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Analysis of possibilities of limitation of natural environment degradation using renewable energy sources.

Analiza możliwości ograniczenia degradacji środowiska naturalnego za pomocą odnawialnych źródeł energii.

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Introduction

The main purpose of this thesis is to study present-day methods of energy generation that utilizes renewable sources, to show global investments in this sector of energetics and to present level of their development on each continent. Moreover, the issue of natural environment degradation due to conventional energy sources usage is raised in this thesis. The author prepares interactive dashboards and visual elaboration that allows to compare the economic, environmental and business effects of exploit mentioned above branches of energy production. In order to prepare that visual elaboration, implementation of advanced business intelligence software – Power BI – is required.

The topic of the thesis was selected due to importance of natural environment condition for all humanity. It is also important in terms of natural resources management and energetic safety of the world. Besides that, role of this thesis is to indicate and underline the importance of renewable energy sources for balanced development of all sectors of economy and especially for future of the Earth.

The thesis is divided into three chapters:

1. First chapter is dedicated to shortly describe origins and history of renewable energetics and to show the main methods of electricity generation utilizing renewable energy sources. This chapter is splitted into four parts: firstly history of energetics itself and history of renewable energetics and current status of energetics are described briefly, then geothermal energetics and techniques of electricity generation using heat contained in core of Earth are described, next part concerns solar energetics and there details of different methods of electricity generation with utilization of solar radiation can be found. Finally, last part of this chapter contains information regarding wind energetics and various wind turbines.
2. Second chapter is created in order to introduce analytical tool - Power BI - that has been used to create analysis and visualization of the data regarding energetic situation in the world and opportunities of renewable energy sources. This chapter is divided into two parts. First one contains detailed information regarding Power BI application and second one shows the structure of the tool, the way of suing the application and its possibilities.

3. The last chapter is dedicated to introduction of the Power BI dashboard that has been created in order to show energetic and environmental situation in the World, the level of renewable energetics advancement on each continent and the possibilities of natural environment situation enhancement via wider application of renewable energy sources. The chapter has been written using logic in which contents of each page of the dashboard are shortly described and then data visualized on the same page is shortly analyzed.

The last part of this thesis contains the summary in which the main information contained in thesis are highlighted and replied. Additionally, conclusions that comes from analysis of the Power BI report are summed up there. Moreover, outcomes regarding analysis of limitation natural environment degradation possibilities with utilization of renewable energy sources can be also found there.

1. Electricity generation using renewable energy sources

Since the beginning of times mankind based its civilization on energy resources utilization. Firstly, only solar energy in its primal form was used and it was done unconsciously. It is the main reason why people settled areas where sunlight was accessible regardless of the season. Then our predecessors noticed that it is possible to process the energy gathered in biomass, via chemical reaction of oxidation. In other words, they discovered fire - first energy source that was exploit with full awareness. As a result, they could spread civilization on new regions that were uninhabited due to unfavorable weather conditions. Throughout next few thousand years people didn’t use any other energy source on constant basis until approximately second century BC, when first water wheels, used as norias and watermills were built [1]. This is how human began taking advantage of kinetic energy of rivers and watercourses. It allowed to improve farmlands irrigation systems, built first water supplies systems and facilitate performing some duties that demand use of manpower.

Since that time people did not make remarkable progress in the field of energetics, except discovery of energetics properties of fossil fuels such us coal or oil, until the middle of XVIII age, when James Watt came up with idea of steam engine and designed first steam machine. This event marked the beginning of the First Industrial Revolution during which industry replaced leading role of agriculture and manufacturing in economy. On account of that mankind faced enormous increase (sixty times) of fossil fuels exploit and demand what is illustrated in chart1.

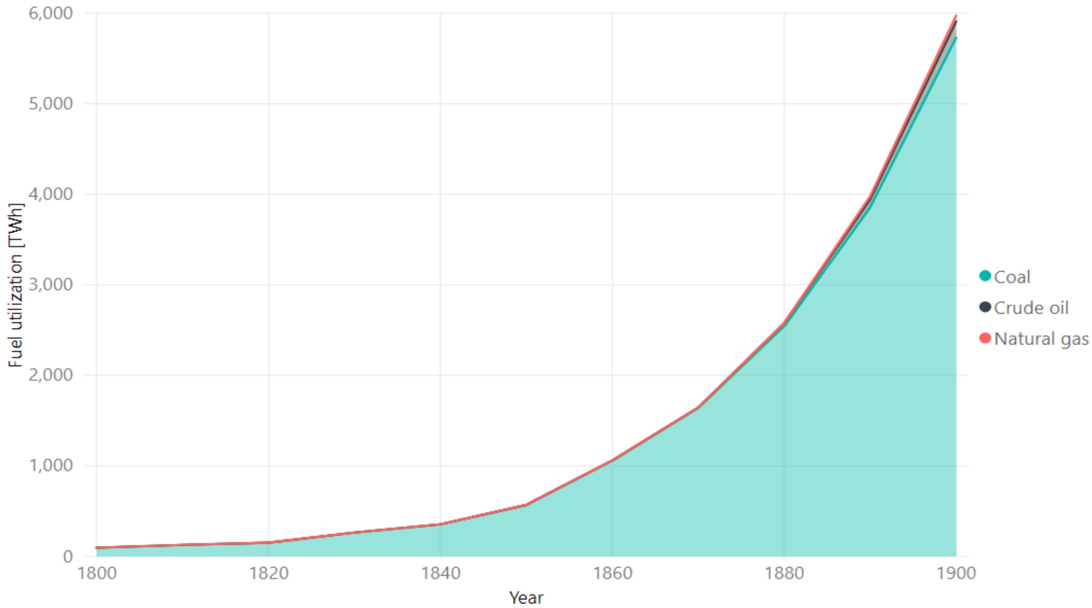


Chart 1. Fossil fuels utilization before and after First Industrial Revolution [TWh]. Source [2]

First Industrial Revolution was only the beginning of significant social and economic changes in the world. After over one hundred years since that event, science began to develop expeditiously, what resulted in many discoveries. Today we call this period in history – Second Industrial Revolution. The most significant invention of that period is electricity. One of the most famous scientific conflicts in history relates to that discovery. It was the dispute between two great scientists: Thomas Edison and Nikola Tesla. They were arguing about the idea of electricity production and distribution. Edison was the proponent of Direct Current and Tesla was the enthusiastic of Alternate Current. As we know scientist from Balkans won the debate and since the end of XIX age, electricity not only started to be applied in wide range of industrial branches but also became indispensable part of life of ordinary people in the majority of countries. Aftermath of described events was quick development of energetics. Among other remarkable inventions, gas turbine was developed, and steam turbines had been enhanced. A lot of power plants were built. They were using mainly fossil fuels to produce electricity. As a result, demand for natural resources such as coal, crude oil and natural gas increased about forty times within one hundred years, what is shown in chart 2:

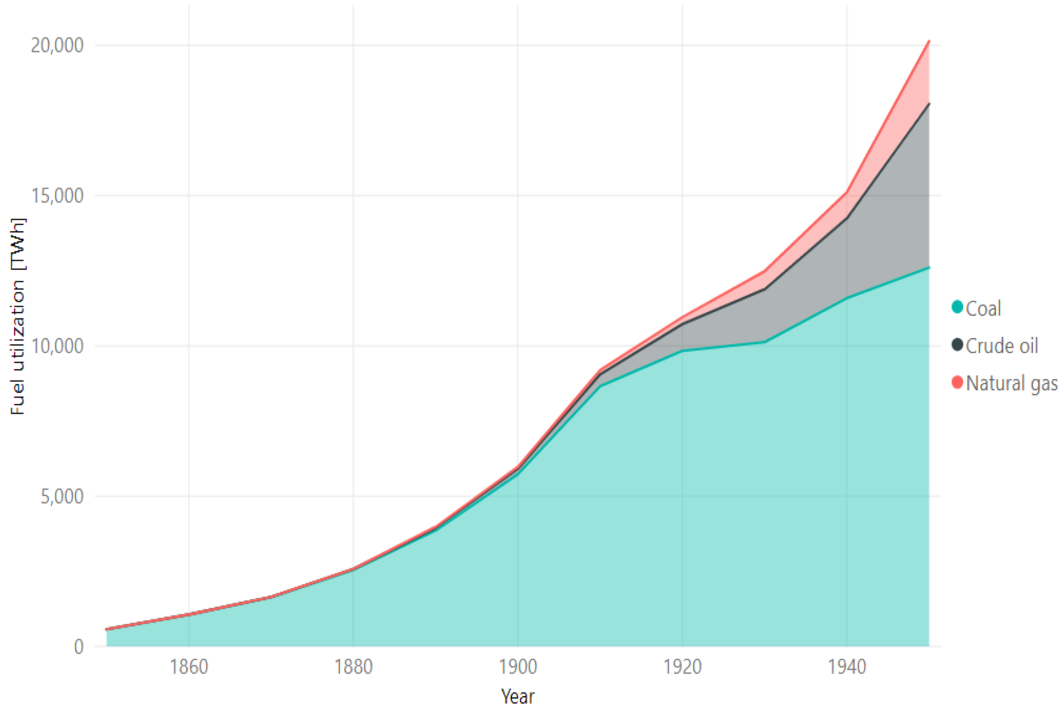


Chart 2. Fossil fuels utilization before and after Second Industrial Revolution [TWh]. Source [2]

The next significant step in field of energetics was made after World War II, when people realized that energy generated as a result of atomic fission could be utilized not only as a deadly weapon but also for the peaceful purposes such as production of electricity. It was caused by immense increase of demand for electric energy induced by the rapid growth of economy, willingness to reconstruct destroyed countries and quick growth of heavy industry. The first nuclear reactor that generated electricity on huge scale also for civil users was built in URRS in 1954. Within next two years, two other powerful countries – Great Britain and USA – opened first nuclear power plants on their territories.

After some time, nuclear power plants were recognized by some governments as a great opportunity to increase diversity in energetics systems of their countries, so since 1954 a lot of power plants powered by atomic fission were built. Although throughout almost 70 years of nuclear energetics history a few dangerous accidents took place, today in thirty countries all over the world there are 442 operating nuclear reactors that are producing almost 400 thousand MW of electric power [3]. All these countries, together with the net electrical capacity of nuclear power plants functioning on their territories, are listed in below graphics:

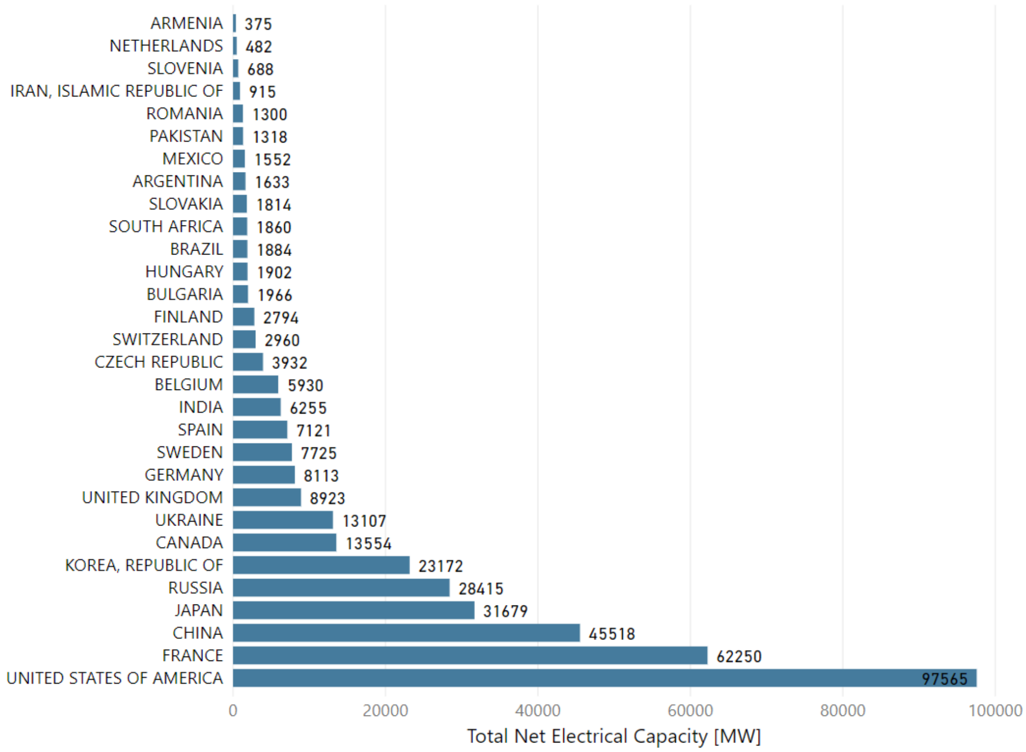


Chart 3. Total Net Electrical Capacity of Nuclear Power Plants per country [MW]. Source [3]

Although people mastered new, very efficient source of energy - nuclear power, it was too little to replace traditional methods of electricity production. On the contrary, resilient growth of industry and constant improvement of life standard in many countries, caused such immense increase of demand for energy that emergence of new power plants powered by coal, natural gas and crude oil was indispensable. As a result, utilization of fossil fuels raised from 20 000 kWh in 1950 to more than 130 000 kWh at the end of year 2017, what is illustrated in chart 4.

Fortunately, in second half of XX century together with increase of economic development, awareness of environmental consequences of such immense exploit of natural resources growth. Additionally, people noticed that electricity is not the sole effect of fossil fuels combustion in power plants. The discussions about excessive production of carbon dioxide, sulfur dioxide, nitric oxide and coal dust began. Concepts such us ozone hole, acid rains and natural environment degradation became commonly known and governments of the biggest countries in the world started to treat mentioned problems very seriously.

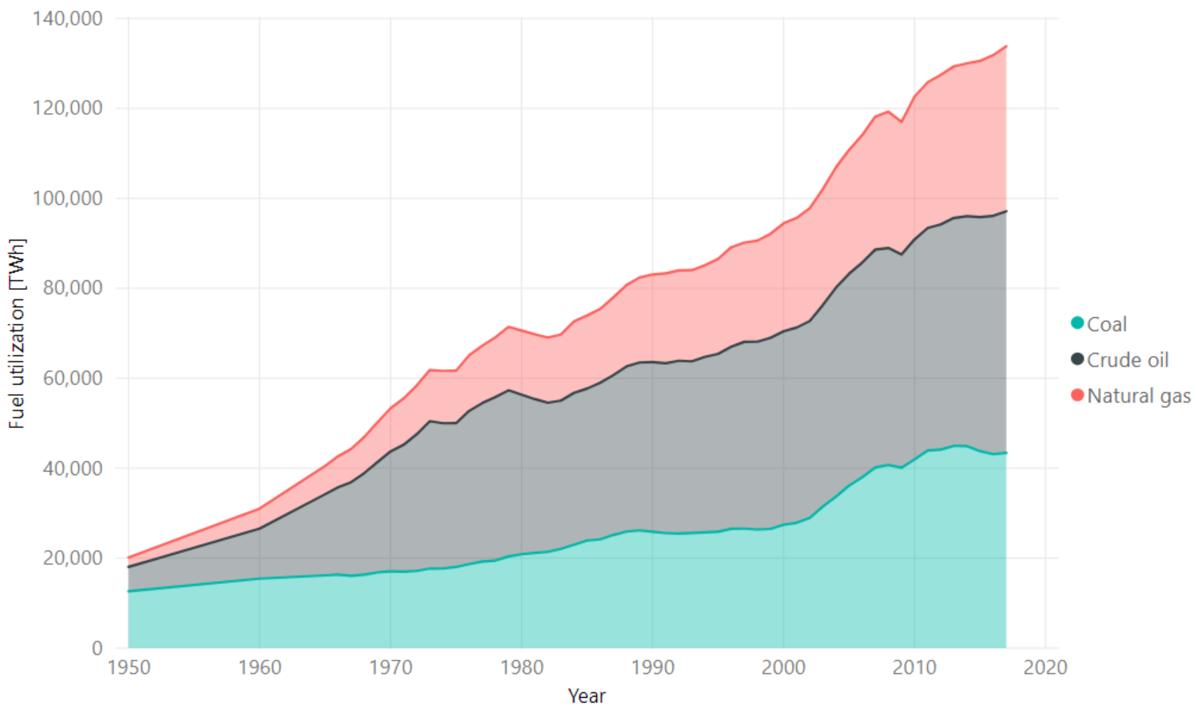


Chart 4. Fossil fuels utilization after Second World War [TWh].

Source [2]

The mankind decided to take some steps to improve environmental situation. The response for new problems were supposed to be researches in renewable energy. The main assumption of this newly created branch of energetics was that people should try to utilize the unlimited sources of energy such as wind, sun, sea tides, river streams and geothermal energy to produce electricity. Exploration of this field of science is still ongoing and from one year to another new ideas of on how to exploit renewable energy are appearing.

All matters mentioned above contributed to creation in of new field of science - environment resource management. That branch of management covers issues like interaction and impact of human societies on the environment [4]. The main aim of environment resource management is to protect and maintain natural environment for future human generations. The vital part of this science discipline is to run researches on how to fulfill social demand for electrical power in the most efficient way, keeping in mind care for natural environment. Possibility of achieving this goal via renewable energy sources will be the subject of consideration of this thesis.

Currently in the world there are a lot of green power plants that are utilizing renewable energy sources to produce electricity. In 2018 they generated over 6000 TWh of electric energy what allowed to fulfill 4% of global requirements [5]. Mentioned statistics are not outstanding but from one year to another there is more and more electricity produced, using environment friendly resources. It is caused by actions of some governments, which implemented special laws by virtue of which specified magnitude of energy must be produced utilizing renewable energy sources. For example, in Poland the goal is to increase contribution of renewable energy sources in electricity production to 15,5% till the end of 2020 [6]. There are many more countries that have implemented such directives, what allowed to double up production of the green energy within last decade. Also, relevance of renewable energy sources other than hydropower like solar and wind power raised significantly. The development of renewable energetics throughout last fifty-three years is shown on below chart:

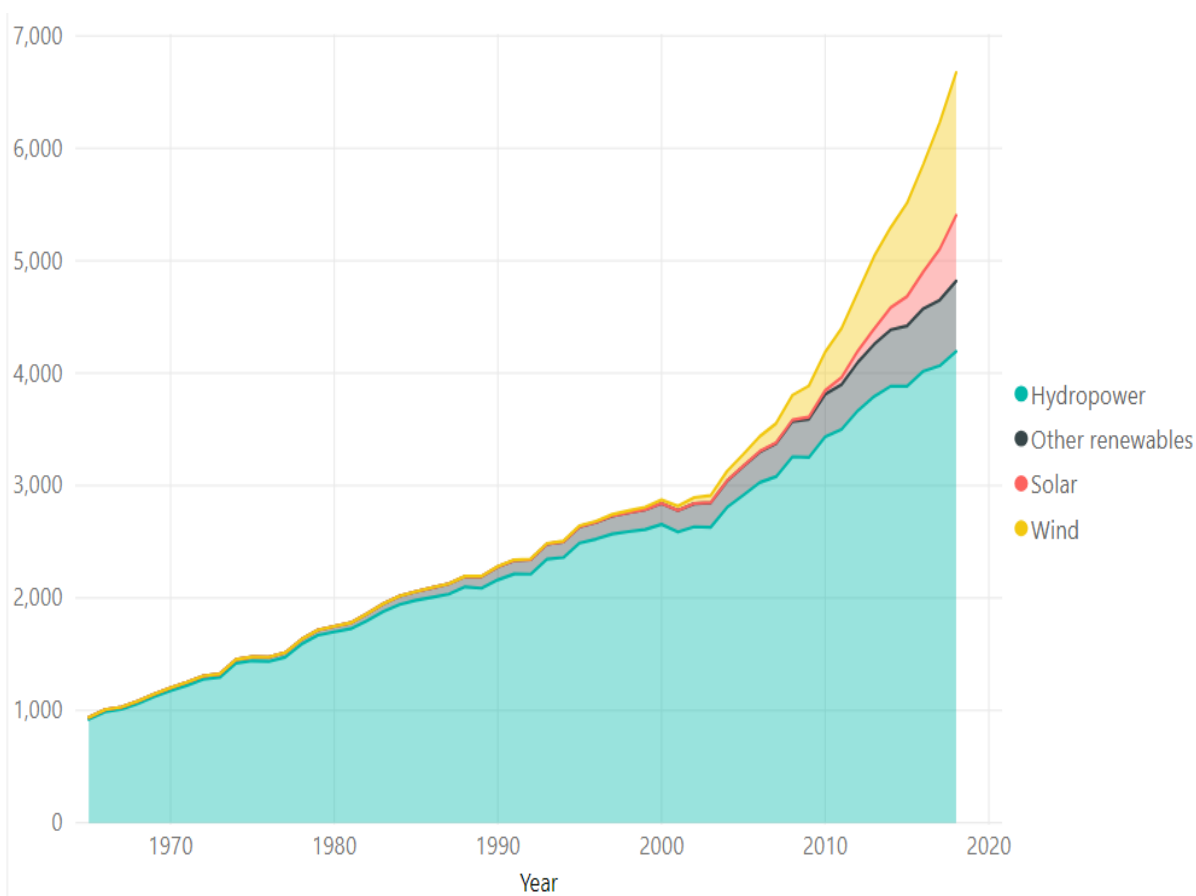
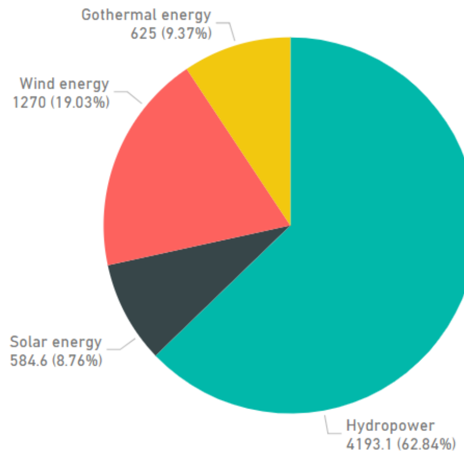


Chart 5. Renewable energy production [TWh].

Source [5]

Although utilization of renewable energy sources accelerated within last few years, mankind still has a lot to achieve in this branch of energetics. Total technical potential of renewable energy resources – that means the total quantity of energy that humanity would be able to produce from solar radiation, wind, thermal energy of Earth core, sea tides etc. using available technologies – is almost equal to 2 100 000 TWh [7]. Total energy exploited by people in 2018 was equal to about 150 000 TWh [5]. That comparison shows how huge potential is hidden in green energy. What is interesting, the biggest part of this technical potential is stored not in the most explored and utilized resources like solar energy, hydropower or wind energy but in other resources that are now not exploited on bigger scale such us geothermal energy that has the biggest technical potential among all green energy sources. The split of technical potential and current use of renewables is shown in below graphic:



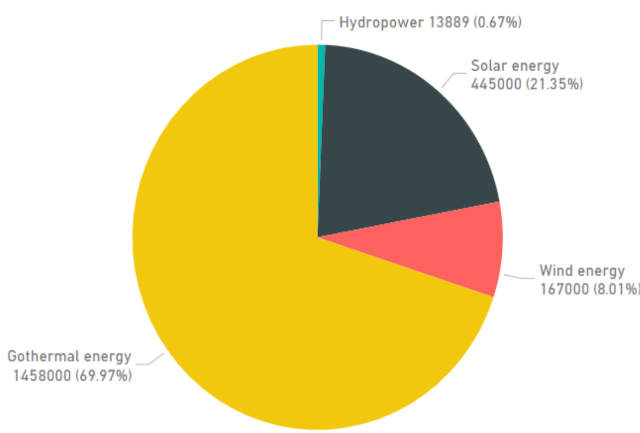


Chart 6. Current use and Technical potential of renewable energy sources [TWh].

Source [5]

Throughout more than five decades of renewable energy development scientists from all over the world were trying to harness the power of nature and came up with a lot of ideas how to produce green energy. Not all that ideas were considered as successful but there were also a lot of concepts and inventions that were found useful and possible to implement on bigger scale. In following chapter, I would like to introduce and describe the most common ways to utilize renewable energy resources.

1.1. Geothermal energy utilization to produce electricity.

As we can see in Chart 6 the biggest potential among all renewable energy sources is in geothermal energy. The quantity of energy visible in graphic is equal to 1.46×10^6 TWh and it is amount of energy that could be utilized by humankind. Although this value is almost tenfold bigger than annual world energy demand, in comparison to all energy gathered inside the Earth in the form of heat – about 3.5×10^{15} TWh [8] – it seems to be a very insignificant value. Such enormous difference between technical potential and total amount of geothermal energy is an outcome of following facts:

a) Only 20% of total energy comes from the crust – the only Earth layer possible to be somehow explored and exploited by human.
b) So far utilization of geothermal energy is limited to areas in which geological conditions are propitious to it. In case of electricity production, the most suitable are locations where geothermal steam in temperature above 150 ℃ is easily available.

The first turbine that was utilizing geothermal steam to produce electricity emerged in 1904 in Italy [8]. It turned out that such method of electricity acquisition might be profitable under some circumstances. Therefore, such application of geothermal steam had spread all over the world and before 1925 geothermal power plants were built in Japan and United States of America. Till the end of 1950 installed geothermoelectric capacity was equal to 128 MW [8]. In these days there are 171 operating power plants that are producing 625 TWh of electricity annually [5] and there are a few places in the world where actions connected with building of geothermal power plants are on different levels of advancement.

As it was mentioned before, to produce electricity from geothermal heat, steam in temperature above 150 ℃ is needed. The places where probability of meeting mentioned requirements is the highest are shown in figure 1.

