Czech University of Life Sciences Prague

Faculty of Economics and Management

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Diploma Thesis

Comparison of Solar Energy Situation Between Czech Republic and Germany

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Jakub Novotný, BSc

Economics and Management

Thesis title

Comparison of Solar Energy Situation Between Czech Republic and Germany

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Objectives of thesis

The aim of the thesis is to analyze and compare solar energy situation between the Czech Republic and Germany.

Methodology

This diploma thesis consists of two parts. First part is Literature review which was done by various methods such as induction, synthesis, extraction and deduction.Second part is focused on analysing which country has better solar energy situation. This is done by analysing both countries separately and then comaring them in various fields.

The proposed extent of the thesis

60 – 80 pages

Keywords

Solar Energy, Czech Republic, Germany, Photovoltaics, Renewable Energy,

Recommended information sources

H.P. GARG, J. PRAKASH., H.P. Garg, J. Prakash. Solar energy: fundamentals and applications. New Delhi: Tata McGraw-Hill, 2000. ISBN 0074636316.

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Expected date of thesis defence

2016/17 SS – FEM

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Declaration

I declare that I have worked on my diploma thesis titled "Comparison of Solar Energy Situation Between Czech Republic and Germany" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague on ______________________________

Acknowledgement

I would like to thank **doc. Ing. Mansoor Maitah, Ph.D. et Ph.D. and Ing. Oldřich Výlupek, MSc, Ph.D.** for their support, supervision and assistance during the assessment of my diploma thesis.

Comparison of Solar Energy Situation Between Czech Republic and Germany

Srovnání solární energie mezi Českou Republikou a Německem

Summary

This diploma thesis deals with the topic of solar energy and problems that are closely connected to it. Its aim is to study solar energy from various points of view and then compare learned information between Germany and the Czech Republic. Upon that the Author makes a conclusion based on given results.

To do this the Author of this thesis had to divide the thesis into two parts. The first part is theoretical and deals mostly with literature that has already been written and published. This includes explaining basic terms, introducing history as well as introduction into the world of solar energy. The Author had to gather data and create literature review to introduce relevant topics to the reader so that it is understandable and easy to read through as well as interesting.

The second part is analytical and is based mostly on the results of comparison and description of the situation that is both historical and current for the Czech Republic and Germany. Results are deeply described and showed in various graphs for good understanding.

Keywords: Czech Republic, Germany, Photovoltaics, Renewable energy, Solar energy

Souhrn

Tato diplomová práce se zabývá tématem solární energie and problémů, které jsou s tímto tématem spojeny. Cílem této práce je důkladně prostudovat téma solární energie z různých druhů pohledu a porovnat získané informace mezi Českou Republikou a Německem. Na základě získaných dat a srovnání Autor provede vyhodnocení a sepíše závěr.

K úspěšnému dosažení cílů bylo potřeba rozdělit práci na dvě části. První část je teoretická a primárně se zabývá literaturou, která již byla napsána a publikována. To zahrnuje vysvětlení základních termínů, představení historie stejně jako úvod do světa solární energie. Nejdříve musel Autor posbírat potřebná data a vytvořit přehled literatury, aby bylo možné důkladně představit potřebná témata čtenáři. To bylo provedeno, aby čtenář rozuměl danému tématu a jednoduše se zorientoval v tématu solární energie.

Druhá část je praktická a je založená převážně na výsledcích získané porovnáváním a popisem situace, která je považována jak za historický vývoj, tak i za současný stav solární energie jak pro Českou Republiku, tak pro Německo. Výsledky jsou sepsány a důkladně rozebrány a následně převedeny do grafů aby bylo ještě snazší se orientovat ve daných výsledcích.

Klíčová Slova: Česká Republika, Německo, Fotovoltaika, Obnovitelné zdroje, Solární energie

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1. Introduction

In current world energy belongs to one of the most important aspects of daily life. Not only because energy is literally vital for life itself, but also because mankind has developed its society and structure upon using energy of various kinds and without it the world would crumble and maybe even disappear. Therefore it has been very important part of human's life to search, research, study, develop and most importantly produce energy to survive. It took men hundreds of years to develop or find new energies. Mankind has gone a long way since using only fire as a source of energy to current forms of energy.

Today there are basically two types of energy resources that are used. First one is energy of non-renewable resources and second one is energy of renewable resources. Even though both types of energy are used for a very long time, non-renewable energy was always preferred and more used since the time humans were developed technologically enough. However, situation is slowly but surely changing. Even though the time of non-renewable energy is not over, mankind is aware that using this kind of energy has massive disadvantages that may not be apparent in short-time scale but definitely in long-term scale. Even though it is currently more efficient, cheaper and generally easier to generate energy with non-renewable resources, most of the world has agreed that it is necessary to reduce using fossil fuel as energy resources mainly because of its high pollution to the environment.

World leaders and most of the nations have agreed, that it is important to protect the Earth and natural living environment for next generations. Furthermore it is not only in line with only agreeing but there are already signed the global pacts and action plans to stop warming of the planet on reducing greenhouse gas pollution by decreasing both energy production and also usage of non-renewable resources. However to maintain the standard of living the humans have and like so much the missing energy has to be replaced by something else. The answer is very simple: renewable resources. Even though the answer is simple, the solution and the process of doing so are definitely not simple at all. Not only there is only very little experience with using these resources, but also the technology is not there yet.

Using renewable resource like wind, hydro and solar energy could not only replace missing energy but potentially even replace non-renewable resource which would greatly reduce the amount of greenhouse gas pollution that humans create. However the current systems like utility grids and transmission & distribution grids are not fully prepared for this change. Even the technologies for electricity production of renewable resources are not developed enough. Photovoltaic cells are still very inefficient and generally the technology around it is still lacking. However the research has been increased massively in last few years and it is apparent that many leading countries in the world are trying not only to develop and research needed technologies but also already install current technologies to help reduce pollution for the future.

That is why this master thesis focuses on one of the renewable resources, which is a solar energy. Not only is this kind of energy being very rapidly researched and developed, but also already installed in many countries over the world. That makes it very important source in current world but mostly for the future as it could cover significant part of the world energy production. Author of this thesis compares Germany and the Czech Republic and their situation in terms of solar energy. The Czech Republic has been chosen, because the Author was born, lives and studies in the country, whereas Germany has been chosen because it plays a very strong role in the world not only in politics, energetics and industry but leading role in solar energy itself. Lastly both countries are neighbours, which makes it even more interesting to compare them in terms of current photovoltaic production, installed capacity, history and even future plans and possible development.

The thesis should therefore shed light on the world of solar energy, photovoltaics and compare both countries in this field.

2. Objectives and Methodology

2.1. Objectives

The aim of this master thesis is to conduct an in-depth analysis and evaluation on what different types of energy resources are there currently utilized by mankind with special focus on renewable energy resources, mainly solar energy & photovoltaics and compare current situation and future plans between the Czech Republic and Germany. Therefore it is vital to analyse and study current energetic situation in its overall scope and particularly solar & photovoltaic situation as well to set both countries into the right context.

This means a great focus is paid to the whole electricity lifecycle starting by production, installed capacity, transmission & distribution grids and ending by consumption and others done for all present resources with the focus on photovoltaics for both countries so they can be accurately compared. This includes comparing technologies and even national action plans for European Union generally and both countries particularly and their country specific approach as photovoltaics is a still developing field.

2.2.Methodology

This master thesis uses mainly comparative and descriptive methods. Methodology is based on the study of relevant literature, publications of solar energy organizations around the world and various internet resources.

The first part is theoretical. This part is mainly based and focused around studying and exploring existing literature that deals with relevant topics which are necessary to understand the topic of this thesis. Then it is formed to informative segments that are dedicated to bringing the reader closer to the topic and drawing him in. It clarifies basic terms and introduces the reader relevant topics and certain problematics tied to solar energy.

Second part is analytical. This part uses mainly comparative and descriptive methods. Main part of this chapter is comparing various aspects of solar energy that are current or historic for the Czech Republic and Germany. Evolution of past situation is very important to determine current existing situation and also predict possible future development in these various aspects of solar energy. The focus is mainly on evolution of production, evolution of installed capacity, energy storage, smart grid and others. This is done by using graphs that help to compare these data between the Czech Republic and Germany. After the comparison the Author forms a conclusion based on the results and data given.

3. Literature Review

This is the theoretical part of this diploma thesis. Its purpose is to introduce and present examples of literature to the viewer and therefore introduce him to basic problems with selected topic. This includes brief history of electricity production from various energy resources and problems that are tied to this topic.

3.1. History of Obtaining Energy

The effort to obtain and use energy has accompanied mankind for thousands of years. Energy use has thus become a guide, but also a condition for the development of human civilization. It is very likely that the knowledge and use of fire by the ancestors of today's man started already a million years ago and was one of the evolutionary factors of the species homo erectus.

For thousands of years the man used the energy to prepare food and to provide heat and light. He was gaining his first energy by burning wood. Already from the beginning we can trace two separate parts - the part of the energy production and the part of the energy usage. During the development of human civilization, there were significant expansions on both parts – energy acquisition and usage. Both parts of the process stimulated each other. New ways of energy production have brought new ways of energy usage and vice versa growing demand for energy motivated producers into new improvements.

For next milestone we can consider the period of formation of the first human civilizations in the ancient world and the use of wind power to drive the boats, wind and water mills, and also production of charcoal and coal for the forge foundries and forges in the manufacture of various tools. People have worked with these energies throughout ancient and medieval history but the real industrial energy use occurred relatively late. (Oulický, 2012)

Next milestone was the emergence of manufacturers and industrial factories in the period from 18th to the 19th century during the Industrial Revolution, when a largely agricultural economy was turned into industrial economy with factory production, mining, transportation and, of course, also much stronger consumption. In the production process there was a transition from manual production in the workshops to the machine production with the help of new energy resources. There were also a significant social, cultural and political changes as well. The enabling impulse in the Industrial Revolution was the use of steam power and improvement of steam engine. Power source site and power use site had to be identical or at least very close for the steam power engines. Each factory had to have its own complete power & mechanical systems including steam power generation, steam engine, transmission shaft and working machines. This problem was resolved just by Next milestone on the way of energy was the invention and vast deployment of electricity. The first electric machines were powered by galvanic cells, the first functional dynamo built in 1867 Werner von Siemens. This invention made it possible to generate a large amount of electrical current, which could be used as universal power. First, electricity was used for lighting, later for power engines. In less than a century all the technical principles were discovered, enabling the generation, transfer and exploitation of electricity. The first water power station in the world was built in 1881 by the Pullman company in England. In 1882 Thomas Alva Edison, American inventor, built in New York the first power plant in the world, which supplied electricity to the residential population on a purely economic basis. Its performance was enough for the activation of the 6000 Edison's light bulbs. Finally the winning arrival of electricity allowed discoveries of alternating current (System three phases; the ability to transform voltage), whose author was Nikola Tesla. The ability to transport the electric energy at long distances with virtually no-lag allowed the geographical separation of the production from the places of consumption, on the other hand have brought the need to build-up the transmission and distribution network connecting all production capacities and all consumers. Entire electric energy process now includes the following sections: (EdisonTechCenter, 2012)

Figure 1: Energy Process

Source: *NREL, 2012*

Next milestone was the introduction of nuclear power in electricity generation in the 1950s, and their vast development later in the 1980s as a response to the world oil crisis. In 2013 there were 432 commercially operated nuclear blocks and total installed capacity was 372 GW. Nuclear power plants in 2014 has generated approximately 2535 TWh, nuclear power contributes around 10.6%.

The last milestone on the way of electric energy development is the production of electricity from renewable energy sources (RES). This trend began at the end of the 20th century and fully develops in the 21. of the century. Worldwide pressure to switch to renewable resources, in particular, has been started by following factors – rapid human population growth, the rapid growth of energy consumption, global warming of the planet caused by greenhouse gas production, decreasing reserves of coal, oil and gas, as seen in the accompanying charts. (EdisonTechCenter, 2012)

The development of electricity production from renewable sources, however, brings a variety of technical and economic challenges that need to be addressed globally. It is the daily and seasonal unpredictability, the need for accumulation, low surface energy density, low efficiency and a higher price. Another challenge is that above mentioned electric energy scheme with large central power stations (generation-transmission-distribution-consumption) is changing with the vast deployment of RES. Consumers become producers and central scheme changes into distributed scheme. It also changes the power flow direction, which has become unpredictable. (Mastný, et al., 2011)

Electricity is currently the most used and probably also best kind of energy mankind has. It is massively spread and used all over the globe and its consumption is increasing every year even to this date.

Specific attributes of electricity:

- Easy to transports across great distances
- Easy to generate in large amounts
- It's transportation is basically instantaneous
- Electricity is very accessible (Everyone has right to connection to electricity for a fair price)
- Low possibility of accumulation (there are various ways currently in research which show promising results for the future)
- In malfunction spreads very quickly from the source though all of the grid which effects other aspects of the grid
- Possibility of transportation or help from other countries when there is shortage of electricity
- Electricity always travels through the point where it has the lowest amount of resistance, which is not always a good thing
- At every single point in time the amount that is produced must be equal to the amount that is consumed to preserve balance and not brake whole system (Mastný, et al., 2011)

3.2. Production of Electric Energy

Mankind does not create electric energy, they rather generate it through other forms of energy. This means that when talking about producing electricity it actually means converting it from primary resources.

Primary resources for electric energy are:

- Solar energy
- Wind energy
- Hydro energy
- Fossil fuels
- Nuclear energy

Energy resources based can be divided based on those criteria:

- Based on renewability
- Based on the location of transformation
- Based on the possibility of usage
- Based on the type of power plants

However the most common is to divide them based on how the electricity is produced and the type of technology.

- Nuclear power plants
- Photovoltaic power plants
- Wind power plants
- Hydro power plants
- Gas plants
- Lignite plants
- Others (Přech, 2010)

3.3. Renewable and Non-Renewable Resources

Non-renewable resources are those resources that do not renew themselves at all or the process takes far too long for economic extraction in a time bearable for a human. This means that such resources are called exhaustible due to their nature, e.g. oil, natural gas, coal and earth minerals. On the other hand renewable resources as the name suggest are those that are replenished fairly quickly despite the usage and consumption. This happens both through biological process or naturally recurring process in a sufficient human time scale, e.g. wind, water, wood, solar. (Friedl, 2012)

3.3.1. Non-Renewable Resources

Looking at non-renewable resources the actual resources are fossil fuels. They are fuels because the energy gained there is from burning those fuels and generating electricity. These fuels were created from prehistoric plants and animals lying for thousands of years in minerals which are easy to burn. Basically there are three kinds of fossil fuels: natural gas, coal and crude oil. They altogether have however the same faults: their stocks are limited and therefore exhaustible and through their transformation a lot of carbon dioxide is launched into the air. These two are very big problems which may not be currently so bad, but they will definitely be in the future. They already have lot of side effects on the nature, most notably greenhouse effect and global warming. Nevertheless from the energetics point of view fossil fuel have still top priority and impact since they produce about 66% of global electricity. They are however not equally distributed over the globe which sometimes creates a lot of geopolitical tension and results in addiction same countries have on other countries. Great example is Europe countries which have to import around 54% of their natural gas and even 80% of crude oil, which together with small import of coal creates a big addiction on import from other countries at around of 50% of all resources used for energy production. (Chang, 2014)

3.3.2. Renewable Resources

Renewable resource of energy is a term used for a special kind of energy types which can be obtained and not depleted. This means that even when used these resource are capable of recharging themselves over a decently short period of time which is good enough for mankind. Such resources include solar energy, wind energy, hydro energy, geothermal energy, biomass and other. According to a Czech law number 180/2005 Sb. about the support for electricity production from renewable resources of energy: Renewable resources are such resources which are renewable, not fossil natural resources of energy, which are wind energy, energy of solar radiation, geothermal energy, hydro energy, energy of soil, biomass energy and others.

Globally speaking renewable resources are a great potential source of energy which is ecologically clean, which could potentially cover all of the current energy demand of whole world. However this is not possible yet since there are few limitations to renewable resources which must be overcome first. They have low flat concentration, high decentralization, variable intensity of production during year but even a day and actually quite decent initial costs. Usually the way to measure the energetic potential of renewable resources is the installed capacity (Pi). However there are many different ways how to measure it and some are even more common though not basic. (Asaff, 2010)

3.3.2.1. Water Energy

Usually called hydropower is actually the largest renewable energy source for electricity generation overall. Hydropower accounted for 16.4% overall electricity generation around the world and 73% of electricity generation from renewables. Though the highest amounts of hydropower potentials are located in Asia and Americas with about 35% of global hydropower potential.

Hydropower actually relies on the water cycle and is therefore important to understand what it is and how it works. At first solar energy actually heats water on the surface of lakes, rivers and oceans which causes the water to evaporate. Then the water vapour condenses into clouds and falls as rain snow and so on. This is collected in streams and rivers, which empty into oceans and lakes where it again evaporates and the cycle begins all over again. The amount of precipitation (rain, snow, etc.) that flows into streams and rivers in a geographical area determines the amount of water available for hydropower production. There are naturally seasonal variations to the amount of precipitation and long-term changes can occur as well such as droughts have a big impact on the hydropower production.

