to be promoted for human wellbeing and environment protection.

As the country proposes energy-saving policies and technology to continuously innovate and advance, and as the industrialization process accelerates, energy issues are increasingly becoming a global concern and hope to be effectively solved, so various types of new energy technologies are gradually being developed.

A. Energy from a source that is not depleted when used, such as wind or solar power.

It is estimated that by the end of 2013, the global crude oil reserve was 1.688 trillion barrels, which is only 53.3 years at current mining rate. In addition, there are approximately 1.1 trillion tons of proven coal reserves worldwide, which will last for approximately 150 years. Natural gas reserves will continue for up to 52 years. People should ask themselves a question - what should we do once all fossil fuel reserves are utilized? Compared to fossil fuels, there is currently not much renewable energy produced, because renewable energy requires higher operating costs and is less efficient than fossil fuels. World energy resources are presented in the form of pie charts. (Figure 1). According to the figure, as of 2017, only 10.4 percent of world's energy is being produced by RE. Of that 10.4 percent only about 1/3rd of the RE is produced from solar, wind, geothermal and biomass and rest is from hydroelectric.

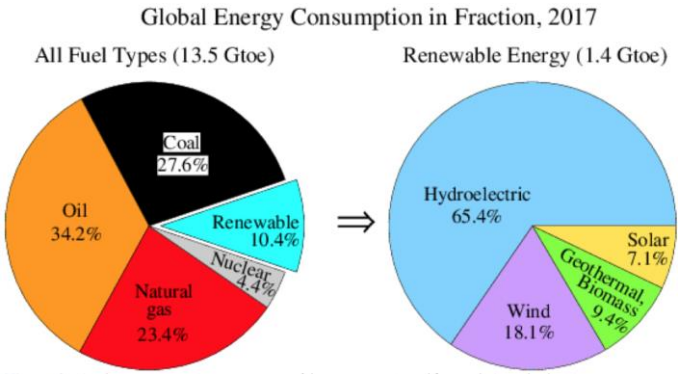


Figure 1. Pie chart representing non-renewable resources (World population clock, 2017) [1]

B. Why are we interested in RE?

It is because we want to reduce CO_2 and other greenhouse gas emissions that are detrimental to our environment and health. Generating power from renewable energy produces the least amount of greenhouse gases and also saves huge operating cost. What does this mean? It simply means that we are producing much less energy from RE and we should increase our share of RE production if we are serious in reducing our Carbon Footprint.

III. Environmental Effects of Non-renewable Energy Sources

Non-renewable energy is an energy that cannot self-sustain naturally. Non-renewable energy includes coal, oil and natural gas, and unlike renewable energy sources such as wind, hydroelectric and solar which can mostly be converted into energy in a clean way, it can lead to harmful emissions during the conversion, and its collection can damage local

wildlife. All of them might cause the environmental effects and contribute to climate change[2]. Some of the most significant environmental impacts are discussed as the following.

A. Greenhouse Gas Emissions

Different types of non-renewable energy fuels produce different levels of greenhouse gases.

For example, coal is considered to be the great contributor of carbon dioxide (CO_2) emissions. In the United States, the carbon dioxide emissions of the electricity industry, calculated in 2017, indicate that 69% comes from coal. However, natural gas produces about 29% of carbon dioxide emissions. Compared to coal, natural gas emits 40% less. [3]

However, this does not mean that natural gas cannot cause climate change, as drilling and extracting natural gas from wells can lead to leakage of methane - a more potent greenhouse gas which is 34 times stronger than carbon dioxide in terms of its potential for trapping heat.

B. Air Pollution

Non-renewable energy not only changes our Earth's atmosphere by increasing greenhouse gas emissions but also emits a variety of pollutants that affect people's health and the environment.

For example, coal-fired power plants are the largest source of mercury emissions in the United States. Once mercury is released into the air, it will deposit on the ground or in the water. Through the food chain it can be accumulate in the organisms of species (like fish) living in the area.

It suggests that it can cause neurological and neurobehavioral effects in embryos and young children.

C. Acid Rain and Water Pollution

Combustion of fossil fuels not only produce CO_2 but other harmful gasses like methane and nitrous oxide and such gases also produced from the industrial processes. They interfere with the natural water cycle and react with water and make rainwater acidic. This is called acid rain. This acid rain not only is dangerous to human but also causes the acidity of natural ocean water to rise and endanger the marine life.

D. Ozone Layer Depletion

CO_2 has no direct effect on ozone layer but it slows down the natural production of ozone and plays its role in the ozone depletion. The ozone depletion is mostly caused by manufacturing chemicals like refrigerants, solvents, propellants which are made of chlorofluorocarbons and hydrochlorofluorocarbons which depletes the ozone layer. VOCs are volatile organic compounds and it is a substance which is found in building material such as plywood, plastic boards and glues. Other sources of VOCs are burning fuels like gas, oil and kerosene.

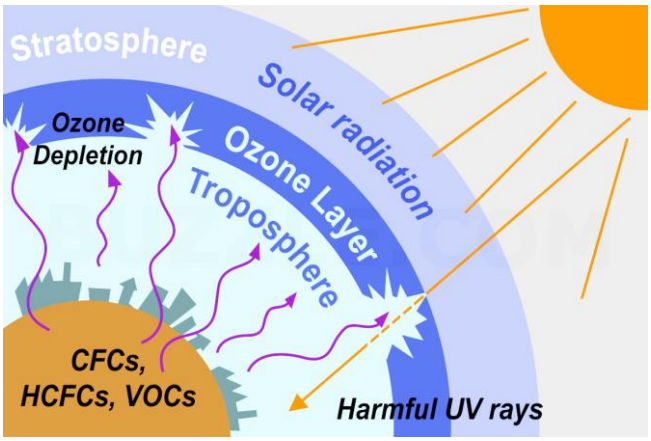


Figure 2. Ozone Layer Depletion

E. Hockey Stick Curve

The long-term trend of the reconstructed annual average NH series (Figure 3) is very similar to the long-term trend of summer temperature reconstruction in the northern hemisphere. It showed a distinctly cold period in the seventeenth and mid-19th centuries, with some warmer periods in the medium term. [4]

Since 1900, emitted the huge greenhouse gases in the modern industrial economy.

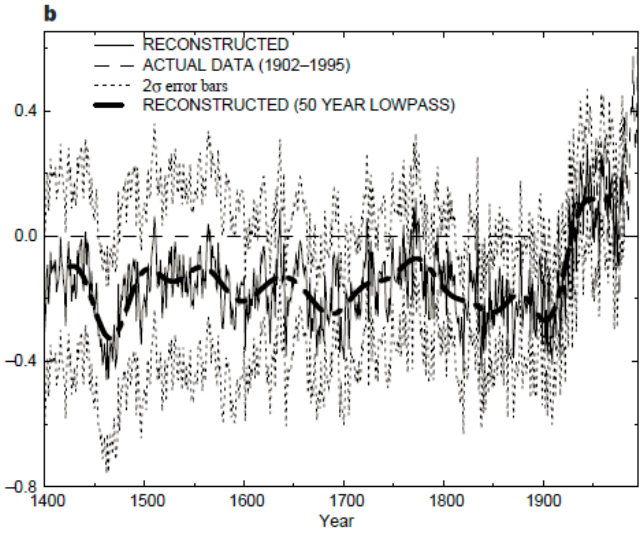


Figure 3. *Northern Hemisphere mean temperature anomaly in °C* [4]

IV. Solar Cell Structure

Basically, the solar cell material consists of 5 layers. The 1st layer is the glass layer, the 2nd layer is the front EVA layer (Ethyl Vinyl Acetate), the 3rd one is the solar cell layer, the 4th layer is the back-EVA layer and the last one is the laminate layer made mostly from Tedlar.

The glass here used should have low iron content and high transmittivity of light. EVA is used for encapsulation. It should have high electrical resistivity, low water absorption and high optical transmission. Tedlar material is white in color and it is used for the back reflection of light.

Not all the light shining on the surface of PV cell gets absorbed and hence converted to electricity. Most of the light that is converted to energy is visible light or infrared. Out of these types of light, only that portion of light whose energy is equal to the band gap energy of the solar cell material, is responsible for the production of electrons and holes in the semiconductor material which produce electricity. The rest of the light either is dissipated as heat and does not produce electricity if the bandgap energy of solar cell material is too high or it simply passes through the solar cell material and does not generate electron hole pairs for electricity generation. The maximum theoretical efficiency of solar cell is called the Shockley-Queisser limit. It was first calculated by William Shockley in 1961. The modern value is 33.7 percent for bandgap energy of 1.4 electron volt (e.V.).

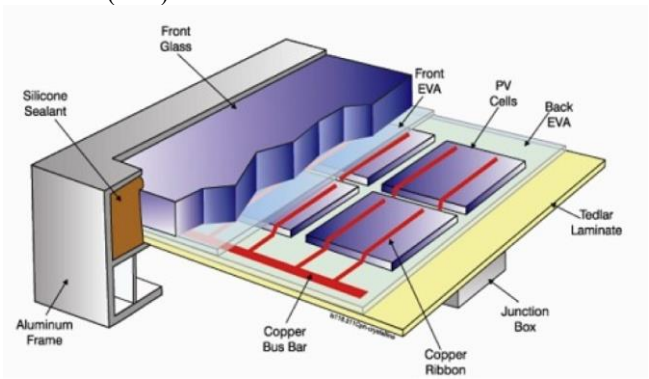


Figure 4 Typical bulk silicon module materials. [5]

V. How To Increase RE Production by Solar Cells

A. *Tandem Cell*

It is actually possible to beat the Shockley-Queisser limit. In tandem solar cell technology instead using single layer of semiconductor, we can combine two different semiconductors with different band gap energies such that the front cell has higher band gap energy than the rear cell, so the light which is not strong enough to make electricity from the first layer passes through it and generates electricity in the second layer because the second layer has lower band gap energy than the front one. In future technologies 4-6 junction cells are also expected.

B. *Energy Harvesting using Light Trapping via Plasmonic Nanostructures*

The plasmonic effect is the interaction between free electrons in metal nanoparticles and incident light.

Plasmonic nanostructures are nanostructures which start oscillating when plasma frequency light interacts with them. Normally these are metals like gold, silver and copper etc. When light begins to interact with them their electrons begin to oscillate. These electrons which oscillate very fast show the properties of plasma which is a fourth state of matter, and that is why they are called plasmonic nanostructures. There are three possible ways in which we can introduce these nanostructures in our solar cells in the upper layer, in the middle layer or in the back side of the PV semiconductor.

In the first one (a) light enters from the gap between the nanoparticles and hits the back reflected coating of the PV semiconductor and reflects back (in the opposite direction) and hits the nanoparticles and is scattered or absorbed by the nanoparticles. In this way light gets trapped and oscillates in the semiconductor material.

In the second one (b), the similar phenomena takes place, but in this layer, there is the semiconductor solar cell so the solar cell directly absorbs the oscillating light and hence efficiency of the solar cell increases.

In the 3rd type (c), the particles are embedded in the back layer of the PV semiconductor, the incoming light after reaching the back layer is interacted with the nanostructures. The nanostructures here are arranged in several channels. In these channels, the light here gets concentrated as if there are tiny suns at the bottom of the solar cells. This concentrated light helps to generate more electron-hole pairs and hence more power.

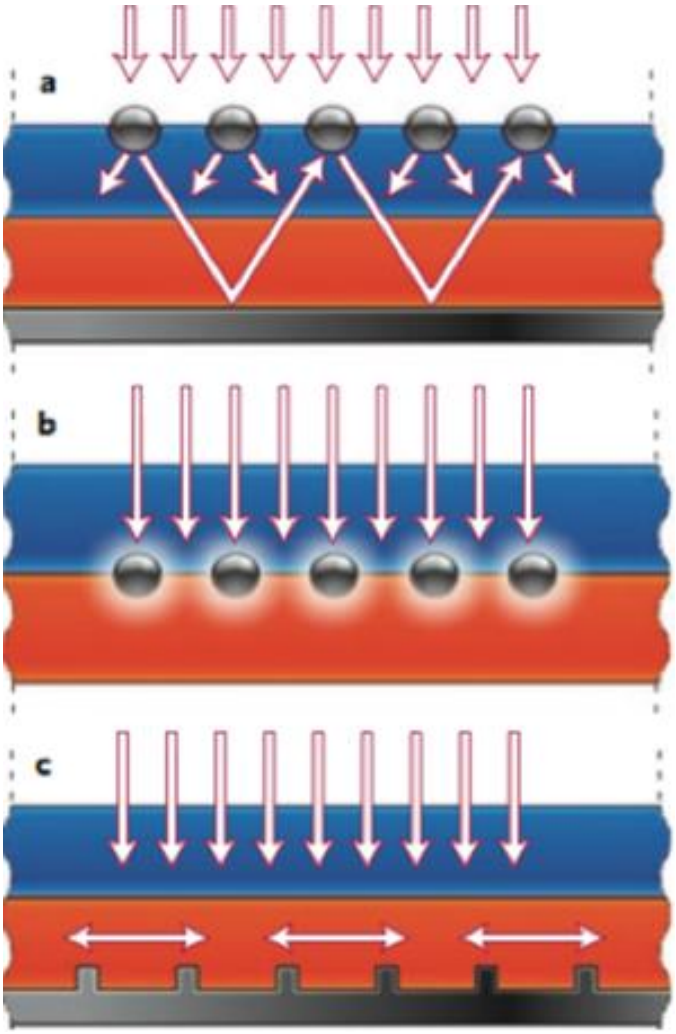


Figure 5 Plasmonic Light Trapping in Thin Film Si Solar Cells [6]

VI. Conclusion

There is an overwhelming evidence that traditional sources of energy are harmful for the environment and human health. Rising sea levels and sudden climate changes are the result of the greenhouse gasses and global warming caused mainly by the use of non-renewable energy sources and possess a great threat to human and marine life. With the increase of energy production from renewable energy. It is possible to curb the environmental impacts due to burning of coal, oil and natural gas for energy production. One practical approach to increase the share of renewable energy from solar is to embed plasmonic nanostructures in the structures of solar cells. This technique is compatible and hence practical with the present-day solar cells use to produce. By simply embedding nanostructures in the thin solar cell material it is possible to increase the efficiency of solar cell and hence more share of energy can be produced by renewables. This solution is also cost-effective which means we will get more energy with some additional investment.

References

[1] Elavarasan, R. M. (2019). The Motivation for Renewable Energy and its Comparison with Other Energy Sources: A Review. *European Journal of Sustainable Development Research*, 3(1), em0076.

[2] Greentumble (2019)
URL: https://greentumble.com/harmful-effects-of-non-renewable-resources-on-the-environment/, (01.04.2019)

[3] EIA, U.S. Energy Information Administration (2019) URL:https://www.eia.gov/tools/faqs/faq.php?id=77&t=11, (02.04.2019)

[4] Mann, M. E., Bradley, R. S., Hughes, M. K. (1998): URL:https://arizona.pure.elsevier.com/en/publications/global-scale-temperature-patterns-and-climate-forcing-over-the-pa (1998)

[5] Napierala, Artur.,(2018) :Power Generation from Solar Energy, lecture martrials, Brandenburg University of Technology Cottbus-Senftenberg, Germany

[6] P Spinelli, VE Ferry, J Van de Groep, M Van Lare, MA Verschuuren, REI Schropp, HA Atwater, A Polman (2012): Journal of Optics (2012)

The Challenge of Storing Energy

Harith Iwas
Business Administration and Engineering student
BTU Cottbus-Senftenberg
Cottbus, Germany
harith.iwas@b-tu.de

Stefan Dress
Business Administration and Engineering student
BTU Cottbus-Senftenberg
Cottbus, Germany
dressste@b-tu.de

Mohd Shadman
Masters in Power Engineering student
BTU Cottbus-Senftenberg
Cottbus, Germany
rashimoh@b-tu.de

***Abstract*— Recently, realizing the approach of deregulation with power industry reformation and fast-growing development of renewables in Germany and other European members it's of great importance to study the energy storage relation with progress of alternatively available energy sources. Non-controllable sources like wind and sun play a vital role. Situations can occur with an excess of energy in the electricity supply system when the installed amount of un-controllable power exceeds the yearly peak load. So, the need of balancing the demand of energy from renewable sources through reliable energy storage systems becomes essential. This paper showcases the key challenges which an Energy Storage Technology faces in future electric power systems, the fast development of volatile energy resources and their increasing share in the energy sector brings significant challenges to the existing power grid due to the high variability of these sources and loads. The aim of this work is analyzing those challenges for Energy storage devices and characterize them by their different operating parameters.**

Keywords*— *Energy storage systems, Renewable energy integration, Energy Conversion, Energy demand.