Figure 1. Areas where conditions are suitable to produce electricity with geothermal energy. Source [9]

Such areas are located mostly on the edges of tectonic plates. After suitable localization is indicated, power plant could be built. The most vital part of each geothermal power plant is turbine. There are two types of turbines mostly utilized in such type of powerhouses:

- atmospheric exhaust conventional steam turbine,
- condensing exhaust conventional steam turbine.

In further part of this thesis, principles of both types of turbines operation will be introduced and explained.

1.1.1. Atmospheric exhaust (back-pressure) conventional steam turbine

The atmospheric exhaust turbines are widely used turbines in geothermal power plants. What makes them so popular? Probably the price. They are the cheapest solution currently available on the market. Their price is so attractive due to simple construction and not complicated principals of operation. Back-pressure turbine working cycle scheme is shown in figure 2.

Geothermal discharge that contains water and steam is taken from production well and transported via valve to the separator, in which water is separated from steam and taken out from cycle. Steam is transported to the main part of turbine – turbo-alternator – which is converting enthalpy owned by steam to mechanic energy of turbo-alternator movement. Then steam leaves cycle in atmospheric pressure through atmospheric exhaust. At the end of the cycle mechanic energy of turbo-alternator is converted to electricity.

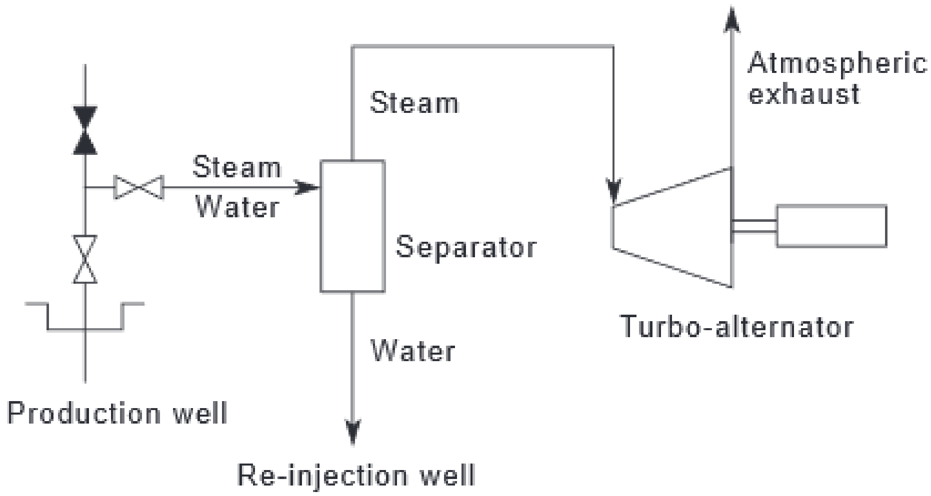


Figure 2. Atmospheric exhaust cycle simplified schematic.

Source [8]

Beside price and not complicated principle of operation, the advantage of atmospheric exhaust turbines is that they do not need external source of power to operate as the only additional equipment is the lubricating oil pump that can be powered by turbine itself. But such turbine has also disadvantages. The most important one low efficiency. Such units are using two times more steam, than condensing exhaust turbines (with the same inlet pressure) to produce kilowatt of energy.

1.1.2. Condensing exhaust conventional steam turbine

The condensing exhaust turbine is the most widely used type of turbine in geothermal power plants. It is improved type of atmospheric exhaust turbine and because of that, it is more complicated. The difference between principles of operating between these two types of turbines is visible on first sight in working cycle schema illustrated in figure 3.

Geothermal discharge that contains water and steam is taken from production well and transported via valve to the separator, in which water is separated from steam and taken out from cycle. Steam is transported to the main part of turbine – turbo-alternator – which is converting enthalpy owned by steam to mechanic energy of turbo-alternator movement. Then low-pressure steam is discharged to the condensing chamber where it is subjected to cooling process during which it liquifies. Heat taken from steam during condensation process is given to environment via cooling tower. At the end of the cycle mechanic energy of turbo-alternator is converted to electricity.

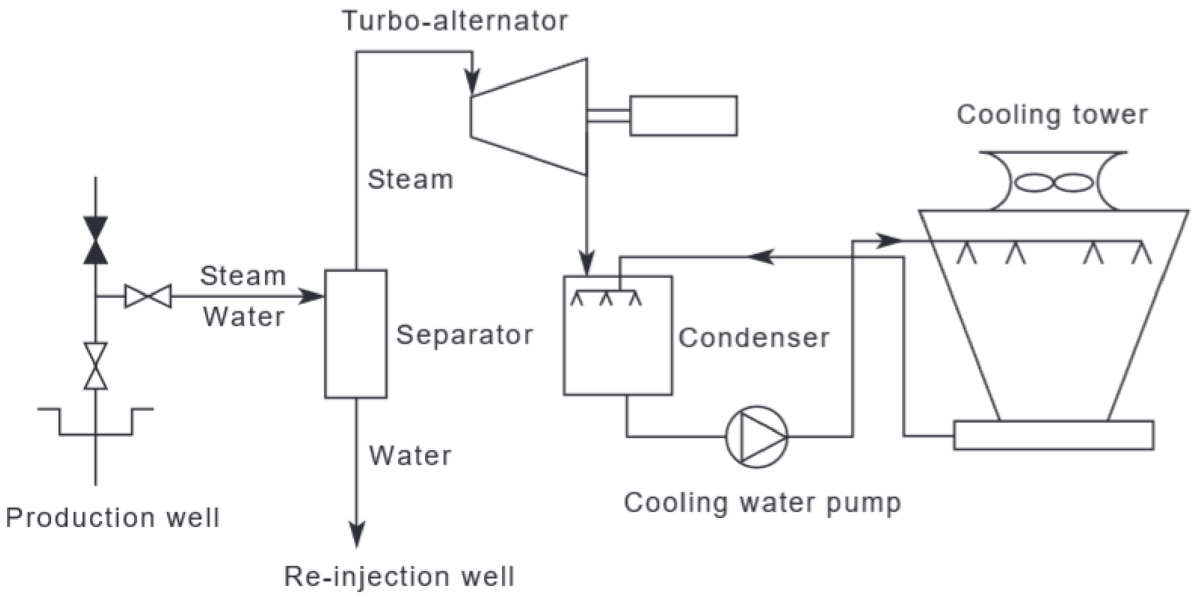


Figure 3. Condensing exhaust cycle simplified schematic.
Source [8]

The main advantage of condensing exhaust turbine is its efficiency. It generates two times more energy from each unit of steam than atmospheric exhaust turbine. The application of condenser also allows to add water pump to the turbine work cycle, what makes whole installation more efficient. But such type of turbine has also disadvantages. The main one is much higher price than the price of back-pressure turbine. Also amount of energy that condensing exhaust turbine utilizes for its own needs is high due to application of cooling water pump and cooling water fans. However, this type of turbine has more positive features, what makes it very popular.

1.1.3. Other types of turbines used in geothermal power plants

Scientists developed also different turbines than described above, that are utilized in geothermal power plants. One example of such turbine is improved type of condensing exhaust turbine. It is adapted to generate electricity from low-temperature and medium-temperature resources by recovering part of heat that is wasted in ordinary turbine. This type of turbine is called binary turbine and it is becoming more and more popular, mostly due to ability to operate with low inlet temperatures (even 85℃). Its working cycle is shown in figure 4.

In this type of cycle, closed circuit occurs. Geothermal discharge that contains water and steam is taken from production well and transported via valve to the heat exchanger in which it transfers its heat to secondary working fluid contained in closed circuit. Secondary working fluid is liquid that has low boiling point, usually n-pentane. It evaporates during contact with geothermal discharge inside heat exchanger. Steam received in that process is transported to the main part of turbine – turbo-alternator – which is converting the enthalpy owned by steam to mechanic energy of turbo-alternator movement and then mechanic energy of turbo-alternator is converted to electricity. Then low-pressure steam is discharged to the condensing chamber where it is subjected to cooling process during which it is giving rest of its heat to the cooling liquid and liquifies. Then, thanks to work done by feed pump, it is transported back to heat exchanger. Cooling liquid, that absorbed heat from secondary working fluid during condensation, is giving that heat to environment via cooling tower.

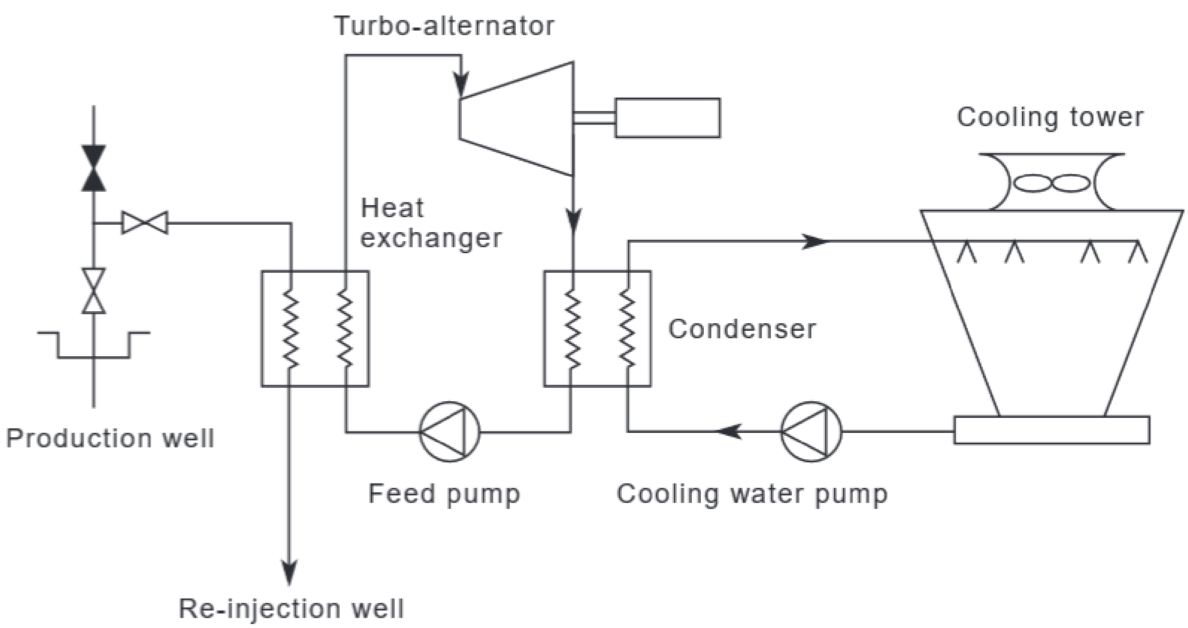


Figure 4. Binary cycle schematic.

Source [8]

The most important asset of binary turbine is that it can produce electricity in conditions in which other turbines are useless. Moreover, thanks to closed circuit, there is no need to separate geothermal discharge to distinguish water. The main disadvantage of such turbine is its high price. Another minus of binary turbine is necessity of feed and cooling water pumps addition to the working cycle, what causes energy usage increase in circuit.

Another example of equipment utilized to produce electricity from geothermal energy is the biphase rotary separator turbo-alternator. It is a device developed to enable using geothermal discharge without separating steam from water in preprocess. It could be used as a supply to condensing turbine or atmospheric exhaust turbine. Example of biphase rotary separator connection with condensing turbine is illustrated in figure 5.

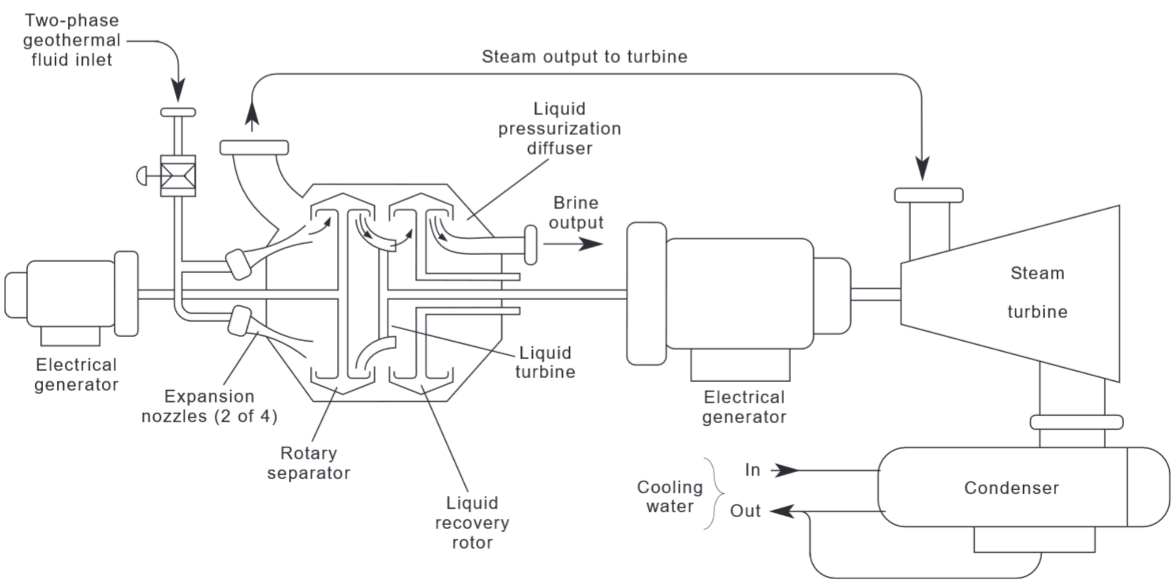


Figure 5. Schematic drawing of biphase separator connected with condensing turbine.
Source [8]

Biphase rotary separator utilizes centrifugal acceleration to separate steam and water. It contains three main components: biphase nozzles, rotary separator and turbine driven by water. Geothermal discharge is transported to the series of nozzles where part of its enthalpy is converted into kinetic energy of fluid. During passing through series of nozzles two-phase fluid is expanding and pressure drops from high inlet value to low outlet value. Right after nozzles, the jet of mixed steam and water with high kinetic energy is received. That jet is directed straight to rotary separator where it gains high centrifugal acceleration. Under influence of centrifugal acceleration lighter steam is separated from water and stays closer to the center of separator. Whereas water is driven to the wall of separator. That wall is equipped with special water transfer holes. Through tchem water is driven to the liquid turbine. Such turbine converts kinetic energy of water to mechanic energy of shaft and then this energy is changed to electricity in the alternator. In meantime steam is directed to the steam turbine that converts enthalpy owned by steam to mechanic energy of shaft. Shaft is connected to alternator that generates electricity. Isometric of biphase rotary separator is shown in figure 6.

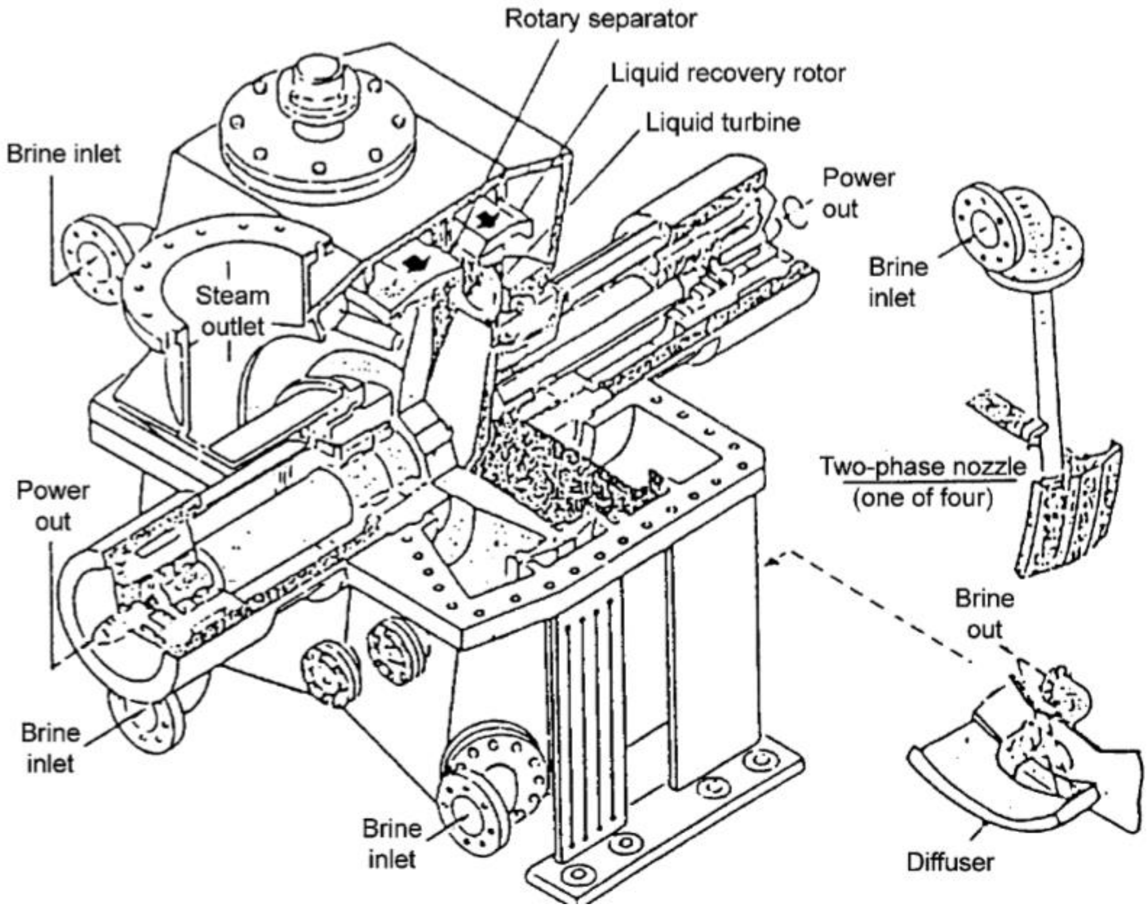


Figure 6. Biphase rotary separator isometric.

Source [8]

1.2. Solar energy utilization to produce electricity

From chart regarding renewable energy sources technical potential (chart 6 of this thesis) we can deduct that the second biggest renewable energy source in terms of its potential is solar energy. More than 21% of whole green energy potential is contained in this source. People are utilizing energy provided to Earth by Sun since the beginning of humanity, but they discovered that it is possible to convert solar energy into electricity only in XIX century, thanks to invention of young French physicist Alexandre Edmond Becquerel. He noticed that it is possible to produce electricity by focusing the light on electrode that is putted to the highly conductive fluid. However, his invention was producing too small amount energy to utilize it in practical way. Only after more than one hundred years in 1954 in United States of America first silicon photo voltaic cell was invented. It was able to produce amount of electricity that could supply electric device for couple of hours. That was the beginning of solar energetics branch. Since then scientists were working on silicon photo voltaic cells improvements and on other ways of solar energy utilization to produce electricity.

The most important thing to produce electricity from the energy that "our star" is providing to the Earth, is easy access to Sun radiation. Unfortunately, sunshine duration is different in each area of the world and what is more in the majority of places in the world, it is very unstable. It means that one day there might be a great weather to produce electric energy and next day such process is almost impossible. There are only a few areas on the Earth where sunshine duration is relatively constant, mostly placed in between circles of latitude. These areas are shown in figure 7.

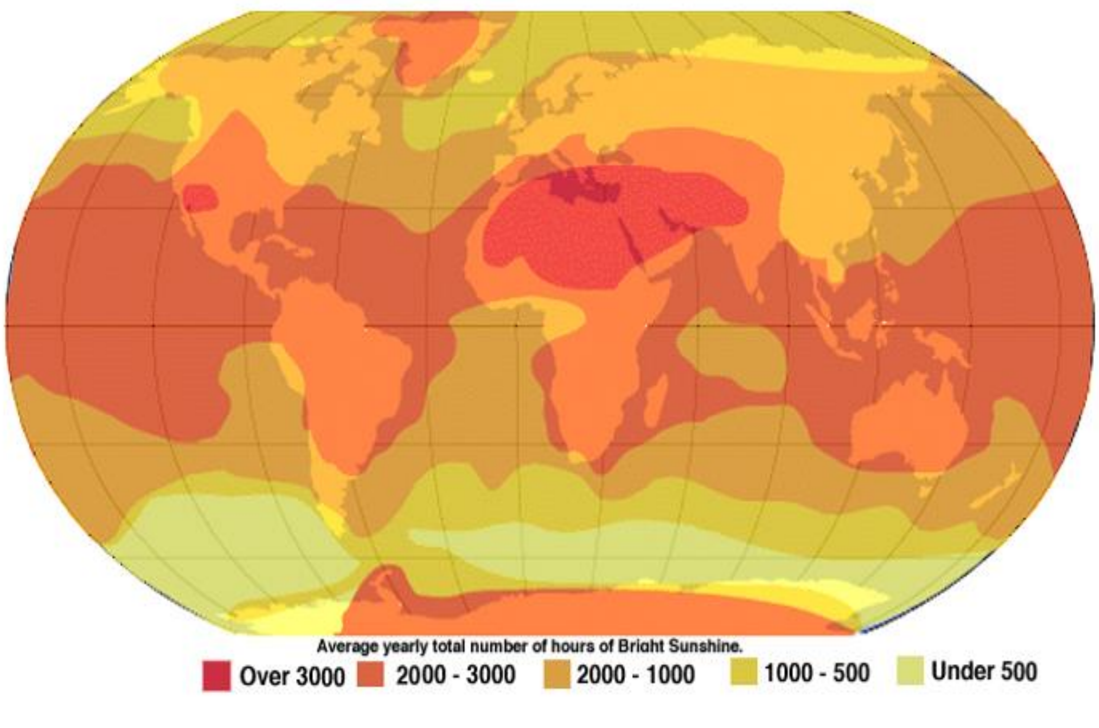


Figure 7. Average sunshine duration in the world.

Source [10]

Currently there are many solar power plants worldwide and they are producing almost 600 TWh of electric energy annually. Such power plants could be divided into two groups:

a) Photovoltaic (PV) power plants – they are utilizing photovoltaic phenomenon to produce electricity.
b) Concentrated solar (CSP) power plants – they are utilizing heat transported by solar rays to change physical state of working fluid and create steam that drives turbine.

In the area of both mentioned groups, there are variety of technologies utilized to produce electricity. In the following part of this thesis only the ones that are used on bigger scale will be described.

1.2.1. Photovoltaic cells

The photovoltaic cells are the first commercially used devices to produce electricity from solar energy. They can be utilized not only to produce energy on huge scale in power plants but also to produce energy for single households and even to produce electricity that supplies objects in space such us International Space Station. They are named after semiconducting materials that they are made of and can be divided into three groups [11]:

a) First generation photovoltaic cells – made of the crystalline silicon. They are first type of such devices that is why they are sometimes called traditional solar cells. In these days they are not used due to high costs of production.
b) Second generation photovoltaic cells – made of the thin film that include amorphous silicon, Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS) cells. They are less expensive than first generation cells, but they also require bigger surface to produce the same amount of electricity as traditional solar cells. Currently they are commercially most significant group in photovoltaic energetics, not only in utility-scale power stations, building integrated photovoltaics power stations but also in small domestic power plants.
c) Third generation photovoltaic cells – made of the several thin-film technologies. They are not yet commercially applied and are still in research and development phase. Many of them are using organic materials, what makes this technology even more eco-friendly.

Principals of all types of solar cells operation are the same and based on the photovoltaic effect. In the following part of thesis, on example of the traditional silicone cell, this phenomenon will be explained. Basic, first-generation solar cell contains 6 layers [12]:

- anti-reflection, transparent coating - glass,
- transparent negative terminal,
- n-type layer - heavily doped semiconductor (n^+-emitter),
- junction,
- p-type layer – doped semiconductor (p-base),
- positive terminal.

The photons contained in solar rays penetrates coating of the cell and are absorbed by semi-conductive material. As a result of absorption, in place of each photon, an electron-hole pair appears. Then the pair is separated in junction area. Hole is transported to the positive terminal and electron is transported to the negative terminal. If both terminals are connected, then electrical energy could be draw off. Described principals of photovoltaic cells operation are illustrated in figure 8.

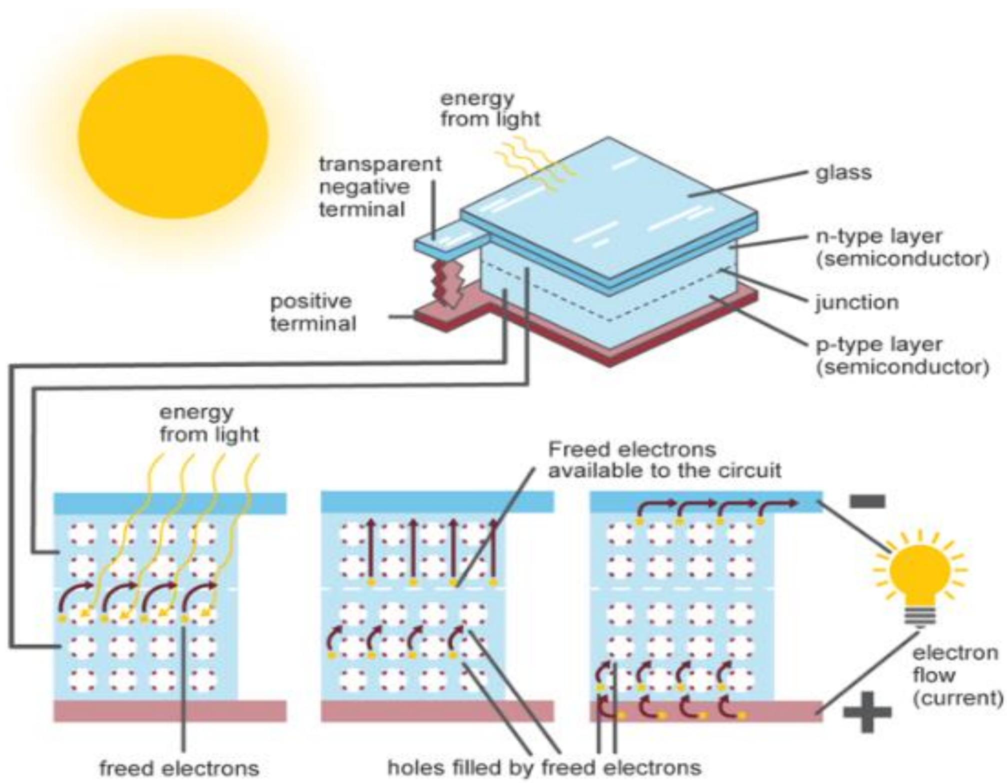


Figure 8. Principals of photovoltaic cells operation.