The way the electricity is generated in hydro power plants is that water flows through a series of pipes and pushes against turn blades in a turbine to spin a generator to produce electricity. (Water for Energy, 2010)

3.3.2.2. Wind Energy

Wind is actually caused by uneven heating of the Earth's surface by the sun. There are lot of materials on the Earth's land and in the water and every one of them absorbs sun's heat at different rates. This is clearly seen in the daily wind cycle which is caused by uneven absorption of solar energy. Over the day the air above land is heated up faster than the above water, which causes it to expand and rise, while the heavier and cooler air rushes to take its place below, creating wind. During night the winds are actually reversed because air cools more rapidly over land than it does over water. The same goes for atmospheric winds which are circulating the Earth but the land near equator is hotter than the land near the North and South Pole.

In current world wind energy is mainly used to generate electricity. The most important factor in using wind energy is actually the speed of wind, since it has the greatest impact on the performance of wind power plants.

Wind turbines similarly to windmills are mounted on high towers where they can capture the most energy. Usually at 30 meters or more above ground, they take advantage of faster and less turbulent wind. Every turbine has blades that catch winds energy and transform it into electricity. These blades act actually like airplane wing and turning shaft spins a generator to make electricity. There are two ways these turbines can be used. Either standalone applications with no connections or connected to a utility grid. Sometimes they are even used with photovoltaic generator system. For utility-scale (megawatt-sized) sources of wind, there has to be a large number of wind turbines that are built closely together to form a wind plant, which can also be referred to as wind farm. Wind turbines can be built bot on land and off-shore in large water bodies like lakes and oceans. (AWEA, 2017)

3.3.2.3. Geothermal Energy

Geothermal energy comes from heat that is within the Earth’s core. Even the word geothermal which is Greek is composed from two words geo (earth) and therme (heat). This kind of energy is usually used as steam or hot water for buildings or to generate electricity. The heat is constantly produced in the Earth’s core and therefore is renewable.

Geothermal energy is produced in the Earth’s core by slow decay of radioactive particles which is a process that happens in all rocks. The Earth’s core is actually hotter than the Sun’s core. The Earth consists from several layers. The core is solid iron and is surrounded by an outer core of hot molten rock called magma. The mantle surrounds core and is about 1,800 miles thick. The mantle is made up of magma and rock. The last layer is crust which is the outermost layer. It forms the continents and ocean floor. It can actually be pretty thick, about 15 to 35 miles on the continents. The crust is broken into pieces called plates. The place where magma comes close to surface is near and around edges of these plates. The heat from magma is then absorbed by rocks and water underground.

Deep wells are drilled in the ground so a hot water from underground can be pumped up and used by people either to heat their homes or to produce electricity. This can also be used either to eat or to cool buildings. There are different applications where some use temperatures near the surface and some use temperatures from deep within the Earth. There are three main types of geothermal energy systems: Direct use and district heating system, Electricity generations power plants and Geothermal heat pumps.

This kind of energy generation requires water or steam at high temperatures (150° to 300°C). Geothermal power plants are generally built near locations with geothermal reservoirs. Usually very close like one or two miles away from this location. The largest generation from geothermal energy is in Island, USA, Japan, Italy and Russia. (Wekesa, 2015)

3.4. Solar Energy

Solar energy comes directly from the Sun and belongs to renewable resources. This is because even though the period in which the Sun radiates energy is limited, this period is so long in actual human measures it seems infinite. The Sun is actually the most important source of energy for life on Earth and not just that, but also a very important part in our history since the Earth is literally rotating around it. The Sun provides us with light, heat and energy without it life on Earth would not be possible. There are two types of solar energy that men are able to acquire from the Sun. One is utilizing solar radiation by directly converting it to into heat or electricity, this is photovoltaics. The second type is thermal system which seeks to store heat that is directly radiated from the sun. (Bechník, 2009)

3.5. General History of Solar

This chapter deals with the usage of the Sun throughout the history of men and how well were they able to utilize it.

Milestones:

- 7th century B.C. – Usage of magnifying glass to concentrate sun's ray the set up fire
- 2nd century B.C. – Archimedes fleet of wooden ships on fire using the reflective power of bronze shields
- 1st to 4th century A.D. – The famous Roman bathhouses utilize position of windows facing south to capture sun's warmth
- 1767 – World's first solar collector build by Horace de Saussure
- 1839 – The photovoltaic was discovered by French scientist Edmond Becquerel
- 1883 – First solar cells made from selenium wagers by Charles Fritts
- 1954 – Scientists in the U.S. have developed the silicon photovoltaic cells thus giving birth to Photovoltaic technology. This was the first solar cells capable of converting enough energy to run everyday electrical equipment.
- 1960 – 14% efficiency of photovoltaics achieved by Hoffman Electronics
- 1972 – World's first laboratory dedicated to PV research and development established in the University of Delaware
- 1982 – The production of photovoltaic around world exceeds 9.3 megawatts
- 1983 – Growth of photovoltaics is at insane speed as only in one year the production is more than doubled at 21.3 megawatts around world and sales at 250 million dollars
- 1994 – Solar cell with conversion efficiency exceeding 30%
- 1999 – Capacity of world's photovoltaics reaches 1000 megawatts
- 2001 – Residential solar power systems were begun to be sold by Home Depot
- 2002 – Successful test conducted on two solar-powered, remote-controlled aircraft by NASA, (Bechník, 2009)

3.6. Photovoltaics

Photovoltaics is a technology that is used for a direct conversion of solar radiation into electricity and is based on the photovoltaic effect. Photovoltaic effect is defined as creation of voltage or electric current between two electrodes attached to a solid or liquid system upon shining light onto this system.

Basically all of the photovoltaic devices use a pn junction in a semiconductor across which the photo-voltage is developed. Such devices are called solar cells. Semiconductor material is a very important part since it absorbs light when it occurs. This means that it has to be able to absorb a very large portion of the solar spectrum. The absorption properties of the material can vary which defines whether the light is absorbed more or less close to the surface. When light falls on the material and is being absorbed, electron hole pairs are generated and if their recombination is prevented they can reach the junction where they are separated by an electrical field. This means that most carriers are generated near the surface even for a weakly absorbing semiconductor like silicon. In order to achieve a high collection probability for the photo-generated carriers the base layer and the pn junction that separates emitter need to be close to the surface. There is also a thin emitter layer above the junction that has a decent resistance, because of that it needs a well-designed contact grid. Usually solar cells are packed together into modules containing either a number of crystalline Si cells connected in series or a layer of thin-film material with same series of internal connection. (Goetzberger, Hoffmann, 2005)

3.7. Photovoltaic Technology Types

There are different types of semiconductor technologies currently in the world of photovoltaic in use for PV solar panels. However, two such technologies became the most widely used: crystalline silicon and thin film. These two technologies are however not the only ones. They are the relevant in terms of current market usage, but are definitely not at the top in terms of efficiency. Multijunction cells are only experimental, but they are the most effective in terms of converting solar radiation in to electricity. (Goetzberger, Hoffmann, 2005)

3.7.1. Monocrystalline Silicon

Monocrystalline panel is the original solar photovoltaic technology and is also called single crystal technology. This technology uses solar cells that are cut from a piece of silicon grown from a single crystal. Panels are usually cut into special patterns because of the oval shape of the crystals, this gives them recognizable appearance. Thanks to that this technology possess unique crystal framework in a grid-like structure. These attributes give it a steady blue colour and no grain marks but most importantly the best purity and highest efficiency levels. This however does not come without a cost since its manufacturing process is the most involved and also it requires the highest purity silicon, which increases costs. Monocrystalline panels are therefore one the most effective but also rather expensive. (Pickerel, 2015)

3.7.2. Polycrystalline Silicon

On the other hand polycrystalline silicon panels sometimes also called multicrystalline are made from multifaceted silicon crystals. This technology is made by pouring molten silicon into a cast. However such a construction method causes imperfect crystal structure. Because of this method crystals look less uniform and resemble pieces of shattered glass with its boundaries. These impurities which arose during the creating process have a negative effect on the efficiency making this technology less effective than monocrystalline even though the gap in effectiveness is closing greatly in recent years. On the other hand this manufacturing process also uses less energy and materials and is there less expensive than its single crystal comrade. Even though less effective the lower manufacturing cost make this technology the most desirable one and is therefore the most currently used one the market around the world as of 2015. (Pickerel, 2015)

3.7.3. Thin-Film

This technology has overall the lowest amount of share on the market, because it has compared to other technologies some disadvantages like low conversion efficiency. On the other hand it has some advantages which make it suitable for more special usage. This technology is more suitable for options with lesser power requirements but need for light weight and portability. Thin film panels are made by placing thin layers of semiconductor material onto various surfaces, which is usually glass. As the name suggest the amount of material used for semiconductor is low – thin. This makes the manufacturing costs the lowest on the market which could be very valuable for future especially in consumer market where prices are important. (Pickerel, 2015)

There are naturally different types of thin film technology based on the material used for manufacturing. The most common type of thin film technology is made from cadmium and tellurium and is put on glass. It is also the most cost-effective to manufacture. One special attribute of this type is that it performs much better in high temperatures and low-light conditions.

Another type is amorphous silicon which is made from non-crystalline silicon. This type was actually the first thin film type to yield a commercial product, used in consumer item like calculators. However, again, it has low efficiency at converting sunlight into electricity.

Third type is called CIGS. It is made from copper, indium, gallium and selenide. This type is actually still rather new and is considered developing PV technology. One advantage of this type is that it can be deposited on many different materials not just glass. (Pickerel, 2015)

3.7.4. Multijunction Cells

This type of technology is purely experimental and is used for research purposes mostly. However it holds the world record for most efficient solar cell at 46% conversion efficiency. Such a high efficiency was achieved at the end of 2014 by Fraunhofer Institute for Solar Energy Systems. (Schneider, 2014)

It is made out of several p-n junctions (usually three or four) each from different semiconductor material. This is done so that each p-n junction will produce electric current in response to different wavelengths of light. Thanks to that it absorbs wider range of wavelengths, thus improving the cell’s conversion efficiency of sunlight to electrical energy. It is also used with a Fresnel lens which concentrates sunlight onto the cell to further increase its efficiency. Such cells are not suited for neither commercial nor customer usage as they are much more expensive both for manufacturing and maintenance. However there is a place for them for example in space programs where every piece of efficiency creates more space which is valuable. Therefore the likes of NASA use this technology. (Kurtz, 2006 and Schneider, 2014)

Table 1: PV Cell in 2015

PV cell type	Market share in 2015	Average Efficiency
Mono c-Si	31%	21%
Multi c-Si	60%	18%
Thin Film	9%	15%

Source: *NREL, 2016, own processing*

3.8. Utilization of Solar Panels

In this part will be explained how can be solar panels be utilized in terms of how many of them are used, for what purposes and who uses them. Generally speaking there are three types that are used in current world. First and biggest type is utility-scale solar panels. Second is commercial and third and last type is residential. (Goodrich, et al., 2012)

3.8.1. Utility Scale Solar Panels

Utility scale solar panels belong to the biggest ones. It means they are build and used in the biggest amount there is. However there is no common definition about the size of utility scale panels, which is kind of strange at first. Some data say it’s greater than 25 kilowatts and some it’s greater than 50 megawatts which is a big difference. This is however cause be the fact that they are built for more than 30 years which caused a big change in the scale, area and number of used panels. Todays utility scale panels are built in much larger numbers than it was before which causes this effect. Generally it is better to describe it by its shape and purpose rather than its scale. Purpose of a utility scale solar facility is to generate large amount of power which is directly fed into the grid, thus supplying utility with energy. It means that basically every single such facility has a power purchase agreement with a utility, guaranteeing a market for its energy for a fixed time. Since such facilities are usually really large there was a trend to build then in unused desert lands. Nowadays they are more and more built on unused abandoned agricultural lands. Most recently some of the most ambitious projects are built really close to cities or in some cases even right in the middle of them. So again about the issues of size. Recent definitions which are decently modest say that the utility size is if greater than 1 megawatt. So the size of the project or facility may differ but it is the purpose and structure that defines it. (Mendelsohn, et al., 2012)

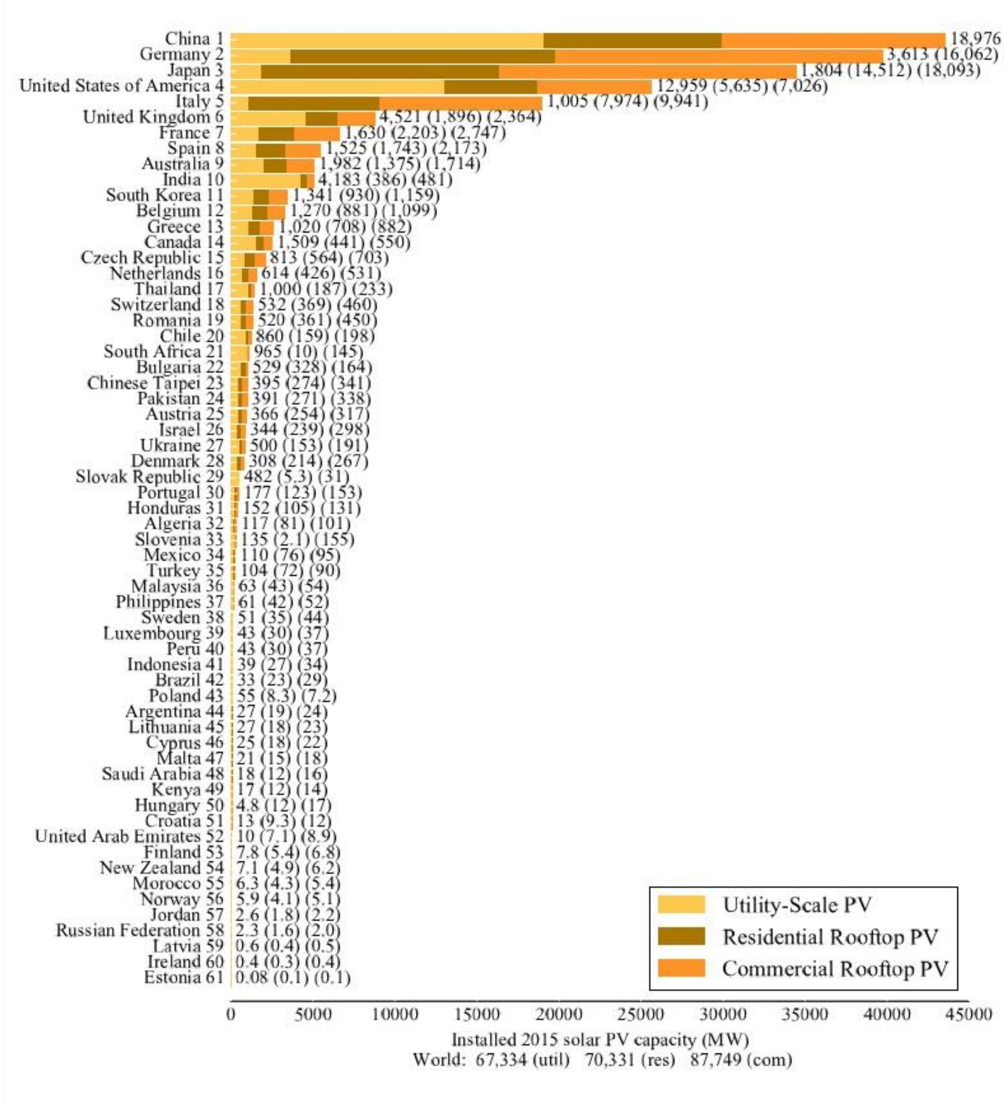
3.8.2. Commercial Size Solar Panels

Second type of solar panels in terms of their usage is commercial. Commercial panels are naturally in smaller scale than the utility ones. This is because the purpose is different. Commercial panels are aiming for supplying commercial buildings of its owners. Some companies want to switch to solar panels for various reasons, be it better public view for their relationship to environment or because they try to save money. These panels are than mounted on building or their rooftops to power them. However such a building does not use so much power therefore the scope of built panels is usually smaller, since there is no need for excessive amount of power. Also there is a limited amount of space that can be used for mounting of solar panels especially in cities. Interesting fact is that commercial panels are almost exclusively in white colour. Commercial panels also tend to be more effective than residential, because there is need of more power than in residential case, therefore the panels tend to be bigger and more effective. It may be surprising but today’s trend is actually really big for commercial PV panels. Lot of companies are actually buying them and installing them even if they do not solely supply and full fill their needs. Looking at year 2015 the amount of installed new commercial solar panels was higher than utility or residential. Also Germany had the highest amount of installed commercial solar panels in 2015 in the whole world. This is actually really impressive since China is currently heavily investing into PV panels on all possible levels. (Goodrich, et al., 2012)