I INTRODUCTION

A core property of electricity is that once it has been generated, it must either be consumed or stored. The dominant product of renewable energy generation is electricity. By their very nature renewable energies are very volatile in generation like wind and solar energy, which depend on weather conditions. The European Commission expects that the share of electricity generated from renewable energies will rise from 25% today to 55% by 2030 [1]. For all these reasons the usage of electricity storage technologies is a crucial factor for the energy transition. According to the European Commission, energy storage is defined as "the act of deferring an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier" [2].

One benefit of using energy storages is the reduction of overall costs of the energy system by avoiding negative energy prices in times of oversupply or shutting down of power plants. Another advantage is the flexible energy generation. In comparison to a coal-fired power plant, which has a boot time of several days, stored energy is available within seconds to hours. Storage Technologies are indispensable prerequisites for improving decarbonization and energy security of the electricity grid. Energy storage helps to integrate variable renewable energies. Energy storage could also be an attractive business case for suppliers, the industry sector and prosumers e. g. arbitrage between storage at low cost energy periods and selling the stored energy in times of high demand [2].

There are different types of challenges when it comes to energy storage: on the one hand there are technical and on the other economic challenges. Additionally, there are political challenges. In general, the storage of energy is associated with losses. As things stand today, there is no optimal storage technology that is better in all aspects than the others.

This paper will present three leading storing technologies: Pumped Hydro Storage, Thermal Energy Storage and Batteries (Chapter 2), will make an overall comparison between them and will point out current challenges of storing energy (Chapter 3). Chapter 4 delivers a conclusion and outlook of energy storage.

II ENERGY STORAGE TECHNOLOGIES

A. Overview

There are a lot of different storage technologies. Some are already technically mature; others are still in the development phase. You can find different qualities and abilities e.g. in availability, timeframe and efficiency. All storage technologies must fulfill the same three process requirements: Charge, Store and Discharge [3]. Subsequently, a classification of the most important storage technologies is made [4].

Mechanical

- **Flywheel**
- **Pumped Hydro**
- **Compressed Air**

Chemical

- **Hydrogen**

Electrochemical

- **Batteries (e.g. Li-Ion)**

Electrical

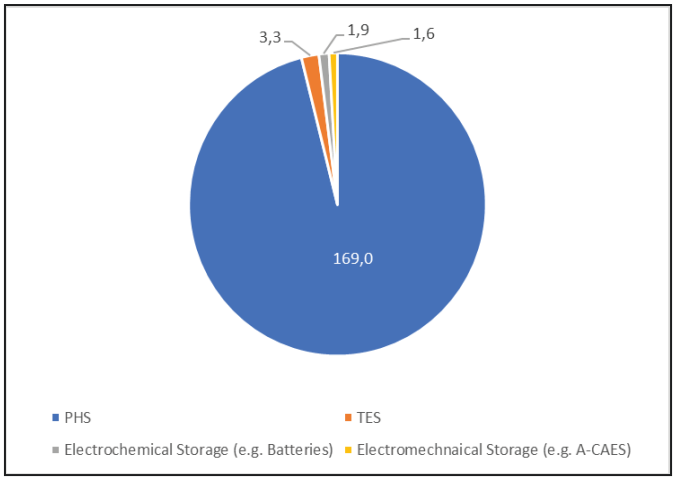
- **Capacitors**
- **SMES**

Thermal

- **Sensible Heat (Molten Salts)**
- **Latent Heat (Phase Change Materials)**

Figure 1 shows the total installed capacity of storage technology globally in mid-2017.

Figure 1 – Total installed capacity of storage technology globally in [GW] in mid-2017 [5][6]



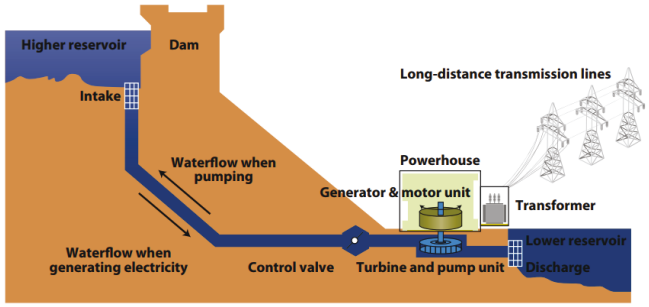
You can see that Pumped hydro storage (PHS) currently dominates total installed storage power capacity, with 96% of 176 gigawatts (GW). China (32.1 GW), Japan (28.5 GW) and the United States (24.2 GW) have the world's largest pumped storage capacity [6] [7]. A total of 6.8 GW of energy storage globally is contributed by thermal, batteries and non-pumped hydro mechanical storage technologies [6].

As part of this paper, we would like to focus on the following three technologies: Pumped Hydro Storage (PHS), Thermal Energy Storage (TES) and Batteries.

B. Pumped Hydro Storage (PHS)

With a 99% share of worldwide storage capacity in 2012, PHS is the most extensively deployed, large-scale energy storage technology by far [5, 6, 8, 9]. Figure 2 shows the schematic of a typical conventional pumped hydro storage system, which uses two water reservoirs located at different heights.

Figure 2 – Schematic description of a PHS plant [10]



The energy is stored as gravitational potential energy. When there is electricity surplus e.g. on windy days or during periods of low demand, water is pumped into the upper reservoir by using this surplus power (lower-cost electricity). On days when demand level is high and wind low, water can be released back into the lower reservoir, passing through the electricity-generating turbine system. The generated electricity can then be fed into the grid. The altitude difference between the two reservoirs and the total volume of water determine the amount of energy that can be stored [5, 6, 10].

Real life application (Goldisthal)

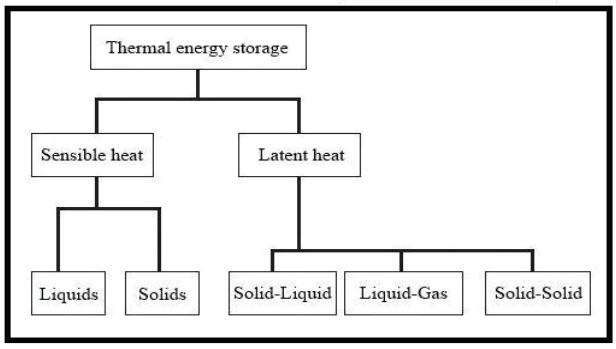
One example of the Pumped Hydro Storage Technology is the pumped-storage power plant in Goldisthal (Germany). It has an installed capacity of 1060 megawatts (MW) and is the biggest plant of its type in Germany and one of the biggest in Europe. The plant has been taken into operation in 2003. The upper reservoir has a usable capacity of 12 million cubic meters. The turbines can run at full load about 8 to 9 hours with that capacity. The total boot time –time from inactivity to full power- is about 100 seconds [11, 12].

Figure 3 – View of the two reservoirs of the Plant in Goldisthal [13]

C. Thermal Energy Storage (TES)

Thermal energy storage (TES) is a process that stores thermal energy by heating or cooling a storage medium which can be used later for heating, cooling applications and power generation as a stored energy source. In Europe, it has been calculated that nearly 1.4 million GWh/year can be saved, and 400 million tons of CO2 emissions avoided, in residential and industrial sectors by more extensive use of cold and heat storage. Storage density, in terms of the quantity of energy per unit of mass or volume, is important for optimization of solar ratio (quantity of solar radiation beneficial for the cooling/heating purposes), appliances efficiency (absorption chillers and solar thermal collectors), and consumption of energy for space cooling/heating room consumption. Therefore, the opportunity of using phase-change materials (PCMs) in applications such as solar system is worth investigating [14]. The main types of thermal energy storage of solar energy are presented in Figure 4. An energy storage system can be described in terms of the following characteristics namely Capacity, Power, Efficiency, Storage period, Charging and Discharging type and Cost.

Figure 4 – Types of solar thermal energy storage (TES) [14]



Capacity, power, and discharge time are interdependent variables. Main parameters for TES systems are given in Table 1, including capacity, power and efficiency. High power capacity and High-energy storage density for charging and discharging are expected properties.

I. Typical parameters of TES systems [15]

TES System	Capacity (kWh/t)	Power (MW)	Efficiency (%)
Phase-change material (PCM)	50-150	0.001−1.0	75–90
Chemical reactions	120-250	0.01−1.0	75–100
Sensible (hot water)	10-50	0.001−10.0	50–90

1) Sensible Heat Storage

SHS is the easiest method based for storing thermal energy by cooling or heating a solid or liquid storage medium (e.g., sand, water, molten salts, or rocks), with water being the cheapest option. The most popular and commercial heat storage source is water, which has a number of industrial and residential applications. State-of the-art projects have showcase that storage water tank is a cost-effective storage option and the efficiency can be improved by ensuring an optimal water stratification in the tank with highly effective thermal insulation.

SHS system utilizes the heat capacity and the change in temperature of the storage medium during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium, the temperature change, and the amount of storage material [16].

$$Qs = \int_{ti}^{tf} m\,cpdt = mc(tf - ti) \qquad (1)$$

where Qs is the quantity of heat stored, in Joules; m is the mass of heat storage medium, in kg; cp is the specific heat, in J/(kg·K); ti is the initial temperature, in °C; tf is the final temperature, in °C. Water appears to be the best SHS liquid available because it is cheap with high specific heat. But, above 100°C, molten salts, oil and liquid metals are used. For air heating applications, rock bed type storage material is used.

Real Life Application

For illustration (Figure 5), the solar district heating "Am Ackermann-bogen" (Munich, Germany) provides solar energy for space heating along with domestic hot water to approx. 320 apartments in 12 multi-story dwellings with about 30,400 m^2 of living space. The system is designed in such a way that it covers more than 50% of the annual heat demand (i.e. nearly 2,000 MWh/a) with help of solar energy collected by 2,761 m^2 of flat-plate collectors. The heat energy absorbed is utilized either directly or stored in a 6,000 m^3 underground seasonal hot water storage. Supplementary heating is given by an absorption heat pump which is driven by the city district heating system using the seasonal storage as a low temperature heat reservoir. This provides a wide operation temperature range of the storage (i.e. between 10-90°C). Direct connection to district system and heating installations in the houses prevents typical temperature drops at heat exchangers which increases the temperature spread. The district system is operating at source temperature of 60°C with a return temperature of 30°C, which is properly monitored. The fraction of solar energy in the second year of operation was 45% and which can reach above 50% after further optimization [17].

Figure 5 –Large Hot Water Storage (construction and final state) combined with Solar Thermal District Heating "Am Ackermann-bogen"in Munich, Germany [17]

2) Latent-Heat or Phase-Change Storage

Latent-Heat or Phase-Change Storage LHS materials are known as PCMs because of their property of absorbing or releasing energy with physical state change. The energy storage density boosts and reduces the volume, for LHS. The heat energy is mainly stored in the phase-change process (at constant temperature) and it is directly in contact with the latent heat of the substance. Application of an LHS system using PCMs is an efficient way of storing thermal energy and has the advantages because of high-energy storage density and the isothermal nature of the storage process.

Phase change materials are applicable for both short-term and long-term energy storage, with the help of variety of techniques and materials. The change in phase could be either a solid/liquid or a solid/solid process. The temperature range plays a vital role for the suitability of a PCM in any application. There are many thermal energy storage applications which use PCMs, which all fit a particular range suitable for their effective thermal performance.

Application of PCM

- Solar Water Heating system
- Buildings
- Air Condition
- Construction materials
- Automobiles
- Telecom Shelters

D. Batteries

Mainly the battery uses chemical reactions in between two or several other electrochemical cells for activating electron currents. For example, they can use sodium sculpture, lead acid batteries and Yom batteries. Batteries help to store electrical energy using chemical reactions. In the other terms, while charging a battery can cause the reactions of electrochemical which will store the energy in the state of chemical form. As per the requirements, reverse type of chemical reaction can lead to flow of charge in electrical current from the battery to the required network. Rechargeable battery or secondary storage is considered one of the oldest energy storage devices that can store electricity as chemical energy. Batteries are produced in variant sizes with storing capacity starting from less than 100 W to several megawatts. Their round-trip efficiency of the energy storage is in the range

of 80-90 % which depends on the operating cycle and the electrochemistry type.

Li-ion battery being the latest technology showcases a large potential in cost reduction because of increasing number of drivers. In meantime the impact of Li-ion batteries in the Electric Vehicle market and their stationary applications as well (seen from Tesla's Hybrid Vehicle and storage battery offerings) are likely to gain orders in large number than other battery technologies available. Emerging technologies employ new materials and innovative configurations to drive performance and cost improvements [18].

Real Life Application

Figure 6 – Tesla Battery Power System in Jamestown, South Australia [19]

The Wind Farm near Jamestown from Tesla (figure 6) can deliver enough power for more than 30,000 homes in case of blackout periods. The Li - ion battery units were produced to deduct power shortages, reduce intermittencies, and manage seasonal peak load and to increase the reliability of South Australia's electrical grid. The same technology that helps to maintain the South Australian grid can also be used by residential to extract energy in the daytime, so it is stored and made accessible day and night, providing constant power even if the grid goes down [19].

III The Challenege of Storing Energy

A. Comparison and Evaluation

As we saw in the chapters before, energy storage technologies have different properties that determine their technical suitability for certain applications which mean that there is no perfect technology for every circumstance or service. In order to evaluate and differentiate storage technologies, several aspects need to be examined. Therefore Table 2 compares all the technologies described before.

II. Technical characteristics of some selected energy storage technologies [4, 20, 21]

	PHS	Battery (Li-ion)	TES
Power rating [MW]	100-5000	0,1-50	0,1-300
Discharge duration (h)	10-100	0,1-5	1-24 h+
Energy density [Wh/kg]	0,5-1,5	75-250	80-250
Efficiency (%)	70-87%	85-90%	30-60%
Durability (years)	40-60 (100)	5-20	10-40
Capital cost ($/KW)	600-2000	1200-4000	200-300
Capital cost ($/KWh)	5-100	600-2500	3-60
Technological maturity (1- lower to 5- higher)	5	4	3-4

PHS

As you can see in Table 2 PHS is a mature technology with a high flexibility and durability, between 40 and 60 years, up to 100 years with major refurbishments. As large volume storage it historically has been used for long storage applications, with discharge times from several hours to a few days. Furthermore, it has a very low self-discharge ratio, which makes it even more suitable for long- term storage. The plant contributes to operation stability of the energy system e. g. frequency regulation. The storage and generation of electrical power is free of CO_2 emissions. Goldisthal is an example for a highly efficient way of electricity storage and generation. The operating costs are low, but the building costs were high (about 623 million Euros) which leads us to the disadvantages. In addition to the high building costs we also have geographical restrictions, since large land use is needed. Also, we have low energy density (large footprint) in combination with a long period of approval and building of the plant [4, 6, 12].