Source [12]

The principals of single solar cell operation were described but to produce electricity on bigger scale, one cell is definitely insufficient. That is the reason why in power plants, cells are connected into solar modules and the modules are combined into bigger groups. Such group of solar modules is able to produce big amount of electric energy in the form of direct current. To utilize that energy for commercial purpose alternate current is needed. To convert one type of current to another in every photovoltaic power plant DC/AC inverter is installed. After conversion, in transformer voltage of produced alternate current is adjusted to the voltage of switchyard and transferred to electrical grid. Simplified scheme of photovoltaic power plant is illustrated in figure 9.

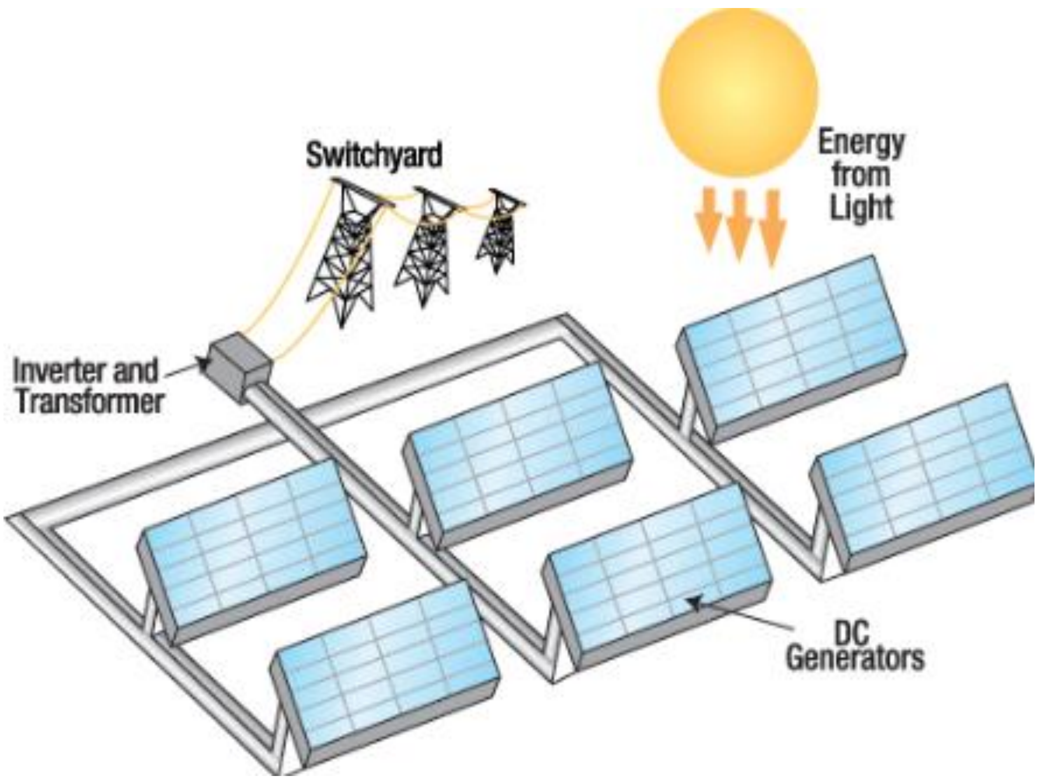


Figure 9. Scheme of photovoltaic power plant.

Source [13]

Characteristic for described technology is its flexibility. It means that solar cells could be utilized to produce electricity for huge range of scales, from small domestic installations to huge over 2000 MW capacity photovoltaic power plants, for example: Tengger Desert Solar Park, China – 1,547MW, Sweihan Photovoltaic Independent Power Project, UAE – 1,177MW, Yanchi Ningxia Solar Park, China – 1,000MW [26]. The biggest photovoltaic power plant in is located in north part of the country and has capacity of 3,77 MW [27]. But the flexibility of this technology is not only with regards to electrical capacity but also to the possibility of building the installation in places where no other power plant could be built, for example on the mountain's slopes, rooftops, artificial islands, façades of the buildings etc. Moreover, in contrary to appearances it is possible to build such power plant not only in countries where average annual temperature is high but everywhere where is solar radiation is accessible. That is why photovoltaic power plants are becoming more and more popular and in many countries' groups of scientists from the best universities are dedicated to work on development of that technology.

1.2.2. Solar towers

The solar towers, also known as heliostat power plants, power towers and central tower power plants is a quite new technology utilized to convert energy of solar radiation into electricity. Its principal of operation is based on concentrate solar rays from big area on one receiver to heat the fluid and as a result turn it into steam, that could drive turbine and generate electricity. The idea itself seems to be not very complicated, but there are a lot of factors, such as apparent Sun wander on horizon, clouds appearances, lack of solar radiation during night etc. that makes such process less effective and difficult to implement on commercial scale. Nevertheless, scientists from all over the world were working on numerous upgrades of that technology and finally managed to face all that obstacles and developed system that allows to produce constant amount of electricity through all day.

In these days, there exist a few commercial power plants that utilizes described technology. Efficiency of Solar Tower Power (STP) power plant work is secured by proper equipment consist of [14]:

a) Heliostat field – it is the huge area (often over 1000 ha) covered by multiple tracking mirrors (heliostats). Single heliostat is consisted of numerous mirrors and is installed on special computer-regulated holder that allows to track Sun rays thanks to ability of dual axis movement. All the heliostats on the field are programmed to focus solar radiation on receiver placed on tower. They are also placed on field in a way that disallow casting shadow by one heliostat to another. The example of single heliostat is shown in figure 10.

Figure 10. Example of single heliostat.

Source [14]

b) External receiver – it is the group of separable panels configured in perpendicular cylindrical structure. Every panel contains tubes with thin walls, made of stainless-steel alloy. All tubes are filled in with heat transfer fluids and have diameter of 20-56 mm. Such receiver is installed around the top of solar tower. The tower could be placed in the middle of heliostat field (surrounding field) or on its edge (north-south) field and has height reaching even 140 m. The example of solar tower with receiver is shown in figure 11.

Figure 11. Example of solar tower with receiver.

Source [15]

c) Heat transfer fluid – the medium that is collecting, storing and transferring heat absorbed by receiver. It fills stainless tubes made of nickel-based alloys that are basic of receiver's structure. Molten salts are the most widely used heat transfer fluids in solar tower power plants. They are so popular due to their excellent effectiveness of thermal energy storage, relatively low costs of utilization and simple technological process. What is more, they are non-toxic and non-inflammable. Despite all mentioned advantages of molten salts, there exists sceptics of their application in solar tower power plants technology due to their thermal stability limits and corrosion-related issues.

d) Power generating unit – it is the most important part of every power plant including solar tower power plant. It is responsible for generating electricity. It is consisted of steam generator (heat exchanger) in which interior, heat transfer fluid passes heat taken from receiver to secondary working fluid that is inside power generation unit's closed circuit and causes change of its phase from liquid to steam. After described exchange heat transfer fluid returns to the receiver and secondary working fluid is directed to the steam turbine which is another part of power generating unit. Turbine converts enthalpy owned by steam to mechanic energy of shaft. Shaft is connected to power generator that generates electricity. Then steam leaves turbine and is driven to the condenser in which its phase is changed to the fluid. After that whole process can be repeated.

Described above process of electricity generation in solar tower power plant is illustrated in figure 12.

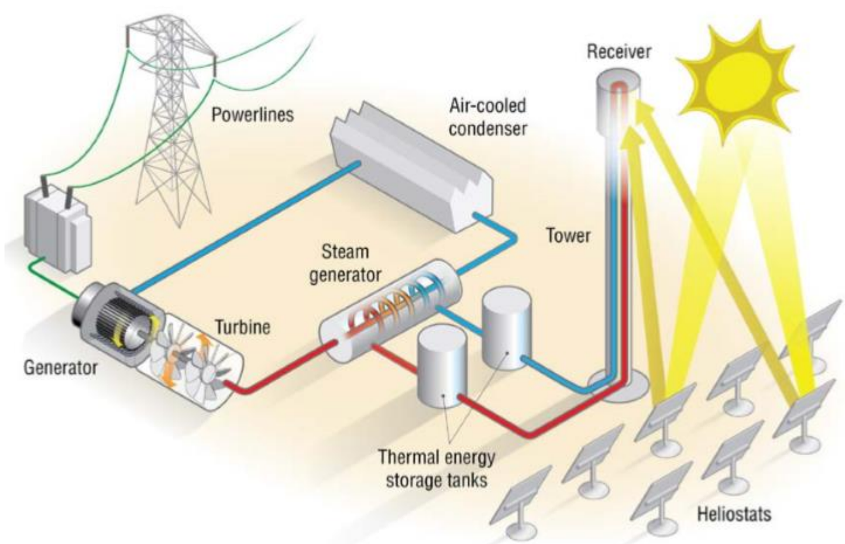


Figure 12. Process of electricity generation in solar tower power plant.

Source [15]

1.2.3. Solar chimneys

The solar chimney is a technology that allows to produce electricity thanks to green-house effect and density difference between hot and cold air and movement of air masses connected with that. This technology is quite new but mentioned effects: movement of air masses due to pressure inequality and green-house effect are utilized by people since many years in different ways, for example in chimney suction ventilated and cooled buildings or to grow plants in greenhouses.

The solar chimney power plant contains three major elements: glass roof collector, wind turbines and chimney. The principal of such power plant operation is very simple. Fresh air from the outside of circular roof collector moves through open area of roof periphery under collectors and is heated by solar radiation. Then hot air is driven, thanks to natural suction generated in chimney, to the middle of collector field, where vertical chimney with large air inlets at its base, is placed. Chimney base and collector roof are connected in a way that prevents air from escape from the installation. Inside the chimney, light hot air rises from the bottom of the chimney to its top. Kinetical energy of air flow is converted to the mechanical energy of wind turbine that is installed near the chimney base and turbines are powering conventional generator that produces electricity [16]. Described above process of electricity generation in solar chimney power plant is illustrated in figure 13.

The single solar chimney power plant is available to produce from 100 to 200 MW of electrical power. Thus, web of connected solar chimneys could replace conventional power plant. Additionally, that technology has many assets, that allows to build solar chimney power plants even in not wealthy countries, especially that a lot of such countries are placed in areas that are perfect to produce electricity from energy provided by Sun. Examples of such advantages are listed below [16]:

- Possibility to utilize both direct and diffused solar radiation, what is crucial to use it in the areas where the sky is frequently overcast, for example in tropical countries.
- Storage of energy without any additional costs. It is possible because the ground under the collector roof absorbs some of heat provided by solar radiation during the day and releases it during the night. Thus, solar chimneys could produce electricity even at night.

- High reliability due to very simple construction (turbines and generator are the only moving parts of solar chimney) and technological process that does not demands high pressures or temperatures.
- No need to utilize cooling factor, for example water. It is very important aspect of that technology for countries that are struggling with shortage of drinking water.
- The building materials needed for solar chimneys (mainly concrete and glass) are easily available almost everywhere in sufficient quantities.
- Not excessive industrial requirements needs to be faced to be able to utilize solar chimney power plants. In majority of countries in the world industrial development level is enough to use that technology.

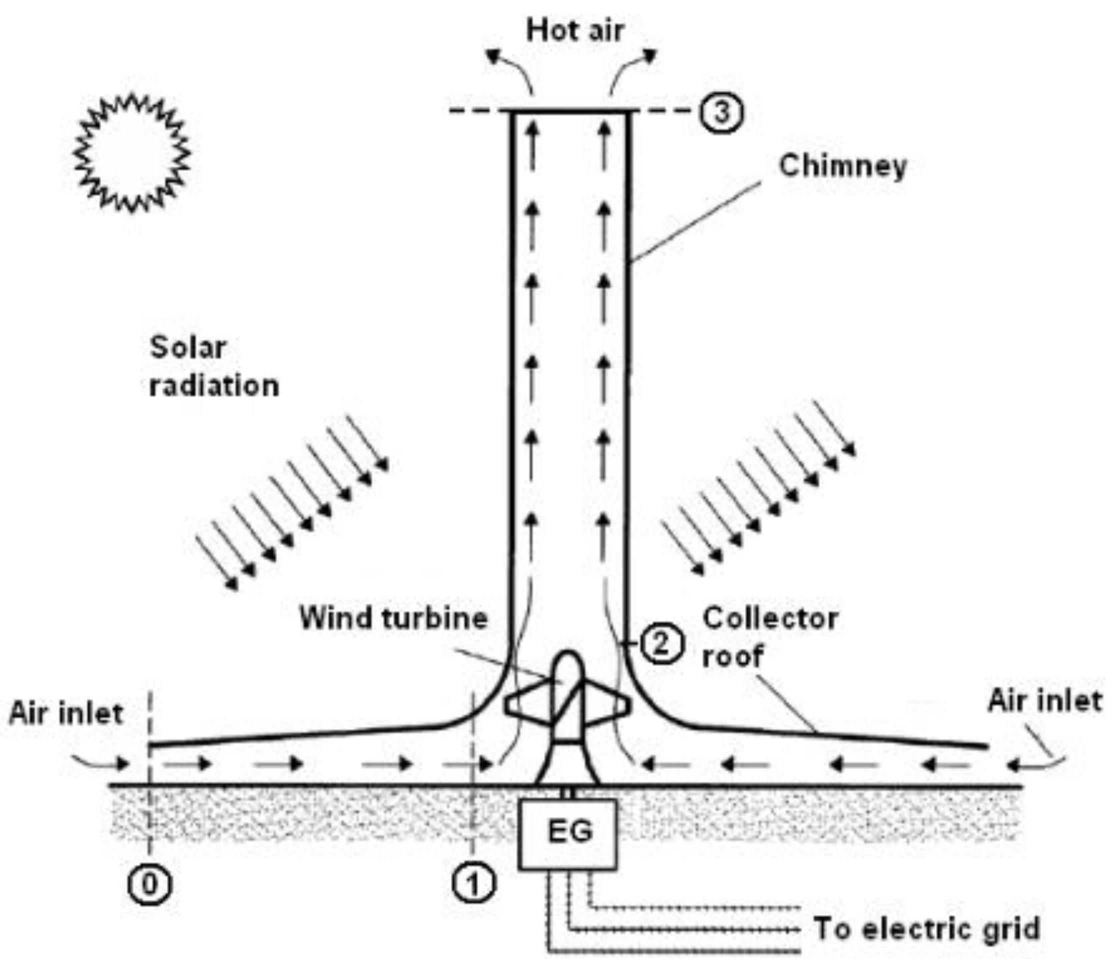


Figure 13. Process of electricity generation in solar chimney power plant.

Source [17]

1.2.4. Solar ponds

The solar ponds are another idea to utilize energy provided by solar radiation to produce electricity. This technology is based on ordinary water heating by Sun rays. Such process was known and used by people since antient times but back then, the level of technical advancement was insufficient to exploit that effect to generate electrical energy.

The solar pond power plant is a very simple construction that is consisted of a solar pond and energy generating unit. Solar pond is the main part of whole construction. It is utilized to collect and store solar energy in the form of heat. It is possible thanks to special structure of the pond that contains three layers and each layer has different level of salinity [18]:

1. Upper convective zone (fresh layer) – it is located at the top of the pond and its temperature is closed to the ambient temperature. It contains the lowest amount of salt (water is nearly clean). Because of the contact with ambient this zone loses stored energy via convection and evaporation.
2. Non-convection zone (salty layer) – it is located in between of pond's top and bottom layer. Its salinity increases with the depth measured from the upper convective zone periphery. Main objective of this layer is to prevent convection from the lower layer, that is why this layer is thicker than others.
3. Lower convection zone (very salty layer) – it is located at the bottom of pond and its temperature might reach even 90℃. The salinity of this layer is the highest. It is also responsible for energy collecting and storage.

Additionally, to increase effectiveness of solar radiation absorption, bottom of the pond has black color. In order to produce electricity, hot water from lower convection zone needs to be transferred to energy generation unit. For that purpose, water pump is installed. When the hot water is provided to the energy generation unit, it is driven to the evaporator. Inside evaporator hot water gives heat to the secondary working fluid. Under influence of heat transfer from water, secondary working turns into a steam. Steam is driven to the turbine which converts enthalpy owned by steam to mechanic energy of shaft. Shaft is connected to power generator that generates electricity. Then steam leaves turbine and is driven to the condenser in which its phase is changed back to the fluid. In condenser water supplied by pump from upper convective zone is utilized as a coolant. Described above process of electricity generation by solar pond power plant is illustrated in figure 14.

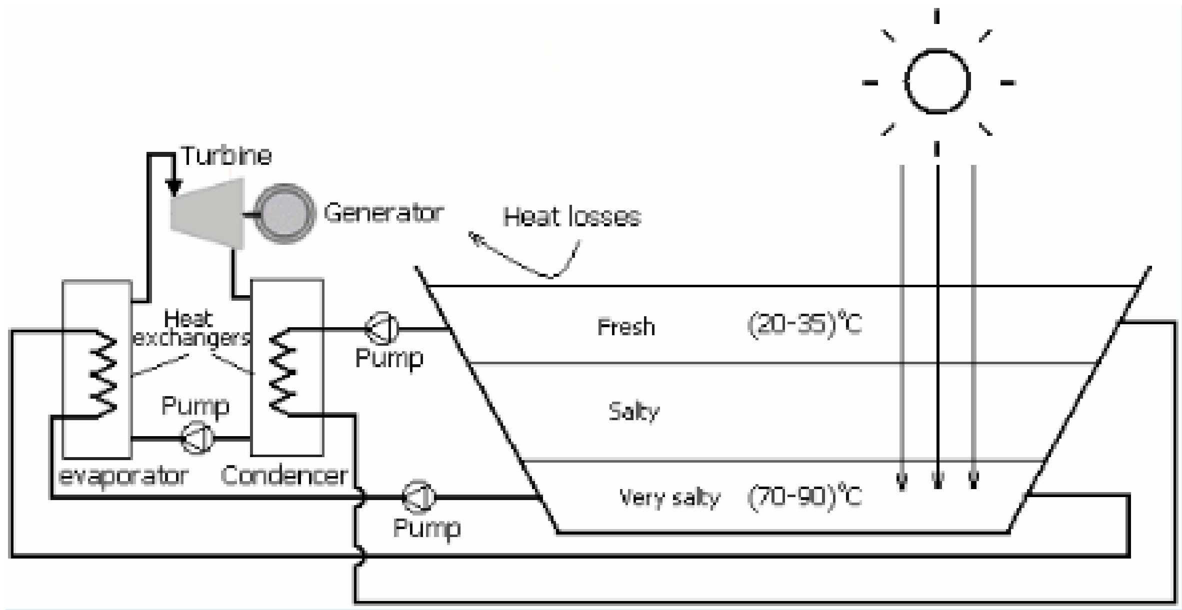


Figure 14. Process of electricity generation in solar pond power plant.
Source [19]

Application of solar pond power plants brings a lot of benefits, that makes this technology more and more important for global renewable energy market. The main advantages of solar pond power plants are:

- Very simple principals of operation, what makes solar pond power plants convenient in use, easy to maintain and reliable.
- No need to implement complicated construction solutions. It makes power plant engineering process simple and in comparison to another technologies, allows to build such power plant quickly.
- Possibility to store thermal energy in lower convection zone without any additional expenses. It allows solar pond power plants to operate even during night and overcast weather.
- Possibility to utilize both direct and diffused solar radiation, what is crucial to use that technology in the areas where the sky is frequently overcast for example in tropical countries.

Thanks to features described above, numerous researches and quick development of that technology, on solar pond power plants might become a solution for providing electricity to areas of the world where people are struggling with lack of its availability.

1.3. Wind energy utilization to produce electricity

Chart 6 shows that the third biggest renewable energy source regarding its potential is wind energy. About 8% of whole renewable energy is consisted in horizontal movement of air masses. For the time being, beside hydropower, it is also the most exploited green energy source. Almost 20% of whole electric energy that come from renewable energy sources is produced by wind turbines what allows to come up with thesis that this technology has been researched very well by scientist and its development blooms.

The history of producing electricity with utilization of the wind is very interesting and began in Cleveland, Ohio where in 1886 scientist, Charles Brush was struggling with lack of electricity, vital to conduct his scientific experiments. To resolve his problem, Brush engineered and constructed in his backyard first wind turbine. It was enormous construction, that weighted over 40 tons and reached over 18 meters height. The rotor of that turbine had diameter equal to 17 meters and was contained of 144 slender blades. Within tower Brush located dynamo and necessary gearing to drive it and in basement he installed 12 batteries. He utilized his wind turbine to provide electricity to his household and laboratory through almost 15 years till the moment when the city of Cleveland began offering the convenience of centrally generated electricity [20].

Although Brush invention was working well and providing electricity from cost-free source, nobody decided to duplicate it or to build something similar and researches on wind turbines slowed down till the end late 1920s when the first commercial producents of wind turbines appeared on American market. They were providing with turbines American farmers that were living too far from power plants to have possibility to join to commercial energetic grid. Also, in these time inventors came up with idea of three-blade propeller appliance to wind turbines and it turned out that it is the most efficient way to produce electricity with their utilization and is used till today.

All described inventions were utilized on small scale, mainly to provide electricity to single households. The reason why bigger power generation units that utilizes wind as a source of energy were not built for a long time is that wind turbines were producing direct current and in all bigger cities alternate current, produced in conventional power plants was used. The invention of power inverter in 1957 was crucial for development of large-scale power generation utilizing wind turbines. First big wind power plants were built on the shoulder of

Crotched Mountain in New Hampshire in December 1980. It was consisted of 20 wind turbines rated at 30 kilowatts each [21]. In these days there are 341 000 wind turbines operating all over the world and they are producing about 1270 TWh of electric energy annually [22].

To be able to produce energy using wind turbines several requirements need to be fulfilled. Among others, the area where turbine is planned to be placed needs to be uninhabited, the region should not be under environmental protection or be the part of birds' migration trail, there should not be also any natural or anthropogenic barriers for air mass flow and what is most important the wind magnitude should be steady and high through whole year. Beside listed conditions there are also a lot of legal requirements regarding topics related to wind energetics that are specific for each country. As it was mentioned above, crucial for wind energetics development in given region are wind conditions and one of the most important of wind features is its velocity. The map that illustrates wind average velocity in the world is shown in figure 15. Areas where average wind velocity measured at the height of 80 m is higher than 4 m/s are considered as suitable for wind turbines.

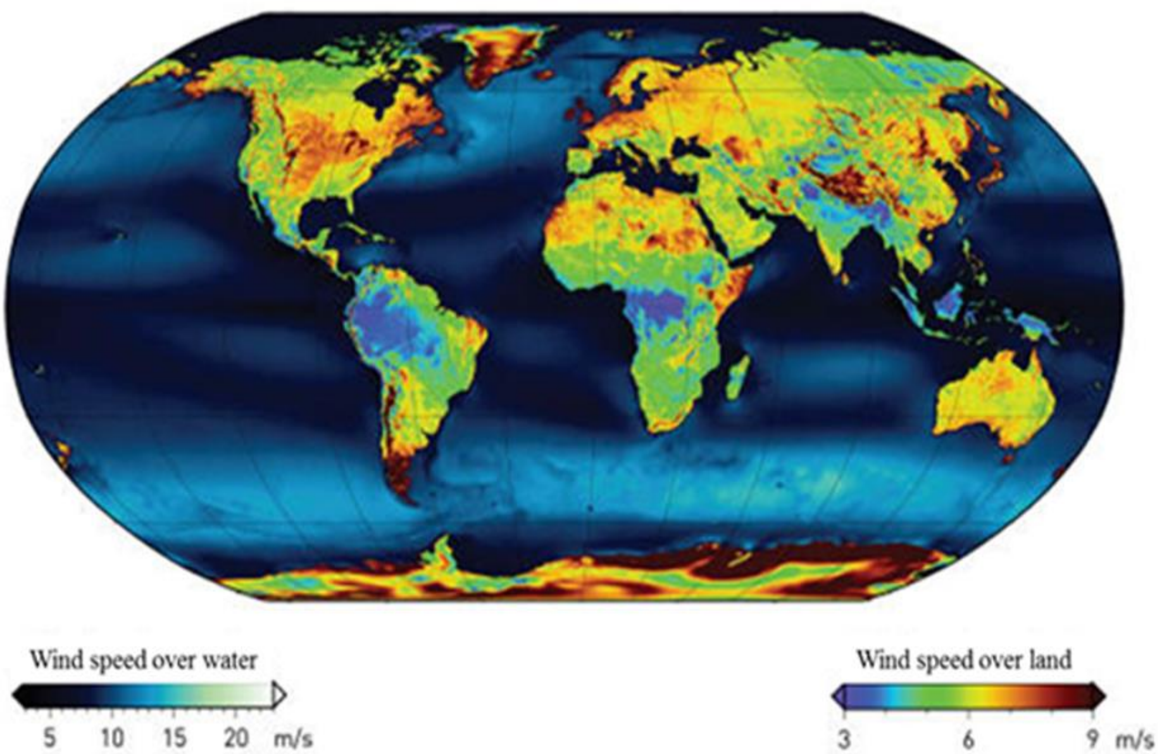


Figure 15. Worldwide average wind velocity map.