3.8.3. Residential Size Solar Panels

Third type in this category is residential. Residential means that solar panels are used to produce energy for individuals and their homes. In terms of scope of solar panels this category is naturally the smallest since the production for a household is very small and therefore there is no need for big and efficient solar panels. Even though this might imply that the cost of solar panel is smaller it actually is not really that different, because the cost of PV panel is in accordance with the amount of power produced by the panel and not its size or weight. Therefore residential panels tend to be 2-3% less effective in producing electricity than commercial panels. While commercial panels are basically almost solely in white colour, residential panels can be both black and white. There is currently a boom for residential panels as can be seen on the graph below. Many people are buying them for their homes so much that the installation of new residential panels around the whole world actually exceeded utility panels. (Mendelsohn, et al., 2012)

Figure 2: Solar Panels Installed in 2015



Source: *Standford, 2016*

3.9. Electrical Grids

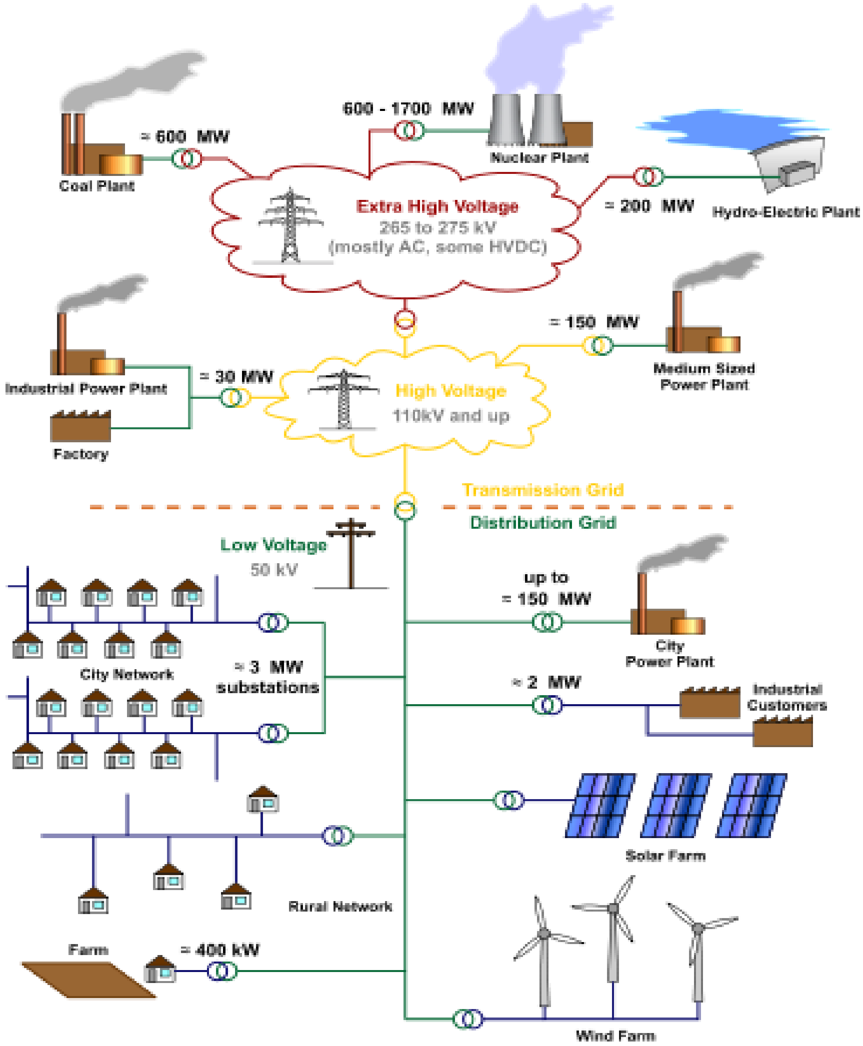
Electrical grid is a thorough connection between devices or facilities for production, transmission, transportation and distribution of electricity including direct connections to consumers and measurement systems as well as directional, protection information and telecommunication technology.

National electrical grids are often divided into three parts:

- Production of electric energy in central power plants

- Transportation grid including export and import connections with other national grids
- Distribution grid including connections to small decentralized production facilities (UCSUSA, 2015)

Figure 3: Electrical Grid



Source: *ČEPS, 2013*

3.9.1. Smart Grid

Smart grid is a highly sophisticated and intelligent grid designed for 21st century. IT is an energy network which can automatically monitor energy which flows through it and adjust accordingly to changes in energy supply and demand. Paired together with smart metering systems, smart grid can reach consumers and suppliers and provide them with information on real-time consumption. Using smart metering devices, consumers have the option to adapt – in time and volume – their energy usage to different energy prices throughout the day and thus saving money on their energy bills by consuming more energy in lower price periods. (Plchút, 2015)

Another great advantage of smart grid is it is able to better integrate renewable energy. Real-time information is key to this integration because as sun does not always shine and wind does not always blow it is vital to adjust accordingly to weather. Weather forecast in combination with information about energy demand can help grid operators to both plan and adjust the integration of renewable energy into the grid and balance their networks. Smart grid also makes it possible for consumers who produce their own energy to sell it base on the changing prices. (Plchút, 2015)

There is a plan for the European Union to replace at least 80% of electricity meters with smart meters by 2020 wherever it is cost-effective to do so. These new intelligent technologies are even able to reduce emissions in the European Union by up to 9% and annual household consumption by similar amounts. EU countries actually conducted several cost-benefit analyses to measure cost effectiveness a created guidelines which are provided by the European Commission. The same analysis was done for natural gas. (Plchút, 2015)

In 2016 the EU Commission published a proposal stating that all consumers should be entitled to request a smart meter from their supplier. Smart are benefit consumers and should allow them to reap the benefit of progressive digitalisation of the energy market via several different functions. The dynamic electricity prices contracts should also be accessible for consumers. (Lallanilla, 2012)

The EU Commission report on the deployment of smart metering found in 2014:

- Almost 200 million smart meters for electricity and 45 million for gas should be ready till 2020 in the EU. This is a potential investment of 45 million euros
- By 2020 almost 72% of European customers is expected to have a smart meter for electricity and about 40% for gas
- Smart meter installation costs on average between 200 and 300 euros
- Smart meter provide savings on average 160 euro for gas and 309 euro for electricity per metering point (distributed amongst consumers, suppliers, distribution systems operators etc.) as well as an average energy saving of 3% (Lallanilla, 2012)

Smart grid is basically an electricity network which is able to cost effectively integrate the behaviour and actions of all users connected to it including generators, consumers and those that do both. This is done to ensure economically efficient, sustainable power system with low losses and high level of quality and security of supply and safety.

Even though currently there already are elements of smartness in many parts of existing grids, the difference between current grids and smart grid is mainly the grids ability to handle more complexity than today in an efficient way. Smart grid uses innovative products and technologies together with intelligent monitoring, control, communication and self-repairing technologies to achieve:

- Provide better connection and operation of generators of all sizes and technologies
- Allow consumers to optimize the operation of a system
- Provide consumers with information and options how to utilize their supply in a more efficient way
- Reduce the environmental impact of the whole electricity supply system by a large margin
- Maintain or even improve current levels of quality, reliability and security of supply systems
- Hold current level of standards in existing services
- Help create market integration towards European integrated market (Lallanilla, 2012)

The implementation will not be easy however it will be possible with the participation of all Smart Grid actors, based on their specific roles and responsibilities. In most European countries distribution network system combine actually several roles, including network operators, metering operators and application and services provider. (Plchút, 2015)

3.10. Electrical Grid in the Czech Republic

The consumption of energetic sources in the Czech Republic is almost by 50% covered by domestic sources. Which means the import is around 50% which belongs to the lowest in the European Union.

The Czech Republic runs a very wide and developed transformation and distribution grid, which provides safe electricity with high guaranty of supply. However most of the grid is actually currently over 35 and more years old and needs lot of modernization and repairs. This modernization, together with repairs need to be within the next 10 to 15 years. This has to be done together with adaptation to new technologies and intelligent grids so called smart grid. This should prepare the grid for modern technologies and even the next evolution of development in this field from the point of resources as well as consumption. Development of the distribution grid used to maintain ministry of industry a trade which also planned slow change from old to new intelligent grids and other devices and rules. The investments into smart grids are investments into infrastructure and will transfer into regulated prices of electricity. The plan for smart grid investments is divided into 4 phases with a finish year of 2040. (Ministerstvo Průmyslu a Obchodu, 2012)

Transmission grid in the Czech Republic was built early in the 20th century together with distribution network. Earlier there was no need for these systems as the industrial age was not ready for this and the technology was not developed enough. 20th century was also a time of first public power stations. It was firstly in 1919 that the legislation was passed for supply of electrical energy to be accessible in whole country. In the next few years the systems was described and prepared to be built and published by the Provincial Authority for Business Promotion in Brno in 1924. (ČEPS, 2017)

The construction of a core transmission network was however completed as late as in 1980. It means it took decades to build at least the backbone of it in the Czech Republic. It currently consists of 400kV power lines with 220kV lines. This construction was actually finished in 1970 however is not used anymore and only serves as a reserve power line. More over the transmission system has 71 transformers and 41 substations for both basic voltage levels. There are older 110kV grids that have been used for distribution purposes since the 1970s. The responsible company for electricity transmission in the Czech Republic is ČEPS – Česká Energetická Přenosá Soustava a.s. under an exclusive licence granted by the Energy Regulatory Office. This company is specifically responsible for several things like: (ČEPS, 2017)

- To provide transmission and system services under non-discriminatory conditions and at competitive prices
- To operate transmission system facilities and the dispatch of system generating sources within the Czech Republic
- It is responsible for interconnection with the transmission systems of neighbouring countries in compliance with ENTSO-E rules

The Czech 400kV and 220kv transmission networks is usually named the "backbone network" and is required for the distribution of the output of large power plants throughout the whole of the Czech Republic and at the same time forms an important part of the international European network. It is used to supply electricity to distribution networks from where the electricity is further distributed to consumers. The current Czech transmission network is interconnected with neighbouring countries networks through cross-border lines and thus enabling its synchronous operation with the interconnected power systems of the rest of the Continental Europe. (ČEPS, 2017)

Transmission is very important part of whole system therefore it is essential it works fine all the time to provide secure supply of electricity to all consumers. The dispatch of generation within the national system, which is balancing the supply of electricity with demand within the licensed are on a minute-to-minute basis, is actually one of the most important things that a Transmission System Operator has to fulfil.

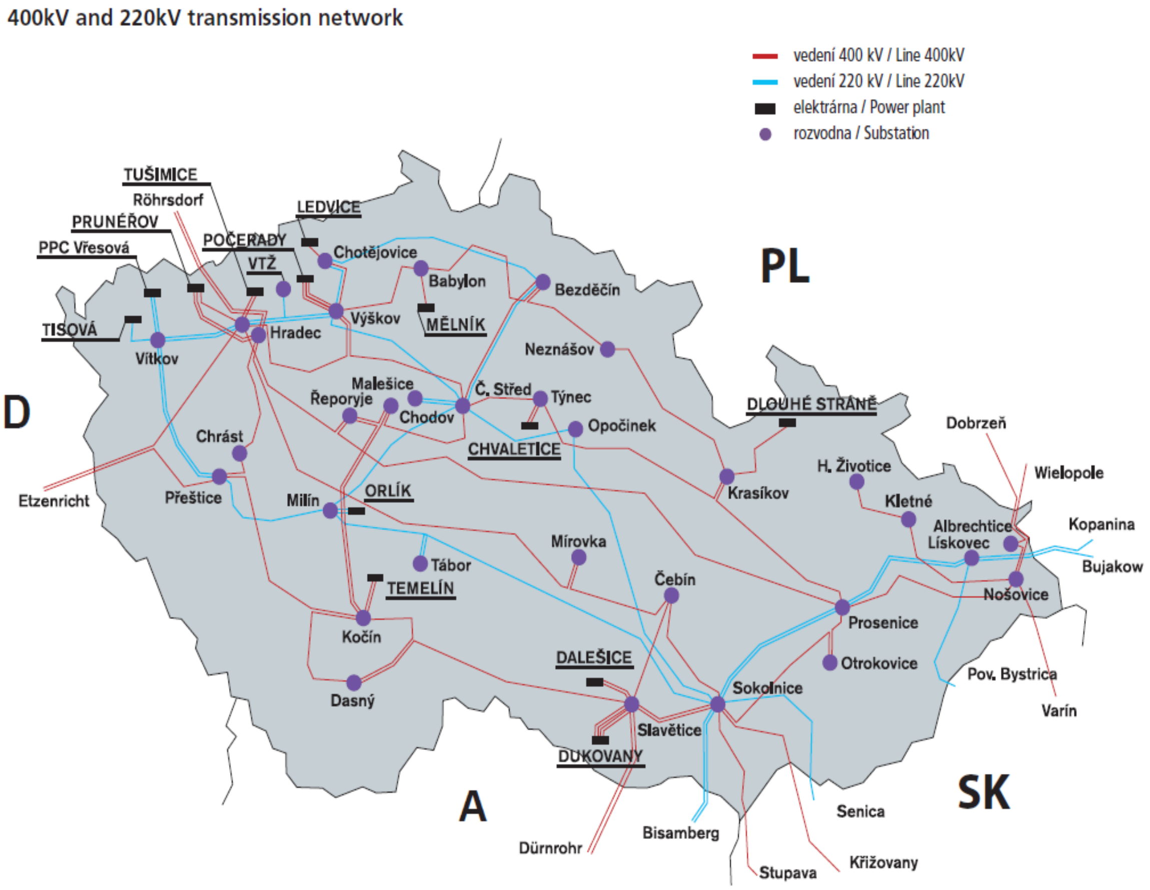
Renewable energy sources have actually changed the very energy source mixture that we used to know. Integrating renewable resources actually imposes higher requirements on the output of these plants to the grid and subsequent onward transferral as well as on the output reserves sources in periods when wind and photovoltaic plants are not generating enough or none energy for the grid. The system is constantly changing and requires the transmission network to be capable of carrying electricity to consumers with increasing demand year by year together with requirements pertaining to the dispatch control of the power systems. (ČEPS, 2017)

The dispatch control of the transmission system comprises of:

- Operational planning - scheduling and dispatch of generation within the Czech power system, scheduling of generation by individual power plants, preparing electricity consumption predictions, forecasting the power and energy balance and planning the structure and volume of ancillary services
- Real-time control – carrying out already prepared plans concerning operational planning and the management of unexpected situations within the Czech power system
- Operational security – analysing currently planned and unplanned situations within the Czech power system and preparing possible measures and solutions
- Operation evaluation – evaluating and analysing the system and its operations in the Czech Republic.

Distribution grid provides distribution of electricity to consumers through the actual grid of connections and lines. Distribution grid is lot of electrical conductions, systems and facilities connected altogether thanks to the 110kV a network. Lower networks are designed to secure the distribution of electricity on designed area in the Czech Republic including measuring systems, protection systems, controlling systems and information systems as well as telecommunication systems like consumer electrical connections owned by the distributor. (Ministerstvo Průmyslu a Obchodu, 2012)

Figure 4: Transmission Grid in the Czech Republic



Source: *ČEPS, 2012*

3.11. Electrical Grid in Germany

Even though there is a huge increase in share of fluctuating renewable resource, especially in Germany, their power grid actually belongs to the best ones and most reliable ones in the Europe and even World. This is very impressive considering the rapid growth of renewable energy in Germany. The power grid in Germany had System Average Interruption Index (SAIDI) of 15.91 minutes in 2012. This index measures the average yearly downtime per customer. This is very impressive since it belongs to the best. On the other hand the Czech Republic had around 140 minutes of downtime in 2012, which is considerably larger than Germany and ranks therefore at the bottom in the Europe. (Amelang, 2016)

The German power grid itself has around 35,000 kilometres of transmission grid, which transmits power at maximum voltage 220 kV or 380 kV. This grid transports electricity over large distances, which means it transports power from where it is produced to where it is demanded. It is also used to export power abroad. Currently only about 0.4% of the German transmission grid is actually laid below ground. (Amelang, 2016)

Distribution grid is used to bring power directly to consumers and is operated by many regional operators (around 900). The distribution grid in Germany consists of 1,679,000 kilometres, which distribute three different level of voltage:

- High Voltage (around 77,000 km) – Transmits power at either 60kV to 220 kV and is used for primary distribution of the electricity to transformer substations in population centres or large energy-intensive companies in the industrial sector
- Medium Voltage (around 479,000 km) – Transmits power at 6 kV to 60 kV to smaller regional substations and larger consumers such as factories or hospitals
- Low Voltage (around 1,123,000 km) – Transmits power at 230 V or 400 V to private households and other smaller private consumers

The transmission grid itself on the other hand is largely owned by the four transmission operators TenneT, 50Hertz, Amprion and TransnetBW which are responsible for the operation, development and maintenance of their respective sections of the grid. Their job is regulation power supply, including balancing fluctuating power from renewables with more predictable generation. (Amelang, 2016)

Power suppliers are obliged to pay a grid fee for the use of their network, which is passed on to the consumer. This is covered for infrastructure costs, invoicing and metering. The grid fee also covers the cost of operating the grid and keeping it stable like voltage and frequency control. Since the big four companies operating the grid have monopoly in their own respective areas the Federal Network Agency puts a cap on what the can charge in grid fees. (Amelang, 2016)

Amprion

- Company that operates the grid in West Germany from lower Saxony to the borders with Switzerland and Austria. (11,000 km)
- This company also coordinates the load and frequency between the four German control areas and is responsible for coordination of exchange programmes for German transmission grid as whole as well as the northern part of the European interconnected system.