Battery (Li-ion)

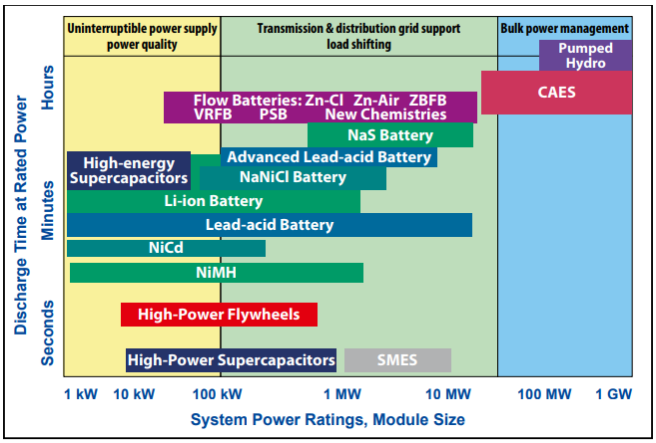
Li-ion batteries have the advantage of high energy density, as well as high efficiency. However, the operating costs are much higher than the other two technologies.

TES

Thermal energy storage offers the option to improve output control for some energy technologies. Some storage materials like the water or ground have universal availability and low cost. Also, the operation and building costs are lower than the other two technologies but also the efficiency is lower. The energy stored decreases with the time due to the heat losses. Some storage technologies are still in developing stage and big surfaces are needed for some seasonal storage [17].

To visualize the differences, an illustration of diverse energy storage technologies, classified by their discharge time and power rating, as well as module size is shown below.

Figure 7 – Positioning of diverse energy storage technologies per their power rating and discharge times at rated power [6]



As we can see in figure 7 PHS are typically used to provide bulk power management and systems like that (e.g. CAES) are located in the upper right corner. On the other hand, there are technologies e.g. flywheels or Li-ion Batteries with much shorter discharge times and are typically used for uninterruptable power supply applications or to improve power quality [6].

B. Challenges

If we look at the question of why energy storage technologies are not yet fully integrated into the energy system, we come across various types of challenges. All storage technologies must provide enough capacity, long-lifespan and a high level of security and efficiency. Technology harmonization and industrial standardization are very important factors for widespread usage of energy storage technologies. This will promote significantly research and development in storage technologies [22]. Moreover, other challenges that must be met are variability of storage in time, specific characteristics of the storage site and the uncertainty of renewable energy generation [23]. Among the specific site challenges are the environmental compatibility and the public acceptance. Ensuring enough political support is also an important challenge for energy storage technologies. Rare raw materials (e. g. cobalt for lithium batteries) to produce storage elements are a limiting challenge [24]. Another challenge is the high costs of development, research, production, installation and operation of storing systems. After all, the task of storage systems is to reduce the overall costs of energy systems [2]. Profitability is a key factor for wide distribution of storage systems among prosumers. A crucial challenge is to always provide sufficient political support for storage technologies and to achieve a stable political and economic framework.

IV CONCLUSION

In summary, the topic of energy storage technologies contains many potentials, but also some challenges. Storage technology is a decisive key to integrating renewable energies into the overall energy grid. As we could see in the comparison of the different storage technologies, there is no optimal storage technology. In the future, it will be important to further advance research in the field of storage technologies. One focus should be on the storage simulation and the optimization of operation in different applications to improve the commercialization of storage technologies [22]. One possibility would be for the state to provide larger subsidies for research into storage technologies. In addition, advertising campaigns for storage technologies should be considered. One could, for example, highlight the advantages of the various storage technologies at energy fairs, in TV commercials and on the Internet. In order to better integrate storage technologies into the energy network, it is crucial to increase public acceptance of these technologies. Interested parties should be aware of the extent to which they benefit from the installation of storage technologies and the subsequent connection to the power grid. The development of energy storage technologies is well under way, but in the future these technologies need to be further improved and promoted.

REFERENCES

[1] Vertretung in Deutschland, “Politische Einigung: Strommärkte werden Energiefluss besser steuern“, https://ec.europa.eu/germany/news/20181219-politische-einigung-strommaerkte_de (03/26/2019 16:30)

[2] European Commission, „Energy Storage – Proposed policy principles and definition”, https://ec.europa.eu/energy/sites/ener/files/documents/Proposed%20definition%20and%20principles%20for%20energy%20storage.pdf (03/26/2019 16:32)

[3] M. Sterner, I. Stadler, “Energiespeicher- Bedarf, Technologien, Integration” Springer (2014)

[4] M. Aneke, M. Wang, “ Energy storage technologies and real life applications – A state of the art review” Applied energy 179 (2016) 350-377

[5] A. Azzuni, C. Breyer, “Energy security and energy storage technologies”Energy Procedia 155 (2018) 237-258

[6] IRENA, International Renewable Energy Agency, "Electricity storage and renewables: Costs and markets to 2030," International Renewable Energy Agency (IRENA), Abu Dhabi, United Arab Emirates2017, Available: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf

[7] Statista.de, “Wichtigste Pumpspeicherkraftwerke weltweit nach installierter Lesitung im Jahr 2018” https://de.statista.com/statistik/daten/studie/310305/umfrage/wichtigste-pumpspeicherkraftwerke-weltweit-nach-installierter-leistung/ (02/22/2019 14:21 pm)

[8] T. Economist, "Energy storage - Packing some power," https://www.economist.com/technology-quarterly/2012/03/03/packing-some-power (02/23/2019 13:00 pm)

[9] A. Abele, E. Elkind, J. Intrator, and B. Washom, "2020 strategic analysis of energy storage in California," University of California, Berkeley School of Law, University of California, Berkeley, California, USA, 2011.

[10] X. Luo, J. Wang, M. Dooner, and J. Clarke, "Overview of current development in electrical energy storage technologies and the application potential in power system operation," Applied Energy, vol. 137, no. Supplement C, pp. 511-536, 2015/01/01/ 2015.

[11] Vattenfall.com, “Goldisthal Pumped-storage Power Plant“ https://powerplants.vattenfall.com/goldisthal (03/17/2019 15:35)

[12] Bundesverband Energiespeicher,“Anwendungsbeispiel Pumspeicherwerk (PSW) Goldisthal“, https://www.bves.de/wp-content/uploads/2017/04/Pumpspeicherwek.pdf (03/17/2019 15:40)

[13] Voith, „Goldisthal, Germany“, http://www.voith.com/ca-en/markets-industries/hydro-power/pumped-storage-plants/goldisthal_main-9879-9879.html (03/17/2019 18:50)

[14] I. Sarbu and C. Sebarchievici, “A Comprehensive Review of Thermal Energy Storage”, Sustainability 2018, 10 (1), 191, pp. 1-32

[15] Hauer, A. Storage Technology Issues and Opportunities, International Low-Carbon Energy Technology Platform. In Proceedings of the Strategic and Cross-Cutting Workshop “Energy Storage—Issues and Opportunities”, Paris, France, 15 February 2011.

[16] Kumar, A.; Shukla, S.K. “A Review on Thermal Energy Storage Unit for Solar Thermal Power Plant Application”. Energy Procedia 2015, 74, 462–469.

[17] Reuss, M., “Solar District Heating in Germany – Findings and Prospects, Proceedings of the ISES Solar World Congress 2011”, 28 August – 2 September 2011, Kassel, Germany

[18] EOS: “NY BEST: Metal-Air Batteries” (2012);MIT Technology Review: “TR10 Liquid Battery”(2009); EASE: “European Energy Storage Technology Development Roadmap towards 2030” (2014); Joint Center for Energy Storage Research (JCESR)

[19] Tesla.com, “Tesla Powerpack to Enable Large Scale Sustainable Energy to South Australia” https://www.tesla.com/de_DE/blog/tesla-powerpack-enable-large-scale-sustainable-energy-south-australia?redirect=no (03/30/2019 14:50)

[20] H. L. Ferreira, R. Garde, G. Fulli. W. Kling, J. P. Lopes, “ Characterisation of electrical energy storage technologies” Energy 53 (2013) 288-298

[21] A. Slaughter, “ Electricity Storage Technologies, impacts, and prospects” Deloitte Center for Energy Solutions (2015)

[22] L. Yao, B. Yang, H. Cui, J. Zhuang, J. Ye and J. Xue, “Challenges and progresses of energy storage technologies and its application in power systems”, J. Mod. Power Syst. Clean Energy (2016), pp. 519-528

[23] J. Haas, F. Cebulla, W. Nowak, C. Rahmann and R. Palma-Behnke,“A multi-service approach for planning the optimal mix of energy storage technologies in a fully-renewable power supply”, Energy Conversion and Management 178 (2018), pp. 355-368

[24] http://www.spiegel.de/wirtschaft/unternehmen/autoindustrie-die-grosse-angst-vor-der-kobalt-knappheit-a-1181584.html (03/27/2019 17:40)

Is the Paris Agreement on the way to transnational climate protection?

George Caliskan
Business Administration and Engineering
BTU Cottbus-Senftenberg
Cottbus, Germany
George.Caliskan@b-tu.de

Ramzi Hassan Saeed Al-Shuga
Business Administration and Engineering
BTU Cottbus-Senftenberg
Cottbus, Germany
Ramzi.Saed@b-tu.de

Ahsam Ahmed
Business Administraion and Engineering
BTU Cottbus- Senftenberg
Cottbus, Germany
Ahsam.Ahmed@b-tu.de

***Abstract*—Climate change poses major challenges to all states, not only nationally but also globally. The Paris Convention attempts to reduce the damage caused. Due to the lack of liabilities, this is only possible to a limited extent.**

Keywords—Paris Agreement, greenhouse effect, green politic, greenhouse gas

I. INTRODUCTION

The Industrial Revolution, through its accelerated development in the fields of technology and science, is leading to serious and lasting changes in economic, social and demographic conditions. Furthermore, the transition from manual to mechanical activities, from manufactories to factories, from individual work to mass production, resulted in a significant increase in productivity. This resulted in various advantages, such as the ending of famines through the mechanization of agriculture [1]. Since then, a persistent improvement of the technologies has taken place, allowing processes to be further optimized. At the same time, humanity is becoming more and more dependent. The latter becomes problematic because the operation of the machines is guaranteed by the combustion of fossil fuels such as lignite, hard coal, natural gas, etc. This releases pollutant gases that increase the concentration of greenhouse gases in the Earth's atmosphere [2]. As a result, temperatures have risen by almost 1°C since pre-industrial times until 2017. To illustrate this, Figure 1 shows the increase in temperature from 1880 to 2020 and the increase in CO2 emissions from 1700 to 2000. The exponential rise in temperature and CO2 from 1950 onwards becomes clear [3]. What could initially be regarded as not serious has a considerable impact on life on Earth. Above all due to the fact that a further increase of 3 °C is expected in the next 100 years [4]. Among the consequences already observed today are [5]:

- Melting of ice caps leading to rising sea levels, flooding and erosion in coastal areas
- Spread of disease
- Increase in heat-related deaths
- Spread of disease
- Increasing poverty and famine in developing countries due to lack of adaption and changing environmental conditions
- species extinction of plant and animal species

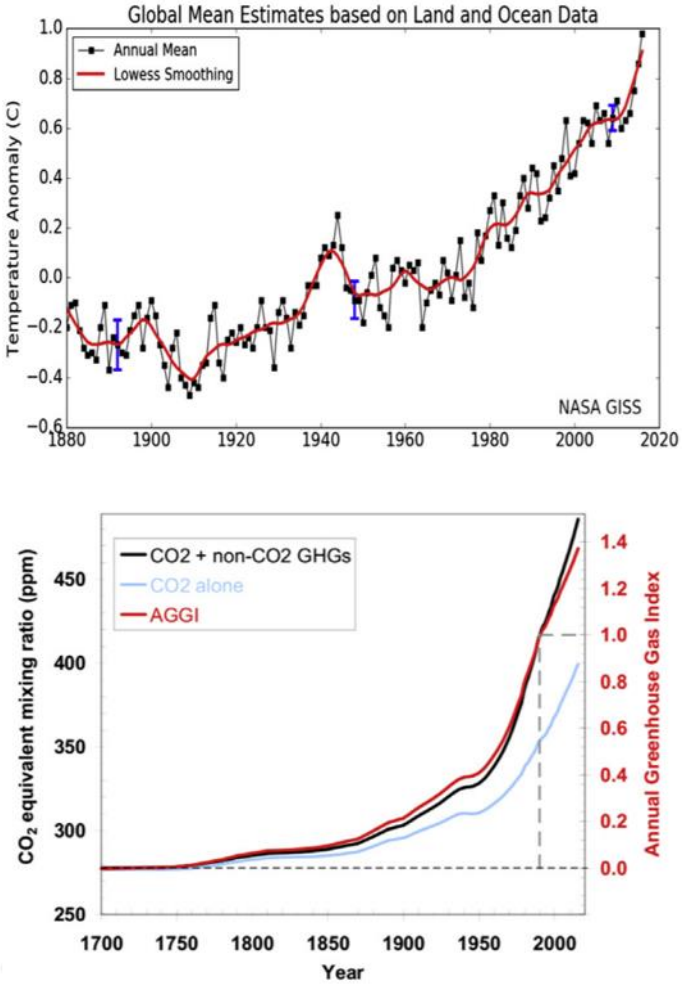


Figure 1: (top) global average air temperature (bottom) greenhouse gas index

II. Paris Agreement

In 2015, 195 states decided to take active action against climate change by adopting an agreement, the Paris Convention. It was the first global agreement in which all states committed themselves to mitigating climate change, but also to adapting to its effects. The agreement came into force after 55 of the parties responsible for at least 55% of global greenhouse gas emissions ratified it on 4 November 2016 [6]. As shown in the figure 2, China and the USA are already responsible for over 40% of global CO2 emissions. Therefore, it is of great importance that both countries participate in the agreement. The agreement has three primary objectives: On the one hand, the global average temperature is significantly below 2 °C compared to pre-industrial levels, but preferably 1,5 °C. The aim is to limit the effects of the temperature rise. The second objective is to help developing countries meet climate change objectives and adapt to climate change. To this end, the industrialized countries are to pool their financial resources and pay 100 billion dollars a year into a climate fund. This point is relevant precisely because of the developing countries' high dependence on the climate. The final objective is to increase adaptability to climate change. No national climate protection targets have been set within the agreement. It is up to each country itself to decide which climate protection targets it wants to achieve. All countries participate under a pledge and review mechanism with nationally determined contributions (NDCs). Pledge and review mean that countries should pledge their NDCs according to their best efforts to lower GHG emissions and after five years, each pledge by every country will be reviewed. Those NDCs should become higher and higher over time [7].

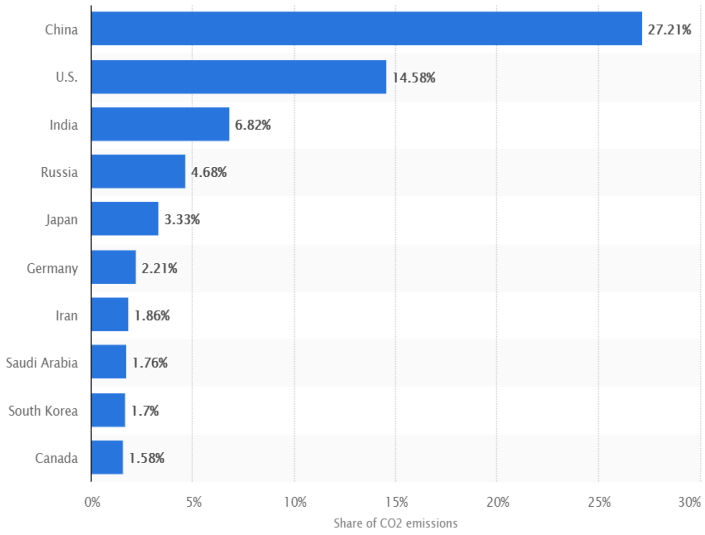


Figure 2: Share of CO_2 emissions

III. Problems of the Implementation

The difficulties encountered in implementing the Paris Agreement are examined in more detail below. For reasons of simplicity, however, this is limited to three main problems.

A. No comparability of the INDC´s

The first problem is that the INDC´s is not comparable and therefore the global goals are out of reach. Brazil can be used as an example. The government announced in 2009 to reduce its C02 emissions from 36.1% to 38.9%. Primarily this should be managed by limiting deforestation in the Amazon. In contrast, however, emissions from the energy and agricultural sectors rose. This example shows that although the announced targets have been met, emissions from other sectors have increased at the same time. This makes it clear that the national targets of the individual states are above global climate policy [8].