Source [23]

1.3.1. Wind turbines overview

In these days there exist a few types of wind turbines and they could be divided into three main categories that are shown in figure 16. The most common ones are the horizontal-axis wind turbines that are splitting into two different subcategories depending on their applications. First subcategory is fast rotation horizontal-axis wind turbine. Such turbines are mainly utilized in commercial big wind power plants or for domestic use in electricity generation purposes. Wind turbine of that type consists of only a few (in majority three) aerodynamically optimized rotor blades that have possibility to be regulate according to wind conditions. Depending on its size, single turbine of this subcategory can provide electric power from 10 kW to even a few MW. The largest turbine available on the market has a power of 8 MW and bigger devices are in test phase. Second subcategory of horizontal-axis turbine is, ancestor of fast rotation turbine, the slow rotation multiblade rotor. Such turbines are characterized by high starting torque, what makes them perfect to drive some mechanical devices like water pumps. The rotation period of these rotors is long, so the rotation speed of the blades is low and as a result wind turbine is not sensitive for variable wind conditions and complicated mechanisms of blades regulation are not needed. To protect turbines from damages caused by storms, mechanical safety system is installed. Due to simple construction, slow rotation horizontal-axis wind turbines are very reliable and have very long operation period that can reach even more than fifty years [24].

The second category of wind turbines are vertical-axis wind turbines. They are less popular than described above horizontal-axis rotors but they are still in use. They can also be divided into two subcategories. First subcategory is known as Darrieus Turbines. They were developed and installed in 1980s in California but since then their further expansion was very limited and they have never become popular. In these days they are mainly used to provide electricity supply in regions where electrical grids are not available. The main reason of their failure on green energy market is that they have more disadvantages than advantages. Their main advantage is that their operation is not dependent on the direction of the wind. Unfortunately, the list of Darrieus Turbines assets over horizontal-axis turbines ends with mentioned feature. When it comes to disadvantages of vertical-axis turbine of this type, list is longer and begins with necessity of help of a generator to start rotation. Next negative aspect of Darrieus Turbine is that they are noisier than turbines of other types and last but not least, such rotors in contrast to horizontal-axis turbines are installed not on high towers but on the ground, what makes them less effective, because wind velocity increases with height. The second subcategory of vertical-axis turbines is Savonius rotor. Machines of that type are used only for research activities like measurement of wind velocity, so they are not important in terms of that thesis [24].

The last category of wind turbines are up-stream wind turbines. They are utilized in solar chimneys. Such installations can be considered both as ones that generates electricity with utilization of solar energy and as ones that generates electricity with utilization of wind energy. In this thesis more detailed description of solar chimneys technology could be found in chapter dedicated to solar energy utilization to produce electricity.

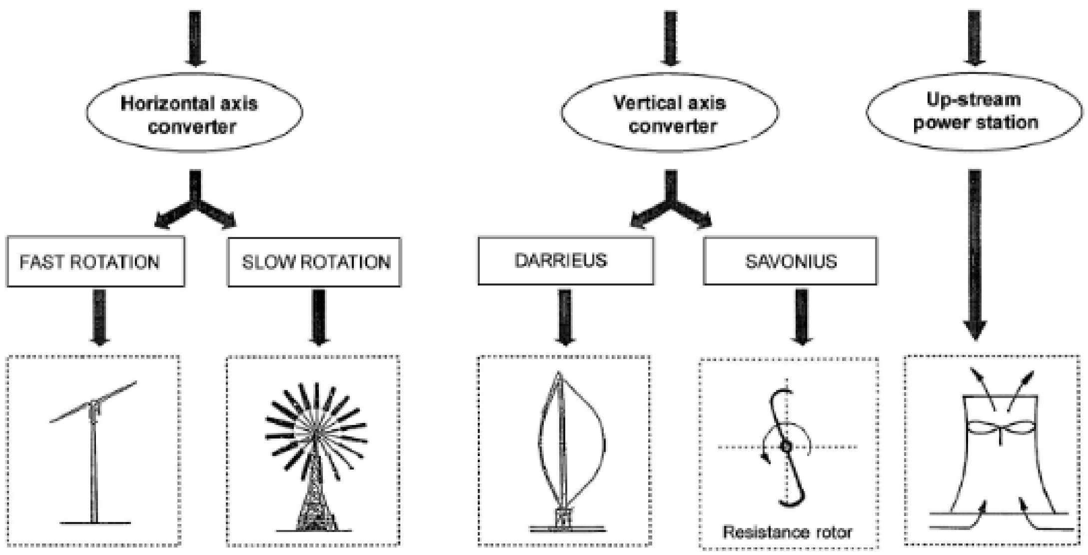


Figure 16. Overview of the wind turbines categories.

Source [24].

1.3.2. Principal of wind turbine operation

As the fast rotation horizontal-axis wind turbines are most widely used type of wind rotors in purpose of electricity generation, their principal of operation will be described in following part of this thesis. Basically, two types of fast rotation horizontal-axis turbines could be distinguished:

a) The design with gearbox – details of this design are illustrated in figure 17. It is the most common technical solution regarding wind turbines. Kinetic energy of air mass movement is converted into mechanical energy of wind turbines blades rotation. The core of rotor is connected to the main shaft that is placed inside turbines hull. Thanks to that connection torque of rotor is transferred to the main shaft that turns slowly and drives racks that are inside gearbox. Through a gearbox torque is transmitted to the high-speed shaft that drives the electricity generator. In safety purposes disk brake is installed in the wind turbine. It is stopping turbine operation when the wind velocity is too high, for example during storm. Gearbox mechanism needs to be lubricated with oil. Due to large friction between racks contained inside gearbox lubricant must be cooled. Rotors of this type used in these days, are also equipped with special devices to measure wind velocity and direction. Fast rotation horizontal-axis wind turbines are installed at the top of the towers and joint to them with rack-and-pinion mechanism that allows the turbine to be rotated to the air movement direction.

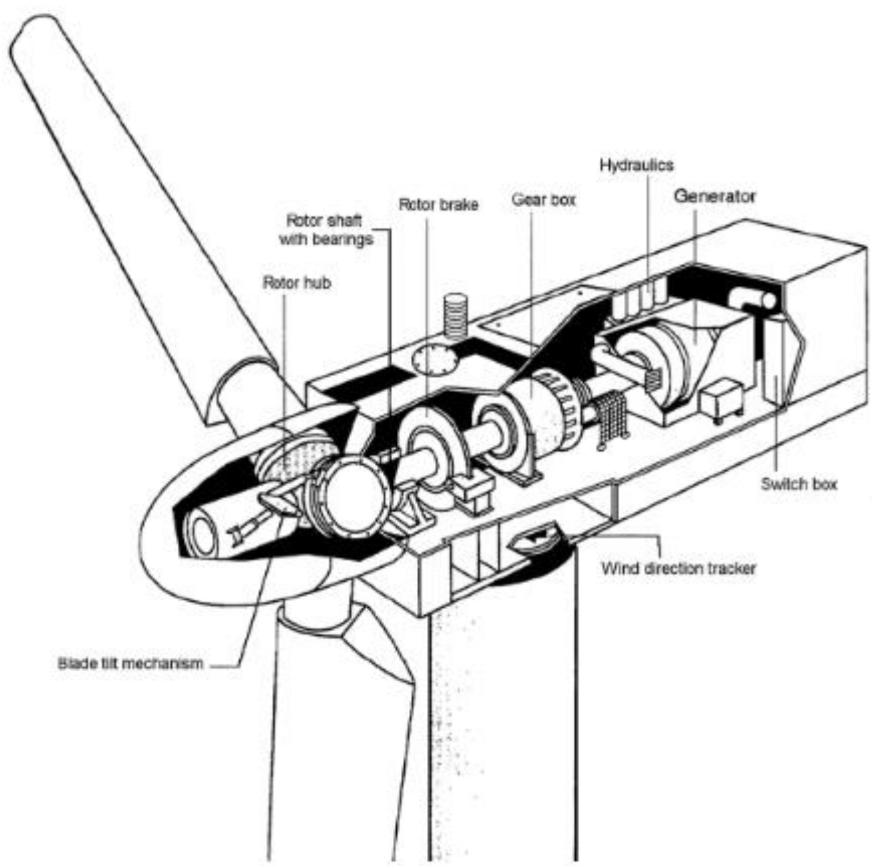


Figure 17. The design with gearbox.

Source [24]

b) The design without gearbox - details of this design are illustrated in figure 18. This technical solution regarding wind turbines is utilized rarely. The principal of such turbine operation is similar to the one with gearbox. Kinetic energy of air mass movement is converted into mechanical energy of wind turbines blades rotation. The core of rotor is connected to the main shaft that is placed inside turbines hull. Thanks to that connection torque of rotor is transferred to the main shaft and in contrast to the design with gearbox, main shaft is connected directly to the electricity generator which is driven by shaft torque and this is the main difference between design without and with gearbox. In safety purposes disk brake is installed in the wind turbine. It is stopping turbine operation when the wind velocity is too high, for example during storm Rotors without gearbox used in these days, are also equipped with special devices to measure wind velocity and direction. As well as others fast rotation horizontal-axis wind turbines, devices without gearbox are installed at the top of the towers and joint to them with rack-and-pinion mechanism that allows the turbine to be rotated to the air movement direction.

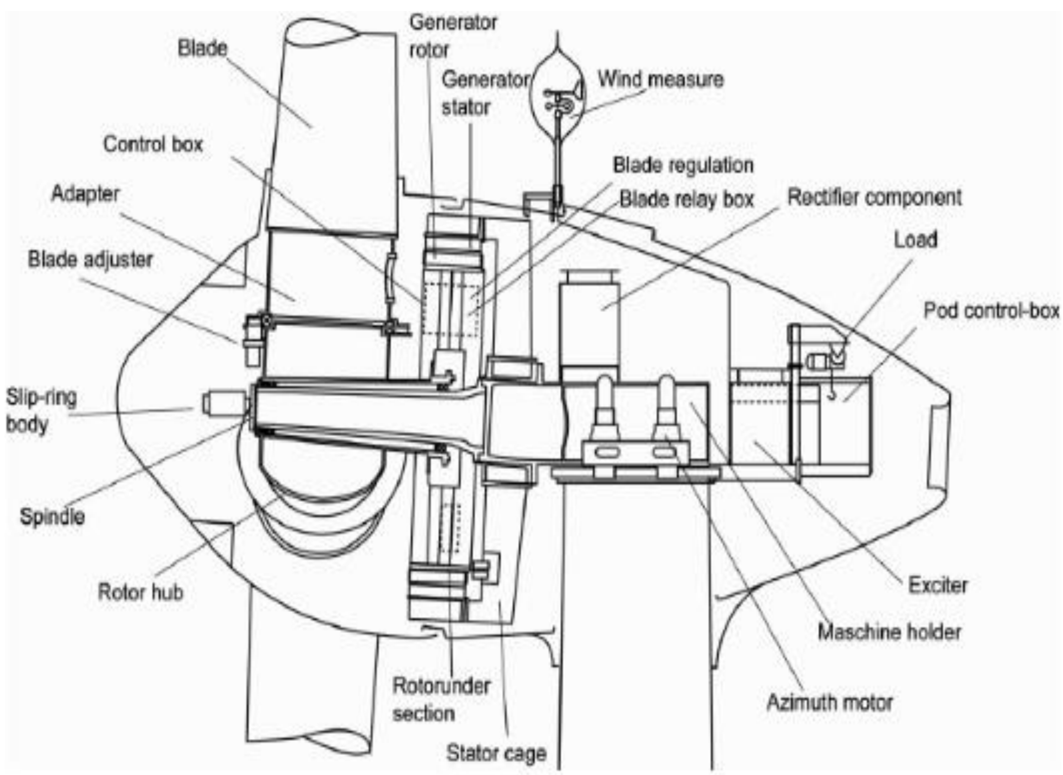


Figure 18. The design without the gearbox.

Source [24].

2. Creation of report regarding renewable energy sources

This chapter of these thesis will be dedicated to show the process of creation of the report regarding energetic and environmental situation in the World, the level of renewable energetics advancement on each continent and the possibilities of natural environment situation enhancement via wider application of renewable energy sources. This report will allow to visualize the most important information regarding renewable energy sources utilization and their impact on environment. What is important from environmental management point of view, report will also show comparison of effect of using green energy with effect of using conventional energy sources. The report preparation and data visualization, in which outcome of utilization of technologies described in first chapter will be shown, are the most crucial parts of the whole thesis as it shows the possibilities of this visualization tool and it is vital for the data interpretation.

2.1. Introduction to the Power BI analytical tool

To prepare the report appropriate tool will be needed. In case of these thesis Power BI application provided by Microsoft will be utilized. It is a business intelligence platform that provides users with tools for aggregating, analyzing, visualizing and sharing data. The application is built in such a way, that users of other services provided by Microsoft (e.g. Excel) are able to use it to create simple visualizations even without any training. A free version of Power BI is available on official Microsoft website [25].

Microsoft Power BI is used by many organizations all over the world to analyze their data and provide user friendly visualizations. The tool supports its users with connect of disparate data sets, transform and clean the data into clear data model and create numerous kinds of charts, graphs and visuals. All created data analysis and visualizations might be shared within the organization through Microsoft web platform where data model can be published by its creator. The analysis created in Power BI might be utilized not only to show existing data but also to examine "what if" scenarios or to illustrate forecasts. One of the most common reasons of Power BI utilization is providing executive dashboards for managers to give them insights if all key performance indicators of given department have been met [25].

Since 2011, when Microsoft introduced first version of Power BI, a lot of data analytics features has been added to the application and producer continues to do so. Almost each month new actualizations of Power BI are available. Below is the list of most important features included in platform [25]:

- Artificial Intelligence – provides users with access to image recognition, text analytics and create machine learning models.
- Hybrid deployment support - this feature allows users to connect Power BI tools with numerous data sources from Microsoft, Salesforce and other vendors.
- Quick insights – this feature lets users to create datasets connected with existing ones and automatically apply analytics to them.
- Common data model support – provides users with the standardized and extensible collection of data schemas.
- Cortana integration – this feature allows users to navigate inside application using natural language. It is popular especially on mobile devices.
- Customization – this feature lets users to import new tools into the application and change appearance of tools already present in application, to meet users' expectancies.
- APIs for integration – this feature allows users to embed the Power BI dashboards in other software products.
- Self-service data preparation – this feature provides possibility of preparation, transformation and integration of data, that can be shared across application models, with Power Query directly into Power BI.
- Modeling view – this feature lets users to divide complex data models by subject into separate diagrams, select number of objects at once and set common properties, modify properties in dedicated pane and set display folders in order to simplify complex data models.

Power BI is consisted of numerous applications and can be used not only on desktop but also on mobile devices or as a SQL Server Analysis Services product. Platform is built in such a way that allows users to create and share business insights utilizing technique that is the most suitable for them and fits to their role in organization. Power BI is consisted of a several components that lets users to create and share their reports [25]:

a) Power Query – a data mashup and transformation tool.
b) Power Pivot – a memory tabular data modeling tool.

c) Power View – a data visualization tool.

d) Power Map – a 3D geospatial data visualization tool.

e) Power Q&A – a natural language question and answering engine.

To utilize Power BI user needs to have at least basic knowledge of two programming languages that are being utilized in application. The first one is DAX (Data Analysis Expressions) – query language developed by Microsoft for tools dedicated to data analysis like PowerPivot, Power BI and SQL Server Analysis Services. It is very intuitive language that is similar to Excel formulas, but it is extended with phrases that allows to work with relational data and perform dynamic aggregation. The second programming language useful during report creation in Power BI is M-code (M stands for data mash-up). It is language that is utilized in Power Query editor to extract and transform the data.

2.2. Building the dashboard in Power BI

To build the report in power bi user needs to get data to the application. Power BI is able to read data from many different sources like Excel (only with extension .xlsx), Text/CSV, XML, JSON, PDF, SQL Server database, Access database and many more. Next step is to prepare data to analysis in Power Query editor. Inside this tool user can merge or append queries, replace values, remove duplicates, change column headers pivot and unpivot columns, change data types, extract characters, add conditionals columns and perform many more action on data. Then user must implement all needed formulas in PowerPivot. In this environment formulas must be created utilizing DAX language. User have possibility to perform mathematical operations on data, lookup values between different datasets, compare data, create various connections between data sets and implement all needed actions to have final form of data with additional calculations. At the end data is ready to be visualized in Power View. In this environment user must choose the most suitable charts and graphs and customize them in such a way, that representation of gathered data is suitable, convenient, user-friendly and what is most important easy to read and interpret. When the report is done user might publish it on Microsoft Power BI web platform. Dashboard creator have possibility to grant access to his report on the platform to the chosen Outlook users. There is possibility to grant access to all reports published by user or to each report separately.

In the following part of these thesis, example of data analysis in power BI step by step will be shown. The final dashboard was created based on the same logic but with utilization of more sophisticated functions and implementation of more advanced report building techniques in purpose of acquire satisfying final view of the report.

Step 1. Import of the data to Power BI.

After the application is opened, dialogue window appears. User has a few possibilities on this stage. He can open recently used Power BI file, upload data for new file, open some video tutorials regarding building simple dashboards or open link to official Power BI webpage. In order to build new dashboard, user needs to upload the data by clicking ***Get data*** button. Dialogue window that appears right after opening Power BI application is illustrated in figure 19.

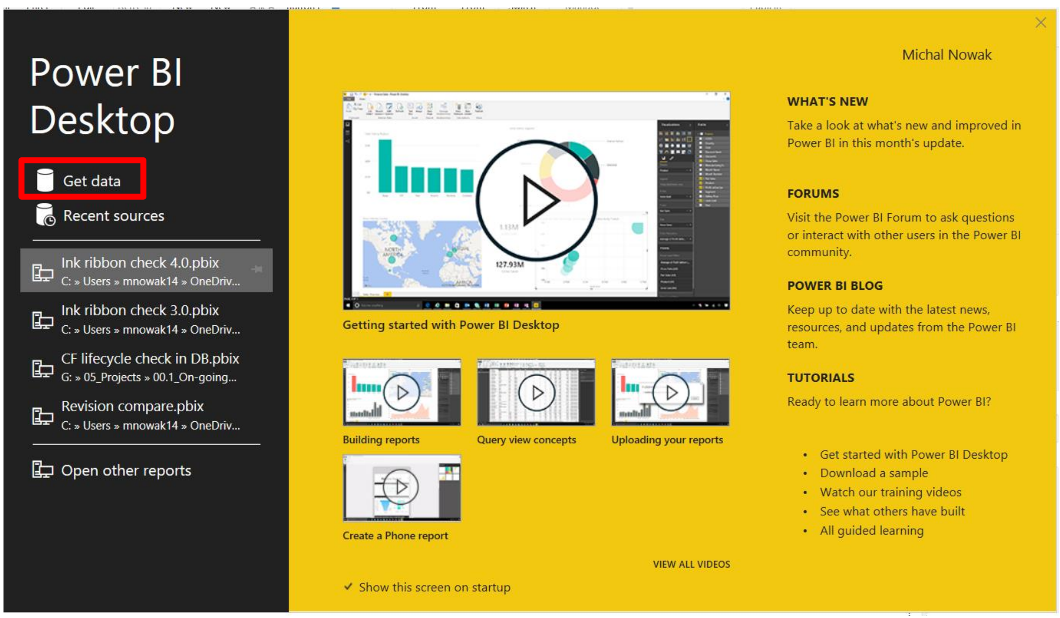


Figure 19. Dialogue window visible after opening Power BI application.

Source: own elaboration

Step 2. Choosing format of the data.

After clicking ***Get data*** button, another dialogue window pops up. Next step for the user is choosing data format, from the list that is available in displayed window. List might be filtered by several types of data. User might also search for specific data format by typing its name in searching window. In case of example that is described in this thesis, data is saved in text (.csv) file so according data type needs to be chosen from the list. To choose data type user must click on its name and then click on button ***Connect***. All actions described in a second step are illustrated in figure 20.

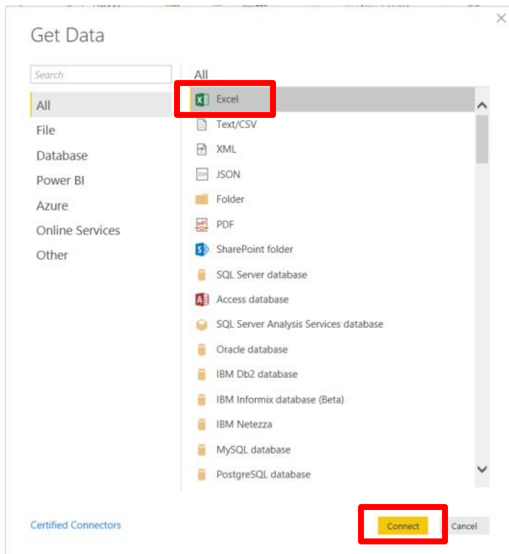


Figure 20. Dialogue window with the list of available data formats.

Source: own elaboration

Step 3. Choosing the file.

After format of the data is chosen, another window appears. In this window all files saved on hard drive in appropriate format could be found. User needs to find the file that he wants to upload to the tool and click on its name. Then, when the appropriate file is chosen user must click ***Open*** button. All actions introduced in this step are visualized in figure 21.

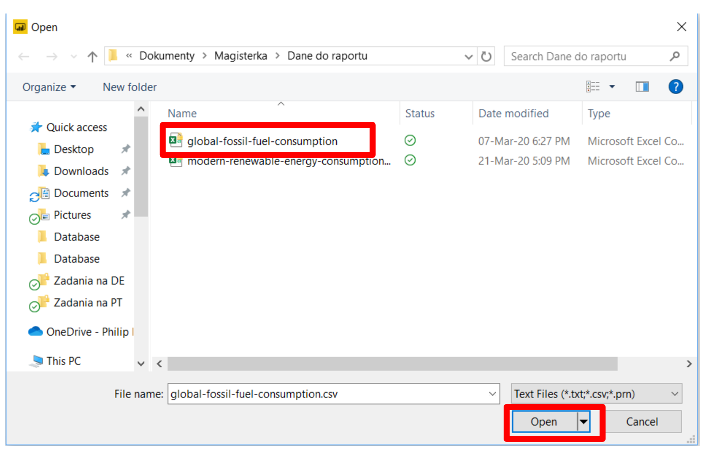
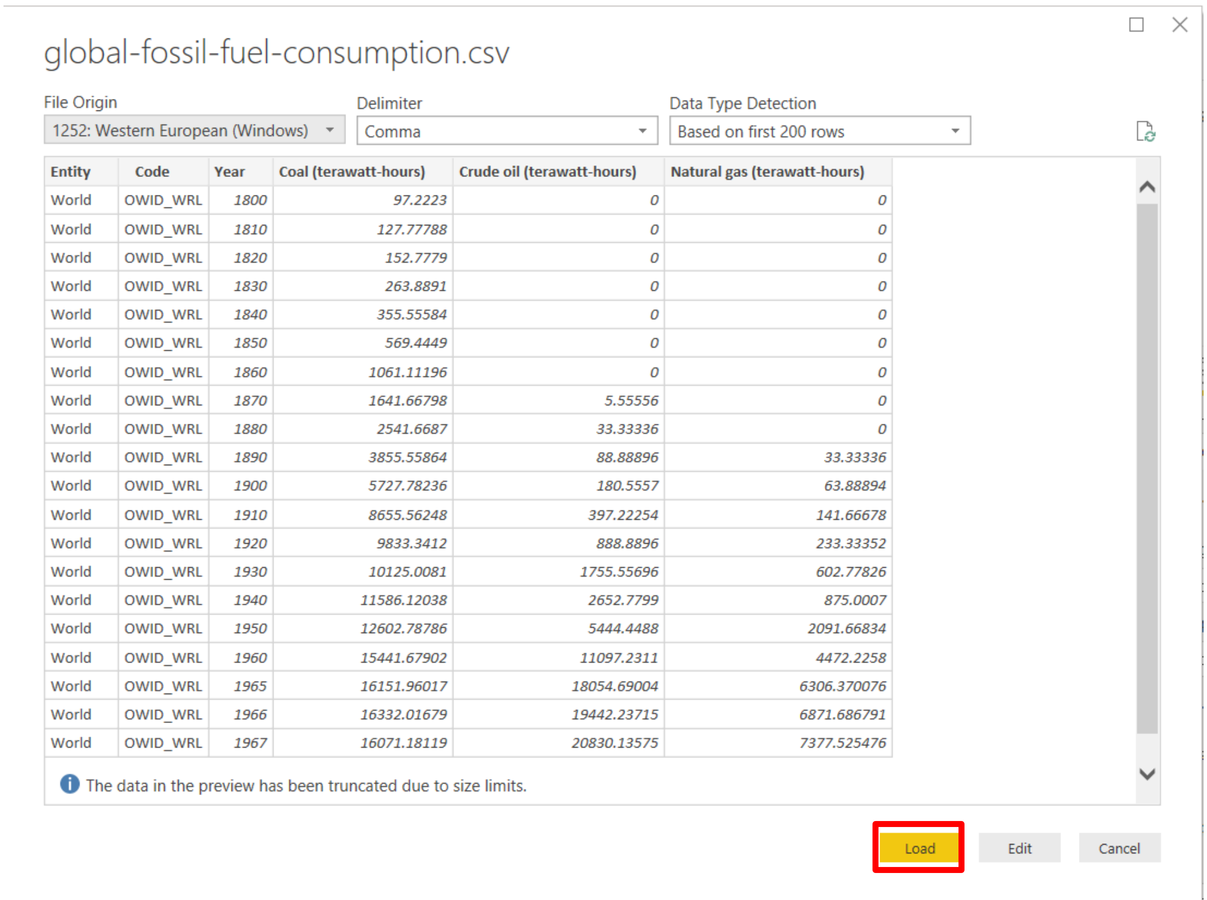


Figure 21. Dialogue window with the files that are possible to be uploaded to Power BI.