TenneT

- This company actually operates around 40% of the German grid running through the centre of the country from north to south. (around 10,700 km)
- The owner is a Dutch company TenneT, which also operates the transmission grid in Netherlands

- It also operates the cross-border interconnections between Germany and Netherlands and Denmark

50Hertz

- Operates the transmission grid in northern and eastern Germany (around 10,000 km)
- Directly connected to the grids in neighbouring Poland and Czech Republic
- Coordinates the interaction of all players of the electricity market in the federal states.
- More than 40% of Germany's installed wind energy output is in this region
- Responsible for connecting offshore wind farms in the Baltic Sea to the German grid

TransnetBW

- Operates the transmission grid in West-South of Germany (3,300) which makes it the smallest operator
- Their grid is connected to the French, Austrian and Swiss networks

Even though German grid belongs to the top of the world there are still many challenges that require investment in development of infrastructure for the future. Thanks to the Energiewende the energy production has become much more decentralized with many small private producers are consumers that are also producing which means the electricity goes in and out of the grid. This means the grid needs to be very flexible in transmitting power in both directions, not only from producers to consumers but also the other way around. (Amelang, 2016)

However the old production power plants with very centralized production are often a long distance from areas of high demand which means even more power has to be transmitted at high-voltage over long distances. It also has to be prepared for lot of power fluctuations since renewable energy production fluctuates with weather and the grid must cope with this.

Naturally there are also factors which do not directly influence the energy transition like the position of Germany on the map which means it plays a big role in transmitting power between Western and Eastern Europe.

The government also provides regulatory oversight to ensure that the grid is available for the use of all market players without any discrimination and to keep charges for its use in check. (Amelang, 2016)

Figure 5: Transmission Grid in Germany

Source: *NEP, 2016*

3.12. On-grid versus Off-grid

This topic is rather focused on the commercial and residential solar panels, since utility solar panels are always on-grid. If a solar panel is off-grid it means it is not connected to the utility grid which distributes or takes electricity from other connectors. Therefore being off-grid means there is a great independency, which means no terms or policies of the local utility, not a system owners subjected to rate increases, blackouts or brownouts. Naturally you don't pay for electricity to anyone as the actual electricity is costly and also off-grid parcels tend to be less expensive. This means that sometimes it is cheaper to build off-grid panels than to extend connection to utility, but not in all cases. It is also easier to expand such a system because there is no need for changing the connection your panels have to the utility grid. There are also some less tangible advantages like a responsibility for electricity usage. On the other hand off-grid system must have batteries at all times. This is another bonus expensive which is a must, because batteries store any surplus energy, which can be used later. Batteries also do not last forever, they need new replacement every five to ten years and they can be quite expensive especially the high end ones. Not only that, but also in the case of extreme production it is possible to reach 100%

capacity of your batteries and any further produced energy is completely wasted. On the other hand in case of bad times and very low production you can be stuck we not sufficient amount of energy to do anything and since there is no connection to the grid, there is no way how to get that energy elsewhere. Naturally no-one wants this to happen, so there is the need to have backup generators, which are expensive both for purchasing and fuelling. In the end being off-grid is quite hard and a big responsibility for anyone. (Woofended, 2009)

There are two types of on-grid system, one with battery and one without. System with battery has actually quite lot similarities with off-grid system since any energy which is not used gets to be stored in the battery and in the case off not sufficient energy the battery can give some. However the difference is that if batteries are fully charged any surplus energy is not wasted but actually is sent via the grid to someone or somewhere else. Furthermore if there is a really low production time and no power left in batter, there is no need for worries since the connection to the utility grid supplies whatever more energy is needed. Thanks to this there is no need to conserve energy at all so there is no need for change of a life style just because of the PV panel.

According to known data the on-grid system with battery seems to be the best overall options. Even though it is not the cheapest one it covers all of the potential problems like low production, or utility grid outage. In this case you have to pay more, but the value gotten out of it is great. (Woofended, 2009)

3.13. Germany and Nuclear Power

Even though this may sound like a bit of an off-topic, nuclear power is actually closely tied to solar power especially in Germany. There are 17 nuclear power plants in Germany (Biblis A, Neckarwestheim, Brunsüttel, Biblis B, Isar 1, Unterweser, Phillipsburg 1, Krümmel, Grafenrheinfeld, Gundremmingen B, Gundremmingen C, Grohde, Phillipsburg 2, Brokdorf, Isar 2, Emsland, Neckarwestheim 2). Nuclear power belonged to a strong producing source in Germany for many years and even though there was incentive to increase renewable resource power generation it was not as strong as what happened in 2011.

In the spring of 2011 natural disaster occurred in Japan. It was an extremely strong earthquake which created tsunami wave. The wave hit nuclear power plant on the shore of Japan, Fukushima. It was destroyed a resulted in nuclear break and lot of lives lost. It was brought up again how dangerous nuclear power plants are especially the production and the waste this is extremely dangerous for many years after. (Smedley, 2013)

A coalition government which was formed after 1998 federal election had the phasing out of nuclear energy as a feature of its police. However nothing really happened and with a new government in 2009, the phase-out was cancelled. That was until 2011 and the Fukushima disaster. After this disaster the public opinion of nuclear power changed drastically and people started to protest against it and basically forced the government to take action. They reintroduced the shutting down of nuclear power plants and introduced a very ambitious plan to do so. Replace all the nuclear power plants with renewable energy. There were 17 reactors in Germany which produced around one quarter of its electricity. However after the new government policy to shut down all the nuclear power plants until 2022 and to replace it with renewable energy, 8 nuclear power plants were shut down immediately in March 2011. The plan for the shutdown of the rest of the power plants was formed, with some to be shut down earlier and some as late as in 2022. The aim was to reach that renewables contribute 80% of Germany's energy by 2050. (Smedley, 2013)

In a 28 November 2015 Special Report *The Economist*, having pointed out that French households pay about half as much as German ones for electricity, commented: "*Germany has made unusually big mistakes. Handing out enormous long-term subsidies to solar farms was unwise; abolishing nuclear power so quickly is crazy. It has also been unlucky. The price of globally traded hard coal has dropped in the past few years, partly because shale-gas-rich America is exporting so much. But Germany's biggest error is one commonly committed by countries that are trying to move away from fossil fuels and towards renewables. It is to ignore the fact that wind and solar power impose costs on the entire energy system, which go up more than proportionately as they add more.*"

3.14. Feed-in Tariff

Feed-in tariff is a policy designed to help grow renewable energy technologies by bringing investments. This is done by offering long-term contracts to renewable energy producers which are dependent on the costs of each technology. This means that it reflects costs which are currently higher or lower and based on that the producers are payed.

This policy was invented and first implemented in Germany in the early 1990's. Naturally it was modified from that time. This tariff is based on the premise that renewable resources are more important than other sources of energy. Thanks to that governments which implemented this policy guarantee investors that a certain amount of investment will be paid back no matter what the electricity price is. (Divišová, 2013)

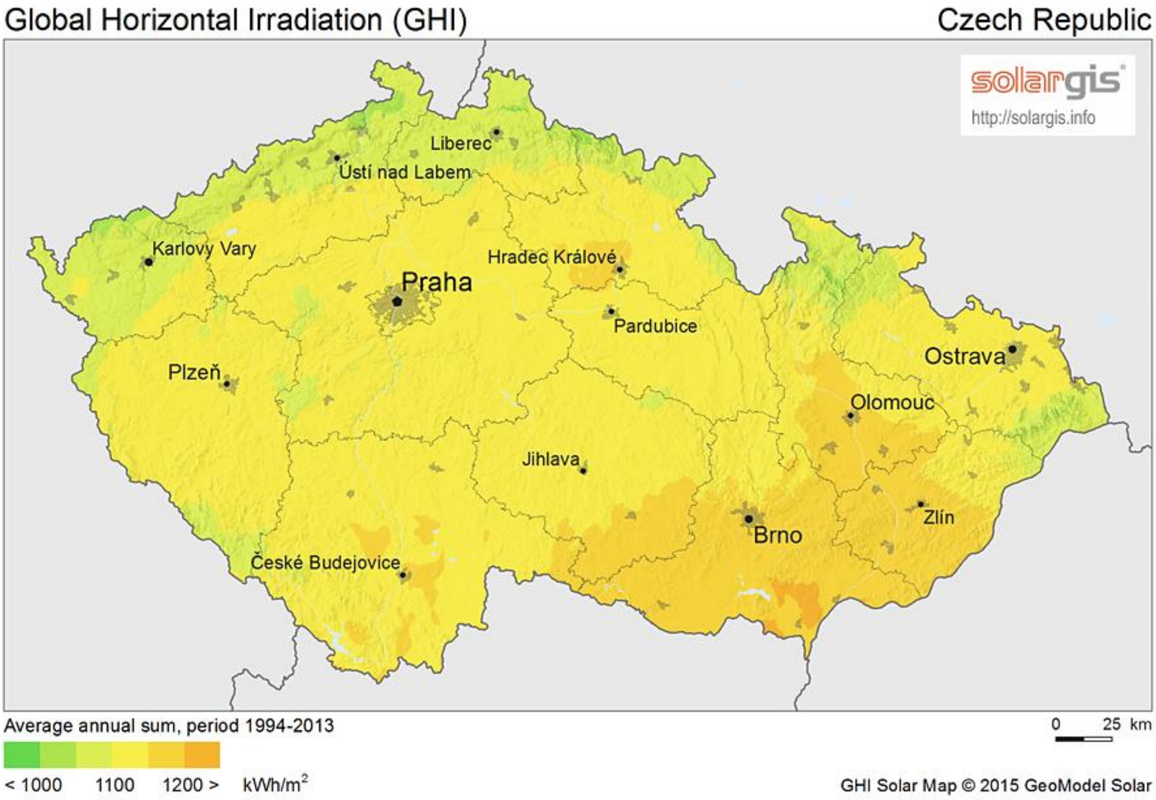
This tariff even though originates from Germany, was adopted by many other countries. Beside Germany this policy is implemented in countries like France, Ireland, Netherlands, China and Japan. Czech Republic did adopt this policy as well, which was in 2005, however it was cancelled at the end of 2013 for all new renewable energies (exception wind, hydropower and biomass) which was view very controversial. Not only that, but it also meant extending 28% tax on solar system which was applied retroactively, which was received very negatively by the producer and investors. (Divišová, 2013)

3.15. The Czech Republic

The Czech Republic is a country located in Central Europe. It is bordered by Germany, Poland, Austria and Slovakia. Population of Czech Republic is approximately 10.5 million people. It covers area of 78.8 square kilometres. There are three historical regions: Bohemia, Moravia and Silesia. The landscape of the Czech Republic is actually rather variable since there are mountain ranges around its borders but also lowlands in north Bohemia and south Moravia. It has a continental climate, which means it has warm summers and cold and snowy winters. Thanks to its geographical positions there are rather big temperature differences.

The Czech Republic is average in Europe in terms of potential PV production, naturally thanks to its geographical position in Europe. Looking solely at the map of the Czech Republic, which can be found below, it is apparent that the potential production is rather balanced across whole country with the exception of mountains in the north and lowlands in the south of the country. (Stiburek, Jestřáb, 2009)

Figure 6: Solar Map of the Czech Republic



Source: *Solargis, 2015*

3.16. Germany

Germany is a country located in central-western Europe. Its neighbours are the Czech Republic, Poland, Austria, Switzerland, France, Luxembourg, Belgium and Netherlands. The area of Germany is in total 357.168 squares kilometres. It has a population of approximately 82.1 million people which makes it the most populated country in EU. It is bordered by the North Sea and the Baltic Sea. Germany has all kind of geographical bodies thanks to it rather great area. Lowlands can be found in the north of the country and going south there are many uplands in the central Germany. In the south there are more and more mounts with the Alps being most dominant. Naturally in terms of climate there are differences between south and north as in the south there is continental and in the north rather almost oceanic climate. This makes the winters decently cool and summers decently warm.

The solar potential in Germany differs decently from north to south as can be seen from the map below. While in the north the potential productions is the lowest in the country the further south you go the higher production you get peaking in the far south of the country. There is a rather exceptional potential in terms of potential production in

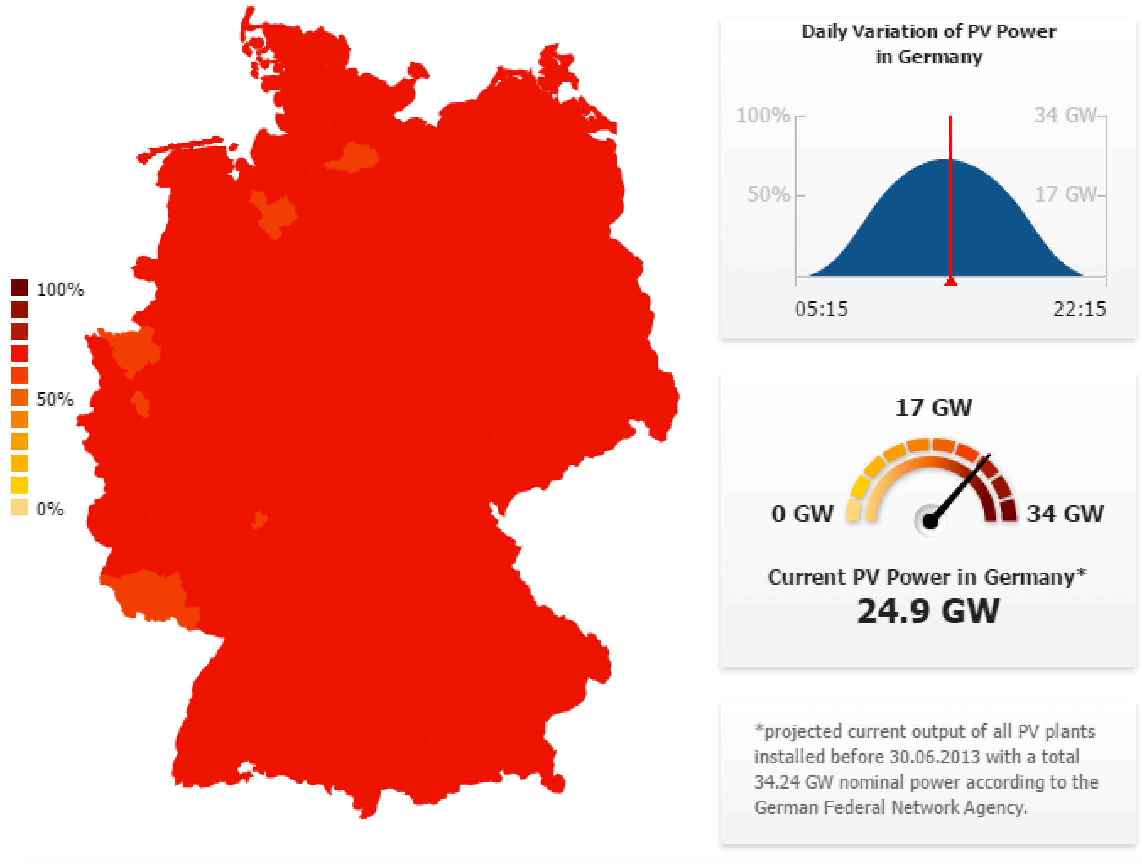
Germany. Beside that the map shows only standard values for Germany's geographical position. (Stewart, et al., 2010)

Figure 7: Solar Map of Germany

Source: *Solargis, 2015*

The picture below is a representation of one of the best days for solar energy in Germany that happened in the last several years. It shows a peak production of 24.9 GW from a maximum capacity of 34 that was installed in Germany at that time. It also shows how the production changed over the course of one day and peaking at around 13:00 CET. It is also apparent that most of the solar panels were functioning at around 70-80% of their maximum capacity at that time. There are also different regions shown.