B. No sanctions

Another problem is that the agreement does not lay down sanctions for non-compliance with climate targets. It is therefore obvious that states should leave action to others and benefit from it. This problem is also known as freeriding [9]. This problem is particularly confirmed because climate change is a problem for the general public. All countries benefit from the reduction of greenhouse gases. If one state assumes 100% of the responsibility, all other states also profit from it. Moreover, the benefits of green policies will not be seen by current voters, but by their descendants in the coming decades. As a result, countries' emissions are still high and countries have little or no incentive to actively address them, which ultimately has a negative impact on the common good [10]. Nordhaus sees the reason for freeriding in the fact that states cannot be forced to join a global agreement. In addition, there is no international government that can impose sanctions [11].

C. Maintaining the Integrity of the Specifications

The last problem is the almost unconditional withdrawal from the agreement. This is governed by Article 28(1) of the Agreement, which provides that after a period of three years from the date on which the Convention has entered into force for the Contracting Party concerned, a written notification to the UN Secretary-General shall withdraw from the Convention. This resignation shall, however, only become legally valid in accordance with paragraph 2.

The USA announced on 1st June 2017 that it will withdraw form the Paris Agreement. However, the United States constitutionally adopted the agreement on 04 November 2016. Thus, according to Article 28, they can only withdraw

on 04 November 2019 after submitting the notification of withdrawal. However, the withdrawal will take effect at the earliest one year after receipt of the notification of withdrawal, i.e. on 4 November 2020. Until then, however, the USA remains a full member of the Paris Agreement with all its obligations. But they don´t have to worry about sanctions [12].

IV. Consequences of the resignation of the USA

The withdrawal of the USA from the Paris Climate agreement has consequences not only for America, but for the whole world. Climate researchers have found out, that the sea and air could warm up by 0.3 degrees if the USA does not curb greenhouse gas emissions. This would make heat waves more likely, sea levels rise, glaciers thaw and extreme weather conditions threaten. In addition, the withdrawal could also encourage other countries to withdraw from the agreement, which would ultimately accelerate the increase in average temperatures. Furthermore, this could lead to the problem of freeriding described above [13].

From a financial point of view, the withdrawal of the USA is fatal for climate protection projects. The USA invested around one billion dollars in such projects. Two to three billion dollars per year were planned to support poor countries in order to provide them with extreme weather protection on the one hand and low-emission energy technologies on the other. However, these payments would be cancelled completely as a result of the withdrawal. This would lead to significant setbacks in assistance to developing countries.

The withdrawal from the agreement is mainly justified by the resulting competitive disadvantages for the USA compared to China. As the agreement allows China to further increase its greenhouse gas emissions by 2030. At this point, as has already been shown with the example of Brazil, the prioritisation of national targets over global targets is discussed [14].

V. Conclusion

The current version of the Paris Agreement contains far too many shortcomings. As a result, the agreement is increasingly encountering problems in the implementation of transnational climate protection.

Due to the lack of agreed sanctions within the agreement, there is no incentive on the part of the states to pursue the climate goals with ambition. The alternative of doing nothing and instead profiting from the actions of other states (freeriding) is perceived by some states as a more attractive alternative. Above all in order to gain a competitive advantage over the competition, as could be shown with the help of the USA. In addition, the own national goals are above the global ones, which ultimately results in damage to the common good.

It can therefore be concluded that the Paris Agreement is not on the way to transnational climate protection.

To achieve this, cooperation between all states would be necessary. Especially those countries that are responsible for the largest share of CO2 emissions, in order to avoid freeriding. In addition, it would be necessary to formulate strict sanctions for non-compliance with the targets. This would give every state an incentive to actually implement the targets that have been set.

VI. Reference

[1] Jürgen Mirow, “Geschichte des deutschen Volkes: Von den Anfängen bis zur Gegenwar”, Gernsbach, pp. 502-503,1996

[2] Edward Anthony Wrigley, “Energy and the English Industrial Revolution”,Cambridge University Press, p. 101, 2010

[3] Bela Torok and Timothy Dransfield, “Green Chemistry”, Elsevier Science & Technology, pp. 211-212, Nov. 2017

[4] https://www.bpb.de/gesellschaft/umwelt/klimawandel/183026/auswirkungen-des-klimawandels
12/04/2019; 08:23 pm

[5] https://ec.europa.eu/clima/change/consequences_de
12/04/2019; 08:24 pm

[6] https://unfccc.int/process/the-paris-agreement/status-of-ratification
12/04/2019; 08:24 pm

[7] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
12/04/2019; 08:26 pm

[8] https://www.giga-hamburg.de/de/system/files/publications/gf_global_1501.pdf
12/04/2019; 08:26 pm

[9] Cooper, R. N., “The Case for Pricing Greenhouse Gas Emissions. In: Global Carbon Pricing: The Path to Climate Cooperation”, Cambridge, London: The MIT Press, p. 3, 2017

[10] Gollier, C., Tirole, J., “Effective Institutions against Climate Change. In: Global Carbon Pricing: The Path to Climate Cooperation”, Cambridge, London: The MIT Press, pp. 166-167, 2017

[11] Nordhaus, William., “Climate Clubs and Carbon Pricing. In: Global Carbon Pricing: The Path to Climate Cooperation”, Cambridge, London: The MIT Press, pp. 112-113; 2017

[12] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
12/04/2019; 08:26 pm

[13] Zhang Hai-Bin, Dai Han-Cheng, Bua-Xia Lai, Wang Wen-Tao, “U.S. withdrawal from the Paris Agreement: Reasons, impacts, and China´s response“, 2017

[14] Alex Bohanowski, “Was der Ausstieg der USA für die Welt bedeutet”, 2017

VII. Figures

[1] Bela Torok and Timothy Dransfield, “Green Chemistry”, Elsevier Science & Technology, pp. 211-212, Nov. 2017

[2] https://www.statista.com/statistics/271748/the-largest-emitters-of-co2-in-the-world/
12/04/2019; 08:25 pm

German and Indonesian Policy on Renewable Energy

Novendhi Reiner Maturbongs

Chair of Energy Distribution and High Voltage Engineering

Brandenburg University of Technology

Cottbus, Germany

maturnov@b-tu.de

***Abstract*—Germany and Indonesia have distinct characteristics in terms of electricity consumption and generation. Apart from their social and geographical differences, government regulations are also playing a key role on deciding which type of energy source they used to fulfill the electricity demand. This paper provides a brief comparison between each energy mix, energy market, renewable energy policy facts and some challenges they face on fulfilling the electricity demand.**

Keywords—Germany, Indonesia, electricity, renewable energy, policy

I. INTRODUCTION

Indonesia is an archipelagic country with more than 255 million citizens, 17.000 islands and located in south east Asia. Lying along the equator, Indonesia's climate tends to be relatively even year-round and it has a wet and a dry season. Germany is situated in central Europe with more than 82 million citizens and has 4 seasons along the year. Based on these characteristics, Indonesian and German have their own behavior on energy consumption. The following example will show the comparison in the household sector.

In 2017, German households consume electricity more than 129 TWh. The room heating utilizes for around two thirds of the energy consumption, while the other one third is used to produce hot water and to power the domestic appliances. [1]. Meanwhile in Indonesian household sector final energy consumption is almost 383 million BOE in 2017. More than 48% is fulfilled with electricity and the rest with gas and kerosene [2]. Based on survey results showed that about 53% of electricity was used for cooking, 17% for cooling device, 10% for entertainment device, 5% for lighting and 16% for the other. The appliances categorized as “other” are washing machines, water pumps, irons and hair dryer. [3]

The present work is structured as follows: after presenting the comparison in energy mix in Chapter 2, the energy market for each country is introduced in Chapter 3. Following that, the renewable goal until 2050 and its challenges in Chapter 4 are provided and feed-in tariff implementation in each country in Chapter 5, and Chapter 6 concludes this work.

II. ENERGY MIX

Energy mix describes the combination of the various primary energy sources used to meet energy needs in a certain geographic region. It includes fossil fuels (oil, natural gas and coal), nuclear energy, non-renewable waste and many renewable energy sources (wood, biofuel, hydro, wind, solar, geothermal, heat from heat pumps, renewable waste and biogas). These primary energy sources are used, for example, for generating power, providing fuel for transportation, heating, and cooling residential and industrial buildings.

The energy mix composition for certain region or country depends on the availability of usable resources domestically or the possibility of importing them, the extent and type of energy needs to be met and policy choices determined by historical, economic, social, demographic, environmental and geopolitical factors. [4]

Germany in 2018 had more than 207 GW installed power plants capacity. These power plants generated 565.9 TWh of electricity and the power generation mix includes oil (0.8%), gas (12.8%), coal (12.8%), lignite (22.5%), nuclear (11.7%), renewables (35.2%) and other (4.3%). The renewables figure includes hydro, wind onshore and offshore, solar and biomass. The other energy source includes non-biogenic waste. [5]

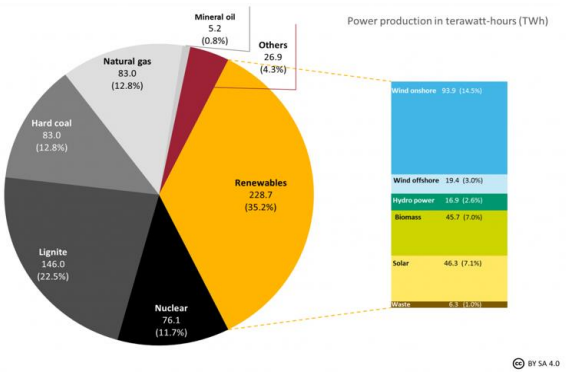


Figure 1: Share of energy sources in gross German power production in 2018 (source: AG Energiebilanzen 2018)

In 2017, Indonesia had approximately 60.7 GW of installed power plant capacity. These power plants generated 254.5 TWh of electricity in 2017. The current power generation

mix includes coal (57.22%), gas (24.82%), oil (5.81%) and renewables (12.15 %) as depicted in Figure 2. The other new and renewable energy include solar photovoltaic, bioenergy and wind. [6]

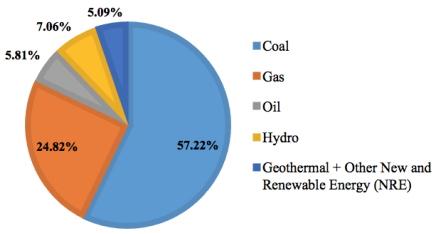


Figure 2: Indonesian Energy Mix 2017 (source: [6])

III. ELECTRICITY MARKET

Germany's domestic electricity market was fully liberalized in 1998 [7]. The transmission system operators (TSOs) keep control power available to maintain stable and reliable supply. Demand for control energy is created when the sum of power generated varies from the actual load (due to unforeseeable weather fluctuations in case of renewable energies). The distribution system operators (DSOs) are tasked to reliably and efficiently running medium to low-voltage distribution systems. DSOs transmit electricity to residential customers and small medium enterprises, as well as being responsible for public lighting, among other things.

Procurement takes place in a competitive tender bidding basis within the German control power market, in which a significant number of suppliers participate. Smaller suppliers are also able to participate in the calls for tender by a pooling process. Almost 90 percent of all power generating plants that capable of providing control energy are eligible to participate at the TSOs.

The German energy market is vertically integrated and supplied by – Amprion (formerly RWE), EnBW Transportnetze, TenneT TSO (formerly E.ON), and 50Hertz Transmission (formerly Vattenfall Europe). A single-price settlement scheme from the minimum of quarter-hour to the block hourly settlement periods are implemented in the four control areas supplied by the four main suppliers, with the European Energy Exchange (EEX) acting as a common point of reference for domestic electricity prices. More than one thousand market participants are active in the fully liberalized German electricity market, with new market actors – who do not own power plants or supplier networks - successfully entering the domestic electricity market. [8]

Figure 3 shows the simplified scheme of the German electricity market. Arrow direction indicates the flow of the energy, with blue color represents the high voltage grid managed by the TSO and the red color shows the low voltage grid managed by the DSO.

Being an archipelagic country, Indonesia's electricity supply is managed through a series of separate transmission & distribution (T&D) grids. There are over 600 isolated grids and eight major networks in total. The state-owned electricity company (PLN) currently has a de-facto monopoly on T&D asset ownership and operations although the private sector is

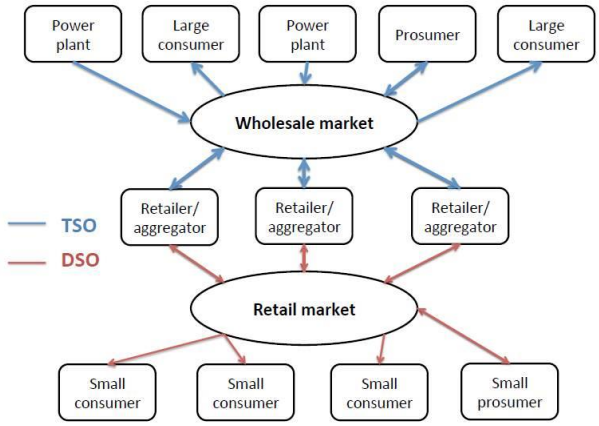


Figure 3: Simplified scheme of the energy market in German (source: www.incite-itn.eu)

legally permitted to build and operate T&D grids for their own purposes. Independent Power Producers (IPPs) build certain transmission lines, particularly for power plants in remote areas, in order to connect the power plants to the closest PLN substations. However, ownership of these transmission lines will typically be transferred to PLN upon the completion of construction.

Some private participation has gradually revealed in Indonesia's electricity generation sector. Prior to 1985, the power sector was entirely government-led, under the direction of the PLN. In 1985, the Government issued a law, which allows the participation of the private sector in electricity generation for its own use and to sell to PLN. The law intended to permit limited participation in electricity generation. Essentially, the law allows the private sectors (IPPs) to supply electricity in Indonesia, which previously was exclusive to PLN. These IPPs were licensed to sell their electricity solely to PLN in accordance with Power Purchase Agreements (PPAs). A PPA is a contract for the sale of energy, availability and other generation services from an IPP. It is normally developed between the owners of private power plants and the electricity buyer, in this case PLN. (see Figure 4).

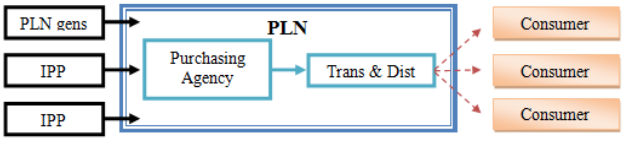


Figure 4: Simplified scheme of the energy market as implemented in Indonesia (source: [9])

Private investments in the form of IPP have helped in reducing the risk of power shortages. The absence of a competitive mechanism to coordinate IPP and PLN generation means that the introduction of IPP generators only represents a modest step towards the wholesale competition. Basically, the timing, capacity and fuel supply choice of new generation investments, as well as the day-to-day dispatch of plant, are determined internally by PLN [9].

IV. Renewable Policy, Goals and Challenges

In 2010, Germany's long-term goals were for the first time defined for the share of renewable energy in the consumption of electricity and in the overall final energy consumption [10]. After the Fukushima nuclear disaster in 2011, the German government rebuilt the plan for the nuclear phase-out. This transformation of the energy system became known as the *Energiewende*. The core of the concept is to transform from fossil and nuclear energy generation towards the development of an energy system that by the year 2050 is to be virtually greenhouse gas (GHG)-free and based on renewable energy sources (RES). To be more exact on renewable energy plan by increasing the share of renewables for electricity generation to at least 38% in 2020, 50% in 2030, 67% in 2040, and 80% in 2050, and the share of renewables in final energy consumption to at least 30% by 2030 and at least 60% by 2050. [11]

One of the challenges that the German government faces is that a large quantity of electricity produced by wind turbines are mostly located in the north and east of Germany as well as on the sea. However, the main electricity consumers, e.g. large industries, are situated in the south of the country and the existing grid is designed on an east-west axis. [12]. Moreover, the electricity generated by renewable energies fluctuates according on the weather. In order to balance the fluctuation, distribution grids must be digitalized and upgraded to a so-called "smart grid". In smart grid, the electricity communication is interconnected between customer, utilities, transportation, storage, distribution and with smart metering so that the electricity generation and consumption could be coordinated efficiently and well-adjusted on short notice [13]. For these reasons, the German government planned to invest a new grid system and infrastructure.