Source: own elaboration

Step 4. Final loading of the data.

When the file is chosen, dialogue window with data preview pops up. Thanks to that user can check if data format and content are suitable for him and if he wants to finally upload the data in that form. If user is one hundred percent sure that all information visible in preview is correct, he must click on button ***Load*** to perform final upload of data. Window with data preview is shown in figure 22.



Entity	Code	Year	Coal (terawatt-hours)	Crude oil (terawatt-hours)	Natural gas (terawatt-hours)
World	OWID_WRL	1800	97.2223	0	0
World	OWID_WRL	1810	127.77788	0	0
World	OWID_WRL	1820	152.7779	0	0
World	OWID_WRL	1830	263.8891	0	0
World	OWID_WRL	1840	355.55584	0	0
World	OWID_WRL	1850	569.4449	0	0
World	OWID_WRL	1860	1061.11196	0	0
World	OWID_WRL	1870	1641.66798	5.55556	0
World	OWID_WRL	1880	2541.6687	33.33336	0
World	OWID_WRL	1890	3855.55864	88.88896	33.33336
World	OWID_WRL	1900	5727.78236	180.5557	63.88894
World	OWID_WRL	1910	8655.56248	397.22254	141.66678
World	OWID_WRL	1920	9833.3412	888.8896	233.33352
World	OWID_WRL	1930	10125.0081	1755.55696	602.77826
World	OWID_WRL	1940	11586.12038	2652.7799	875.0007
World	OWID_WRL	1950	12602.78786	5444.4488	2091.66834
World	OWID_WRL	1960	15441.67902	11097.2311	4472.2258
World	OWID_WRL	1965	16151.96017	18054.69004	6306.370076
World	OWID_WRL	1966	16332.01679	19442.23715	6871.686791
World	OWID_WRL	1967	16071.18119	20830.13575	7377.525476

Figure 22. Dialogue window with preview of the data.

Source: own elaboration

Step 5. Power Query Editor opening.

The sign that the data has been loaded correctly is that, that in the right section of the Power View, entitled “Fields” title of a data file and headers of columns in a data file are visible. To proceed with further analysis user needs to prepare a data in Power Query Editor.

In order to open Power Query Editor, user must click ***Edit Queries*** button which is placed on the top of the screen in the Ribbon. Actions described in this step are illustrated in figure 23.

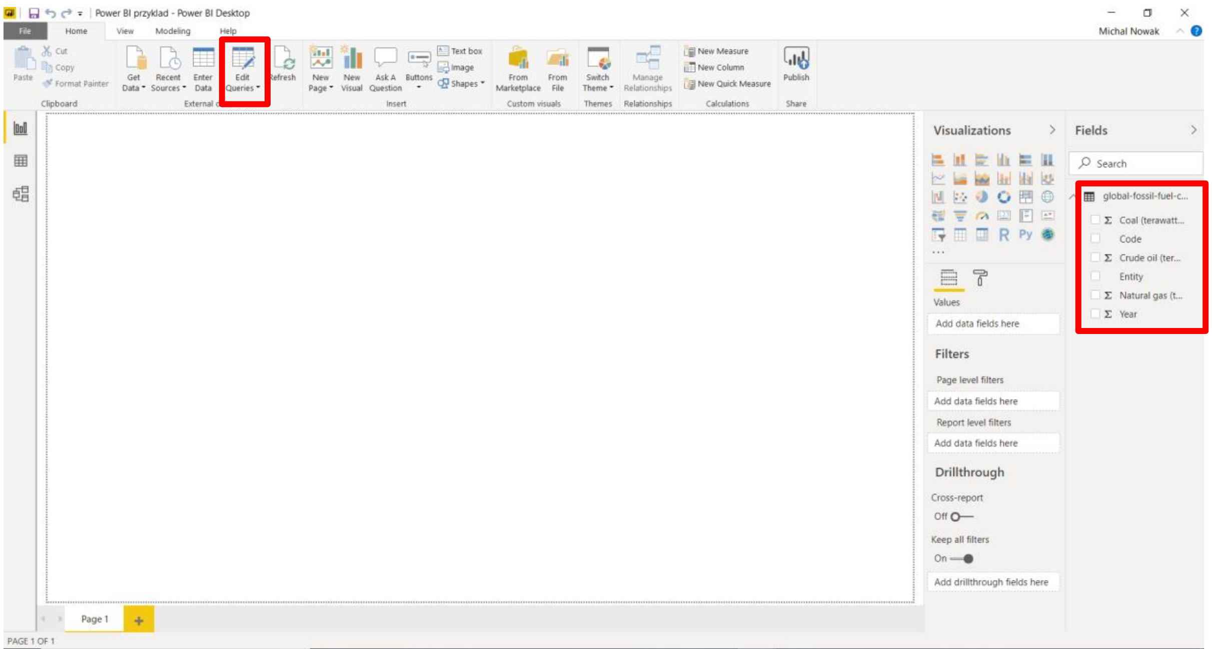


Figure 23. Power View interface right after the data loading.

Source: own elaboration

Step 6. Data preparation in Power Query Editor.

After Power Query Editor has been opened, the interface of application appears. To perform any action in this program, user needs to have at least basic knowledge regarding its navigation. There are four main parts of the user interface. First one is the Ribbon, which is placed from default in the top of the screen. In this part user has access to variable data management functions. Through their utilization user might perform all needed actions to prepare data properly to further actions. Ribbon is divided into five sheets: “Home”, “Transform”, “Add Column”, “View” and “Help”, but only first three from listed sheets consist functions that allows to perform changes on data. Beside functions contained in Ribbon, there are additional useful functions that are contained in dropdown list that appears after right-click on any column header. The second part of interface is named “Queries” and can be found in the left part of the screen. Here user can find the list of all datasets that have been loaded to Power BI or created in application. Third part of the interface is dashboard with data preview. It is placed in the middle of the screen. To change preview from one dataset to another, user must change selection in Queries. The last part of interface is named “Query Settings”. It can be found in the right part of the screen. It is divided into two parts: “Properties” and “Applied Steps”. In Properties user can find name of dataset and has possibility to change it. In Applied Steps user can find list of all actions that have been performed on given dataset and have possibility to change details of each action, delete it or to change chronology of actions. Power Query Editor user interface, together with split on its four main parts is illustrated in figure 24.

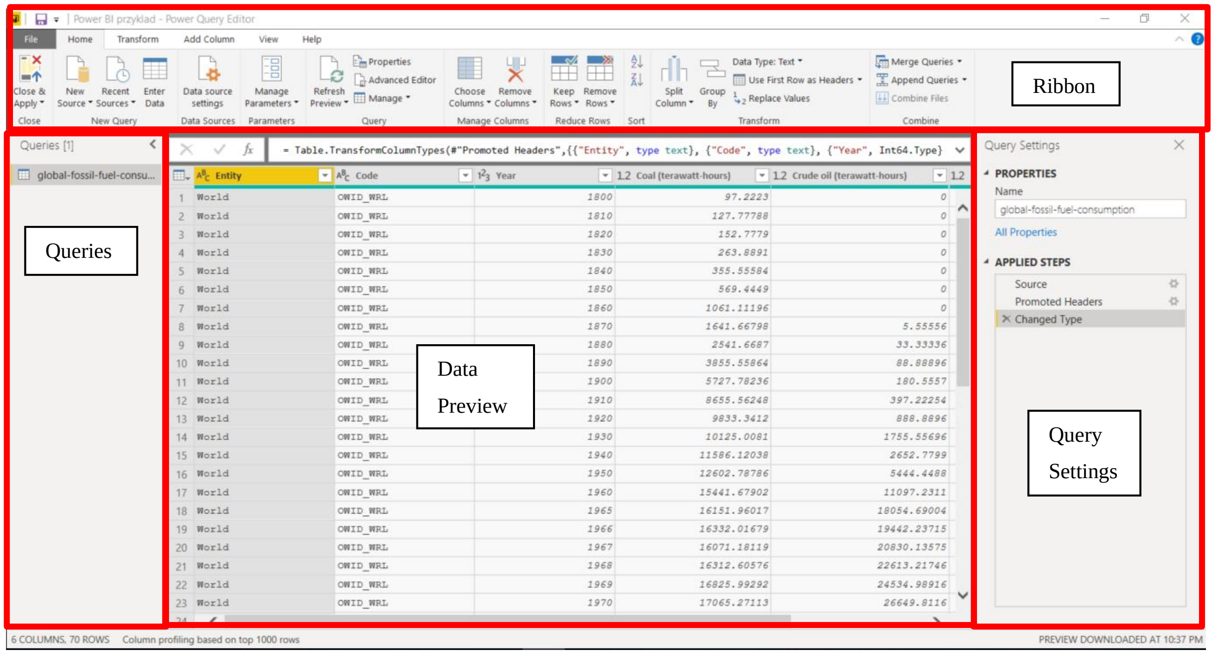


Figure 24. Power Query Editor user interface.

Source: own elaboration

After Power Query Editor is opened, user needs to perform all needed actions on the data, to prepare it for further processing. In case of example introduced in this thesis, in first place not needed columns needs to be removed. There are two ways to do that. The first solution is to highlight not needed columns and choose option ***Remove***. The second solution is to highlight all needed columns and choose option ***Remove Other Columns.*** In contrary to appearances, better idea is to use second solution because it might happen that in future new columns will be added to the source file with data and that way of proceeding prevents from uploading any new columns, and as a consequence allows to avoid errors during data refreshment. In case of given example two columns: “Entity” and “Code”, should be removed. To do that user must press and hold button Ctrl on the keyboard and simultaneously click on headers of following columns: “Year”, “Coal (terawatt-hours)”, “Crude oil (terawatt-hours)” and “Natural gas (terawatt-hours)”. When all mentioned columns are highlighted, user must right-click on any header and then chose option ***Remove Other Columns*** from dropdown list that appears after click. All actions described in this paragraph are shown in figure 25.

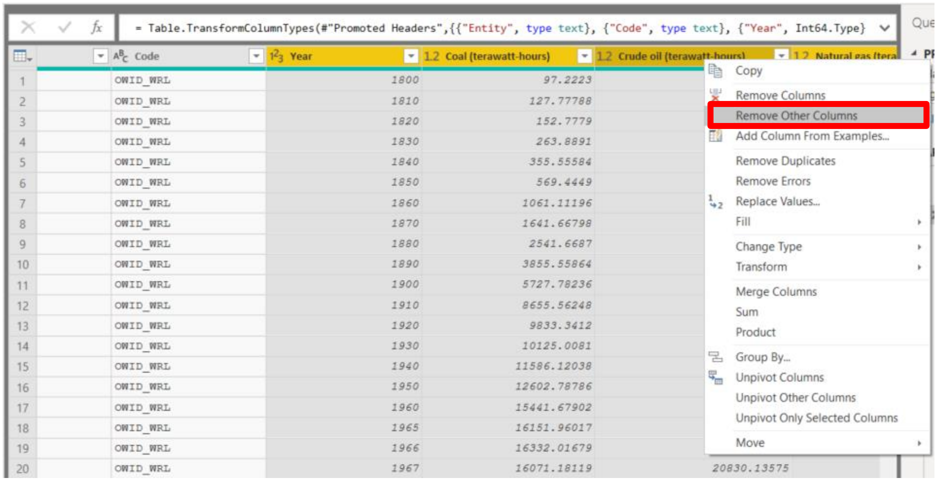


Figure 25. Not needed columns removal in Power Query Editor.

Source: own elaboration

After implementation of all actions described above, only highlighted columns should remain and in the right part of Power Query Editor, in Applied Steps section, new position, named “Removed Other Columns”, should be visible. The view of power Query editor after not needed columns removal is shown in figure 26.

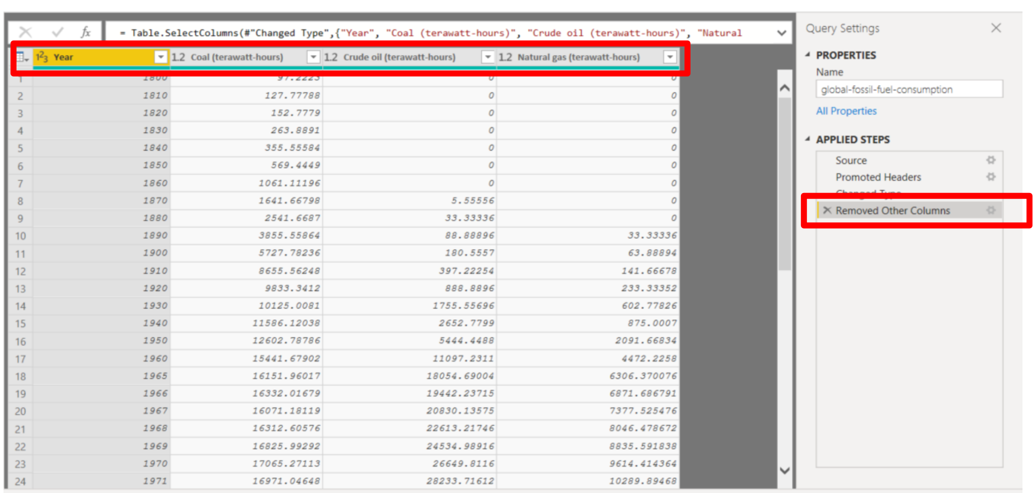


Figure 26. Power Query Editor interface after removal of not needed columns.

Source: own elaboration

The next action required in case of example that is being described in this thesis is renaming of the column's headers. For the purposes of data visualization units of measure in column's headers names are not needed and to make column's headers more esthetic and readable, each word should be written with capital letter. There are two ways of adjusting column's header name. The first one is to double-click on column's header and change its name according to needs. Second one is to right-click on column's header and choose option ***Rename*** from dropdown list that pops up after click and then change column's header name. There is no big difference between these two ways of column's header name adjustment, so user may apply the most suitable method for him. All activities regarding column's header name adjustment, using second of described option, are shown in figure 27.

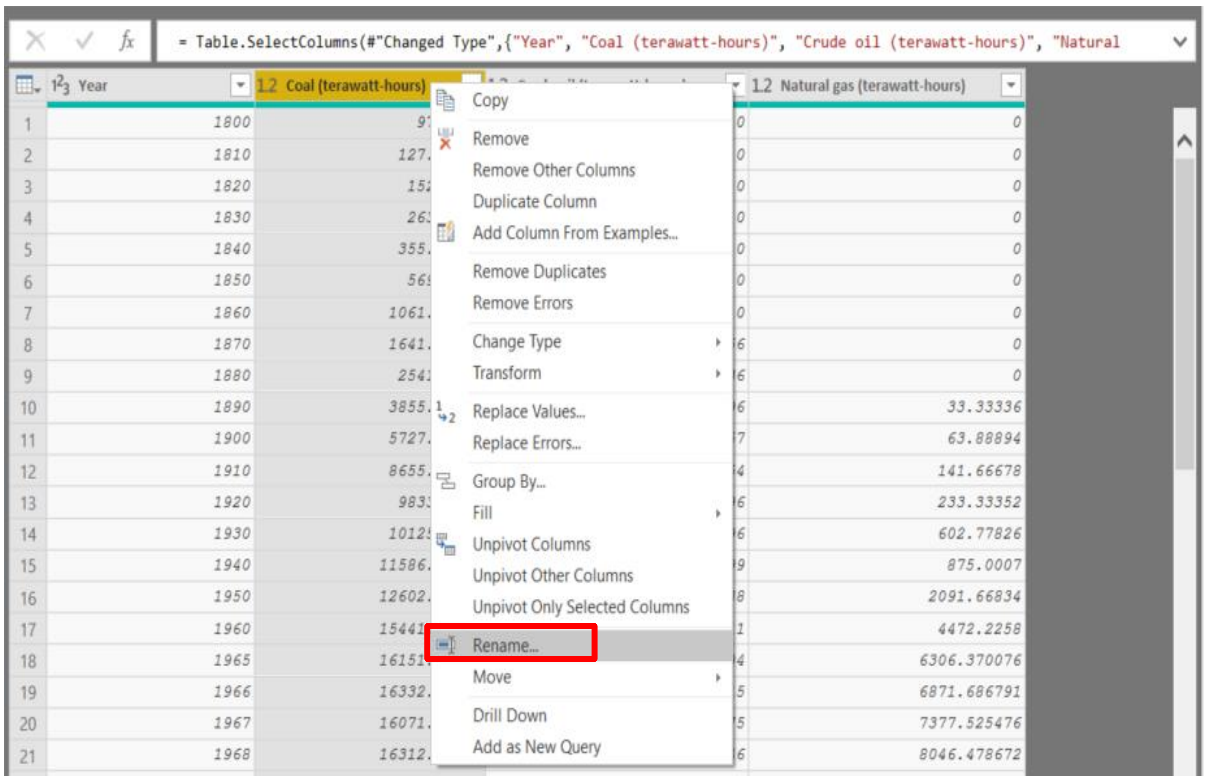


Figure 27. Column header name adjustment in the Power Query Editor.

Source: own elaboration

After implementation of operations described above, all units should be deleted from column's headers, each word in column's header should be written with capital letter and new step, named "Renamed Columns" should be visible in section Applied Steps. The view of Power Query Editor after column's headers names update is illustrated in figure 28.

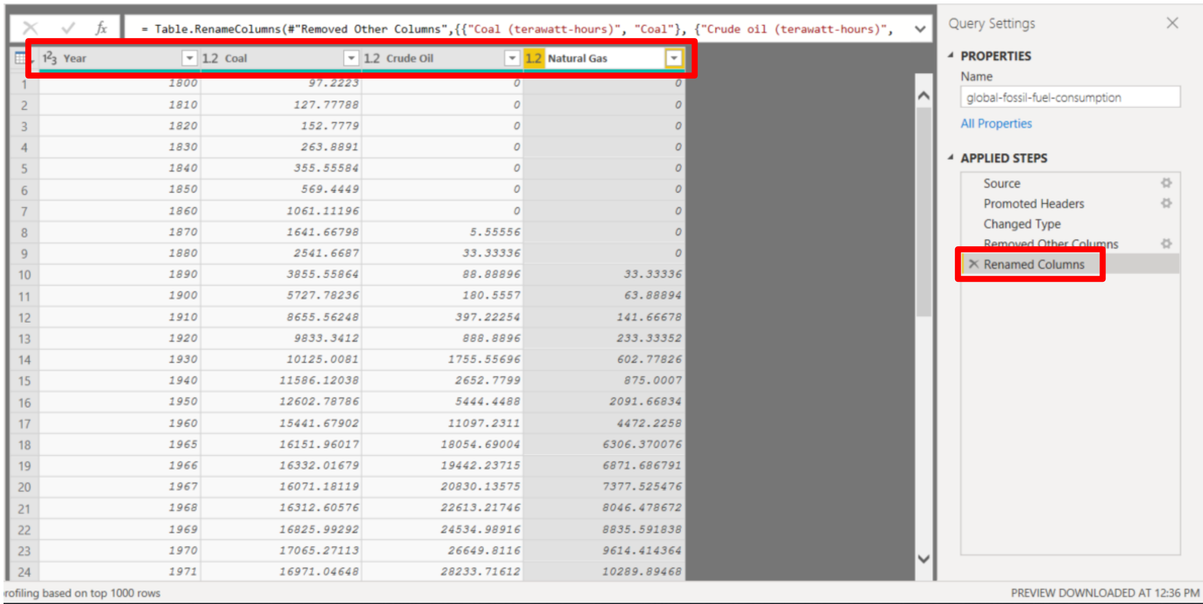


Figure 28. Power Query Editor interface after column's headers names adjustment.

Source: own elaboration

The next step that needs to be implemented in Power Query Editor, in case of example data, is addition of consumptions of each fossil fuel within one year, to receive sum of all fossil fuels consumed during that year and there are two ways to achieve that goal. The first option is to add custom column and use formula written in M-code. To do that user must go to sheet "Add Column" and click on ***Custom Column*** icon. After that dialogue window appears and user needs to adjust new column's header name and write there appropriate formula, which in this case should looks like as follows: *=[Coal]+[Crude Oil]+[Natural Gas]*. When the formula is ready and application gives feedback that there are no errors in it (feedback regarding formula quality is visible in downright corner of the dialogue window), user can apply it by clicking ***OK*** button in dialogue window. To add values in columns utilizing second option, that not requires knowledge of M-code, user must press and hold button Ctrl on keyboard and simultaneously click on the headers of following columns: "Coal", "Crude Oil" and "Natural Gas". Once all mentioned columns are highlighted user needs to go to sheet "Add Column" and click on ***Standard*** icon and choose option ***Add*** from dropdown list. Then new column, named "Addition" should appear. To change its name user needs to procced as it was described in case of another column's headers names adjustment. The main difference between these two ways of summing up values is that in the case of second one additional action (column header name adjustment) is required and in case of big reports with huge datasets, each extra step in Power Query Editor causes prolongation of recalculation and refreshment processes. That is why method that was described in first place is recommended. Illustration of its implementation can be found in figure 29.

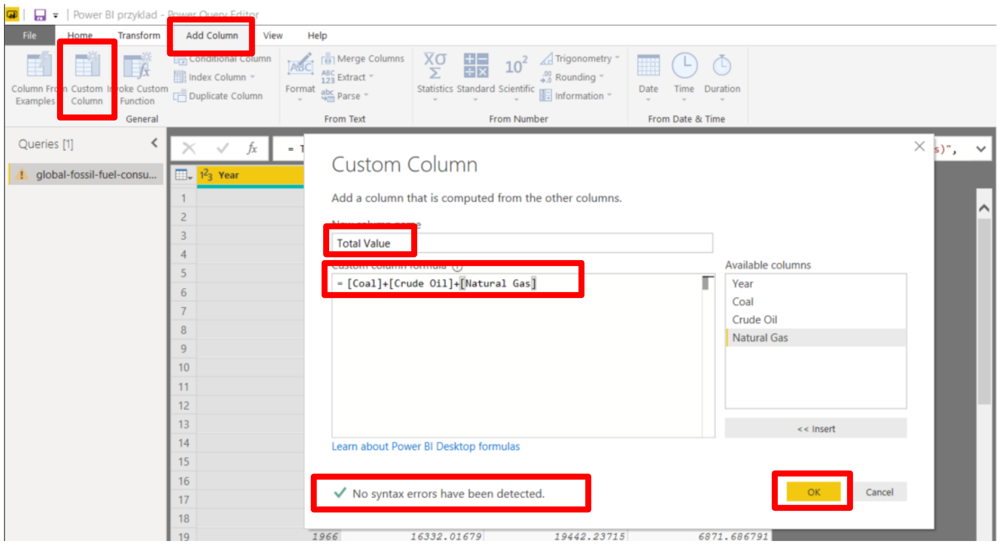


Figure 29. Summing up values from chosen columns in Power Query Editor, using M-code.

Source: own elaboration

As a result of implementation of described operations, new column named “Total Value” should appear in Data Preview section. Also new line named “Added Custom” should be visible in section Applied Steps. Power Query Editor interface after addition of the new column that contains total values of annual fossil fuels consumption is shown in figure 30.

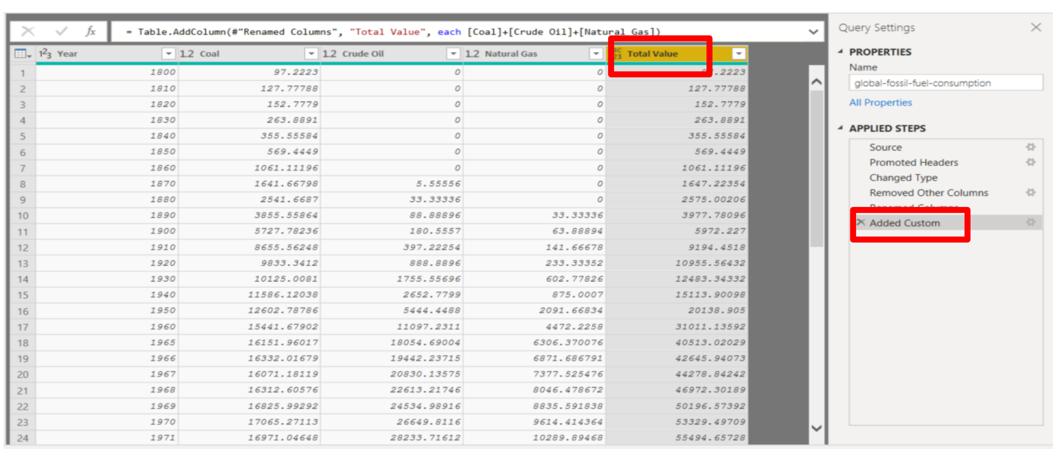


Figure 30. Power Query Editor interface after new column addition.