Figure 8: Relative output from 21.07.2013 – 13:15 Germany



Source: *SMA, 2017*

4. Results

4.1. Advantages of Solar PV

- As a renewable energy supplied by the nature (the Sun) – Solar energy is therefore free and will run out in millions of years
- Since during electricity generation with photovoltaics panels the is no harmful greenhouse gas emissions, thus solar PV is environmentally friendly providing clean – green energy
- PV panels can be built to produce electricity anywhere where there is sunlight
- The generation process of PV is a direct generation way of generating electricity
- Even compared to other renewable energy systems, the operating and manufacturing costs for PV panels are considered to be very low, almost negligible
- The cost of solar panels is currently steadily decreasing every year at a decently fast pace and is expected to have a decreasing trend in the future
- Photovoltaics belong to one of the most researched energy technologies in the moment, which means it is moving quickly forward in terms of increasing effectivity and generally new technologies
- Thanks to the two points mentioned above, PV has quite bright future for economic viability and also environmental sustainability
- Photovoltaic panels are totally silent even when generating energy, which makes them a great choice for urban areas and even for residential applications
- Even though the prices of solar energy panels is steadily decreasing for year and is still expected to, photovoltaic panels belong to one of the renewable energy systems that are promoted and supported by government subsidy funding in many countries. This makes them generally quite attractive investment alternative
- Solar panels that are installed in residential areas are quite easy to install on rooftops or on the ground where they don't interfere with residential lifestyle
- Since there are no moving parts to cause wear and tear, it further decreases the maintenance cost
- There are also more ways how to utilize solar energy. It can produce electricity or heat

Solar energy holds quite lot advantages even though it is relatively young field compared to the likes of fossil fuels. It still has many years of research that lie ahead however it is already today that it present good enough results for regular usage. The thing is there will not be coal, gas and others forever. Which means it is the right time to slowly transfer onto something that can not only replace them but also last for a long time and solar energy could be just it. The other great point is that it is fully natural energy that does not pollute at all, which is a great advantage. Humans should be looking to find more ways to preserve nature for future generations and finding renewable source of energy that generates enough power is just it. If the research moves forward and the efficiency will be increased enough solar energy could be primary source of energy for mankind not only on earth but also in the space.

4.2. Disadvantages of Solar PV

- Solar energy is quite a lot dependant on circumstance that cannot be influenced by men, like on weather. If it is cloudy or rainy the production inevitably decreases
- Naturally PV production is also dependant on the time, meaning when it is night there is no sunlight and therefore no production
- Geographical location is also fairly important since in the north there is less sunlight than in the south. Which makes it naturally more efficient build PV panels closer to equator or generally in hot areas rather than in the northern cold areas where sunlight falls sporadically
- Not only are solar panels needed to have continuous supply of electric power, but also inverters and storage batteries, especially for on-grid connections. This increases the investment cost for photovoltaic panels considerably
- Even though the research is in full speed currently most of the solar panels possess efficiency of only 15% to 25% which is considerably lower to other renewable energy systems
- Even though as is mentioned in advantages PV panels have decently low maintenance and operating costs, they are also very fragile, which makes them vulnerable to outside damages. Therefore additional insurance costs are vital importance to safeguard a PV investment
- Solar panels can actually use up a lot of space. The more power u want to generate the more solar panels you have to build, which can use up big fields that could be used differently
- Even though the prices of PV are decreasing in all fields, the price of electricity which comes from solar panels is still more expensive than other sources

- The initial cost of solar panels is still relatively high

There are still several disadvantages that come from solar energy. One is revolved around intermittency issues that solar energy has, which are caused by weather and others. These can be hard to change or even impossible to eliminate. The second one is actually technology. Many of solar panel problems could be solved with a better technology. This means increased efficiency, where it produces more electricity resulting in fewer panels needed that take up space. Or be it storage problems which are currently decently big. Or if we fast forward many years and humans are able to place huge solar panels on Earth's orbit where they can gather sunlight constantly without any pauses and then somehow transfer them back on Earth to our homes that would be an easy solution.

4.3. Comparison of Electricity Production

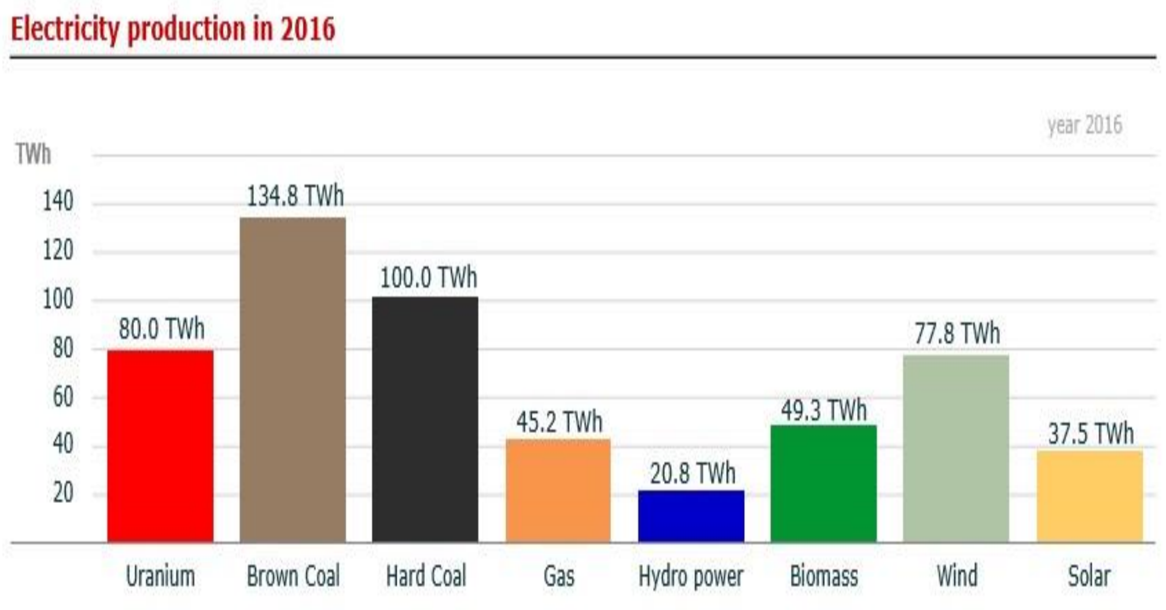
This part focuses on comparing production of electricity in Germany and the Czech Republic. This is done to better understand how both countries work in term of production and to further focus on how each country is focusing or not on solar energy. This is looked at from point of time and also the amount and process of the production

The comparison of the most recent year and data available is 2016. First looking at Germany their production in 2016 was 545.49 TWh which is pretty much the same as in 2015 as it only experienced very small increased by 0.5 TWh which is well below 1% change. Even though Germany is trying to produce energy via renewable sources as much as they can, non-renewable resources are still dominant in their production in 2016. Nuclear power plants produced around 80 TWh which is 7.8%. This is actually a small decrease from previous year since the production in 2015 was 86.8 TWh. This is according to Germany's plan of shutting down nuclear power plants. The highest amount of production was secured by lignite power plants which generated around 134.8 TWh, which is again a small decrease of 3.3% from last year. Lignite power plants are still quite inflexible to sudden high feed of renewable energies which forced some curtails of production. Hard coal plants faced a small decrease at about 5.8% from previous year as well. The total production was 100 TWh. On the other hand gas power plants were the only non-renewable energy resource which faced an increase in production and not a small one. This increase was by 50 % (15.1 TWh) above the level of the previous year to a current 45.2 in 2016. This was probably caused by low gas prices that occurred last year.

Renewable energy resources are a current focus for Germany. However the production of photovoltaics solar panels was only 37.5 TWh which is actually 3.3% lower than previous year. This small decrease is probably caused by different weather conditions and only a small installation rate of 1.2 GW even though the government target was 2.5 GW. The peak of solar power production occurred on 8th May 2016 at 13:00 and was 28.5 GW and 47% of total electricity generation. May 2016 had higher monthly electricity production of solar panels than that of nuclear plants. Wind generated 78 TWh total energy which is a decrease by 1.2 TWh from last year. The wind energy was decently high throughout a whole year as it had six months with higher production than nuclear power plants and a peak production in February which was even higher than hard coal. The smallest amount of production goes to hydropower plants with only 20.75 TWh which is basically unchanged year to year. Biomass on the other hand experienced a small increase of 2 TWh at current 49 TWh. In total, renewable energy sources produced approximately 185 TWh of electricity in 2016. There was no increase compared to 2015 thus their share was around 33.9% of public power supply.

In 2016 there was also an export surplus which reached 50 TWh. This is actually a record compared to previous years which also had records. This year the increase is 4% (2 TWh) above the record in 2015.

Figure 9: Electricity Production in Germany in 2016

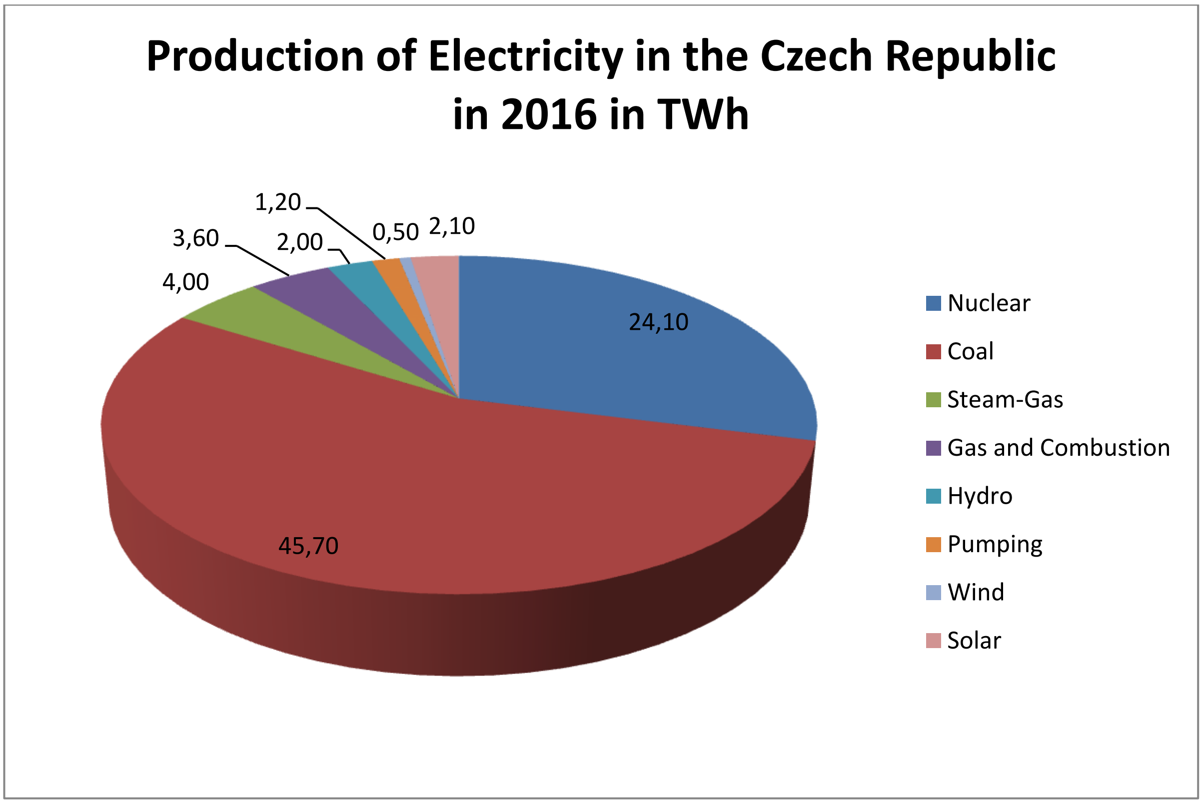


Source: *Fraunhofer ISE, 2016*

The numbers for the Czech Republic are naturally much smaller since it is a smaller country with less people and generally smaller demand for energy. That is why there is smaller amount of power plants that produce energy in the Czech Republic.

The overall production of electricity in 2016 was around 83.2 TWh which is a very small decrease compared to previous year about 0.5 TWh. However only 59.7 TWh was consumed which resulted in 24 TWh exported amount of electricity. Compared to Germany the Czech Republic has much higher share of electricity which is not consumed home and is exported instead. This may be cause by the much smaller overall amount that is produced in the Czech Republic. The highest production in the Czech Republic is secured by the coal power plants by a pretty large margin. In 2016 they produced 45.7 TWh which is about 55% of all production. The second largest portion of produced energy is held by nuclear power plants with 28% share. This amounts for 24.1 TWh for 2016. This is a small decrease compared to year before. Then looking at renewable sources of energy the highest producing were solar power plants with 2.1 TWH in 2016 which is only 2.5% of overall energy. Wind energy produced amounted for 0.5 TWh which is also a very small amount below 1% of production. On the other hand hydro power plants did almost as well as solar one with 2 TWh.

Figure 10: Production of Electricity in the Czech Republic in 2016



Source: *ERÚ, own processing, 2017*

This clearly shows that Germany produce overall much more electricity than the Czech Republic does, however that is just to be expected and natural looking at how big the countries are, how many inhabitants they have and the overall demand resulting from it. Even though Germany tries to be producing green energy they are still heavily dependent on coal power plants just like the Czech Republic is. However the share of Germany's coal power plants is smaller than Czech's. This is a result of their efforts and even more so apparent looking at the share of renewable resources. If counted together renewable resources actually produced 185 TWh in Germany which made up around 33.9%. This is really high number that clearly demonstrates their effort. On the other hand the Czech Republic renewable resources produced only 6.8% of all energy in 2016. This is a much smaller share than in Germany. This is a very clean sign that there is a much longer history of renewable resources in Germany than in the Czech Republic. Even further can this be seen when realized that the share of renewable resources in the Czech Republic is actually smaller than only the share of solar energy in Germany, which is 7 % while CZ has only 2.5% even though solar power plants were the highest producing renewable source of energy. This is a considerably smaller amount especially with the fact that both countries have mostly same conditions for generating solar energy with the exception of south Germany, but nevertheless this is a big difference. This difference is even much greater in wind energy generation. While the Czech Republic barely has any wind power plants and thus the generation is the lowest of all sources for it, Germany's wind power plants actually generate the highest amount of all renewable resources amounting for a decent share of overall energy. The clear result is that Germany is actually really trying to produce their energy via renewable resource as much as possible while the Czech Republic has very limited amount.

4.4. Comparison of Evolution of Electricity Production

In this part the electricity production in both countries is looked at specifically from point of their evolution over time and what it meant for the countries and other generating resources

Looking at the table below, we can see that Germany's overall production did not have any big shocks over the years. It is also apparent that their primary production source has been coal for many years. This is no surprise as this is same for most of the countries around the world and also as coal is a steady energy source which can be relatively easily operated compared to those like wind or solar energy. It is also not surprising to see the decrease in nuclear power plants production from year 2011 when the German government decided to pursue a very ambitious of plan of shutting down all nuclear power plants down. As can be seen they are actually holding on to this plan as they already shut down several plants and the amount of energy produced from them is almost halved now. However the missing energy has to come from somewhere else and that where renewable resources come to play especially wind and solar ones. Hydro plants had already decent amount of production and history before 2011, but this resource is limited by nature itself. That is why Germany invests heavily in new resource like wind and solar energy. Wind did have some plants installed already but a big raise after 2011 can be seen to generate more clean energy and to replace missing energy from nuclear power plants. Very similar role plays solar energy. Even though it may seem there was no production around 2000 it is not actually true, there was. However the production was so low that it was basically non-factor in Germany's production. There were solar power plants as early as in 1990, but for more than 10 years the production was so low that it did not even reach 0.1% of overall energy generation. This changed after 2005 and further increased its production. Germany is aiming to increase their PV production however this year they failed to do so thanks to a low installation of new solar panels (they did not reach their goal of annual installation amount for photovoltaic panels in 2016). This resulted in a halt to the rapid increase which was seen in last years. Nevertheless Germany is still very committed to increase their PV production as their research is currently one of the best in the world in this area and brings therefore results like the most efficient current solar cell in the world.

Table 2: Evolution of Energy Production in Germany

[TWh]	Coal	Gas	Nuclear	Hydro	Wind	Solar	Overall
2000	291.4	49.2	169.8	24.9	9.5	0	576.6
2005	288.2	71	163	19.6	27.2	1.3	620.6
2010	262.9	86.8	140.6	21	37.8	11.7	628.6
2011	262.4	82.5	108	17.7	48.9	19.3	608.8
2012	276	70	94	20.5	45	28.5	617
2014	273	61	97.1	19.6	57.3	36.1	627
2015	272.2	62	91.8	19	79.2	38.7	646.9
2016	260	78.5	84.9	21.5	79.8	38.3	648

Source: *DE Stastis Statistisches Bundesams, 2017, own processing*

The Czech Republic as even more stale production than Germany does and there can be seen some similarities. The Czech Republic has to primary sources that generate energy. The first one are coal power plants, which produce the most in the Czech Republic with an insane share of around 55%. The second one is nuclear power plants, which have the second highest share of energy production in the republic. They generally have around 30% of overall production with only a little variation over the years. Even though 2016 seems to have a decrease this is only a temporary as it was caused mostly by unexpected shut down of one of Czech's nuclear power plants. Therefore it is expected to rise back to around 30 TWh per year in the future as the Czech Republic does not have any plans for increase or decrease. Together coal and nuclear power plants account of an insane share of almost 90% of all energy produced in the country. This shows how small the room left is for renewable energy production. Wind production is almost non-existent in the country. Hydro power plants produced just a small amount a little bit smaller goes to solar power plants. However hydro production is much longer history than solar one. First decently large amount of solar panels was built around 2010 in the Czech Republic and most of the plants were built till the end of 2011. From that year almost no new production occurred in the Czech Republic and there are very low plans for it currently which is given mostly by the policies of Czech's government which cancelled all feed-in-tariffs by the end of 2013 as one of the few European countries.