In October 2014, the Government of Indonesia authorized regulation on the National Energy Policy (NEP). This policy would reduce gasoline dependency, increase the use of renewable energy and contribute to cut the GHG emissions. NEP sets a clear target of the share of each type of primary energy from the year 2025 up to the year 2050 and for the share of new and renewable energy is to be at least 23% in 2025 and at least 31% in 2050, as long as the economics conditions comply.

In many parts of Indonesia, the generation capacity struggles to keep up with the electricity demand. Figure 5 shows the detail information on electrification rate across Indonesian region. From this information, it could be known that blackouts remain common across Sumatera, Kalimantan, Sulawesi and eastern part of Indonesia. This is one of the reasons for development in Indonesia's power infrastructure. Since 2015, Indonesian government has an ambitious plan to deploy 35 GW of new generation capacity by 2019 to overcome the electricity shortage across the nation and to stimulate industrial and regional growth [14].

The 35 GW program dramatically reduces both demand forecasts and planned capacity targets. In terms of technology, these changes have been applied across-the-board with both large thermal coal- and gas-fired plants being dropped or postponed and also reduction in the share of renewables. However, the program has been officially delayed until 2024 due to economic reasons, which are pressure on the Rupiah and import restriction. [6]

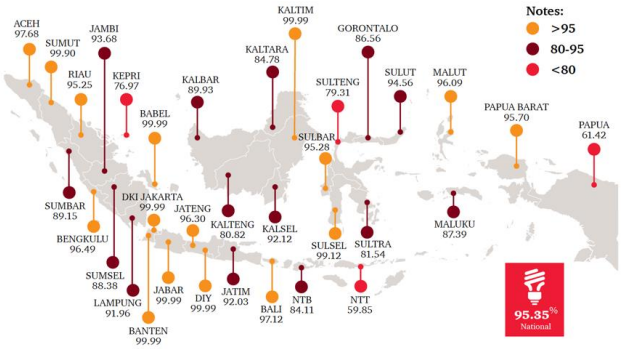


Figure 5: Electrification Rates in Indonesian Provinces (in %) (Source: 2017 Performance Report of MoEMR)

V. Feed-in Tariff

The Feed-in tariff (FiT) is one of the recommendations for entry level and intermediate level countries aiming to increasing the share of RE. The reasons are its high replicability and effectiveness in creating the market with attractive tariff for each electricity generated from renewable technologies. FiT combines three main things, namely long-term contract, guaranteed access to the grid network, and agreed electricity purchase prices. It is the one of the most implemented mechanism in the world. [15]. The RES that are supported with FiT are wind power, solar photovoltaics, biomass, hydropower, and geothermal.

Germany's FiT is reflected in its renewable energy act. Based on the latest amendment in 2017, small RES plants up to 100 kW are eligible for feed-in tariff. The eligibility is coupled to the obligation of the plant operator to feed the electricity into the grid in the months for which the operator raises the claim of receiving the financial support. Regardless of the size, all plants are eligible in exceptional cases for a feed-in tariff reduced by 20%, but no longer than three consecutive months and no more than six months within a calendar year. In this case, the exceptional reduction would be that the RES plant capacity more than 100 kW and sold under FiT.

The amount of the FiT is defined by law and varies according to the technology specificities. For example in geothermal energy source, the specified tariff would be €ct 25.2 per kWh minus the reduction of €ct 0.2 per kWh.

The tariff payment period is eligible 20 years from the day of commissioning. For plants receiving a FiT, the period may be expanded until 31 December of the 20th year. [16]

Meanwhile in Indonesia, FiT is introduced in 2013 for RES from solar energy and the latest amendment from the Ministry of Energy and Mineral Resources (MoEMR) in 2017 regulates a new mechanism to determine the tariff of renewable energy generation including solar, wind, hydropower, geothermal, biogas, biomass, waste and ocean energy.

The amount of FiT is determined through negotiations between IPPs and PLN by benchmarking against regional average electricity generation cost (BPP) in the region where the project is installed. The regional BPP value varies based on the region, from the lowest US$ct 6.81 per kWh mostly in Java-Bali region to the highest US$ct 20 per kWh in the eastern region.

The new regulation represents a move back to PLN having control over the tariff negotiations through B2B arrangements. Moreover, instead of evaluating the tariff through the marginal economic value of the project investment, the regional BPP becomes the main benchmark for the tariff. For example in solar, wind, biomass, biogas and ocean energy if the Regional BPP exceeds the National BPP then the maximum benchmark tariffs are 85% of Regional BPP. B2B tariffs will be used in the event that the Regional BPP is less than or equal to National BPP [6].

VI. Conclusion

In the present study, the comparison between German and Indonesian power system and infrastructure through energy mix, electricy market, policy regarding renewable energy and some challenges they still struggle with has been brought.

As the comparison discussed, the German electricity system and infrastructure are beyond advance compared to Indonesian, where Indonesian electricity system still struggles on the fulfillment of its national energy demand. Germany has already succeed in fulfilling its energy demand with an unique combination of energy mix. They even strives to achieve 80% dependence on the renewable energy source electricity generation by 2050 through a constant technology advancement of electricity generation from renewable energy sources and also includes the electricity infrastructure. Meanwhile, Indonesia aims at minimum 31% reliance on electricity generation from renewable energy sources by 2050 with a note for the economic condition adjustment. Considering that Indonesia is an archipelago and in many area it still need to invest on its electricity infrastructure and power generator so that the utility could reliably meet the electricity demand and prevent the blackouts. There is also a distinction in the electricity market where Indonesia's electricity market is a monopoly market while Germany's is a fully liberalised one.

The similarities is that both countries have awareness on the environtment by changing its own policy, set a long term goals to minimize the use of conventional power plant and increase the share of power generation from renewable energy sources. Moreover, feed-in tariff are introduced with some adjustment following the specific condition in each country.

Finally, political condition in each country also play a key role on deciding its national guiding line to set the general policy and goal on its energy mix, stimulation of renewable energy technology growth and also the awareness to contribute on reducing the effect of the climate change.

References

[1] Deutsche Energie-Agentur, [Online]. Available: https://www.dena.de/en/topics-projects/energy-efficiency/private-households/. [Accessed 4 March 2019]

[2] Ministry of Energy and Mineral Ressources Republic of Indonesia, Handbook of Energy and Economic Statistics of Indonesia, Jakarta: Head of Center for Data and Information Technology on Energy and Mineral Resources, 2018.

[3] H. Matsumoto, R. Kimura, L. Susanti, I. Sukarno,, "Residential energy consumption in a local city of Indonesia," 2013.

[4] Planete Energies, [Online]. Available: https://www.planete-energies.com/en/medias/close/about-energy-mix. [Accessed 4 March 2019].

[5] Clean Energy wire, December 2018. [Online]. Available: https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts. [Accessed 4 March 2019].

[6] PwC, Power in Indonesia : Investment and Taxation Guide, 2018.

[7] "German Energy Industry Act," 1998.

[8] German Trade and Invest, [Online]. Available: https://www.gtai.de/GTAI/Navigation/EN/invest,t=the-german-electricity-market--a-brief-overview,did=622868.html. [Accessed 2 March 2019].

[9] D. Setyawan, "Assessing The Current Indonesia's Electricity Market Arrangements and The Opportunities to Reform," 2014.

[10] German Federal Ministry for Economic Affairs and Energy (BMWi), "Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply," 2010.

[11] C. Gerbaulet, C. Kemfert, C. Lorenz, P-Y. Oei, C. von Hirschhausen, Energiewende "Made in Germany", Springer, 2018.

[12] Planete Energies, [Online]. Available: https://www.planete-energies.com/en/medias/close/challenges-facing-energiewende. [Accessed 6 March 2019].

[13] Federal Ministry for Economic Affair and Energy (BMWi), [Online]. Available: https://www.bmwi.de/Redaktion/EN/Artikel/Energy/smart-grids.html. [Accessed 8 March 2019].

[14] President of Indonesian Republic, [Online]. Available: http://www.presidenri.go.id/program-prioritas-2/tiga-sasaran-program-listrik-35-000-megawatt.html. [Accessed 3 March 2019].

[15] R. Ferroukhi, "Renewable energy tariff based mechanism," IRENA, 2012.

[16] "German Renewable Energy Source Act," 2017.

Possibilities and perspectives of diagnosis and condition monitoring of power transformers and switchgear assemblies

Harald Jendrian
Chair of Energy Distribution and High-Voltage Engineering
Brandenburg University of Technology
Cottbus – Senftenberg BTU CS
Cottbus, Germany
harald.jendrian@b-tu.de

***Abstract*—The main motivation to deploy a monitoring system and apply diagnosis techniques is the intention of asset owners to operate their equipment secure and economical reasonable. The following paper introduces the status quo of recent concepts, devices, measuring and testing techniques of high-voltage products with an emphasis on power transformers. It explains the main differences of monitoring devices and diagnosis techniques. Furthermore, the recent testing techniques are mentioned in order to determine a power transformer's condition. At the end a scenario tube states four possible scenarios in which the role of condition monitoring and diagnosis may lead to in the future.**

Keywords—high-voltage engineering, diagnoses, condition monitoring, power transformers, switchgear, scenario technique, power system operation

I. Introduction

By law the Transmission and Distribution system operators are forced to operate their grid infrastructure secure, reliable and with an economical concern. But also, other asset owners such as, power plants, can be considered as a critical infrastructure.

Within those power assets, those transformers are commonly the most expensive devices and of high importance. Especially at spots of heavy industries and small and medium-sized factories, often there is no redundancy. A secure power supply is therefore directly related to the supplying transformer's condition [4].

Asset owners started to deploy protection and monitoring devices to get an idea of the condition of the transformer before a failure may occur to avoid a longer outage [4].

For the time being, the asset owners using information of condition monitoring measurements to effect smarter investment decisions. Therefore, those research and developments are driven more likely as a market-pull rather than a technology-push.

In this paper, the recent monitoring devices and diagnosis techniques are considered. Furthermore, it gives also a strategic outlook where those concepts may lead to.

II. Asset Management

Over the years, the owners of power assets and grid infrastructure have been elaborated strategies to develop and commission projects (e.g. transmission lines or substations), as well as maintenance activities to follow their target providing energy sufficiently and reliable.

Therefore, methods and strategies are to be considered in order to plan, operate and modernize such assets. Following the DIN EN 13306, the maintenance activities can be distinguished into [5]:

1. Preventive maintenance
1.1. Time-based maintenance
1.2. Condition-based maintenance
1.3. Predictive maintenance
2. Corrective maintenance
2.1. Deferred corrective maintenance
2.2. Immediate corrective maintenance

Using robust methods of monitoring, a more sophisticated procedure of condition-based maintenance can be established [2]. Moreover, with further diagnosis techniques this may lead to an overall predictive maintenance, respectively.

III. Diagnosis and Monitoring

All the efforts of measuring and testing techniques and diagnosis can lead to a reliable statement of the overall steady-state condition of e.g. synchronous generators, power cables or transformers [1],[4],[5].

Another reason is to stack historic data over the lifetime of the device is to relay on a *data base* for fault detection and troubleshooting [1], [4].

The following Figure 1 shows the state-of-the-art transformer monitoring and diagnosis in a hierarchical manner.

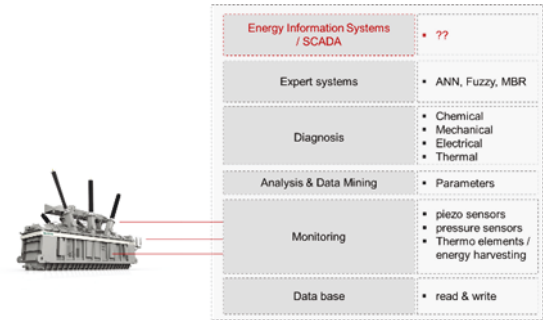


Figure 1 State-of-the-art transformer monitoring and diagnosis

Monitoring means all the devices with direct function to measure necessary data to evaluate a steady-state condition. Hereby, all the sensors are considered either installed or deployed temporarily. Therefore, you can distinguish between [1],[4],[5]:

- Online monitoring, that provides signals and data while a device is energized.
- Offline monitoring, that provides signals and data while a device is de-energized.

In addition, other computer-aided functions as visualization with an interface or comparison between live and historic data can be considered within the monitoring system [1].

By means of *Analysis & Data Mining* other operation-related parameters can be calculated to estimate the steady-state condition of a device and therefore, is able to draw conclusions about a secure operation [1].

Diagnosis is understood as the automated interpretation of signals, data and corresponding parameters which allows a concreate evaluation of the steady-state condition of a certain device or an electric power system as such [1],[4].

Moreover, so-called *Expert Systems* will be developed that uses clustering, artificial neuronal networks or deep learning methods to identify certain pattern which might cause damage or lead to a failure [1]. Those expert systems are the main resources to accomplish a robust monitoring and diagnosis system in a complex data base.

That derived information can be implemented in so-called higher decision and optimization methods within *SCADA* systems to increase the share of automation of electric power systems.

IV. Power Transformers and Switchgear Assemblies

When it comes to power transformers, monitoring and diagnosis provide benefits for the asset owner. On the one hand there are cost-saving benefits by shifting a time-based monitoring to a condition-based monitoring that reduces the frequency of equipment inspections and intervals. But it also implies strategic benefits in preventing greater damages [6],[2].

Important transformers might show either symptoms of overheating, evidence of excessive moisture or degradation of dielectric integrity of the overall insulation [6].

The transformer is one of the major devices within power grids and an electric machine of high importance. Therefore, protection devices were developed in an early stage. The *Buchholz relay* works not only for protection purposes but also states the transformer's condition [4]. Within oil-immersed tanks, those relays can detect internal defects e.g. short circuits between windings, due to gassing and oil flow [7],[8]. Because the fault might be far advanced to detect the needed gassing or oil flow, the Buchholz relay has its limits detecting failures in an early stage.

Another well-known monitoring procedure is a *dissolved gas-in-oil-analysis* by taking probes of oil regularly, you can draw conclusions of the transformer's condition evaluating certain key gases inside the oil. Gases typically found in insulating liquids under fault conditions are e.g. Nitrogen, Hydrogen, Carbon dioxide and Methane [6],[4].

In terms of a power transformer's operation the temperature is a well-known indicator and of great practical importance [4]. In order to have a good overview of the temperature, it is mainly used to measure the *upper coil temperature* using resistance temperature detectors and the *temperature inside of the limb assemblies* such as the transformer windings. For the time being, these so-called hot spots cannot be measured directly but having current transformers installed, from which a temperature can be derived. According to IEC 60076-7 standard, a sophisticated *thermal model of the transformer* can be established using those measured temperatures. This model involves e.g. the copper losses and iron losses as heat sources, the ambient temperature and thermal capacitances.[4],[9]

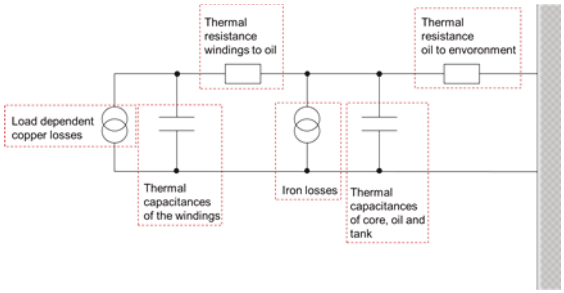


Figure 1 Thermal two-body model for a power transformer according to IEC 60076-7

As a result of the weight of the insulating oil and iron core material, the power transformer is associated with a relevantly high *heat capacity*

$$C = \frac{Q}{\Delta\vartheta} \tag{1}$$

which results to *thermal time constants* in the range of hours of power transformers for transmission purposes [4],[6].