Source: own elaboration

Although the new column is visible in Power Query Editor user interface, the data that is contained in this column has incorrect format. Application automatically assigned the data format as "Any" and to perform any calculation, the data in format "Decimal Number" is needed. There are two ways of changing data format in Power Query Editor. The first one is to go to sheet "Home", click icon ***Data Type*** and choose correct data type from dropdown list. Another solution is to click on data type icon placed next to column heard name and then choose correct option from the dropdown list. Both described methods are equal, so user can choose the one, that is more suitable for him. The second solution of data type selection is illustrated in picture 31.

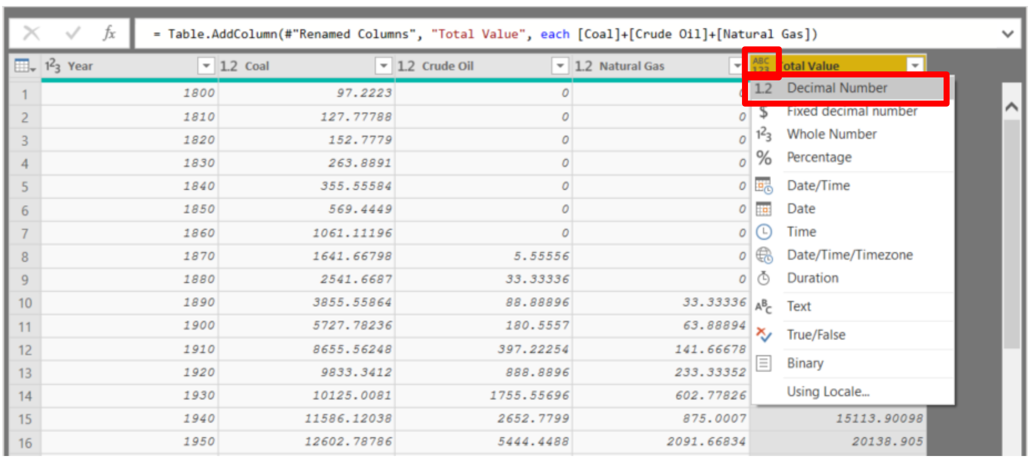


Figure 31. Data type selection in Power Query Editor.

Source: own elaboration

The sign that data format was changed, is that new line named "Changed Type1" in Applied Steps section appeared. The Power Query user interface after data type change implementation is illustrated in figure 32.

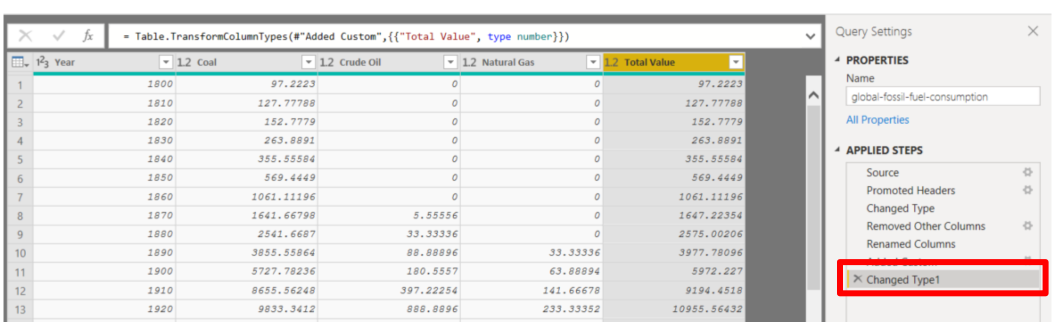


Figure 32. Power Query Editor interface after data type update.

Source: own elaboration

After all changes described in this step are applied, user can close the Power Query Editor. In order to do that, user must go to sheet Home in Ribbon and click on ***Close & Apply*** icon. Above procedure is shown in picture 33.

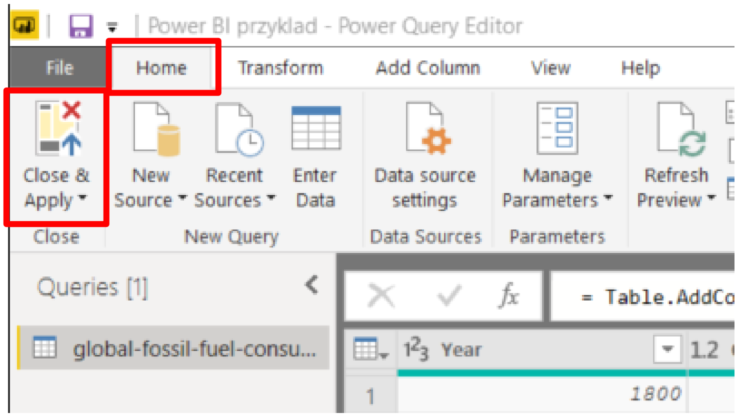


Figure 33. Correct way of closing Power Query Editor.

Source: own elaboration

Step 8. Data preparation in Power Pivot application.

When the Power Query Editor has been closed and all changes performed in it have been successfully applied to the model, user must implement further data processing in Power Pivot application. To open it user needs to click ***Data*** icon in Power View. Instruction, how to open Power Pivot application is illustrated in figure 34.

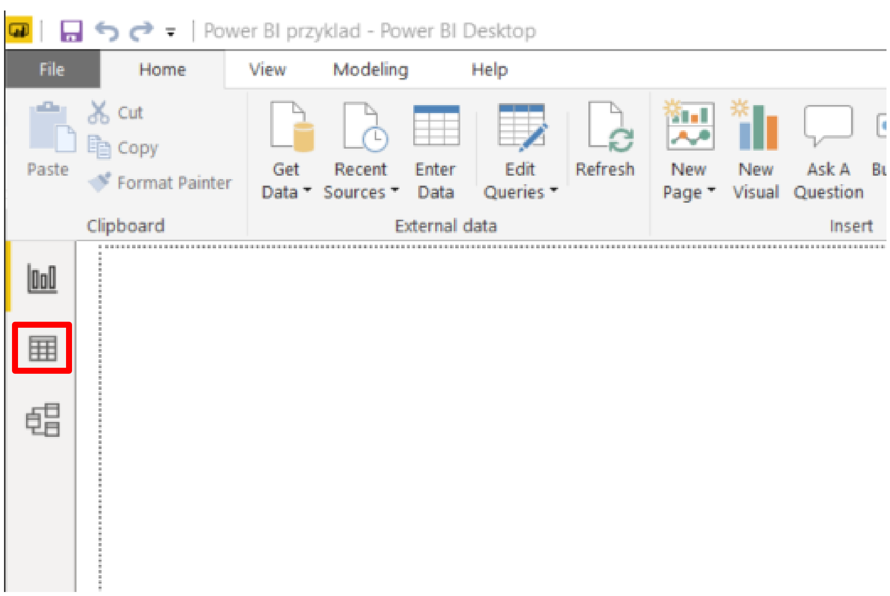


Figure 34. Power Pivot application opening.

Source: own elaboration

After Power Pivot application is opened, its interface appears. To perform any action in this program, user needs to have at least basic knowledge regarding its navigation. There are three main parts of the user interface. The first one is the Ribbon which is placed from default in the top of the screen. In this part of an interface, user has access to basic data management functions. Ribbon is divided into three sheets: “Home”, “Modeling” and “Help”. The second part of the interface is dashboard with data preview. It is placed in the middle of the screen. The last part of interface is named “Fields”. It can be found in the right part of the screen. There user can find the list of all datasets. Each dataset name contained in this part of interface has hidden list of column’s headers which appears after clicking on given dataset. By choosing different datasets names user is able to change data preview. Also new columns added in Power Pivot application are appearing in this section. In contrast to Power Query Editor, to perform any action on data in Power Pivot application, user must know programming language. In this case it is DAX language. Another important information about this program is that the only way to maintain data in it, is to add new columns or measurements with functions written in DAX language. Power Pivot user interface, together with split on its three main parts is illustrated in figure 35.

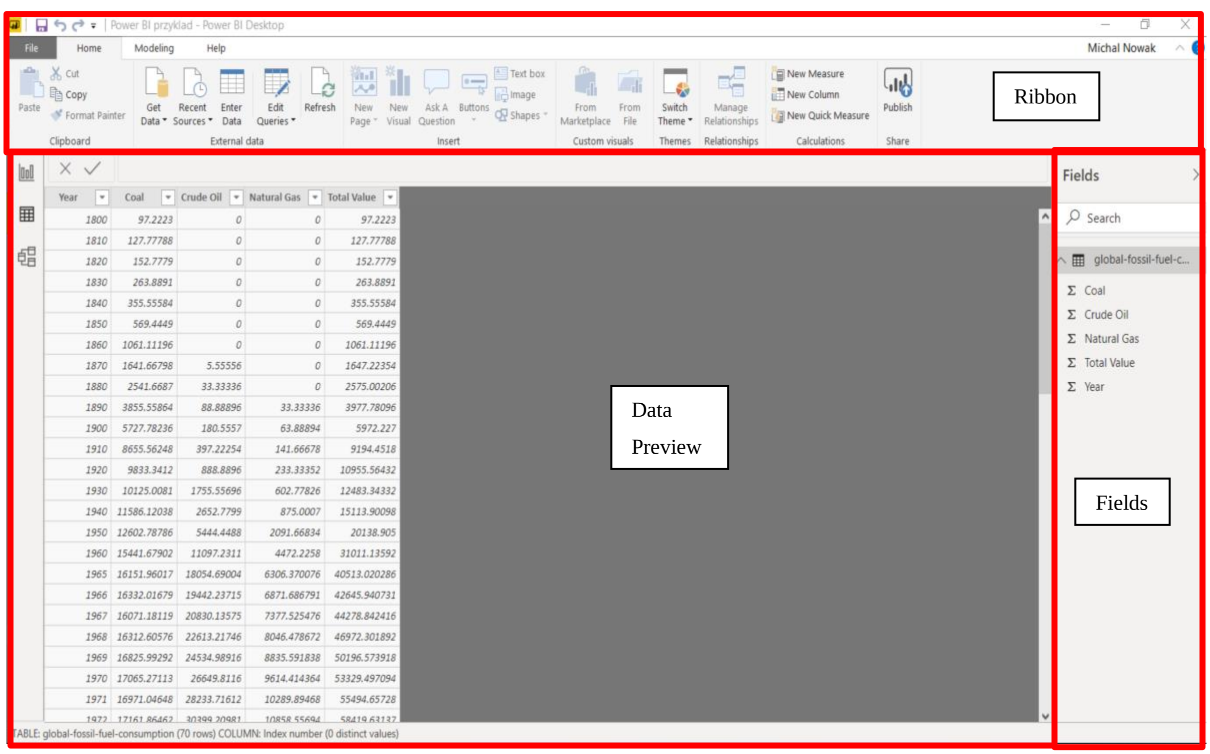


Figure 35. Power Pivot application user interface.

Source: own elaboration

The first action that needs to be performed in Power Pivot application, in case of example that is being described in this thesis, is addition of column with each row index number. To do that user needs to click on ***New Column*** icon and write following text to formula bar:

Index Number =
CALCULATE (
    COUNT ('global-fossil-fuel-consumption'[Total Value]),
    ALL ('global-fossil-fuel-consumption'[Total Value]),
    FILTER (
        'global-fossil-fuel-consumption',
        'global-fossil-fuel-consumption'[Total Value]
            <= EARLIER ('global-fossil-fuel-consumption'[Total Value])
)
)

and press ***Enter*** on keyboard.

As a result, new column, named “Index Number” that contains index number of each row should appear in data preview and new row in section Fields should be visible. All described operations are shown in figure 36.

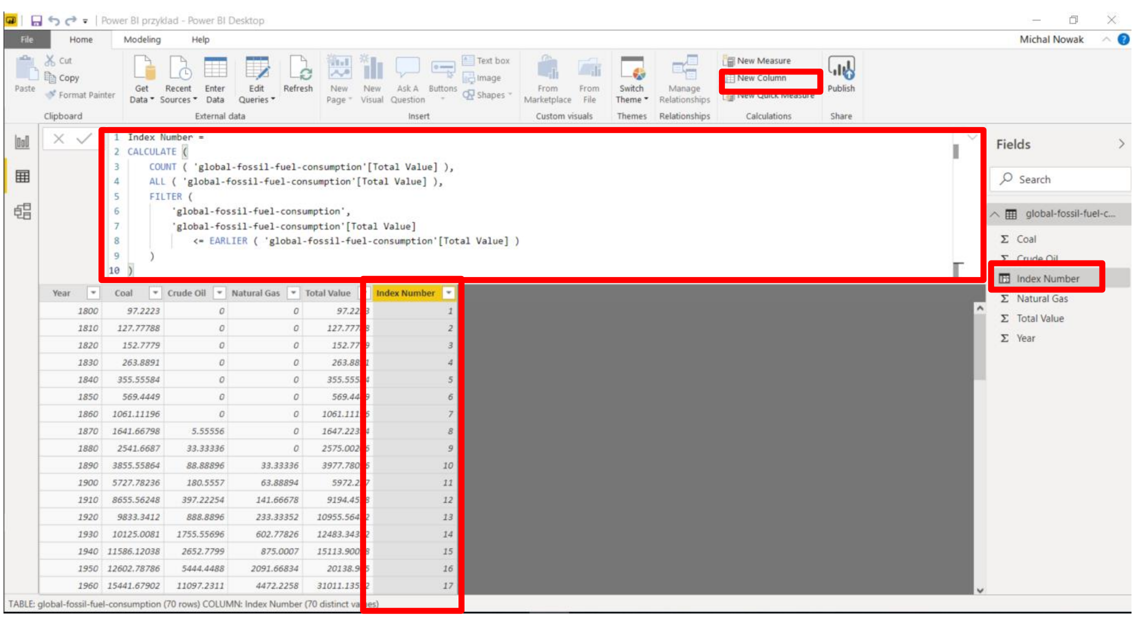


Figure 36. Column with index number of each row in Power Pivot application.

Source: own elaboration

The next thing that needs to be performed on example dataset is addition of column with difference in the total fossil fuels consumption between year from current row and year from row above. To do that user needs to click on ***New Column*** icon and write following text to formula bar:

```
Difference Between Total Values =
VAR RowAbove =
    CALCULATE (
        SUM ( 'global-fossil-fuel-consumption'[Total Value] ),
        FILTER (
            'global-fossil-fuel-consumption',
            'global-fossil-fuel-consumption'[Index number]
                = EARLIER ( 'global-fossil-fuel-consumption'[Index number] ) - 1
        )
    )
RETURN
    'global-fossil-fuel-consumption'[Total Value] - RowAbove
```

and press ***Enter*** on keyboard.

As a result, new column named "Difference Between Total Values" appears. It contains result of subtraction of value from current row of "Total Value" column and value from above row of "Total Value" column. Also, in section Fields new row "Difference Between Total Values" should appears. All described operations are shown in figure 37.

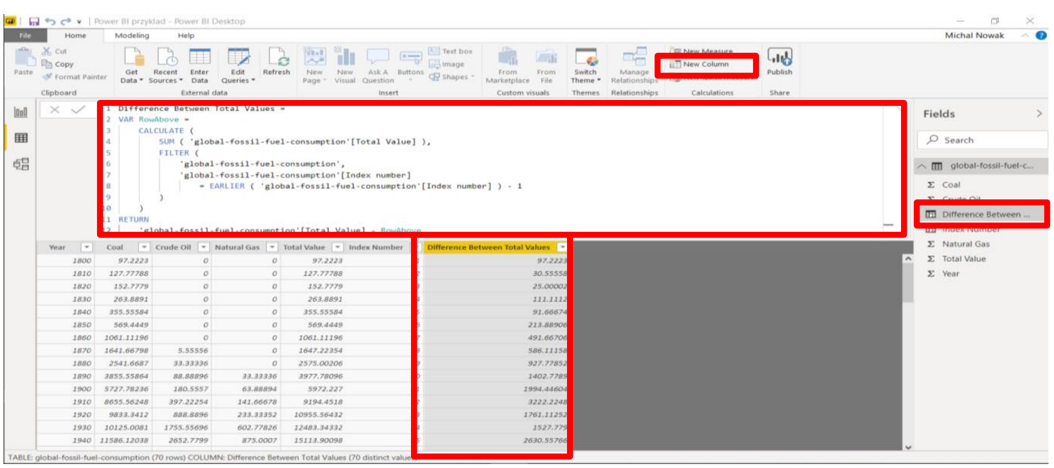


Figure 37. Column with value difference addition in Power Pivot application.

Source: own elaboration

Another operation to be done on data from example in Power Pivot application is addition of column that would divide years from first column into three categories: fossil fuels utilization upraise caused by First Industrial Revolution, fossil fuels utilization upraise caused by Second Industrial Revolution and fossil fuels utilization upraise after World War II. To do that user needs to click on ***New Column*** icon and write following text to formula bar:

Time Periods =

IF (

'global-fossil-fuel-consumption'[Year] <= 1900,

"Fossil fuels utilization upraise caused by First Industrial Revolution",

IF (

'global-fossil-fuel-consumption'[Year] <= 1950,

"Fossil fuels utilization upraise caused by Second Industrial Revolution",

"Fossil fuels utilization upraise after World War II"

)

)

and press ***Enter*** on keyboard.

As a result, new column, named "Time Periods" appears. It contains three categories that divide years from first column. Also, in section Fields new row "Time Periods" should appears. All described operations are shown in figure 38.

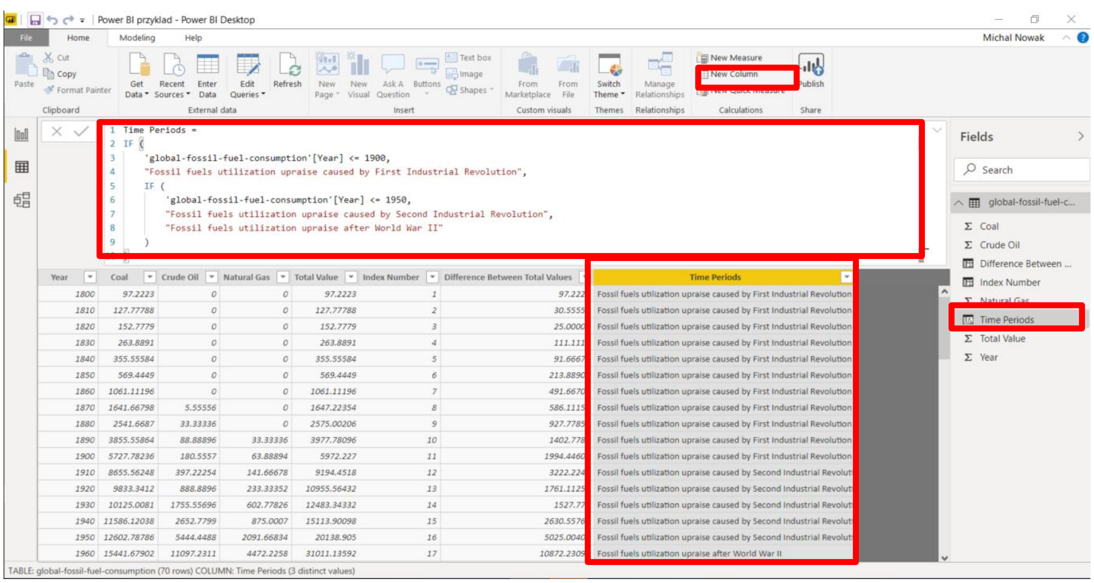


Figure 38. Column with time periods categories addition in Power Pivot application.

Source: own elaboration

The next step of example data preparation is manual addition of the new data inside Power BI, to have possibility of data filtration in future visualizations. To enter a new dataset manually in Power Bi application, user needs to go to the Ribbon and click ***Enter Data*** icon. After that dialogue window with the empty table appears. In a table user needs to write values that are needed. In dialogue window user has also possibility to name the new dataset and adjust column's headers of a new data according to his needs. In case of example that is being described in this thesis, both new dataset and only column header will be named: "Time Periods" and there will be three following values in column: "Fossil fuels utilization upraise caused by First Industrial Revolution", "Fossil fuels utilization upraise caused by Second Industrial Revolution" and "Fossil fuels utilization upraise after World War II". After new table is filled in with correct input, user must click ***Load*** button. All operations described in this paragraph are illustrated in figure 39.

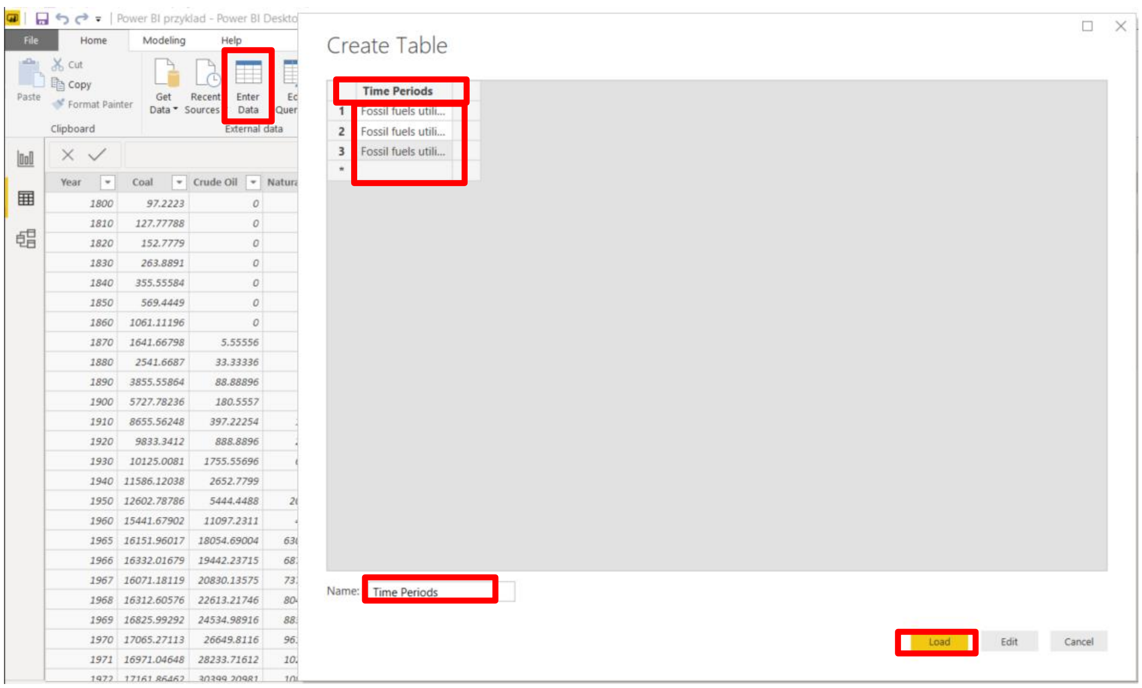


Figure 39. Manual data input to Power BI application.

Source: own elaboration

After manual data implementation, the new row with name of created dataset in section Fields should appear. After clicking on that new dataset name, dropdown list that consist only one position (named the same as column header of new table) occurs. Power Pivot user interface after addition of new dataset is shown in figure 40.

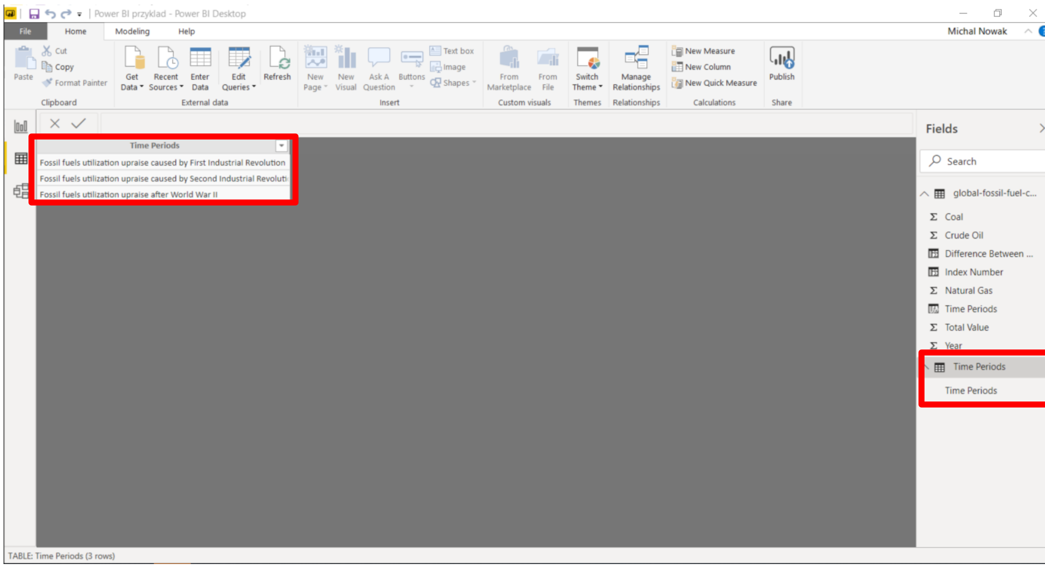


Figure 40. Power Pivot application interface after manual data implementation.

Source: own elaboration

As the new dataset is available in the Power BI application, user needs to connect it somehow with existing dataset, to have possibility of further data filtration in visualizations. To do that utilization of another part of Power Pivot application, called “Model”, is required. To open it user needs to click third (bottom) icon placed in the left side of interface, near the Data Preview section. The instruction on, how to open “Model” interface in a Power Pivot is illustrated in figure 41.