Table 3: Evolution of Energy Production in the Czech Republic

[TWh]	Coal	Gas	Nuclear	Hydro	Wind	Solar	Overall
2000	51.8	0.9	13.6	2.3	0	0	73.5
2005	49.9	1	24.7	3	0	0	92.6
2010	46.9	1.1	28	3.4	0.3	0.6	85.9
2011	46.7	1.1	28.3	2.8	0.4	2.1	87.6
2012	44.3	1.1	30.6	2.7	0.4	2.2	88.1
2014	44.4	2.2	30.3	2.9	0.5	2.1	86
2015	44.2	1.9	26.8	3	0.5	2.2	83.8
2016	45.7	2	24.1	3.2	0.5	2.1	83.2

Source: *ERÚ, 2017, own processing*

Both countries have some similarities in their energy production like the top producing source being coal. However the difference is that Germany has lower overall share for about 10%. Furthermore the biggest difference is the evolution of nuclear power plant production and its consequences. While the Czech Republic is satisfied with its current nuclear production and policy not only for past but also for years to come Germany has experienced a big shock in 2011 after the disaster in Japan Fukushima. After this horrible event, public opinion of nuclear plants has quickly gone downhill and people basically forced their government to act. Only after few months from this disaster German government decided to get rid of all the nuclear energy and shut down all of their nuclear power plants by the end of 2022. Several plants were shut down the same year and the rest of them are scheduled for doing so. This however meant that Germany needed to fill the missing production somewhere else. This was one of the reasons which ignited a boom of renewable energy in Germany. Yes they were installing renewable energy power plants before, but not to such an extent. This can be seen from a steady increase in both Wind and Solar energy production over the years in Germany. Since solar energy is younger and technology is not as advanced as it needs to be the higher production is still in wind. However the research in PV is very good in Germany so it is possible that they will continue to build more of solar panels as is their current plan. On the other hand the Czech Republic not only has very low renewable resource production of electricity, but they even do not have any future plans or policies for increasing it. This can be interpreted as a worrying trend especially since most of the European countries plan to increase renewable power plants.

4.5. Comparison of Evolution in Installed Power Generation Capacity

One thing is the annual production, and other thing is installed power generation capacity. But both are very important. However installed power capacity means what is the maxim capacity that an installed system is capable of producing in perfect conditions. This is especially true for renewable power plants like solar and wind since even though they are designed for a certain capacity they very rarely run at 100%. It is actually the exact opposite and they actually run well below full capacity most of the time.

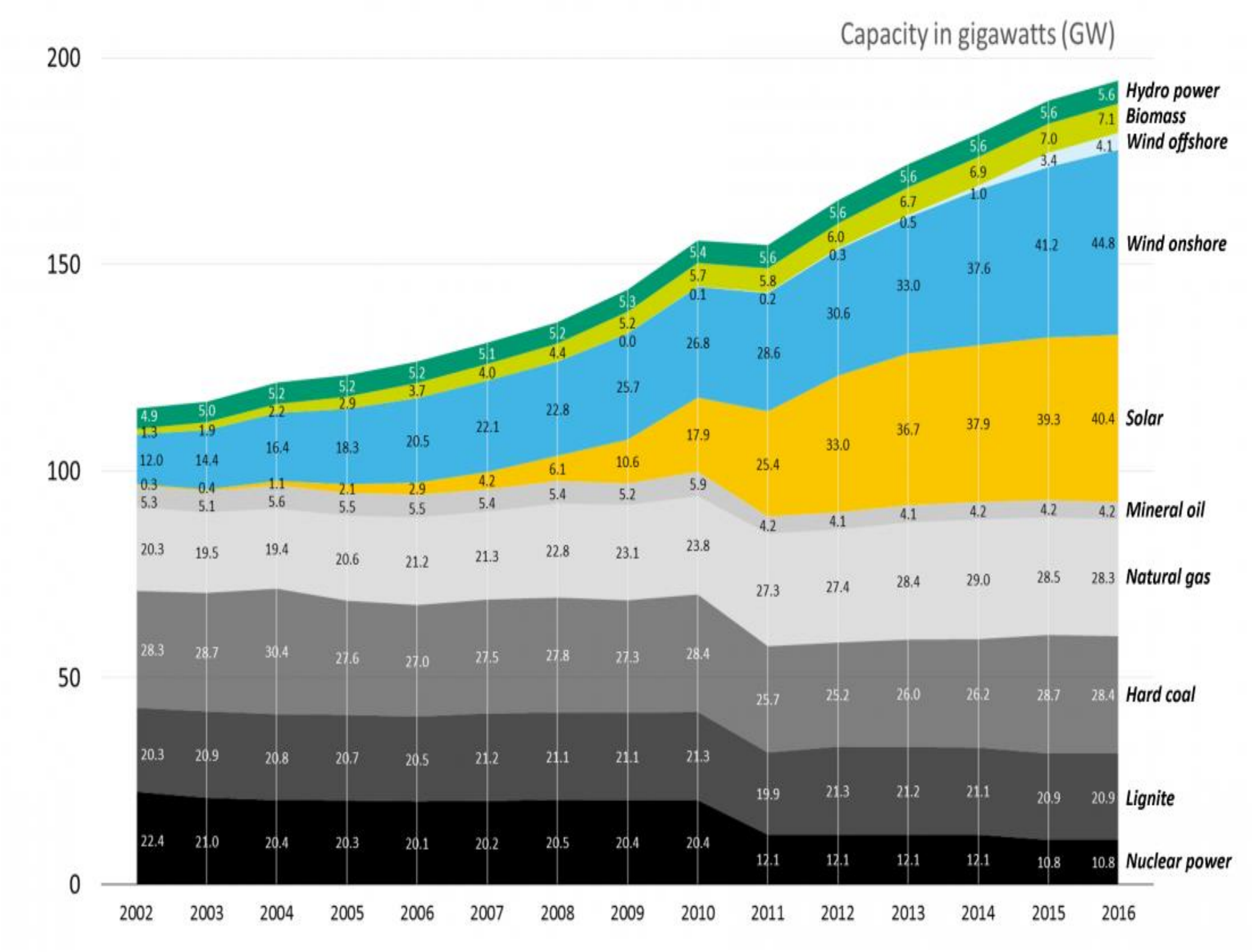
It is therefore interesting to compare installed capacity with actual production. Looking at the graph below it can be seen how the installed capacity changed in Germany over the years. It is again very apparent that the main producing sources and coal, gas and nuclear power for many years. Furthermore there are no new installations in recent years, except with some new installation for gas power plants in 2011. On the other hand it is apparent that instead of installing new power plants there are existing ones being shut down instead. This is mostly true for nuclear and coal power plants in 2011. This is a result of happening in 2011 when German government decided to follow an ambitious plan of shutting down all nuclear power plants and drastically increasing the share of renewable resources by the end of 2022 and 2050 respectively. This happening was a result of Fukushima disaster in Japan.

The year 2011 also sees a massive shift from nuclear to renewable power plants. There are many new installations in wind and solar energy. Even though wind energy had already been established in Germany there are many new power plants built within few years increasing its total capacity from 26.8 to 44.8 GW in 6 years which is almost double. On the other hand solar energy was just slowly becoming relevant when this happened. It meant a huge increase in new solar power plants with few years. The total capacity went from 17.9 to 40.4 GW which is most than doubled in 6 years. There is a plan to increase solar capacity by 2.5 GW every year which was actually done until the last year. However the plan is to continue building at least 2.5 GW a year in the future.

The interesting part is comparing the installed power generation capacity with actual production in the Germany. According to the installed capacity Germany should have about 50% of all energy from renewable source. However this is not the case since renewable power do not work the same way non-renewable do. There has to be ideal conditions in order for solar power plants to produce the maximum amount of energy they can. Nevertheless even in the best days, which are only very few a year, solar power plants actually produced only around 70% of their total installed maximum capacity. There is basically no way to reach 100% of all installed capacity in production due to various reasons like technical reasons and also weather conditions. Thanks to this it is possible to limit or restrict individual plants to 70 percent of their maximum power capacity, which would lead to only 2 to 5 percent loss of revenue. Such a statutory regulation is also actually in place from 2012 in Germany.

Another positive thing about solar power is that it is complemented by wind power. It means that high solar irradiance is negatively correlated with high wind speeds. So if the Sun shines a lot it means there is almost no wind and the other way around. This actually means that are is constant feed of renewable energy that Germany has access to. It is therefore very beneficial to have those two renewable sources in balance and expand them together and not only focus on one of them.

Figure 11: Installed New Power Generation Capacity in Germany 2002-2016



Source: *Clean Energy Wire, 2016*

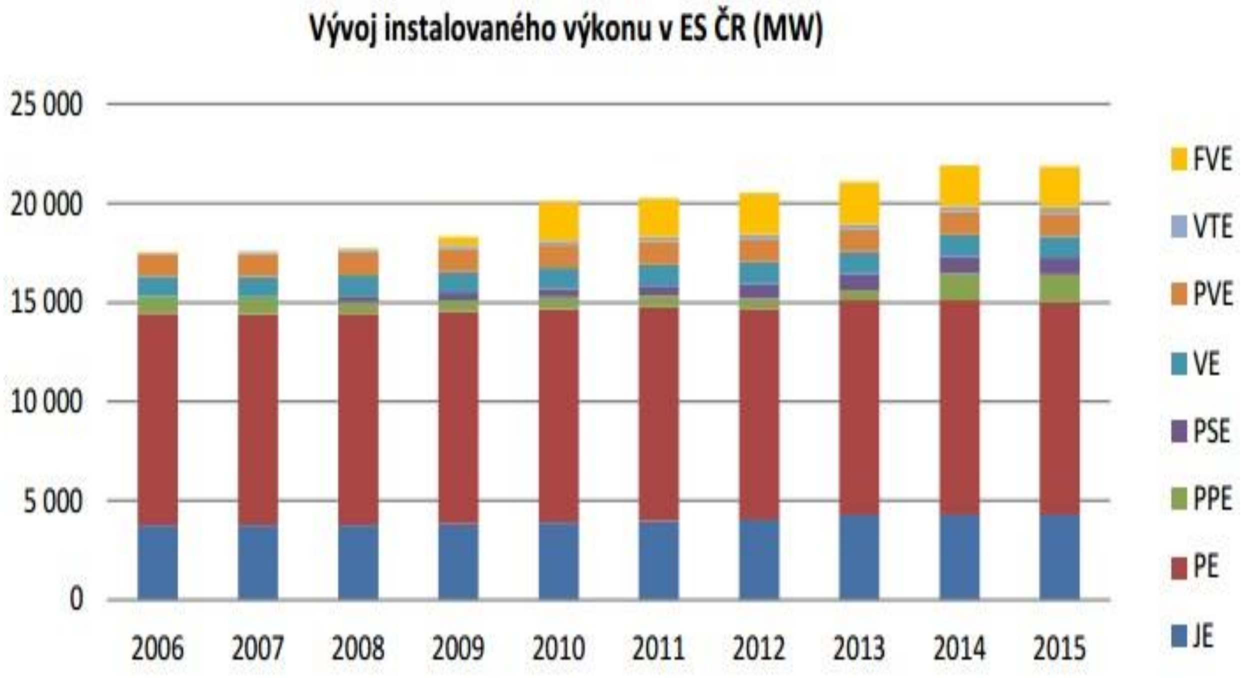
The Czech Republic has only a little variation in their new installed power generation capacity in last 15 years. There are already established coal and nuclear power plants that provide most of the energy for them. Over the years there is only a very small increase in capacity for nuclear power plants however only about like 500 MW which is not much. For coal power plants there are even small change where one year the capacity increases by 100 MW the next year it goes down by 100 MW but nothing major at all.

The same goes for hydro power plants where they were already established for a long time and there was basically no increase at all. The only decently recognizable change is in wind a photovoltaic energy. Wind energy increase from year 2006 to 2015 by 240 MW which does not seem much but it is actually 7 times higher capacity than it was in

2006 which is definitely major. However even bigger change happened in solar energy capacity increase. From 2006 where the capacity was around 0.2 MW increased over 10 years by an enormous margin to 2074 MW in 2015. This is an insanely high increase and most of it actually happened in only two years. In 2008 the capacity of solar energy generation was 39.5 MW however on the end of 2010 the capacity raised to an insane number of 1959 MW. This means that over 95% of all installed capacity of solar power plants in the Czech Republic happened in only two years. After that there were only few new solar panels built and the peak of the solar capacity was in 2013 and reach 2 132 MW. From this year the capacity is actually very slowly decreasing.

Comparing the actual capacity to production shows that it is very similar and almost mirrored in term of shared produced energy. Every type of production has actually decently same share compared to its installed share of capacity.

Figure 12: Installed Net Power Generation Capacity in the Czech Republic in 2006-2015



Source: *ERÚ, 2016*

The comparison of evolution of installed capacity between Germany and the Czech Republic shows that both countries start decently same. Assuming the gross difference in the amount is ignored but rather focused on the percentage share and evolution, it is apparent that both countries have long lasting base in coal and nuclear power plants installed many years ago as their main sources of energy. However the difference is that while the Czech Republic remains at around same capacity, Germany decides to reduce their coal and nuclear power plants capacity by a large margin 2011. This follows the natural disaster in Fukushima which resulted in the government decision to shut down all nuclear power plants and replace the missing energy with renewable one. This is a turning point for Germany where they reduced non-renewable capacity and increase renewable one. Both wind and solar energy power plants are built across whole Germany to increase the energy capacity and to fulfil the plan that was set in 2011. So while Germany is installing new solar and wind panels the Czech Republic is already after its biggest boom and is without and future plans on new installations. Whereas Germany still has a very ambitious plan of installing 2.5 GW a year which they could not reach in 2016, but should aim to do so in 2017 if they want to continue successfully their plan.

Interesting matter in installing new PV systems is also in what capacity and by whom were they installed. Looking at Germany and comparing overall installation capacity with different shares of capacity installed we can see that between the years 2000 and 2008 where the overall capacity was really low in Germany, most of the PV system were built with very small capacity. Looking at the graph below, it shows that the most built categories are the two smallest ones – up to 10 kWp and 10 to 100 kWp. The other two categories accounted only for a small percentage share between those years. This means that solar panels built in that time were mostly individual and small farmers while the reminder was divided between commercial enterprises, project planes and investment funds. However the top 4 producers of electricity in Germany (EnBW, RWE, Eon and Vattenfall) were avoiding PV systems. There could be many reasons for this.

- The power consumption in Germany declines steadily since 2007. Building new PV plants would reduce the utilization of existing power plants thus increasing export
- Since PV electricity is generated during the day at times when demands is at peak, this lowers the market price of electricity. Big power plants operators were able to sell base load power at lucrative price during midday. Since 2001 PV decreased the price on the energy exchange which led to dramatic slumps of profit.
- There are needed new radical business models since PV production has to be decentralized compared to largely centralized coal and nuclear power production

However this somewhat changed for the big four companies between 2010 and 2013 where they recognized they have to go with the flow and not only because of the happening in 2011 and the government's plans with renewable energies but also because they wanted to have their cut of share. This resulted in transferring employees into their renewable energies department as well as building their own solar power plants. This can be very well seen on the graph where in the last 7 years the share of small capacity power plans built has declined and the share of the biggest capacity power plants with more than 500kWp has increased by lot getting almost 50% of overall built capacity every year. The interesting thing is that the third middle group with 100 to 500 kWp is the least built group overall across the years.

The situation in the Czech Republic on the other hand is much different. Before 2008 there were almost no solar panels in the country. The few existing one were mostly residential or owned by small firms. No big installations at all. However this changed with the two years PV boom that occurred in the Czech Republic. This boom occurred thanks to the support that the Czech Republic's government put in place. The support prices were set up so high that everyone who could tried to build some solar panels. That is why the amount of installed solar power plants raised so insanely high just within two years. Within those two years even the biggest solar power plants in the Czech Republic were built. Many companies and wanted to build their own PV facility with no exceptions. Even the biggest producer of electricity in the Czech Republic installed several solar power plants in the country and currently holds the biggest one. However as quickly as this boom appeared it also disappeared. After 2010 there were almost no new installations built and even the government recognized that the support prices were not sustainable and were set way to high and actually completely cancelled them.

Therefore the installation rate in Germany in much more steady with every year having a fair contribution compared to two year boom that happened in the Czech Republic. From this we can also see that while Germany has a plan for future of photovoltaics and probably bright one, it seems that the Czech Republic has no future plans and probably not even a future, since there are no new big PV projects planned. So while Germany continues to build new solar power plants the Czech Republic will probably only maintain current ones.