Usually, the transformer is operated up to 120°C at its hot spots for common material but can be operated for an overload with 1,5 times the nominal current for a maximum duration of 30 minutes but may not exceed 140°C in total. Transformers which reach those temperatures are considered to *accelerated aging* [4].

In comparison to those *chemical* and *thermal measuring techniques*, there are standard *electrical and dielectric testing techniques* which are commonly used to estimate the steady-state condition of a transformer, but only be applied when the advice is de-energized. The main techniques are the following [2],[4],[10]:

- Measuring impedance
- Measuring insulation
- Measuring loss factor
- Measuring transformer ratio
- Measuring frequency response
- Measuring short-circuit impedance
- Measuring partial discharges
- Measuring polarisation and depolarisation currents
- Measuring recovery voltages

For now, these electrical measuring and testing techniques are to be deployed while the testing device is de-

energized and therefore is considered as off-line monitoring. When increasing the share of automation in future power grids, a selection of those methods needs to be implemented while the transformer is energized.

Furthermore, there are other techniques available to determine the *oil pressure*, to monitor the *on-load tab changer* and *transformer bushings* [2],[4].

When it comes to substations and switchgear assemblies monitoring devices and diagnosis techniques are not applied on a regular case. One reason for that, is the layout of air-insulated substations. At spots of high importance, those assets are designed with multiply busbar arrangements and couplings as well as sectionalisation to provide a variety of switching options [8],[9]. When a failure may occur, those assets remain on operation but only partly de-energized e.g. busbar section A can carry the load of busbar section B.

Although there exist monitoring devices for gas-insulated switchgear e.g. for *SF_6-Leakage* or *Circuit Breaker's auxiliary engine*.

The role of monitoring and diagnosis can become more important in low and medium-voltage application, since there is usually no such redundancy as in high-voltage grids. When increasing the share of decentralized energy systems especially in those lower voltage levels, the operators need to know live data about the condition of those power assets in order to secure a reliable energy supply under uncertainty and fluctuations, caused by renewable energies in-feed.

V. SCENARIO TECHNIQUE

The scenario technique is mainly used for strategic planning e.g. research activities and product developments. Following this procedure, it serves the willingness to identify certain developments within an industry sector. Usually, the scenario technique is done by several steps [11],[12]:

- Collect data and information
- Identify possible disturbances that effects future scenarios
- Elaborate correlations and label future scenarios

The main idea is to overview the possible scope rather than to forecast the exact future. At the end, this procedure may lead to a scenario tube to state the expectations, respectively [11].

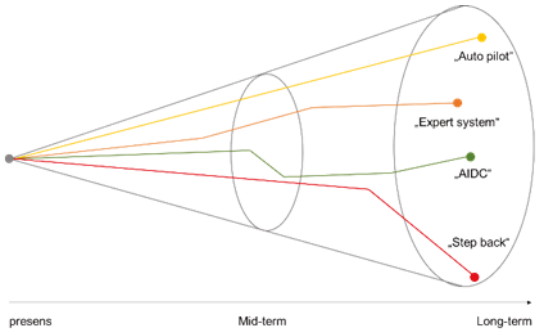


Figure 3 Scenario tube

According to the energy transition in Germany, the recent developments may lead to the following scenarios:

The *Asset investment decision criteria (AIDC)* summarizes the efforts using monitoring and diagnosis to lower maintenance costs and improve CAPEX and OPEX investment decisions.

Furthermore, the scenario *Expert system* headlines the capability to operate power assets with uncertainty in supply and demand of electric power with the usage of Big Data approaches. Here, we can expect to operate decentralized islands and several balancing regions using SCADA systems.

By means of an *Auto pilot* a fully-integrated energy system can be understood. Therefore, we expect a decoupling of supply and demand while the power system operates as well as the energy trading runs automatically having e.g. artificial neuronal networks in use.

Having also a pessimistic scenario, a *Step back* might be possible, if a major problem or malfunction occur e.g. war, cybercrime or human incompatibility with higher radiation exposure.

VI. CONCLUSION

When it comes to power transformers, an application of monitoring devices and diagnosis techniques seams to be of high importance. It also shows several benefits lowering costs to operate such assets. When increasing the share of decentralised energy systems up to 80%, data in real time is necessary. Therefore, monitoring devices and diagnosis techniques have potential to increase the share of automation within power grids and contributes further technology to fulfil the energy transition to obtain a non-CO2-based energy system. Several scenarios can be elaborated which results in further research and development portfolios.

VII. REFERENCES

[1] Muhr, M.; Pack, S.; Schwarz, R.; Körbler, B.; „Monitoring und Diagnostik in der Hochspannungstechnik", e&i elektrotechnik und informationstechnik, 2002

[2] Gockenbach, E.; Borsi, H.; „Aktueller Stand der Monitoring – und Diagnoseverfahren für Leistungstransformatoren", e&i elektrotechnik und informationstechnik; 2007

[3] Kutzer, M.; Kornhuber, S.; „Werterhalt con Transformatoren: Auslegung – Diagnose – Wartung; e&i elektrotechnik und informationstechnik, 2014

[4] Küchler, A.; „Hochspannungstechnik: Grundlagen – Technologie – Anwendung; Springer"; 2009

[5] DIN EN 13306:2018-02; Instandhaltung – Begriffe der Instandhaltung; Dreisprachige Fassung; 2018

[6] Harlow, J.H.; Electric Power Transformer Engineering, 3rd edition, CRC Press

[7] ABB "Switchgear Manual", 12th edition, 2011

[8] Hosemann, G.; Elektrische Energietechnik; Band 3: Netze; Springer; 2000

[9] ABB Review "Transformer Special"; 2016

[10] Omicron Energy GmbH, „Diagnose von Leistungstransformatoren" 2018

[11] Mieke, C.; Nagel, M.; Methoden zum Innovationsmanagement; UVK; 2015

[12] Bongers, T.; Bewertung von Netzausbauplänen für das deutsche Übertragungsnetz mithilfe der Szenario-Technik; Dissertation; 2018

Optimistic vs. pessimistic view regarding the scarcity of oil

B. Sc. Maximilian Bernecker
Brandenburg University of Technology
Cottbus Senftenberg
Chair of Power Distribution and High Voltage Engenieering
Cottbus, Germany
maximilian-bernecker@gmx.de

Sander Philipp
Brandenburg University of Technology
Cottbus Senftenberg)
Chair of Power Distribution and High Voltage Engenieering
Cottbus, Germany
sandephi@b-tu.de

The following paper examines the issue of resource scarcity, in particular oil, from a pessimistic and optimistic point of view. Indicators are used for this purpose and arguments from both sides are compared and finally evaluated.

Keywords — scarcity, resources, oil, indicators

I. INTRODUCTION

At the beginning of the 1970s, there was a growing awareness that humans will not be able to access limited resources unlimitedly. This was triggered, among other things, by the report of the Club of Rome "Limits to Growth "[1]. One of the best-known theories of scarcity "the Peak of Oil" was published in 1956. On the one hand these theories reinforced the developing concerns and fears which are rooted in the problem that unlimited economic growth is confronted with only limited resources. On the other hand, there was the hypothesis that technical innovations can avert shortage situations through more effective use or extraction opportunities. The representatives of both sides were divided into two camps of pessimists and optimists. In the following, the availability of oil is assessed based on common indicators. Afterwards, the pessimistic and optimistic views and its most important representatives will be compared. Finally, a brief evaluation of the topic will be given.

II. SCARCITY AND INDICATORS

Table 1: comparison indicators, Source: own representation, [8], [10].

indicators	**resource: oil**			
	1980	***1990***	***2000***	***2010***
Stat. range in years	28	44	43	42
Average price in Dollar	***1980-89***	***1990-99***	***2000-09***	***2010-17***
	23,11	18,33	49,60	82,54

Different indicators are used to assess the availability/scarcity of a raw material. Table 1 shows the evaluation of the scarcity of oil reserves by the static range and the resource price. What is conspicuous here is the different statements of the respective indicators and thus also the possibility of interpreting the scarcity issue. For example, the static range assesses the availability situation of oil as constant over the last 30 years. Many possible interpretations impede the objective assessment of the raw material situation. In contrast, the price of resources has risen significantly. Under the simplified view of the formation of the price through supply and demand, this indicator allows the objective conclusion to be drawn that either availability decreases or deteriorates, or demand increases, or both.

III. OPTIMISTIC AND PESSIMISTIC VIEW

A. Pessimistic view

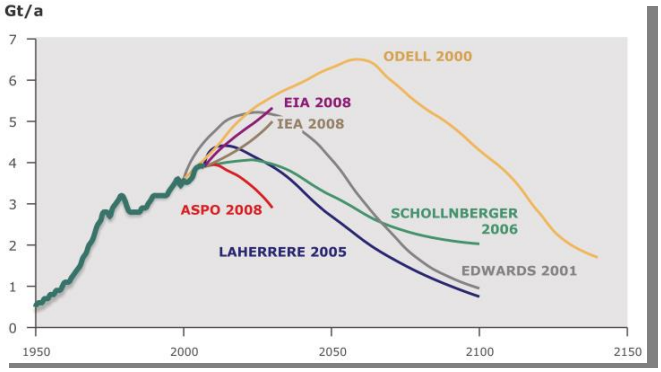


Figure 1: Forecasts oil production, Source: [8]

In 1956, the American geologist Marion King Hubbert published the peak oil theory which states that global oil production will first reach its maximum before declining inexorably and causing a collapse of the world's oil-dependent economy. Fig. 1 shows that most current forecasts correspond to the essence of the peak oil theory when viewed in isolation from the predictions of the time. Institutes such as the IWR Institute in Germany do not assume that the oil companies had correct reports on the actual oil reserves. The Institute also accuses oil-producing countries of secrecy in order to avoid harmful speculation. This leads to the conclusion that the process of oil decline is creeping and largely unnoticed by the public [2]. In addition to the effects on transport and the energy sector, the Institute criticises above all the burning of the imitated raw material instead of using it for the production of pharmaceuticals. As a result, medicines for future generations are already being destroyed today [2].

In addition to works such as "The Population Bomb" (1968) by Paul R. Ehrlich and "The Suicide Program" (1973) by Gordon Rattay Taylor, the work "The Limits to Growth" (1972) published by the Club of Rome stood out. This work attracted a great deal of public attention to the debate surrounding the use of resources and the authorship of Dennis Madlow. The key point of the report was that mankind was not only threatened by the nuclear threat of the time, but could also be transformed into a catastrophe by peaceful but uncontrolled growth [3]. The statements in the report were supported by a world simulation model created by a team from the Massachusetts Institute of Technology (MIT) [4]. The world model was built to investigate five major trends of global concern – accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a

deteriorating environment [5]. The main message is: “If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity [6].“ The growth pessimists assume that economic growth and environmental quality are in conflict with each other. One resulting demand is that the economy should be limited to "zero growth"

B. Optimistic view

The BP Group estimates the static range of oil in 2018 to be around 50 years [10]. In 1980 BP estimated the static range of oil at 40 years [10]. Accordingly, in the last 40 years more reserves have been tapped than used up. This is also where the main argumentation of the optimists comes in. One of the main representatives is Julian Simon. He wrote “The Ultimate Resource” in 1981. In it the theory is formulated that rising commodity prices leads to discovering more of the commodity, dealing with it more economically, and ultimately finding a substitute for it [7]. He concludes that novel technologies can stop scarcity of raw materials. Simon is completely convinced that any progress will improve people's lives.

Forecasts from the Club of Rome's "Limits to Growth" report have not materialized. One reason for this is that it considers the statistical range and not the dynamic range. Another reason why the forecasts have not been met is that the possibility of recovering non-energy resources has not been taken into account. In addition, the calculation of the static range for absolute scarcity is based on reserves, which are not, as is to be expected, continuously decreasing but may also increase as a result of new technological advances. Fig. 2 shows, that the reserves for oil have grown from less than one hundred billion tons in the 1970s to about 160 billion tons by 2007. This is due to new technological innovations such as modern exploration techniques including 3D and 4D seismic [9]. Another example of the increase in oil reserves is the extraction of oil from shale rock. The global reserves of shale oil are so extensive that it is estimated that they amount to 413 Gt worldwide. As a result, there has been an increase in reserves in recent years [7]. This assumption is supported by the view of the World Energy Council. They assume that the steadily increasing demand for energy can be met well into the 21st century [9]. In summary, the optimistic view is that the shortage of raw materials will be halted solely by ongoing technological development. In addition, not only are substitutes for certain raw materials being researched, but new mining and production methods are being developed to make the extraction of raw materials more efficient. Progress also leads to new sources of supply being researched and made accessible.

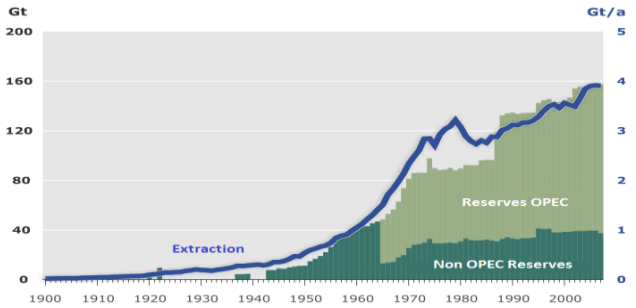


Figure 2: Development of reserves and extraction

IV. Conclusion

The development of oil reserves over the last 40 years contradicts the pessimists' predictions of scarcity at that time. Unpredictable technological developments, as the optimists suspect, facilitate the economic exploration of unconventional deposits such as oil sands, deep sea or polar caps. In its Energy Outlook 2019, BP forecasts only a slight increase in oil demand, despite the anticipated increase in global energy demand by around one third by 2040 [12]. Around 85 % of the growth will be generated by renewable energies and natural gas. Efficiency increases in the transport sector and more economic oil substitutes will reduce the share of oil in the world's primary energy needs [12]. The question of when global oil production will peak due to a lack of reserves will be replaced by the question of when demand for oil will peak. It turns out that the optimists' criticism of the pessimists is gaining ground with regard to oil. Overall, it is assumed that oil and gas reserves will not be depleted for the 21. century [9]. The possibility that the pessimists in particular have triggered the change with their prognoses is beyond objective assessment. However, they should certainly have a share in it.

Reverences

[1] Klaus Mathis, “Nachhaltige Entwicklung und Generationengerechtigkeit”, Mohr Siebeck, 2017, pp. 91-92.

[2] www.iwr-institut.de/de/presse/presseinfos-energie-ressourcen, Date: 2.04.2019, 17:43

[3] http://1000dok.digitale-sammlungen.de/dok_0073_gwa.pdf Datum: 20. September 2011 um 19:55:04 Uhr CEST. © BSB München

[4] https://www.clubofrome.org/report/the-limits-to-growth/

[5] The Limits to Growth: A Report to The Club of Rome (1972) by Donella H. Meadows, Dennis l. Meadows, Jorgen Randers, William W. Behrens III Abstract established by Eduard Pestel

[6] Donella H. Meadows Dennis L. Meadows, “The limits to growth”, Universe Books, 1972, p. 23.

[7] Robert Levine, “Optimisten gegen Pessimisten“, Zeit Online, 2014

[8] Energierohstoffe 2009, Reserven, Resourcen, Verfügbarkeit, Federal Institute for Geosciences and Natural Resources, Hanover Germany 2009, pp. 32-45. , p 237.

[9] Manuel Frondel, Cristoph M. Schmidt, „Von der baldigen Erschöfpung der Rohstoffe und anderen Märchen“, Leibniz-Institut für Wirtschaftsforschung, Essen, 2007

[10] BP Statistical Review of World Energy, bp, 67. Edition 2018

[11] BP Statistical Review of the world oil industrie, 1980

[12] BP Energy Outlook, 2019 edition, p. 79.

Figures

Figure 1: Forecasts oil production, Energierohstoffe 2009, Reserven, Resourcen, Verfügbarkeit, Federal Institute for Geosciences and Natural Resources, Hanover Germany 2009, p. 237.