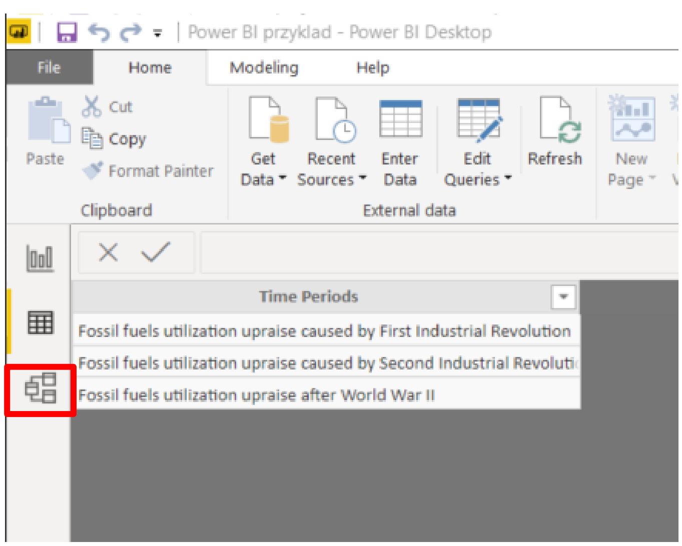


Figure 41. Model interface in Power Pivot application opening.

Source: own elaboration

After Model part of Power Pivot application is opened, its interface appears at user's screen. The interface of this program is very similar to interface of Data part of Power Pivot application. It is divided into four main parts. First part is Ribbon, which is also placed at the top of the screen and it is divided into three sheets: "Home", "Modeling and "Help" but the functions contained there are different than it was in Data part. This difference is present because in Model part user works on whole datasets and in Data part user performs his actions inside datasets, on columns. The second part of the interface is dashboard with data preview. It is placed in the middle of the screen and in this section, user can find boxes that are representing separate datasets and lines that are representing connections between datasets. The next part of the interface is named "Properties". There user can find basic information about highlighted column of dataset, such as its name, data type, format, etc. The last part of interface is named "Fields". It can be found in the right part of the screen. Here user can find list of all datasets. Each dataset name contained in this part of interface has hidden list of column's headers which appears after clicking on given dataset. Model part of a Power Pivot user interface, together with split on its four main parts is illustrated in figure 42.

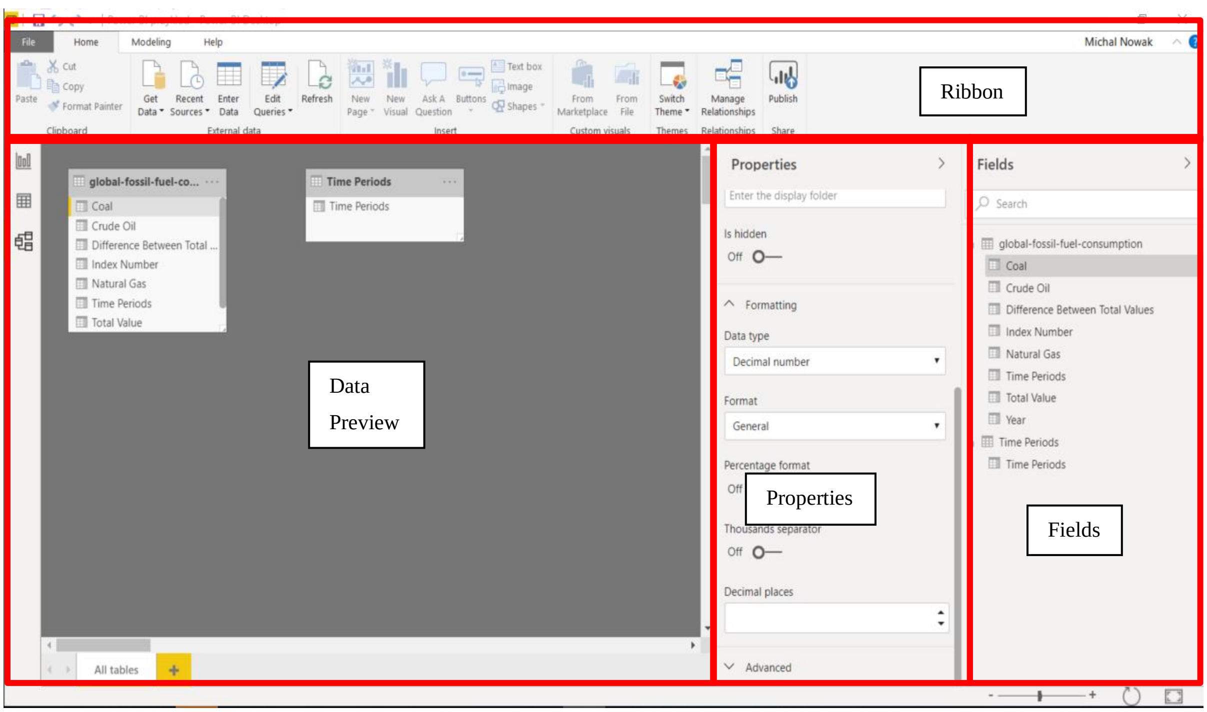


Figure 42. Model part of Power Pivot application user interface.

Source: own elaboration

Once user is familiar with the interface of Model part of Power Pivot, he can start creation of connection between datasets. In example data, there is need to create connection between "Time Periods" columns in "global-fossil-fuel-consumption" and in "Time Periods" datasets. In order to do that, user needs to drag column header name from box that is representing "Time Periods" dataset and drop it on the appropriate column header name in the box that is representing "global-fossil-fuel-consumption" dataset. Once it is done, line that represents connection between datasets should appear in Data Preview section. When the connection between datasets is created, user must check if it has correct properties. To do that he needs to right-click on line that is representing connection and chose option ***Properties*** from dropdown list. Illustration of actions described above can be found in figure 43.

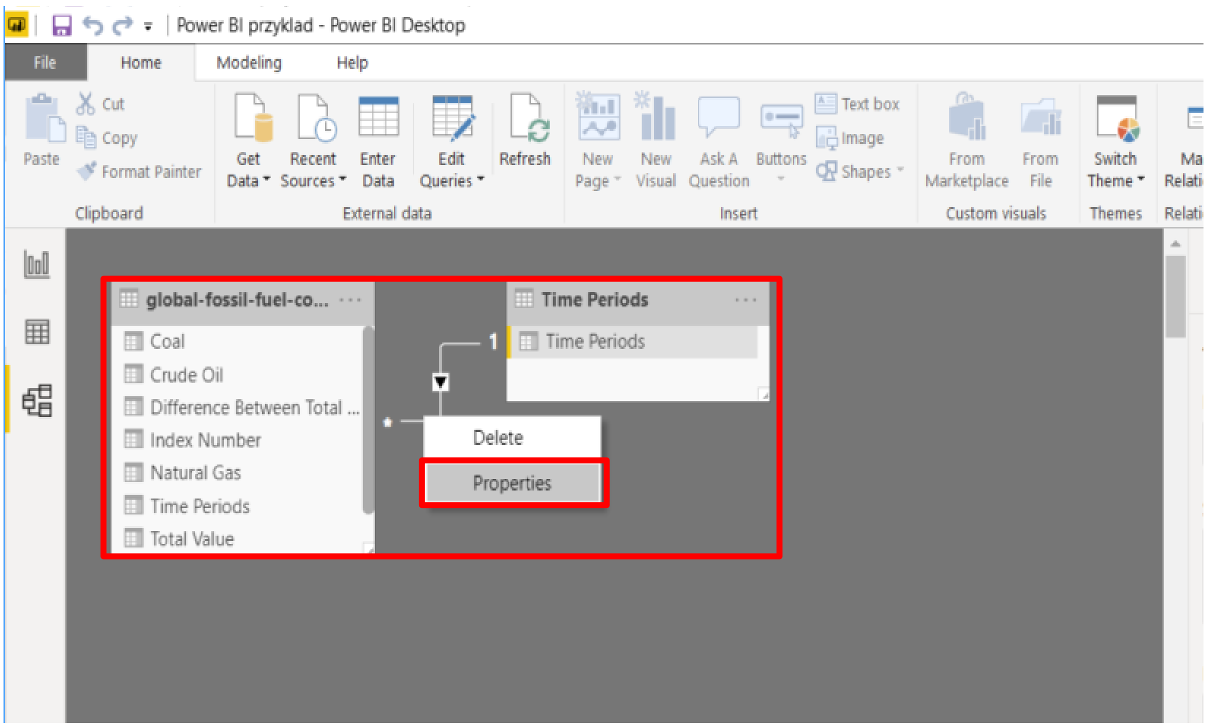


Figure 43. Creation of connection between datasets.

Source: own elaboration

After the option ***Properties*** has been chosen, dialogue window appears. There user has possibility to change column's headers between which connection is created and chose correct connection type. After all details of link between datasets are established, user must click ***OK*** button to confirm that he accepts all connection properties. All operations described in this paragraph are shown in figure 44.

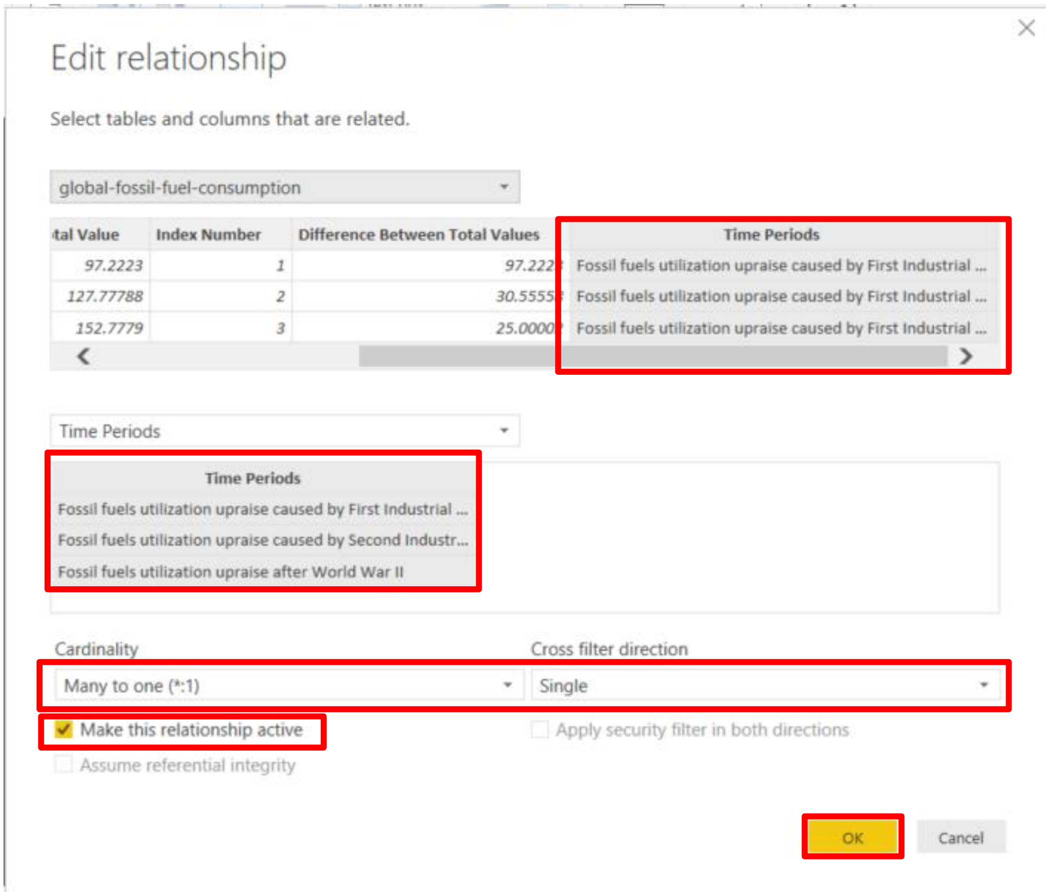


Figure 44. Dialogue window of properties of connection between datasets.

Source: own elaboration

After setting relationship between datasets, data is prepared to build visualizations in Power View application. To open mentioned program, user needs to click Report icon, that is placed in the left part of interface, near the Data Preview. Instruction how to open a Power View application is illustrated in figure 45.

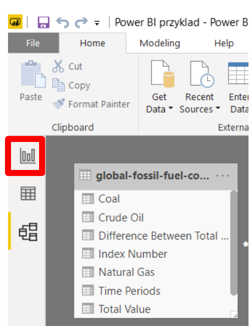


Figure 45. Power View application opening.

Source: own elaboration

After Power View application is opened its interface appears. It is built based on the same logic as Power Pivot application. It has four main parts. The first part is traditionally Ribbon, that is placed on the top of the screen. Ribbon it is divided into three sheets: “Home”, “Modeling and “Help”. In this section user can find numerous functions connected with preparation of data visualization. The second part of interface is Dashboard, where all data visualizations are being displayed. It is the most important part of whole Power BI application. The next part of the interface is named “Visualizations”. There user can find numerous charts, tables, filers, matrixes, gauges, maps, infographics and graphs, that he can choose to represent data that was previously prepared in Power Pivot and Power Query. In this part user can also adjust properties of chosen visualization and set filters on them, to present only that range of the data that is needed. The last part of interface is named “Fields”. It can be found in the right part of the screen. Here user can find list of all datasets. Each dataset name contained in this part of interface has hidden list of column headers which appears after clicking on the given dataset. From there user takes data to be visualized in Dashboard part of a Power View application. User interface of Power View application, together with name of each of its parts is illustrated in figure 46.

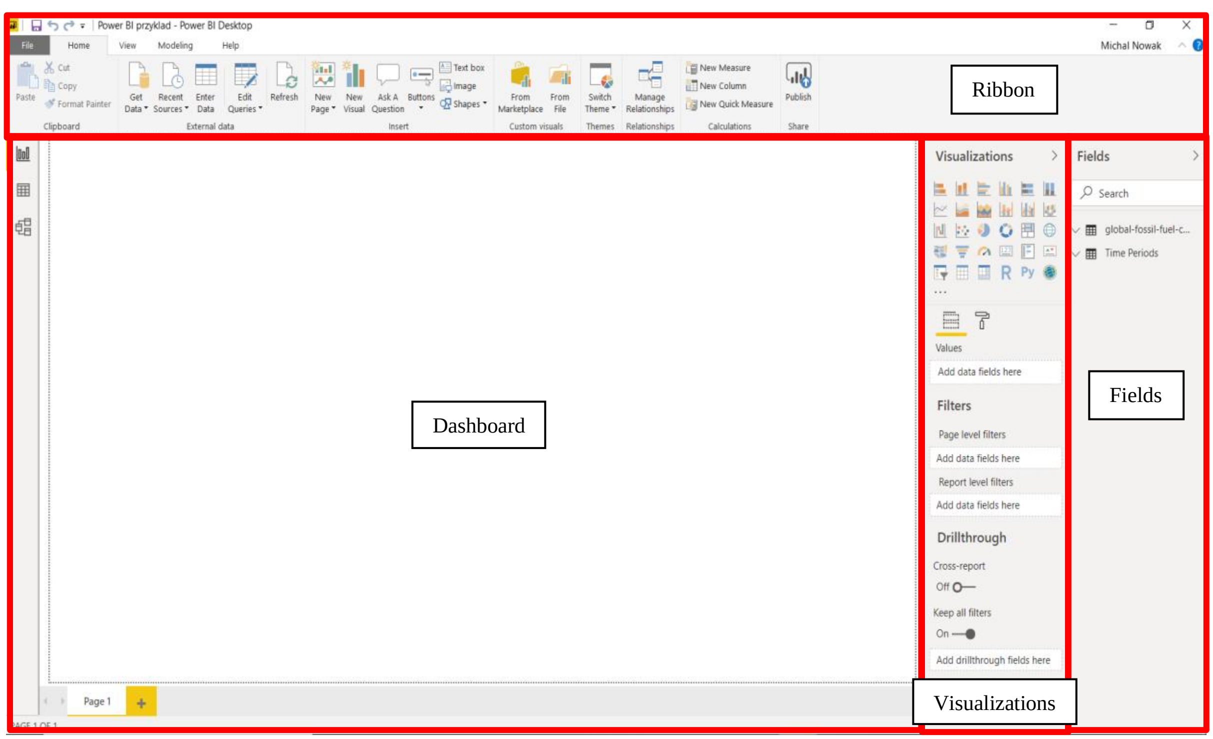


Figure 46. Power View user interface.

Source: own elaboration

Next step is building of the first visualization in the Power View application. In case of example data, this visualization will be illustrating how consumption of fossil fuels has been changed since 1800 till 2017. The best way to show mentioned data is to use the stacked area chart, which can be found in Visualizations section of interface. To choose it, user must click on the icon that represents it. Then, when empty chart is visible in Dashboard section, user must choose appropriate data, that should be visualized, from section Fields. When the chart is visible on the screen, user needs to adjust its size and place it in the most suitable location on the screen. To change size of the chart, user needs to click on its corner and drag it with the cursor. To change location of the visualization, user must click on its area and drag it. The effect of implementation of all actions described in this paragraph is visible in figure 47.

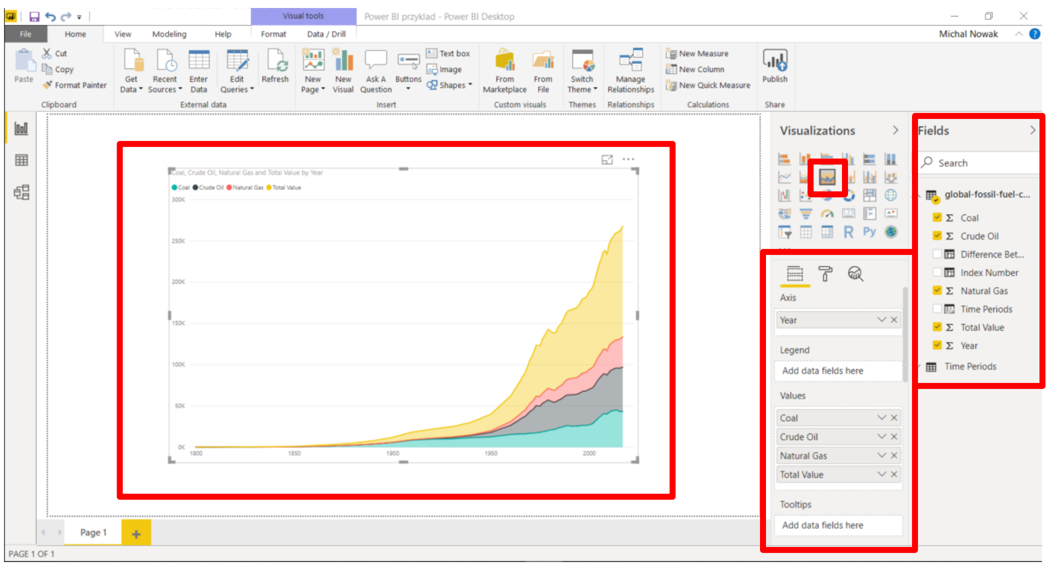


Figure 47. Stacked area chart creation in Power View application.

Source: own elaboration

Once the chart is created, user must adjust its properties, to make it easier for interpretation. To do that, he needs to change subsection of Visualizations from one called Fields, to one called Format. To do that he needs to click on paintbrush icon and then adjust appropriate options that appeared, to his needs. In example that is being described in this thesis, there is need to change: the size of font, the chart title and its localization, the axis titles and the legend localization. Beside listed attributes of the chart, user might also adjust the colors of the data presentation, the chart background, add and remove the axis gridlines, add the chart boarder and many more. Stacked area chart with adjusted properties is shown in figure 48.

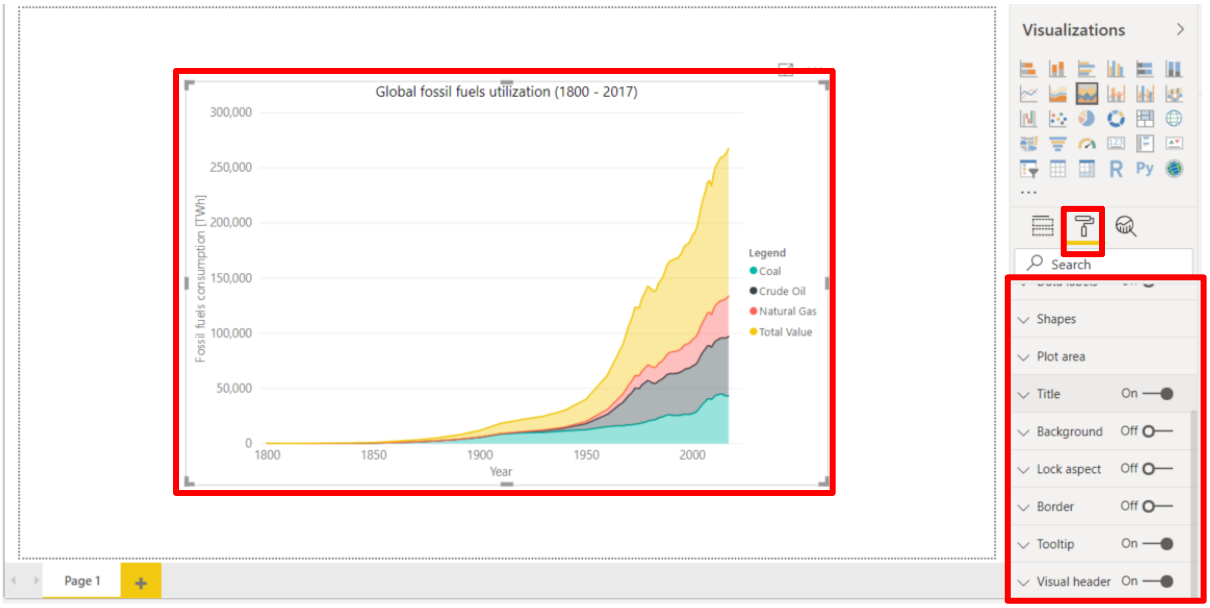


Figure 48. Stacked area chart after properties adjustment in Power View application.

Source: own elaboration

Next step in case of example data is adding the filters, to have possibility of checking the data from different period more precisely. First filter will be the slider with possibility to choose any data range. To add this kind of filter user must go to the section Visualizations and click icon that represent the slicer. Then, when empty slicer is visible in the Dashboard section, user must choose appropriate data, that should be visualized, from section Fields. When slider is visible on the screen, user might adjust its properties in the same way as it was in case of chart. The illustration of slicer with adjusted properties can be found in figure 49.

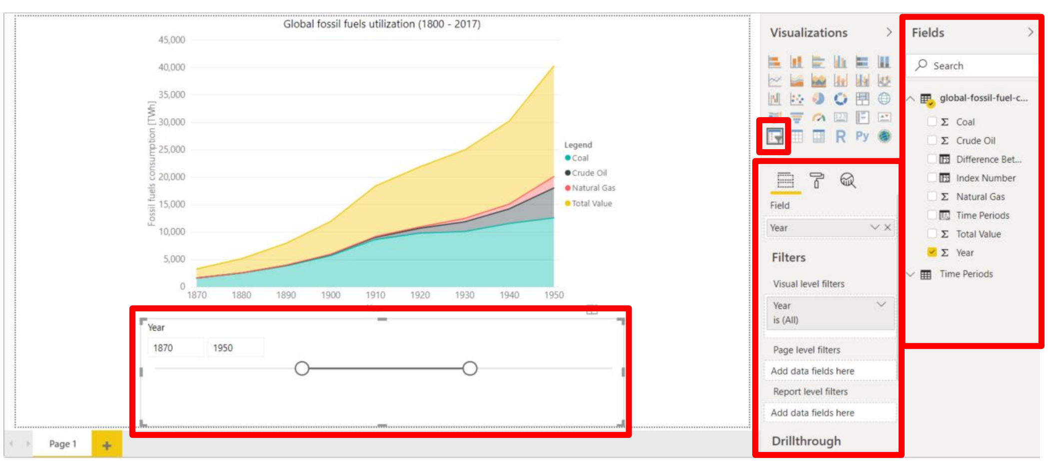


Figure 49. Slider addition in the Power View application.

Source: own elaboration

Then, there is need to add visualization that will allow to filter the data from chart by significant periods in history that have been added to Power Bi with "Time Periods" dataset. To do that user can use one of the options available in Visualizations section, but he can also download fancier slicer from marketplace. To do that, user must click dots icon (it is placed under the icons that are representing charts) and chose option ***Import from marketplace***. The instruction on, how to open marketplace is shown in figure 50.

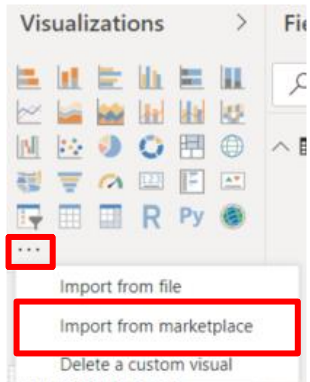


Figure 50. Marketplace opening in Power View application.

Source: own elaboration

After choosing ***Import from marketplace*** option, dialogue window appears. In this window user can find the list of visualizations available on marketplace. After needed position has been found by user, he must click ***Add*** button to import new visualization to desktop Power BI application. In case of example data user needs to import "Chiclet Slicer" from marketplace. The instruction, how to import new visualization from marketplace is illustrated in figure 51.

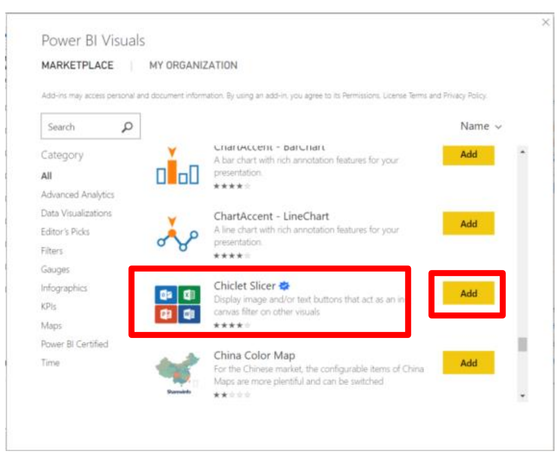


Figure 51. Import of the new visualization from marketplace.