Figure 13: Number of PV Systems Annually Installed in Germany

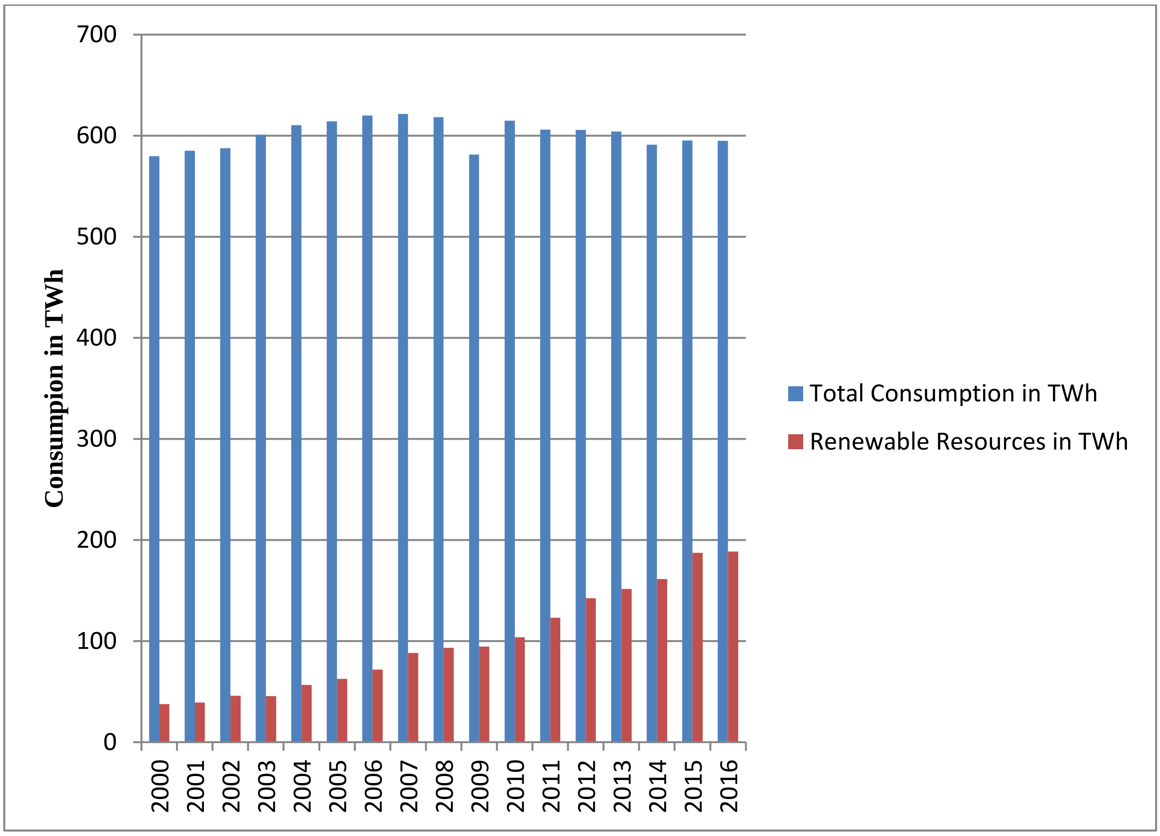
Source: *Fraunhofer ISE , 2016*

4.6. Comparison of Energy Consumption

One thing is knowing how a country does in terms of production, which is important, but it is only a half the picture when talking about energy. The other very important part is the overall consumption. It completes the picture about energegtics.

Even though it may be surprising to many people, but the German gross electricity consumption is actually decreasing since 2007. However before that Germany had gross electricity consumption just above 500 TWh annually and rising. In 2003 in reach 600 TWh for the first time in German history and was still going upwards. The peak came in 2007 with 621.5 TWh. However after that it experienced a big dip in energy consumption with 2009 and 581TWh which was mainly due to economic crisis which happened that year. In 2010 the consumption recovered to 614.7 TWh, but the following years are nevertheless trending downwards. The last 3 years are actually bellow 600 TWh annual consumption again.

Figure 14: Gross Electricity Consumption in Germany



Source: *DE Statis 2017, own processing*

4.7. Comparison of Electricity Price and It's Structure

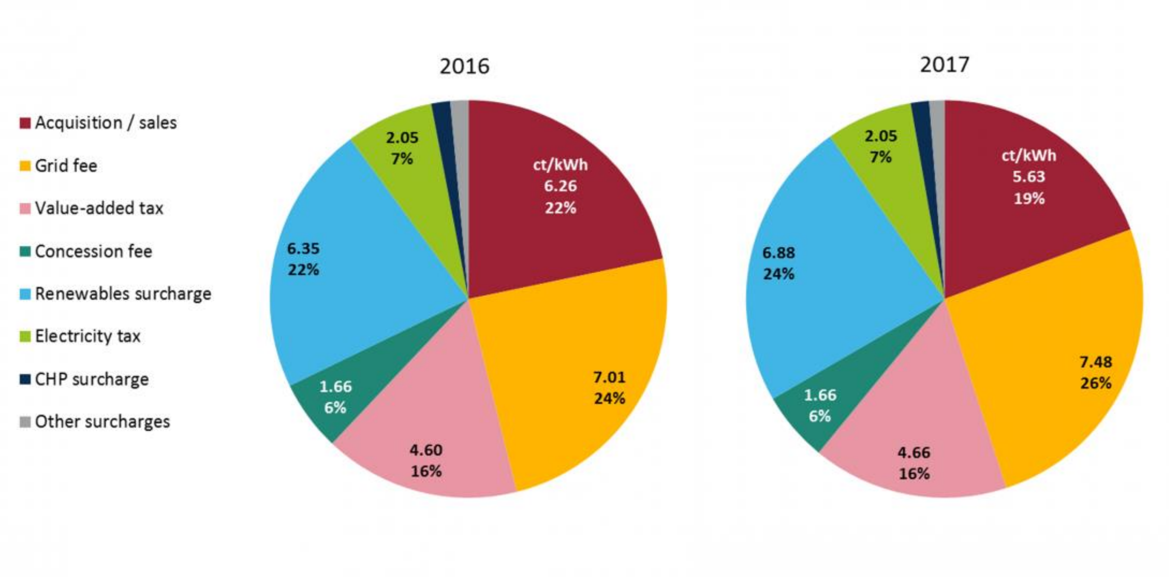
This chapter looks closely at the current price of electricity for households in both Germany and the Czech Republic and what the price actually consists of. First Germany: the current average price in Germany for 2017 is 29.16 ct/kWh. Second the average price in 2017 in the Czech Republic is 3.71 Kč/kWh which is around 13.72 ct/kWh when converted.

Now a closer look at Germany and the current price. First off, the price of electricity for households consists of several parts that make together the final price. It is not only the raw price of electricity. The interesting part is that more than a half of the price for households and small business in Germany consists of politically determined components. It is actually 55% of German household's power bills which is decided by politics and this includes things like charges for using power grids, levies for other service, and for financing investment in renewable energy as well as two kinds of taxes. Then there is the rest of the price which consists of power price itself and the supplier's margin, which are set by the market. It is important to note that commercial customers are exempt from some of the components. Furthermore even though the state sets more than a half of the price, it only actually receives revenues from the two taxes and concession levy. The other levies go to grid operators, renewable power producers and some generators.

Direct look at every part of the price in Germany as can be seen in the graph below.

- Cost of power for suppliers (19.3%) – This part is the profit margin and supplier's cost of purchasing power on the market currently for some 5.63 ct/kWh
- Grid Charges (25.7%) – This is set by the federal grid regulator and it is charges for using the power grid. 7 ct/kWh
- Renewable energy surcharge (23.6%) – The renewable energy surcharge pays the state-guaranteed price for renewable energy to producers and is currently 6.88 ct/kWh
- Sales tax (value-added tax) (16%) – This tax make about 16% of the after tax price which is some 4.6 ct/kWh. The tax itself is 19%
- Electricity tax (7%) – This tax is also called ecological and is paid for using power, accounts for 2.05 ct/kWh
- Concession levy (5.7%) – It is a levy on the use of public space for power lines that the utility passes on to the consumer. It is around 1.66 ct/kWh
- Others levies and surcharges

Figure 15: Composition of power price for households in 2016 and 2017 in Germany



Source: *Clean Energy Wire, 2017*

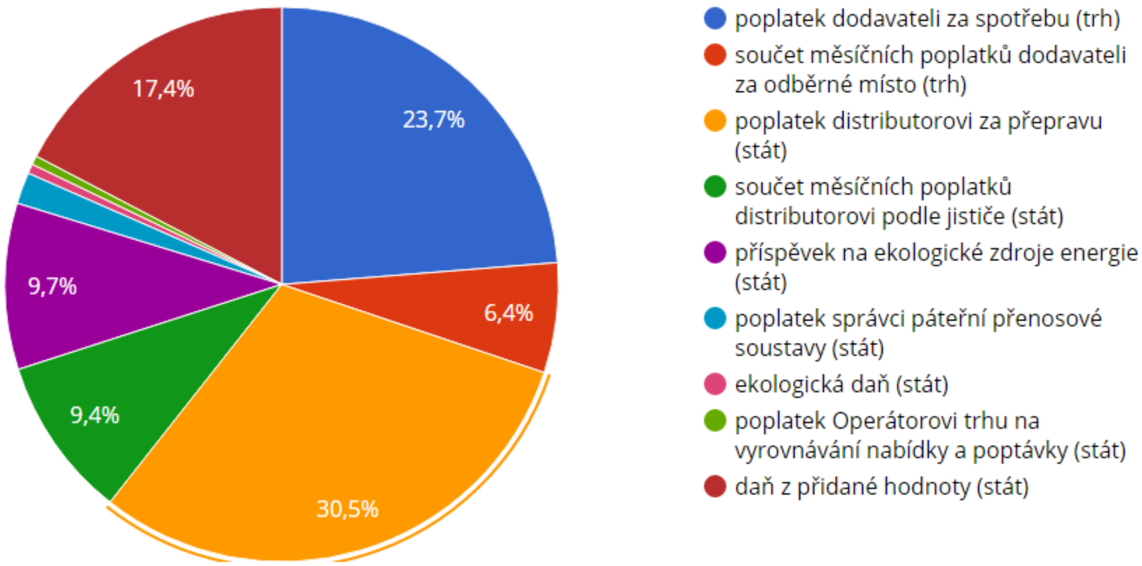
Closer look at the price of electricity for the Czech Republic: the average price for households is 3.71 Kč/kWh or 13.72 ct/kWh. This is straight up much lower price than Germany has and that is by a lot. German families have to pay more than twice for every kWh which is quite a big difference. However Germany belongs to the countries with the most expensive electricity not only in Europe but even in the World. On the other hand the Czech Republic belongs to the countries with the lowest prices at least in Europe.

However the current average price in the Czech Republic consists of many factors like in Germany. What makes electricity generally more expensive is its transport since there is no effective way to store it. Therefore the distribution through electric lines and even taxes which are both given by state have to be paid.

- Distribution charge (30.5%) – Charge that is paid to the distributor for distributing electricity. Is given by state
- Charge to the distributor for consumption (23.7%) – This is a charge to the distributor for consuming the electricity and is given by market
- Value added Tax (17.4%) – Classic tax paid and given by the state
- Renewable energy contribution charge (9.7%) – This is a charge paid for helping run and develop renewable energy in the Czech Republic and is given by the state
- Distributor charge for breaker (9.4%) – This charge is sum of monthly charge to the distributor for according to the breaker and it is given by the state
- Distributor charge of distribution place (6.4%) – This is sum of monthly charges to the distributor for location of distribution and it is given by market
- Others

As can bee there are lot of charges that are actually connected to the distributor of electricity. This may seems somewhat suspicious since the largest distributor and owner of grids and power plants in the Czech Republic is only one company ČEZ. Therefore lot of money go to their pockets even though there are few other smaller companies. Another notable part is that the charge for renewable resources is much higher in Germany than in the Czech Republic. However it is understandable given the renewable energy development there is in both countries.

Figure 16: Electricity Price and Structure in the Czech Republic



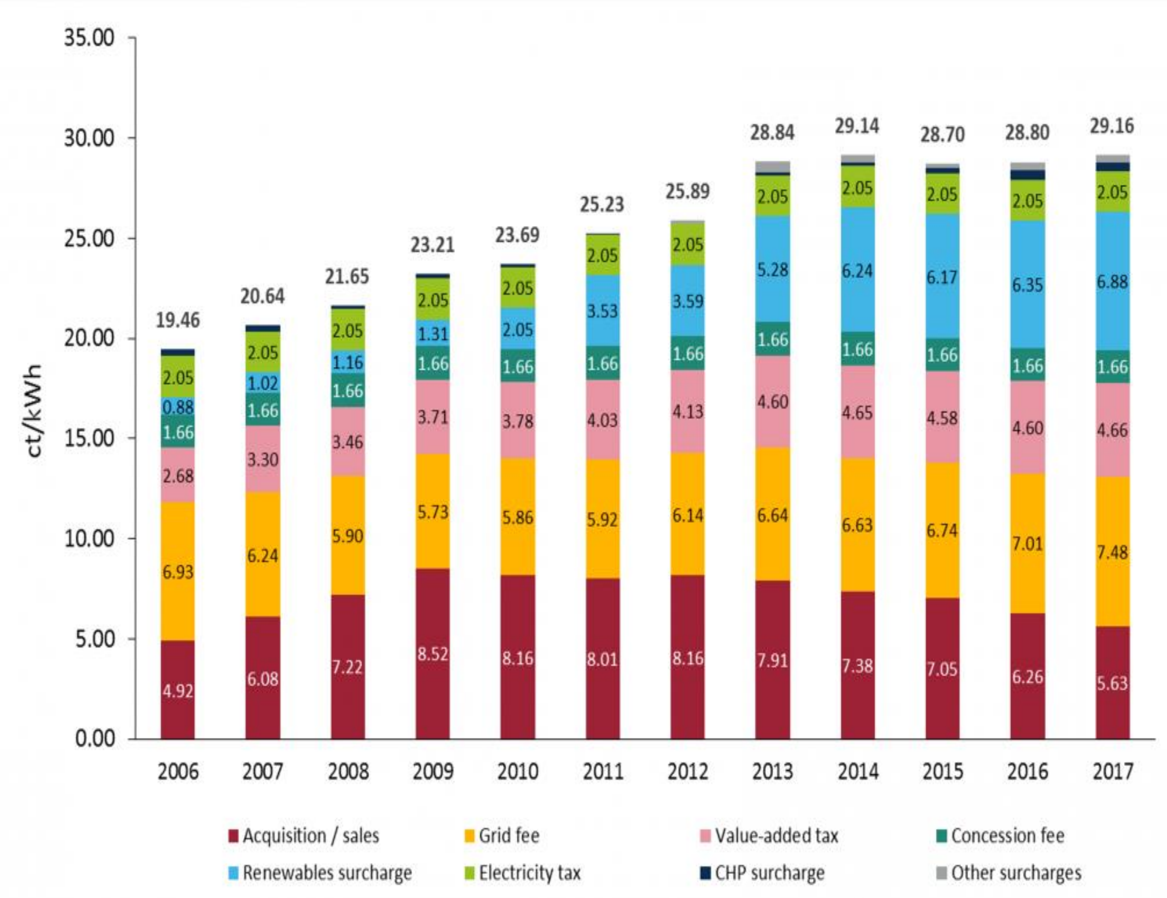
Source: *KupniSíla, 2017*

In the graph below can be seen the evolution of power price composition in Germany over ten years. The price in 2017 is 68% above the average price in 1998 levels. Looking at the graph and how it evolved it is apparent that the price was rising for many years before it peaked in 2014. In the early years after 2006 the average price increase is due to the acquisition of electricity price from the producers itself. However this peaked in 2009 and after this year it is actually slowly decreasing every following year. Nonetheless the overall price is still rising thanks to the Renewables surcharge which was increasing as well. At first the annual increase was only very small, but after 2010 it jumps up very quickly every single year till 2014 where is the first overall price peak as well as Renewables Surcharge first peak. The following year there is a small decrease however after it, it rises again and they year 2017 is actually the current highest peak in both overall average price and Renewable Surcharge. Another reason to this was the increase in Grid Fee that begun in 2009 after few years of decreasing trend.

Interesting part is that the increase in Renewable Surcharge copies the increase in installed capacity in Germany, which means the more renewable power plants are built in Germany the higher the price is. From this it is apparent that there is a direct increase in price thanks to the renewable resources that German people are willing to pay on their journey to clean energy.

The increase in Grid Fee can be a result of renewable resources as well since they impose larger burden on the grid then regular energy resources, thanks to their imbalanced energy production caused by weather.

Figure 17: Evolution of Average Power Price Composition in Germany



Source: *Clean Energy Wire, 2017*

4.8. Comparison of Feed-in Tariff

Another very important thing to look at is feed-in tariff. Feed-in tariffs very basically invented in Germany and then widely adopted and used by many other countries. The purpose of feed-in tariff is to accelerate investments in renewable technologies like photovoltaics. This is achieved by providing long-term contracts to renewable energy producers. This provides compensations to the producers as well as long-term contracts that help finance renewable energy investments and provide price certainty. A very important part of feed-in tariff is a tariff degression. It is mechanism which makes the price decrease over time. This is done in order to encourage technological cost reductions.

Looking at the Czech Republic and the feed-in tariff that was there, it is apparent that in the beginning, it was pretty high. There were two categories based on the overall installed capacity. The first and smaller one was for instalments with capacity smaller than 30 kW. The second and bigger one was for instalments with capacity greater than 30 kW.