Figure 2: Development of reserves and extraction, Energierohstoffe 2009, Reserven, Resourcen, Verfügbarkeit, Federal Institute for Geosciences and Natural Resources, Hanover Germany 2009, p. 37.

Advantages and disadvantages of the usage of renewable power-plants

Alexander Hänicke
BTU Cottbus-Senftenberg

Cottbus, Germany
haeniale@b-tu.de

Torben Stender
BTU Cottbus-Senftenberg

Cottbus, Germany
stendtor@b-tu.de

Roderic Frantzheld
BTU Cottbus-Senftenberg

Cottbus, Germany
frantrod@b-tu.de

I. Introduction

During the last ten years the German power-grid structure gets suspect of a constant change. The main crucial factor for the constant change of the power-gird is the increasing usage of the renewable energy sources. In addition to the commercial use of energy sources the implementation of photovoltaic systems in the private sector increases too. This change causes a different requirement profile for the existing power-plants. The usage of the renewable energy sources is one key factor for achieving the CO_2-goals, reducing the coal-consumption and elimination of the nuclear power-plants. Until 2018 the average percentage of renewable for the time range of one year increased to 40 percent. The most common used renewables are wind-power, photovoltaic-systems and biomass. To ensure the basic power level the most used power supplies in Germany are coal power-plants, nuclear power-plants and gas power-plants. The following article should give an basic overview over the change of the structure in the German power-grid regarding the history and actual data.

II. Fossile Power-Plants

A. Development of Fossile Power-Plants

At the end of the 19th century the first conventional power-plants were built. The main power source was fossil coal as hard- or soft coal. In Germany the most coal-power plants are running on soft coal, due to geological source of soft coal in Germany. Till 2005 81 percent of the energy demand was covered by fossil energy. The percentage of fossil energy sources fell form 84 percent in 1990 to round about 50 percent in 2018. This trend is effected by the extension of renewable energy sources.

B. Fossle Power-Plants today

The general composition of the fossil power-plants consist of 81 percent coal power-plants and 19 percent gas power-plants. The fossil power plants are covering 45 percent of the total energy demand. Because of the constant operating costs and the permanent availability the soft coal power-plants are the most used power sources for the basic load at the power supply system.

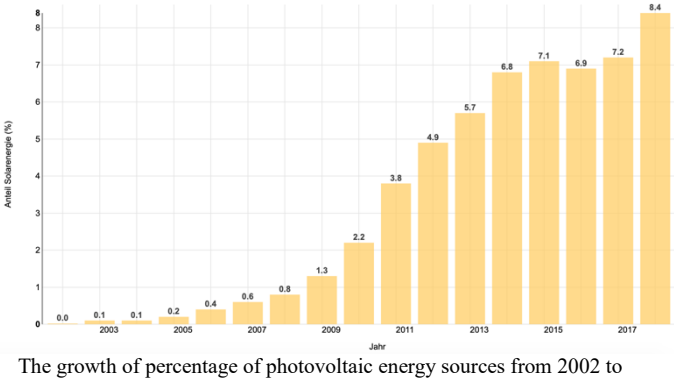
C. Problems/ Future Requirements

On the downside of the coal power-plants is the big amount of environmental pollution effected by running them. .In addition to the pollution by running the power-plants, the influence on the environment while extracting the fuel should not be disregarded.

III. Photovoltaic Power-Plants

A. Historic Development of Photovoltaic in Germany

In 1954 the first solar system was introduced. The whole system had size of two by two centimeters and an efficiency of 6% due to technical limitations. The further development of the photovoltaic systems started twenty years later in 1974. This development was triggered by the oil crises. The use of grid-connected photovoltaic systems at private households started in 1980's in the USA. Six years later, triggered by the Chernobyl accident, the use of photovoltaic systems increases in Germany. The biggest "boom" of photovoltaic systems took place in 2004. Until 2015 an photovoltaic-power of 227 GW was installed. In 2018 the percentage of generated power from photovoltaic systems was in average 8% of the whole energy generation.

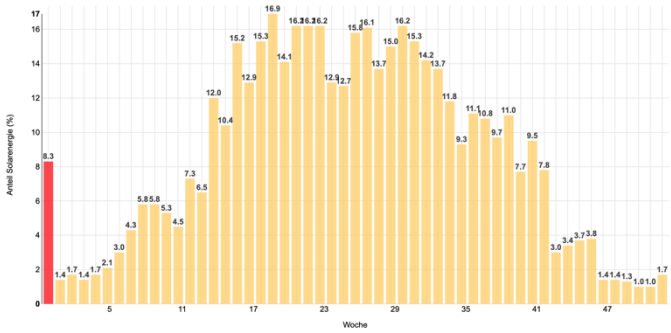


The growth of percentage of photovoltaic energy sources from 2002 to 2018 [1]

This bar chart shows the growth of the percentage of photovoltaic energy sources.

B. Usage of Photovoltaic today

The further development of photovoltaic systems is triggered by the availability of fossil energy sources and by aim to achieve the CO_2 goals. One of the biggest problems by using the renewable energy source the photovoltaic system is the reliability. The maximum power-output is strongly connected to the season, place of installation and the weather conditions. These factors are leading to a fluctuating power-output. At peak-periods, in the time range form end of April to end of June, the percentage of photovoltaic generated energy could rise up to an maximum of 17 percent. In off-peak seasons like December the percentage could fell down to one percent of the total energy generation. This characteristic shows the need of flexible and fast reacting technology which guarantees the basic load level at the power grid. The following bar chart shows the available portion of solar energy over the complete year 2018. This chart highlights the seasonal connection of the energy generation by photovoltaic power plants.

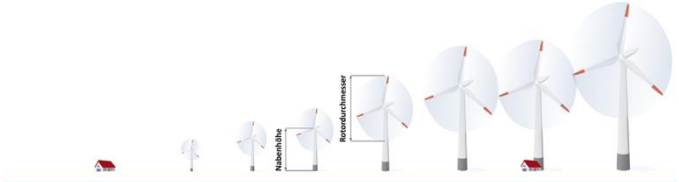


Seasonal connection of the energy generation by photovoltaic power plants [2]

IV. Wind Power-Plants

A. Historic Development of Wind Power in Germany

In the 1940's the first large-scale wind power-plants were build. The serial production of wind turbines was introduced in the 1950's. Since 1970 the development of the wind power-plants were pushed to gain independence from fossil power sources. In the 1990's the first wind parks with an total power output of 100MW were build. The wind turbines which are used today have an individual power output of 6 to 8 MW. The following illustration shows the design process of the wind turbines since 1980.



	1980	1985	1990	1995	2000	2005	2010
Nennleistung (in kW)	30	80	250	600	1.500	3.000	7.500
Rotordurchmesser (in m)	15	20	30	46	70	90	126
Überstrichene Rotorfläche (in m²)	177	314	707	1.662	3.848	6.362	12.469
Nabenhöhe (in m)	30	40	50	78	100	105	135
Jahresenergieertrag (in MWh)	35	95	400	1.250	3.500	6.900	ca. 20.000

The evolution of wind generators from 1980 to 2010 [3]

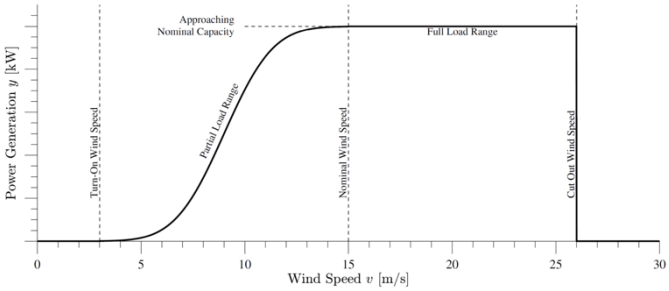
B. Usage of Wind Power today

The wind energy sector is divided by place of installation in on- and offshore wind power-plants. In 2018 the wind energy had an average percentage of 20 percent and a maximum percentage of nearly 30 percent of the total energy generation at peak-performance. The bigger part of the gained energy is generated in onshore wind power-plants. The following bar chart shows the growth of the percentage of photovoltaic energy sources from 2002 to 2018. At first sight it is recognizable that the percentage increases over the last 16 years form 3.2 percent to 20.4 percent.

The growth of percentage of wind power from 2002 to 2018 [4]

C. Problems

By using wind energy as energy source there are serval issues. For example the produced power form a wind turbine regarding the windspeed. The following line graph shows that the minimum wind speed at hub height to produce nominal power is 15 m/s which is a heavy breeze. So the full load range is limited to days with high windspeeds.



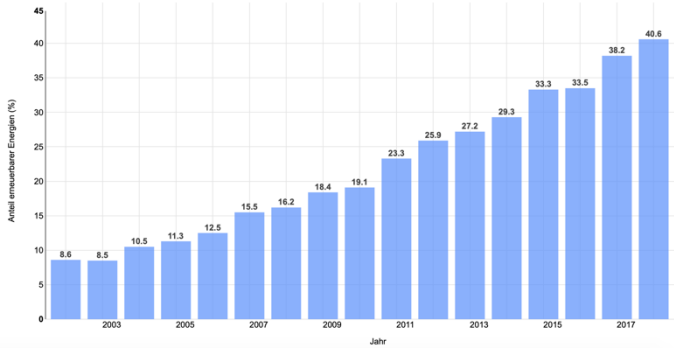
The performance of wind generators connected to the wind speed [5]

In addition the recycling of the wind turbine blades is a problem, because of the used materials. The wind turbine blades are constructed from glass-fiber reinforced plastic which is limited recyclable. The recycling takes place with a huge amount of energy input at a high cost level.
Another problem by using wind power plants is the reliability and the energy storage at peak-performance.

V. Conclusion

The usage of renewable energy sources gives the possibility of reducing the CO_2-emmissions, but it brings new challenges. For example the implementing forecast algorithms and controllability to make the take most use out

of renewable energy sources. Since 2018 the amount of renewable energy sources is capable of fulfilling the complete energy demand, if the weather conditions are right. The Following bar chart shows the growth of renewable energy sources in general.



The growth of percentage of renewable energy generation from 2002 to 2018 [6]

To make the most out of the renewable energy sources it has to be ab combination of fast reacting reliable fossil power-plants and the renewables. Other possible adaptations are building thermal storage solutions, improve the load management, replace old slow reacting coal power-plants by gas-steam power-plants. The gas-steam power-plants are capable of reacting to the fluctuation power output of the renewable power-plants and this guarantees the basic load level at the power grid.

[1] 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX (https://www.energy-charts.de/ren_share_de.htm?source=solar-share&period=annual&year=all)

[2] 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX (https://www.energy-charts.de/ren_share_de.htm?source=solar-share&period=weekly&year=2018)

[3] https://www.lubw.baden-wuerttemberg.de/erneuerbare-energien/

[4] 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX (https://www.energycharts.de/ren_share_de.htm?year=all&source=wind-share&period=annual)

[5] Janosch Henze „Von der Bestimmung zur Vorhersage: Wie sagt man den Netzzustand vorher?"

[6] 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX (https://www.energycharts.de/ren_share_de.htm?year=all&source=ren-share&period=annual)

[7] https://www.solaranlagen-portal.de/photovoltaiktechnik/photovoltaik-energie.html

[8] https://www.solarbranche.de/ausbau/deutschland

[9] Dr. Harry Wirth „Aktuelle Fakten zur Photovoltaik in Deutschland" (https://www.ise.fraunhofer.de/de/veroeffentlichungen/studien/aktuelle-fakten-zur-photovoltaik-in-deutschland.html)

[10] Umweltbundesamt „Daten und Fakten zu Braun und Steinkohle"

[11] https://www.windbranche.de/windenergie-ausbau/deutschland

[12] https://www.unendlich-viel-energie.de/erneuerbare-energie/wind/entwicklung-der-windenergietechnologie

[13] https://www.weltderphysik.de/gebiet/technik/energie/windenergie/ausbau-der-windkraft/

[14] https://www.umweltbundesamt.de/daten/energie/stromverbrauch

Clean Air by Siemens

Roy Steffen Werner Urban
Chair of Energy distribution and high voltage engineering
Brandenburg University of Technology Cottbus-Senftenberg
Cottbus, Germany
urbanroy@b-tu.de

***Abstract*—SF6 is the most used insulating and breaking medium in GIS applications at the high and medium voltage area. But because of its high global warming potential and the change of society for more environmental engagement some alternatives to SF6 were researched. While this researches some Materials came to be the best choice as an alternate for Schwefelhexafluorid. One of those is the clean air technologies which is in use by Siemens.**

The major benefits and disadvantages of the clean air technology as well as of some more best choice alternatives to SF6 will be shown and on the basis of this shall follow a conclusion about the functionality of clean air as a alternative to SF6.

***Index Terms*—Clean Air, Blue GIS, SF6 alternative, Siemens**

I. Introduction

SF6 is a wildly used material in the Gas Insulated Switchgear technology and we own much knowledge about its functionality and usage in Medium and High voltage switchgear since it is in use since the 1950s. It sadly also has a deep impact to the environment in term that it has a 23,500 times higher effect on the global warming than CO_2. [1]

Therefore SF6 is listed in the Kyoto Protocol and needs to needs to take a special focus to preserve the environment. To do so SF6 needs to be reduced, recovered and re-used. Right now there are several technics in use and in development to replace SF6 and with them reduce the usage of it. The most common alternatives used by ABB, GE and Siemens are vacuum circuit breaker with an insulation of Dry air up to 170kV as well as the use of g3. Whereat Siemens uses and develop the vacuum and dry air technologies and ABB and GE the g3 gasmixures. [2]

The Term clean air stands hereby for the usage of dry air as a gas-mixture of 20% O_2 and 80% N_2. With this mixture as insulation vacuum circuit breaker are in use for uo to 145 kV.

Technics like vacuum interrupter technology is already established since several decades and has proven itself up to 145 kV. Just in the last year Siemens enveloped a SF6-free GIS for 170 kV. The important advantages of vacuum circuit breaker and therefore the clean air technology is the high number of short-circuit current interruptions, of operations under lead conditions and the reliability as well as save solution. Siemens gathers all environment friendly vacuum and clean air switchgear in its ”blue” portfolio also called blue GIS. [3]

II. Environmental Compatibility

Clean air as a mixture of oxygen and nitrogen has the advantage to be approximately similar to the environmental air and therefore not being a threat to the environment.

The g3 is a mixture based on 3M^{TM} Novec^{TM} 4710 and CO_2. The is 3M^{TM} Novec^{TM} 4710 also not toxic but has to be mixed to a relation of 1 to 9 with CO_2 to not liquidate. Herewith the mixture is only toxic in big amounts. [2] The global warming potential is still high with about 2200 times the one of CO_2. [8]

III. Usability in GIS

Because the gas in the GIS is under pressure there have to be special care by using a vacuum circuit breaker. This comes from the usage of a bellows which make it difficult to obtain a certain pressure at the vacuum circuit breaker. Therefore a three phase spacer between the busbar and the interrupter Unit has to be inserted (see Figure). [5]

By using a modular system to ensure a high versatility the GIS by Siemens already ensure this kind of spacer is already included. [4]

Another problem of clean air and the vacuum circuit breaker are the dimensions of the resulting switchgear. To have sufficient insulating properties of clean air it must be under an higher pressure and/ or the distance between the contacts have to be increased. At the Siemens blue GIS portfolio they researched the the optimum balance between costs, pressure and distance of contacts. [6] With that the dimensions of a Blue GIS are in comparison with a SF6 GIS higher (Blue GIS (8VN1):1000x3200x5500 /SF6 GIS (8DN8): 1200x2500x3520) [4] [7]. With this dimensions more space and planning will be needed to build in existing or new facilities. GIS with clean air also need more often maintenance. [8]

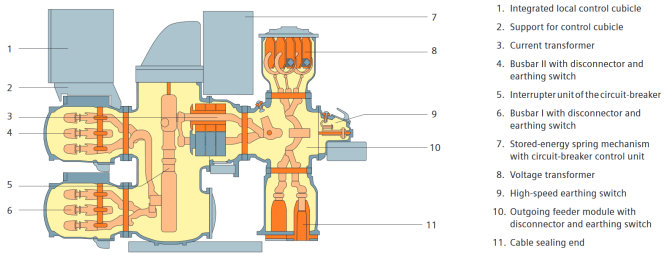


Fig. 1. Sectional view of a SF6 GIS [4]

The g3 gas-mixture has a dielectric performance of 85% to 100% of SF_6 depending on the pressure and temperature. Even the Switching performance of g3 is similar to SF6. With those properties the SF6 GIS needs only a few adaptions to work with g3. [8]

With this the GIS dimensions do not change as extremely as with clean air. Also the GIS with g3 do not depend as much on vacuum circuit breaker technology as clean air.

IV. Summary and Conclusion

I shows the summary of the properties of the discussed technologies. The disadvantage of clean air is primarily its qualitiy as insulation medium and with it the dimensions of its facility as well as its dependency of needing maintenance. Therefore the costs of planning a facility and of the maintenance through the lifetime will be high.

But the act of maintenance will be easier with clean air, because there are not so much precautions to take care of like at SF6 or g3 to not freeing them. Herewith the costs per maintenance per lifetime for clean air are maybe not this much larger than the ones of g3 or SF6, but also the GIS needs to be disconnected from the Grid for maintenance activities and therefore has a big disadvantage.

The big advantage of clean air is that it is complicity save for the environment. While small amount of SF6 and g3 leak out of the GIS and the companies still have to find better ways for reusing and decreasing this leak. The user of the GIS by than still needs to pay environmental costs and has costs in measuring the loss of SF6 or g3.

TABLE I
Properties of g3, SF6 and clean air [8] [9] [5]

Property	SF6	clean air	g3
Insulation Medium	1	≈0.33	≈1
GWP	23900	0	2210
Carrier Gas needed	No	No	Yes
Possibility for maintenance	Low	High	Low
Molecular weight	149	25.8	195
Boiling point	-68.3 °C[a]	≈ -180 °C	-4.7 °C
Freezing point	-50.7 °C	≈ -210 °C	-118 °C
Vapor pressure	2149 kPa	560-790 kPa	297 kPa
Dielectric strength at 1 bar	14.0 kV	12.0 kV	27.5 kV
Atmospheric lifetime	3200a	-	30a
Dimensions in comparison to a SF6 GIS	1	>1.5	1

[a]sublimation point

The big advantage of clean air is that it is complicity save for the environment. While small amount of SF6 and g3 leak out of the GIS and the companies still have to find better ways for reusing and decreasing this leak. The user of the GIS by than still needs to pay environmental costs and has costs in measuring the loss of SF6 or g3.

Also the high boiling point of -4.7 °C is a disadvantage for GIS with g3, so it cannot stay outside a building otherwise the clean air GIS.

Overall the clean air GIS has a some disadvantages and advantages versus other used GIS technologies and right now it depends on the main gaol of the user which he buys. But with further research and more advantages in the MV and HV area (like the 175 KV now) it will lead to the main used GIS.

References

[1] C. Preve, D. Piccoz, R. Maladen, "Application of HFO1234ZEE in MV switchgear AS SF6 alternative gas," 24th International Conference & Exhibition on Electricity Distribution (CIRED), pp. 42–45, June 2017.

[2] Y. Kieffel, F. Biquez, P. Ponchon, T. Irwin, "SF6 Alternative Development for Highe Voltage Switchgears," 2015 IEEE Power & Energy Society General Meeting, July 2015 .

[3] S.Giere, D. Helbig, M. Koletzko, S. Kosse, T. Rettenmaier, C. Stiehler, N. Wenzel, "Vacuum interrupter unit for CO_2-neutral 170kV/50kA switchgear," ETG-Fb. 157: VDE-Hochspannungstechnik , pp. 28–31, November 2018.

[4] Siemens AG, "Brochure GIS 8DN8 up to 145 kV," https://assets.new.siemens.com/siemens/assets/public.1508758057.1f7c76e334a1ef65e7ea6f21534a57888676136c. e50001-g620-a122-x-4a00-en.pdf[05.04.2019].

[5] T. Rokunohe, Y. Yagihashi, K. Aoyagi, T.Oomori, F. Endo, "Development of SF6-Free 72.5 kV GIS," IEEE Transactions on Power Delivery, Vol. 22 No. 3, pp. 1869–1876, July 2007.

[6] T. Heinz, D. Helbig, J. Teichmann, S. Wethekam, U. Prucker, M. Konermann, M. Engel, C. Wolf, "145 kV Vacuum Circuit Breaker and Clean Air Intriment Transformer - Performance, Installation- and Operation Experience," ETG-Fb. 157: VDE-Hochspannungstechnik, pp. 183–188, November 2018.

[7] Siemens AG, "Flyer 8VN1 blue GIS bis 145 kV," https://assets.new.siemens.com/siemens/assets/public.1541966714.1f338d6d66d6c97e73cdd979ad1cd5f1d9acaefd.emhp-b10016-01-7600-8vn1-blue-gis.pdf[05.04.2019].

[8] B. Wölke, M. Ramesch, F. Lembke, "Application of an environmentally friendly SF6 free medium voltage switchgear technology in a pilot setup," ETG-Fb. 157: VDE-Hochspannungstechnik, pp. 210–215, November 2018.

[9] J. G. Owens, "Greenhouse Gas Emission Reductions in Power Equipment through use of a Sustainable Alternative to SF6," 2016 IEEE Electrical Insulation Conference (EIC), June 2016.

Wind Power

Aijia Ding
Verfahrenstechnik - Prozess- und Anlagentechnik
Fakultät 2: Umwelt und Naturwissenschaften
Xi'an, China
dingaiji@b-tu.de

Yiling Wang
Umweltingenieurwesen
Fakultät 2: Umwelt und Naturwissenschaften
Xinjiang, China
wangyili@b-tu.de

***Abstract*—Wind energy is a new type of renewable energy that is well known. This paper introduces the basic situation of German wind farms, introduces the development scale of offshore and onshore wind power in Germany in recent years, and compares the advantages and disadvantages of offshore wind farms and onshore wind farms and their applicable conditions.**

***Keywords*—wind energy, offshore wind farm, onshore wind farm**

Introduction

Wind energy is an available energy that is provided to humans due to the work of air flow. It is a renewable energy source (including water energy, bioenergy, etc.). The kinetic energy of the air stream is called wind energy. The higher the air flow rate, the greater the kinetic energy. People can use windmills to convert the kinetic energy of the wind into a rotating motion to propel the generator to generate electricity.

The method is to transmit the rotational power of the rotor (composed of aerodynamically driven blades) to the generator through the drive shaft. As of 2008, wind power generated by the world is about 94.1 million kilowatts, and the power supplied has exceeded 1% of the world's consumption. Although wind energy is not the main source of energy for most countries, it has grown more than four times between 1999 and 2005.

Modern use of turbine blades converts the mechanical energy of the airflow into electrical energy to become a generator. In the Middle Ages and Ancient times, windmills were used to collect the mechanical energy used to grind grain and pump water.

Wind power is used in large-scale wind farms and in locations where power is isolated, making a significant contribution to local life and development.

Situation in Germany

German wind turbines generated more than 105 million kilowatt hours (kWh) of electricity in 2017. Around 16 percent of German electricity came from wind power. The most wind power was generated in 2016 in Lower Saxony. With more than 19 million kilowatt hours (kWh), the northwestern federal state occupies a clear leading position in the federal states of Schleswig-Holstein (approx. 14.8 million kWh) and Brandenburg or Saxony-Anhalt (8.9 and 6.9 million kWh) on. Together, these four countries produced almost two-thirds of all German wind power generation. But other countries also generate noteworthy yields, with wind power generation in Hesse alone, with 2.2 million kWh, could cover more than the electricity requirements of all German airports.

The largest contributor to total power generation was the wind in Schleswig-Holstein, which achieved a wind share of 42.5 percent in 2015. In addition to the coastal state of Mecklenburg-Western Pomerania (41.1 percent), the landlocked states of Saxony-Anhalt (28.9 percent) and Rhineland-Palatinate and Lower Saxony (with 24.5 and 24.2 percent) also have

high shares in wind power generation that this form of energy can not only be used by maritime communities.

In total there will be 28,179 wind turbines in Germany in 2018. Most of them will be in Niedersachsen in 2018 (6,185), which is almost a quarter of all facilities. Lower Saxony is also among the top performers in terms of installed capacity. Other important wind power countries are Brandenburg (3,807 installations), North Rhine-Westphalia (3,435), Schleswig-Holstein (3,271) and Saxony-Anhalt (2,859). Wind power in Bavaria is still lagging behind. Only 1,212 plants generate clean electricity there. In the city state of Berlin even only 10 plants were built. Although wind energy in Hamburg is better positioned in kW per km² plants in urban areas, it still has a clear upside.

This shows another Hanseatic city: Bremen. There are already 91 plants in spite of smaller area and in the city with 483 kilowatts per square meter in Germany the highest achievement in relation to the country surface is installed. Wind energy in Baden-Württemberg is still waiting for the breakthrough. Although the state government has set the legal framework for accelerated expansion, only 760 plants are in operation there[1].

The potential of wind energy is far from exhausted in any of the countries. According to a prognosis of the Federal Association of Renewable Energies, wind power can generate 204 million kWh of electricity in 2030, while 139 million kWh onshore alone. A total of 189,000 MW of power could be installed if two percent of the land area - which corresponds to the objectives of many federal states - are used for wind energy. By far the greatest potential lies in Bavaria, the largest federal state in terms of area, where wind energy plants with a capacity of 41 GW would be possible. But there is still a lot of potential for expansion in the other major German states of Lower Saxony, Baden-Württemberg and North Rhine-Westphalia. In Bremen alone, where nearly 102 percent of potential has already been tapped by 2018, there is not much room left for further expansion. Otherwise, with the exception of Saxony-Anhalt, Schleswig-Holstein and Brandenburg, no state has achieved even half of its potential wind energy output.

Industrial climbers at a wind energy plant. But not only for electricity generation, wind energy has become a decisive factor, also economically, the wind energy industry from Germany is indispensable. In 2016, 160,200 people were employed in the wind energy industry, more than 10,000 more than in the previous year. Most jobs were able to combine the very active Niedersachsen both in production and in the application of wind energy. Wind energy, however, had the greatest importance for the domestic labor market in Saxony-Anhalt, where there are 15.9 employees per 1,000 employees in wind energy. Thus, every 75th job depends directly or indirectly on wind energy.

Onshore Windfarm

Wind turbines use the energy of moving air to generate electricity, onshore winds are turbines located on land, and offshore wind turbines are located out at sea or in freshwater. Onshore wind power is the core of Germany's transition to low-carbon power generation. Over the years, Germany has been a leader in the installed capacity of onshore wind power in Europe.

For the full year of 2018, onshore wind power supplies about 89.5 terawatt hours (TWh) to the grid, and in 2018 produced nearly 15% of the Germany’s power mix, making it the single most important renewable energy source to date. In the first six months of 2019, onshore and offshore wind power provided nearly a quarter of net electricity. As of July 2019, there were 29,248 onshore turbines with a capacity of 53,161 MW.

So far, most wind turbines have been built in the northern half of Germany, where favorable wind conditions also contribute to the early development of wind farms. However, wind power expansion in central and southern Germany has been catching up in recent years as the increasing turbine efficiency can already be used in areas with weaker inland average wind conditions.

In Germany, the average turbine capacity increased by more than 3.3 MW in the first half of 2019, the hub height was 133 m, the rotor diameter was 122 m, and the average height more than doubled. At the same time, the new device can generate more energy in the desired position. At a lower number of rotations, they are made to reduce noise. Large onshore turbines are available for up to 6,000 homes [2]. Wind power generation in Germany usually peaks in winter, partially balancing the low power input of solar installations during the year.

Offshore Windfarm

Offshore wind power is a relatively young industry branch. Alpha Ventus, Germany's first offshore wind farm, began trial operation in 2009. In 2018, Germany added 136 turbines in the North Sea and the Baltic Sea with a capacity of 0.96 gigawatts (GW). In 2017, turbines installed in the territorial waters of Germany accounted for about 40% of the world's total capacity, making it the world's second largest wind power market in the world after the UK [3].

With an average capacity of 7.1 megawatts (MW) and an average rotor length of 158 meters, the new turbines have not only developed rapidly since the introduction of the early 21st century, but are also larger and more productive than turbines operating onshore. They provide electricity almost all year round and are almost twice as productive as land-based turbines [3].

Most German offshore wind turbines are located in the North Sea, more than 1,000 from the west coast of Germany, and there are only more than 200 turbines in the Baltic Sea in the east. Wind power production in the North Sea is on average higher than in the Baltic Sea.

Advantages and Disadvantages

1. Onshore:

Although wind power is a clean, non-polluting, renewable energy source, it does not produce any pollutants compared to thermal power, nor does it consume any non-renewable energy that pollutes the environment. However, during the construction and operation of wind farm have varying degrees of impact on the ecological environment.

During the construction period, the wind farm will cause the trees to be felled, the turf to be removed; the vehicles, the construction machinery to crush the vegetation; the wind turbine foundation to occupy a permanent land. Such vegetation damage will cause a little bit of soil erosion. However, if the construction is completed, effective afforestation is carried out. When the vegetation is restored to a certain extent, the impact of wind farm construction on regional soil erosion will be restored. During operation, the noise of the fan may have an effect on the birds, or the fan may collide with the birds.

In addition to environmental and biological impacts, onshore wind power faces other challenges: onshore wind speeds are more difficult to predict than offshore winds. Since turbines are optimized at a specific speed, they may lose efficiency if the wind speed is too slow or too fast.

Similarly, on-land winds change more frequently. The turbine must face the direction of the wind to operate effectively.

But relative to the wind at sea, people are more familiar with the wind on the land. We can point to examples of the success of onshore wind energy in the world. More than 40% of Denmark's electricity comes from wind power, and 75% of it comes from onshore turbines [4].

The infrastructure required to transfer electricity from onshore turbines is much cheaper than offshore wind turbines. Onshore winds are also competitive in the larger renewable energy market because it is currently the cheapest form.

2. Offshore:

The biggest advantage of offshore wind power is the constant wind speed on the high seas, allowing offshore wind farms to produce twice as much power as similar turbines on land. This aspect helps to increase the reliability of power generation. The annual production of offshore wind farms exceeds 90%, making it a form of renewable energy production. If some people think of onshore wind farms as threatening farms or other private land. Offshore winds do not interfere with land use.

But the technology required to transfer energy from a turbine in a water body is expensive. Because of the extreme weather at sea, such as storms, high-wave offshore wind farms are subject to more wind and wave losses than onshore wind farms, increasing operating and maintenance costs. At the same time, the installation and fixation of offshore wind farms is also more expensive than onshore wind farms [5].

Policy

The energy transition plan refers to the plan for Germany and other countries to transition to a sustainable economy. The ultimate goal is to replace non-renewable energy sources such as coal with renewable energy. Renewable energy sources include wind, hydro, solar (photothermal, photovoltaic), geothermal and tidal energy. These renewable energy sources will replace non-renewable energy sources such as fossil fuels and nuclear fuels [6].

Reference

[1] LAK 2018, statistische Landesämter, AGEE stat2018.

[2] German onshore wind power – output, business and perspectives, 25 Jul 2019, Sören Amelang Benjamin Wehrmann.

[3] German offshore wind power - output, business and perspectives, 21 Jan 2019, Benjamin Wehrmann.

[4] Where the wind blows – onshore vs. offshore wind energy, 06 April 2016 Holly Roberts.

[5] Offshore wind energy – clean power from the sea, Foundation offshore wind energy.

[6] Federal Ministry for the Environment. Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global [Long-term Scenarios and Strategies for the Development of Renewable Energy in Germany Considering Development in Europe and Globally] (PDF). Berlin, Germany: Federal Ministry for the Environment (BMU). 29 March 2012.