FiT in the Czech Republic was 50 ct/kWh in 2007 for lesser capacity instalments, but in that time there were almost no photovoltaic panels built in the Czech Republic with only a very little capacity. In 2008 there is no change in feed-in tariff and only a very little change in installed capacity. In 2009 there are first big photovoltaic power plants build in the Czech Republic and at the end of the year the overall installed capacity is much higher than the year before. This reflects on the FiT as it decreased a little in both 2009 and then at the beginning of 2010. However the biggest boom in installed capacity came in 2010 where most of all Czech PV capacity was built. Suddenly Czech government had to react to this massive increase in built capacity however it was too late. This is because all the solar power plants build in 2010 secured a very solid FiT of 44 ct/kWh for small ones and 41 ct/kWh for big ones. This was a really great deal for producers however very bad for Czech government. As a reaction there is a very big dip in FiT from 44 ct/kWh to 30 ct/kWh for smaller solar plants. This is the biggest decrease in one year that was seen in the Czech Republic, however came in too late. That is because after 2010 the photovoltaics boom is over and basically no more plants were built at all.

Even though there were no solar power plants built since 2011, only solar panels with very small capacity that have no influence on national scheme, the FiT were continuously decreased by the Czech government year after year. At the end of 2013 the Czech government decided that, because of former FiTs that were set too high, it is not sustainable and they completely cancelled it. This means that from 2014 there were no more FiTs for photovoltaics in the Czech Republic, however the old ones were still applied for many years forward. Since the old ones are the highest, they are the ones that matter the most.

Table 4: PV Feed-in-Tariff Evolution in the Czech Republic

Year	Installed Capacity	FiT [ct/kWh]	Installed Capacity	FiT [ct/kWh]
2007	Less than 30 kW	50	More than 30 kW	47
2008	Less than 30 kW	50	More than 30 kW	47
2009	Less than 30 kW	48	More than 30 kW	44
2010	Less than 30 kW	44	More than 30 kW	41
2011	Less than 30 kW	30	More than 30 kW	22
2012	Less than 30 kW	22	More than 30 kW	20
2013	Less than 30 kW	11	More than 30 kW	8
2014	Less than 30 kW	0	More than 30 kW	0
2015	Less than 30 kW	0	More than 30 kW	0

Source: *ERÚ, 2016, own processing*

Germany on the other hand has a more sophisticated system set up for many years. Compared to the FiT system in the Czech Republic they have PV panels divided into two groups: rooftop mounted and ground mounted, based on where they are installed. Rooftop mounted panels are than furthermore divided into four groups based on the installed capacity:

- First – up to 30 kW
- Second – above 30 kW
- Third – above 100 kW
- Fourth – above 1000 kW

This system goes more deeply in dividing the solar panels in order to secure better conditions for everyone. From the table below can be seen that German FiT system promotes solar panels with the lowest capacity. These are mostly residential solar panels placed on top of houses of regular people. These get the highest amount off support from the government. On the other hand the least amount of support is given to ground mounted panels, which tend to be built in large numbers and therefore with much greater capacity.

However that does not mean that the support is low. On the contrary the FiT used to be pretty high for every category in 2004. However this is a time when there is still a small amount of solar panels in Germany with a low installed capacity. However as more solar panels are installed the FiT decreases over time. However there are shockingly big differences between years like in the case of the Czech Republic. Germany decreases the FiT steadily every year, as more panels are installed. The biggest decrease was actually between 2009 and 2011, where there were big increases in solar power plants installed capacity. This meant German government had to react and decrease it more than in the past. However they did not cancelled it as did the Czech Republic, but only lowered it more. After 2011 the decrease is not as rapid, since the amount of new installed solar panels was slowly declining year after year.

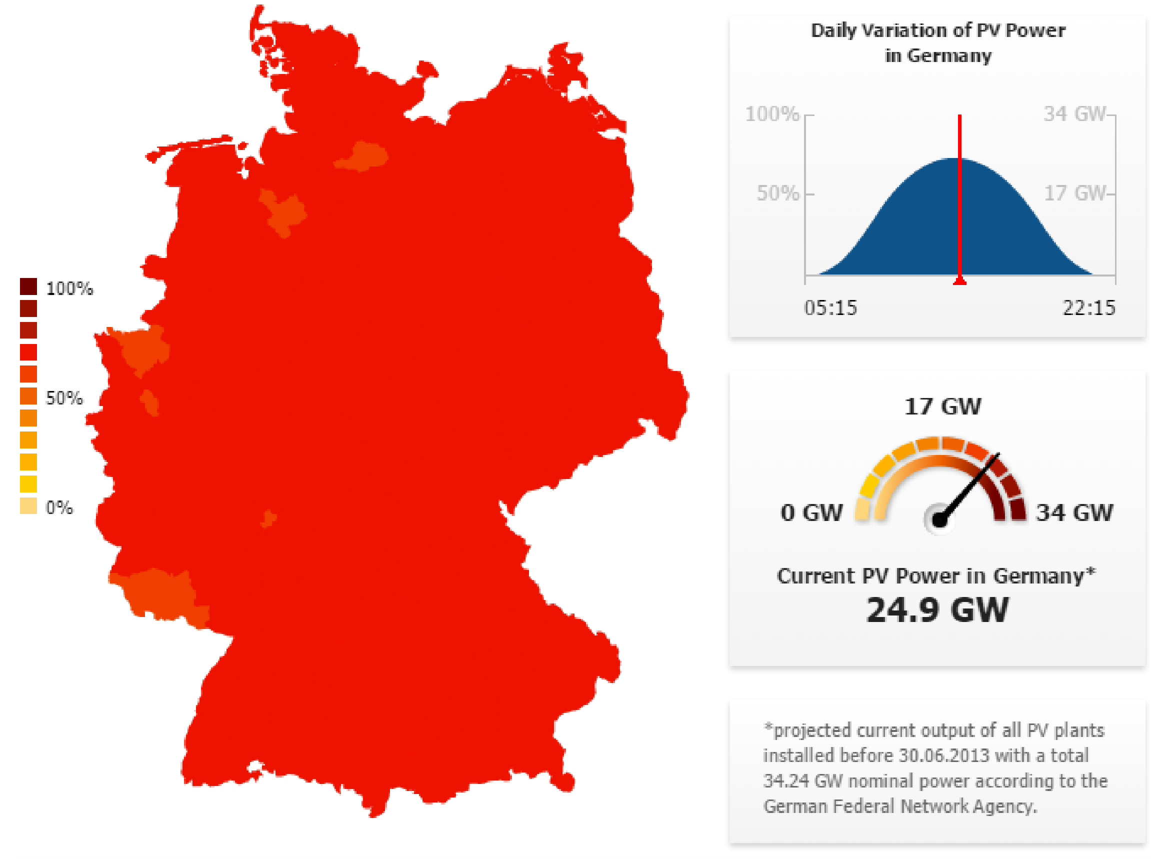
Nevertheless, the FiT decrease from 57 ct/kWh to 13 ct/kWh, over ten years for the smallest group in Germany. That is a very big change, but it is not so surprising. Not only did the amount of solar panels installed skyrocketed but also the costs went down, which means there was no need for such a high FiTs.

In 2011 the German system has also seen a change. The Groups were somewhat changed but most importantly the degression of the FiT was set to a certain percentage, so the amount actually changed every month and not only every year. This makes the system much more flexible to future fluctuations or big booms.

Table 5: PV Feed-in Tariff Evolution in Germany

Year	Rooftop Mounted [ct/kWh]				Ground Mounted [ct/kWh]
	Up to 30 kW	Above 30 kW	Above 100 kW	Above 1000 kW	
2004	57.40	54.60	54	54	45.70
2007	49.21	46.82	46.30	46.30	37.96
2008	46.75	44.48	43.99	43.99	35.94
2010	39.14	37.23	35.23	29.37	28.43
2011	28.74	27.33	25.86	21.56	22.07
2012	24.43	23.23	21.98	18.33	18.76
2013	15.07	14.30	12.75	10.44	10.44
2014	13.01	12.34	11.01	9.01	9.01

Source: *DE Statis, 2016,*



own processing

The FiT system in Germany is much more sophisticated compared to the system in the Czech Republic. This may be due to the fact that the Czech government was not ready for this and did not do enough research. This resulted in a big and also a very short boom in the Czech Republic, which was still backed by a very high FiT. The Czech government reacted by a big decrease and in the end by full cancel of the FiT. However that was far too late and many already made pockets full.

On the other hand German government did not abandon their plan of support nor did they cancel any FiTs. They continue with their support to photovoltaic industry even though it burdens their budget. However they are much more dedicated in this matter than the Czech Republic government is.

4.9. Future of Photovoltaics in Germany and the Czech Republic

Even though both countries are part of the European Union which sets energy and climate targets reality might be pretty different for both countries. First of all the target of the European Union is set for 2020, 2030 and 2050. Targets for 2020 are:

- Reducing greenhouse gases by at least 20% compared to 1990 levels
- 20% of energy from renewable sources
- 20% energy efficiency improvement

Targets for 2030 are:

- Reducing greenhouse gases by at least 40% compared to 1990 levels
- 30% energy efficiency improvement
- Interconnection for electricity transportation between other EU countries, at least 15%
- 27% and higher energy from renewables

Targets for 2050 are:

- Reducing greenhouse gases by at least 80% compared to 1990 levels

These targets are set for all EU countries, but is there even a chance for them to be fulfilled? For Germany it is definitely doable for the Czech Republic is seems not so much. However where is the difference, the core one? Even though this may sound rather strange the first and core difference between the Czech Republic and Germany is common people. Looking at Germany and their evolution of energetics overall as we know it, would not be possible without their people. It was around 2011 and after Fukushima incident in Japan that raised huge wave of negativity in German people towards nuclear energy. It was so intense they organized demonstrations and even blocked the transportation of nuclear waste with their own bodies. This forced the German government to act. Not because some politician wanted to, or because of some regulation, but because people did not like their current energy state. Therefore Germany created plan called "Energiwende", which sets targets for Germany not only in terms of renewable energies but also to shut down nuclear power plants. Even though this seemed very radical and hasted Germany has done so and are carrying on with this plan. Not only did they shut off several nuclear plans but also build lot of renewable power plants every year for already 7 years in a row. Now what remains for Germany is to continue building more wind and PV plants right. However it is not that easy. Focusing only on solar power is not efficient thanks to its limited time of production. Even though it reduces CO2 that is released into the air, the current technology is not allowing for solar energy domination on the market. Yes the power is potentially very good and Germany has the drive to focus on solar power, but there are still lot of obstacles which need to be overcome first. One of the problems is storage of electricity. Currently there is a minimum consumed energy every day mostly at night that is produced by nuclear power plants which are very hard to shut down. However how do we get that missing power in case of shutting down nuclear power plants? The grid needs to be at balance at every single point in time. The amount of energy that flows into the grid need to be also consumed otherwise it falls down. However the flow of energy from not only solar but also wind power plants are very volatile and not controllable. So if Germany wants to continue their current pace and actually reach set targets, they will need to adjust their grid to be more suitable for solar energy. In case of home solar panels there needs to be also a change in the connection to the grid. Definitely one of the most important things is also a way to storage energy. That should help bring solar power even more forward.

In the end Germany is on a good way reaching their targets not only because they are trying to reach them, but also because of their research. Their research belongs to one of the top ones in the world and they fuel lot of money into it. This should bring photovoltaics quickly forwards.

On the other hand the Czech Republic is in a much different current and future state. Above is mentioned how the will of people is very important in the event and evolution of their country. In the Czech Republic there is only very little will and definitely almost no action taken to reach EU targets. Where is no will, there is also no action. There are little to no future plans for installing new solar power plants in big. Even though there are still people willing to buy residential solar panels, it will do only very little in national scale. There is almost no movement in terms of renewable energies in the Czech Republic. Even more so after the end of solar boom in 2010 the government made sure that they don’t want any new solar power plants with their set taxes and called feed-in-tariffs.

Unless there is a big change Germany will continue to have bright future in photovoltaics while the Czech Republic might have none.

5. Conclusion

Solar energy industry has been growing worldwide for several years now and the amount still increases every year even though the possibilities of using solar power plants vary a lot. It is very dependable on the geographical location and what kind of weather rules there. That is why countries that are located far to the South or to the North are not suitable for solar energy production compared the countries located near the Equator.

However Germany and the Czech Republic are located right next to each other and even though they are much different in size, they have still very comparable solar conditions. This means that the amount of average solar radiation that falls in both countries is pretty comparable (both countries have average annual sum around 1050 kWh/m^2) with the only exception being very south of Germany where the solar radiation fall is greater (around 1200 kWh/m^2). Nevertheless the overall potential in terms of radiation fall is comparable.

It is also important that both countries are part of the European Union. This means that both countries have similar obligations. The European Union wants every country to reach certain limits like reducing greenhouse gases and certain share of energy from renewable resources. There are targets for 2020, 2030 and 2050. These targets apply for every European country. Even though they may seem difficult to fulfil, they are not, for certain countries that is. Germany has already exceeded some of these targets and even set more ambitious ones for themselves, while the Czech Republic is still far from reaching them.

The reason Germany can easily reach those targets is, because they their history of renewable energies is much longer than in the Czech Republic and not only that. They are willing to generate clean energy if it means higher costs. Germany has set for themselves to build 2.5 GWh of solar panels every year to increase their renewable energy production, which they are generally holding up to. The amount of solar panels and solar power plants is steadily increasing over many years now which as a result increases the overall capacity and the power generation. They are already so far that in 2016 the renewable energy supplied around 33% of all electricity needed. Which is really great number considering the amount of people living in Germany.

Big event for Germany happened in 2011, when a natural disaster destroyed Fukushima in Japan, which resulted in a public resentment towards nuclear power in Germany. It was so strong the government had to reintroduce nuclear power plants shut down plan. They actually shut down several of their power plants which meant they had to generate that missing power somewhere else and renewable energy is the exact right source. From that point in time Germany invested lot of resource to increase their renewable resources power generation which meant they also had to invest a lot in research since the technology of photovoltaics was lacking a lot at that time. Not only is the effectiveness low but also there are problems in terms of transmission, generation and storage. However this does not slow down the rate or amount of new photovoltaic panels installed.

On the other hand the situation in the Czech Republic was completely different. There were almost no solar panels prior to 2008. However after the Czech government set up a support for new solar power plans basically within two years more than 95% of all Czech solar capacity was built. In such a short time every big or small company build a solar power plant, however the government soon found out that the set up help was too high and not sustainable for a long time and they cancelled it very shortly after. This situation therefore resulted in a two years boom of solar energy in the Czech Republic and after it nothing. Since then there are almost no new solar panels built or planned even though the Czech Republic is still far from reaching the targets set up by the European Union.

Overall while Germany is trying hard to build new solar power plants and develop new technologies in this field Czech Republic does basically nothing at the moment. It seems government it satisfied with a low solar energy production which is one of the lowest in the EU and does not really care about fulfilling targets given by the European Union. On the other hand Germany is one of the top countries in solar technology research and world solar capacity instalment, which clearly shows their dedication in this matter. Even though it means they will have to improve their transmission and distribution grids, which are already one of the best in the world.

However since photovoltaics is a decently young and not enough developed technology, it means that there are some drawbacks when investing heavily into it. Since Germany has so many solar power plants and renewable energy power plants in general it makes their electricity much more expensive. It actually is one of the most expensive ones in the world which is a result of a really big Renewable Surcharge fee which is around 24% as of now in increasing every year. On the other hand the electricity price in the Czech Republic as well as the Renewables Surcharge is much lower.

Even though the consumers have to pay more because of this, they are still willing to do so and still want to consume clean energy instead of nuclear or fossil power which is currently still cheaper. This seems to be the biggest difference. It is true that the Czech Republic is behind basically in everything. Whether it is share of production, consumption or installed power. There really is not a field in which the Czech Republic is better than Germany except maybe that the average price of electricity is lower. Germany is truly one of the top countries in photovoltaics whether it is technology, research or installed annual power. On the other hand the Czech Republic actually belongs even to the worst countries in Europe in terms of solar energy.

However where does this drive come from? What is the core difference? The Author of this thesis thinks the core difference in in people that live in these two countries. While German people seem to really care about their environment to such an extent that they are capable of doing public demonstration against nuclear power and even paying more for electricity because of more expensive renewable power, the people in the Czech Republic seem to not care at all. It is very simple, because the government in Germany is pushed by the public opinion against the nuclear power so much that they had to fully commit and invest into renewable and solar energy. German people are willing to do small sacrifices to have clean energy, that the German government tries really hard to provide. On the other hand there really is nothing happening in the Czech Republic except maybe plain words from government about reach the European limits, but in reality these cannot be reached if there is no effort to do so at all.

Overall the solar energy situation is much better in Germany than in the Czech Republic from every single aspect like technology, research, production, installed capacity and others. However there is also a big difference in the mind-set of people and government between these two countries. One seems to really care about future of the Earth while the other only about their profits.

It is actually surprising how big the gap between the Germany and the Czech Republic is there. If there is a chance for the Czech Republic to catch up to Germany even closely, it will take many years to do so.

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