Source: own elaboration

The sign that new visualization has been successfully imported to Power BI, is presence of the new icon in Visualizations section. Next user must click on this new icon and after empty chicklet slicer has been appeared in Dashboard section, user must choose the proper data from section Fields to be visualized. In case of example data, it should be the column "Time Periods" from "Time Periods" dataset. When chicklet slicer is visible on the screen, user might adjust its properties in the same way as it was in case of chart or slider. The illustration of chicklet slicer with adjusted properties can be found in figure 52.

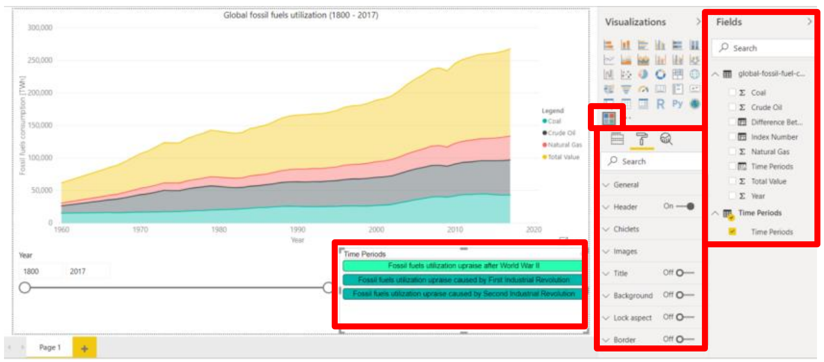


Figure 52. Chicklet slicer addition in Power View application.

Source: own elaboration

After all actions described above have been performed, dashboard with example data is ready. If user wants to share his report with other Power BI users, he needs to publish it on official Power BI webpage. To do it, user needs to click on ***Publish*** icon, that is placed in Ribbon of Power View application. Then dialogue window appears, and user must choose the destination of report publication. After the place where dashboard should be uploaded is chosen, user must click ***Select*** button. Operations from this paragraph are shown in figure 53.

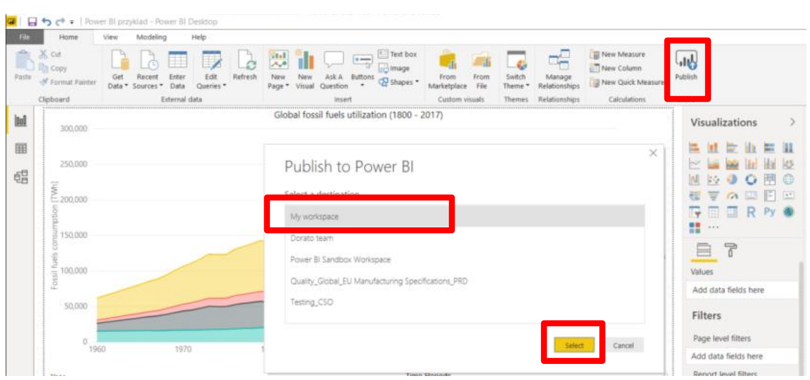


Figure 53. Power BI dashboard publishing on workspace.

Source: own elaboration

3. Report results analysis

In this chapter of these thesis, results of dashboard creation in Power Bi will be presented and analyzed. Dashboard was created in order to visualize data regarding renewable energy sources utilization to prevent natural environment from degradation and their role in electricity generation. Both mentioned aspects are very important in terms of environmental resources management. Report is divided into five main sections:

- First one contains information regarding total electricity generation.
- Second one contains visualizations regarding utilization of fossil fuels.
- Third one contains data regarding emission of pollutions.
- Fourth one contains data regarding nuclear power plants capacity.
- Fifth one contains data regarding renewable energy sources.

After dashboard is opened user can see welcome page of report. There he can find report title and creator's name. Beside that names and logos of university and faculty are also placed on welcome page. In the right-bottom corner of the page user can find the button that opens the report. To proceed with further dashboard analysis, user needs to click it. Welcome page is illustrated in figure 54.

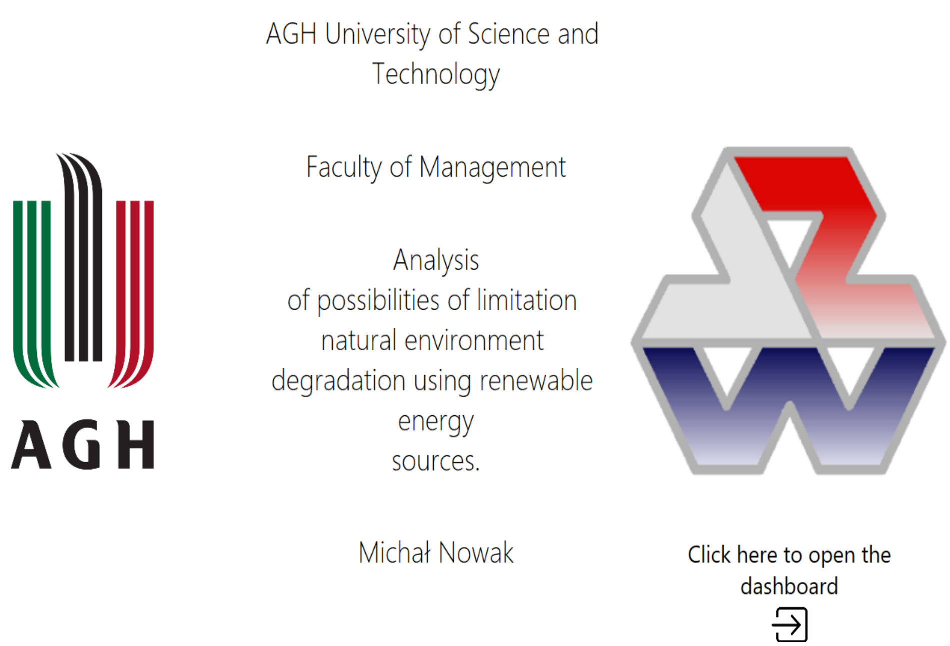


Figure 54. Dashboard welcome page.

Source: own elaboration

The next screen that appears after leaving welcome page, contains table of dashboard contents. Each page title has colored background and each color is related to the separate section of dashboard (e.g. green background color is related to the part of dashboard that is dedicated to renewable energy sources). In order to go to the given page from the list, user needs to click the button that is placed under page title. In the left-bottom corner of the page with dashboard contents user can also find two buttons. One of them leads back to welcome page and second one leads to the page, where sources of data used to build dashboard are listed. Page with dashboard contents is illustrated in figure 55.

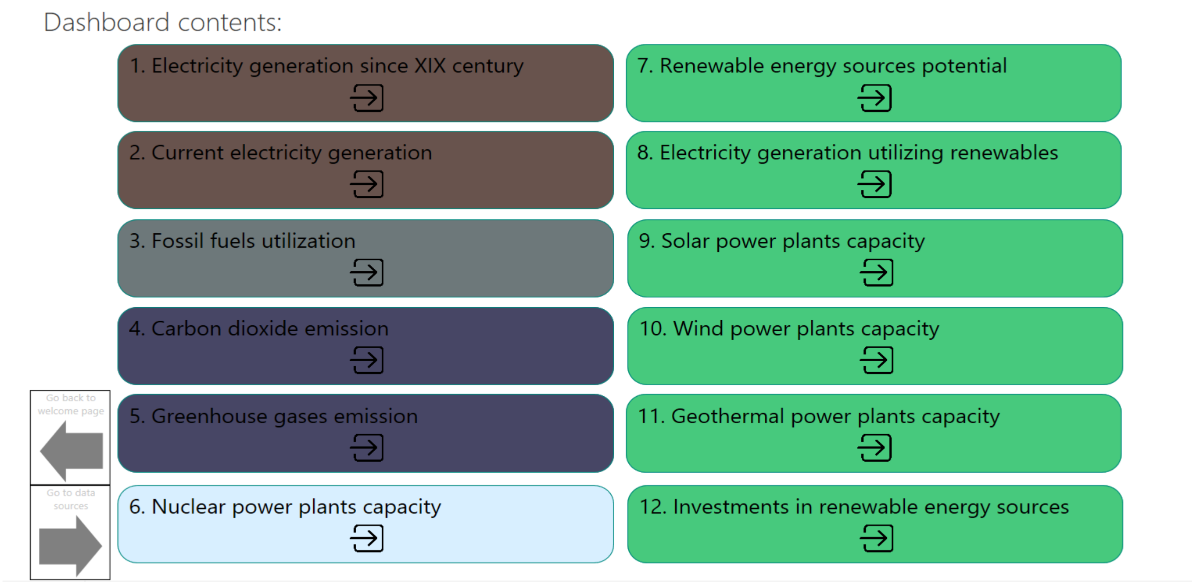


Figure 55. Dashboard contents.

Source: own elaboration

In the following part of this thesis each section of dashboard will be described in detail in separate subchapters.

3.1. Electricity generation

In this subchapter of the thesis user can find answer for questions regarding historical aspects of electricity generation and which energy source has been utilized on the widest scale since XIX century. Moreover, data regarding current electricity generation and its split by each energy source was gathered and visualized in the part of the dashboard that is being described in detail in this subchapter.

The next screen that appears after opening of the first position from dashboard contents: ***Electricity generation since XIX century***, illustrates visualization of the electricity generation in terawatt-hours since 1800 to 2018. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by source of energy and by range of years. To remove filters, user needs to click ***Remove Filters*** button. The visualization of data regarding electricity generation since XIX century is illustrated in figure 56.

The main conclusion from analysis of this visualization is that for almost 150 years since 1850 only traditional biofuels and fossil fuels were utilized to generate electricity. Only since 1950 renewable energy sources have begun to be utilized to generate electricity on significant scale. Although share of renewables in total electricity production grows ever since the middle of XX century, vast majority of electric energy is still produced with utilization of fossil fuels. What is also worth mentioning, the share of nuclear power plants in electricity generation balance has grown significantly since first commercial utilization of this energy source in the second half of XX century and although development of this technology has been stopped or even regressed due to some serious accidents (e.g. Chernobyl, Fukushima), electricity is generated with utilization of nuclear reactors on huge scale till today.

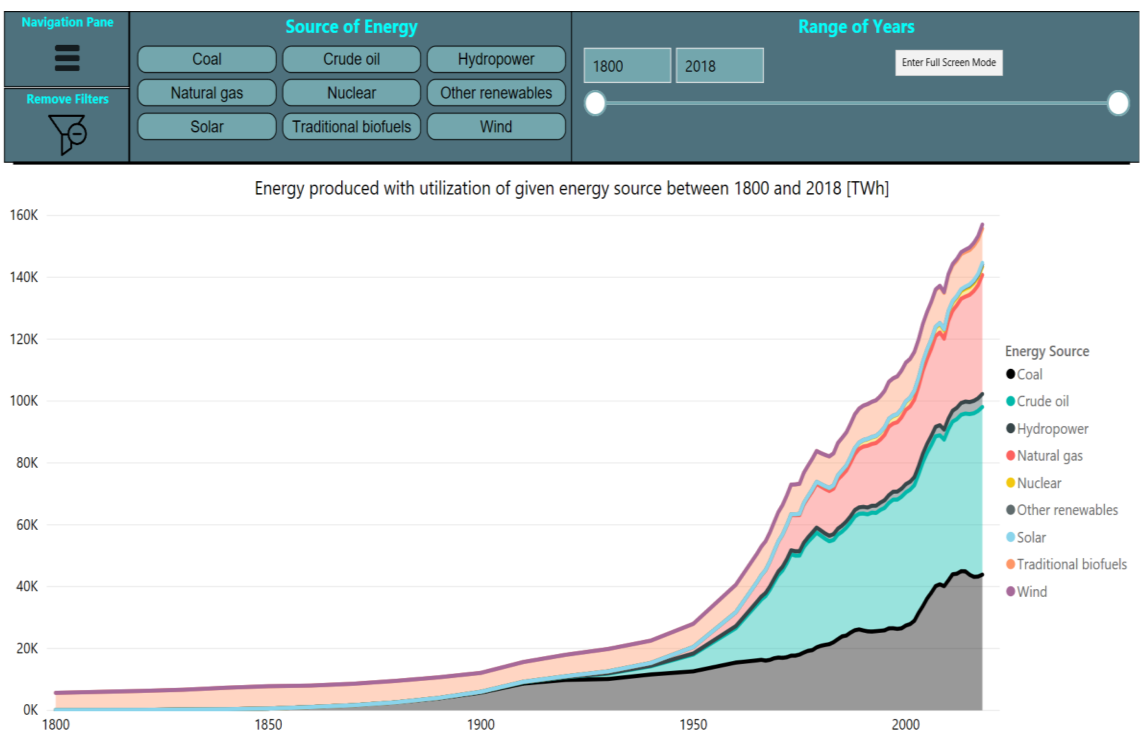


Figure 56. Visualization of the data regarding electricity generation since XIX century.

Source: own elaboration

In the filtration pane user can find also ***Navigation Pane*** button. After clicking on it, dialogue window with list of pages and icon with section symbol pop-up. In order to go to chosen page, user must click on the icon that is placed next to page title. From this level, user can also go back to welcome page or go back to the visualization. To do that he needs to click on the appropriate arrow. The navigation pane and section symbol are illustrated in figure 57.

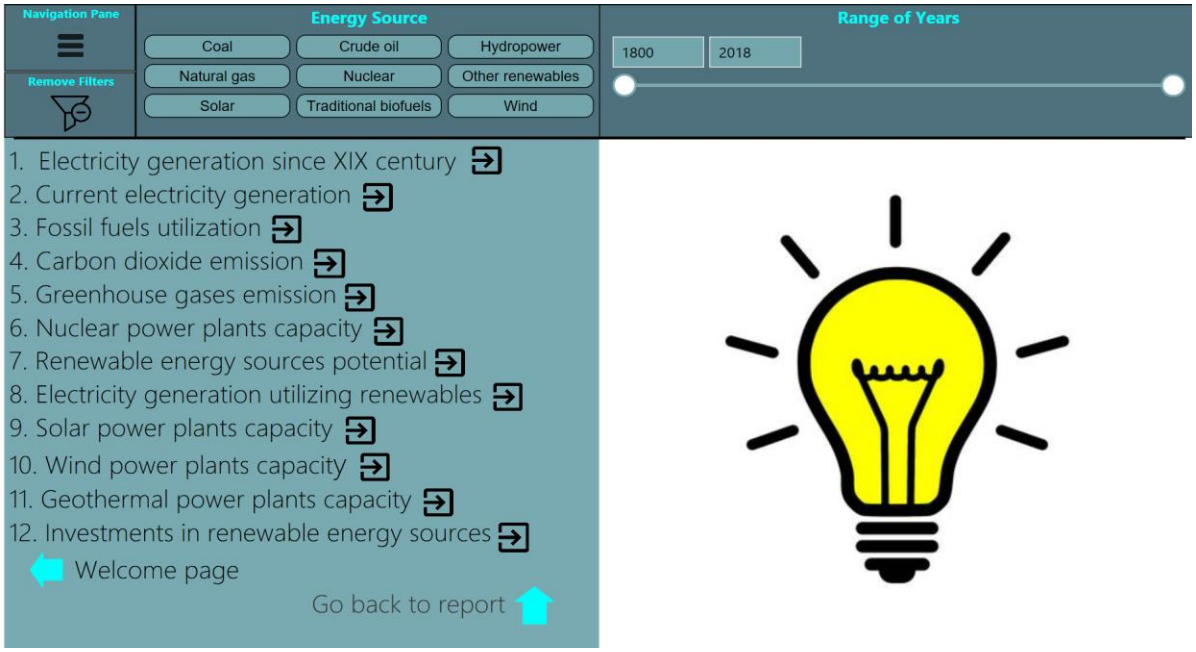


Figure 57. Navigation pane and icon with section symbol.

Source: own elaboration

The next page contains visualization of data regarding current electricity generation. There user can find following information:

- Total value of electricity generated in 2018, expressed in terawatt-hours,
- Value of electricity generated in 2018 by selected energy source, expressed in terawatt-hours,
- Percentage of electricity generated in 2018 by selected energy source,
- Share of electricity generation in 2018 by energy sources.

In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by energy source and by range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding current electricity generation is illustrated in figure 58.

In the visualization we can find the balance of electricity generated by each source and analysis of it, leads to sad conclusions that electricity produced with utilization of renewable energy sources provides only 18% of total value of energy generated in 2018. Nuclear power plants generated only 11% of electricity in 2018. As a result, just 29% of electricity was generated by environment friendly energy sources. Remaining 71% of electricity was produced with utilization of fossil fuels.

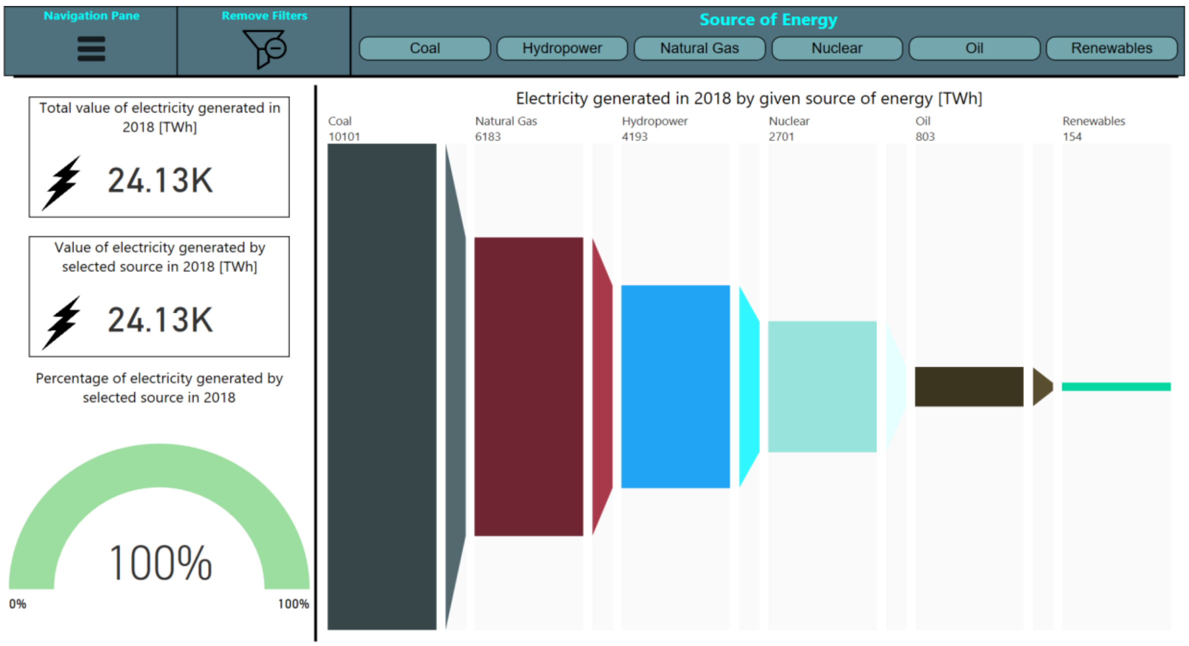


Figure 58. Visualization of the data regarding current electricity generation.

Source: own elaboration

3.2. Fossil fuels utilization

In this subchapter of the thesis user can find answers for following questions: “What is the scale of fossil fuels utilization?”, “How huge was the increase of amount of fossil fuels utilized for electricity generation in past years?” and “How long will humanity be able to utilize fossil fuels on such level?”.

The next page of the report is entitled: “Fossil fuels utilization” and contains visualizations of data regarding estimated number of years of fossil fuels reserves left and utilization of fossil fuels since1800 to year 2017. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by fossil fuel type and by range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding current electricity generation is illustrated in figure 59.

From analysis of the visualization, user can conclude that utilization of fossil fuels grows constantly since year 1800. The next thing that is visible during analysis of that page of the report, is that the first fossil fuel that has been utilized by humanity is coal, then after almost 100 years people started to use oil and as a last of available fossil fuels people started exploiting natural gas. Another outcome of visualization placed on this page is that the known reserves of fossil fuels will run out in114 years for coal, in 53 years for natural gas and in 51 years for crude oil.

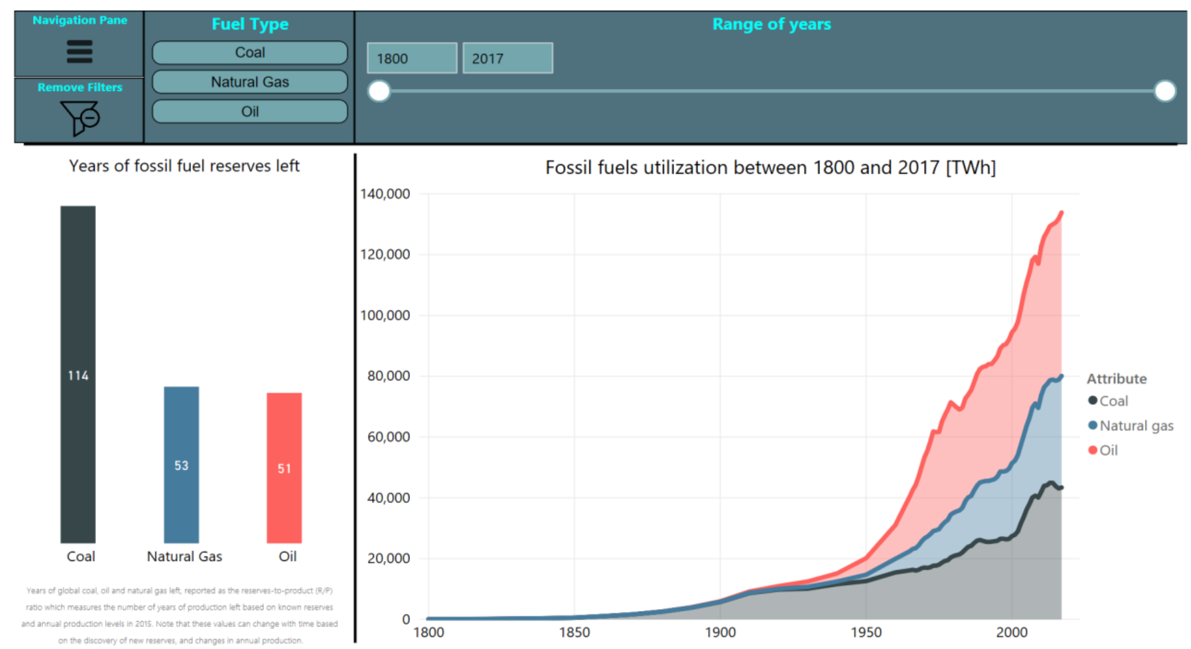


Figure 59. Visualization of the data regarding fossil fuels utilization.

Source: own elaboration

3.3. Pollutions emission

In this subchapter of the thesis user can find answers for questions regarding amount of carbon dioxide emitted by fossil fuels within last three hundred years. There is also detailed description of visualizations that provides information about greenhouse gasses emission with split by sector of economy, to indicate the negative influence of conventional energetics on our environment in past twenty-five years.

The next page of the report contains visualizations regarding carbon dioxide emission that comes from utilization of fossil fuels. There user can find following information:

- Total value of carbon dioxide emitted in selected range of time, expressed in tones,
- Value of carbon dioxide emitted by selected fossil fuel in selected range of time, expressed in tones,
- Percentage of carbon dioxide emitted by selected fossil fuel in selected range of time out of total carbon dioxide emitted in the same range of time,
- Share of carbon dioxide emission since 1751 to 2017.

In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by fossil fuel type and by range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding carbon dioxide emission is illustrated in figure 60.

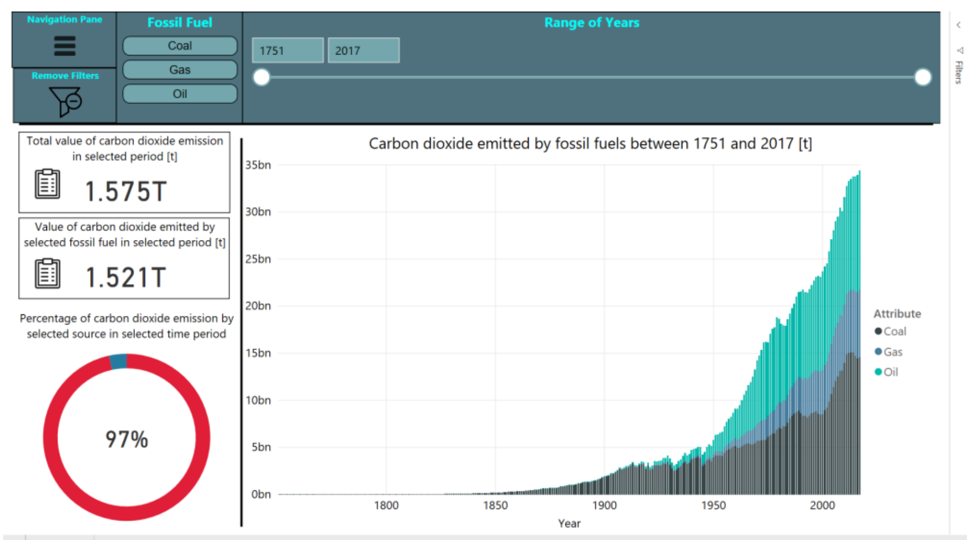


Figure 60. Visualization of the data regarding carbon dioxide emission.

Source: own elaboration

The main conclusion of the analysis of visualizations contained on this page of the report, is that vast majority of emitted carbon dioxide emitted since 1751, comes from utilization of fossil fuels. But there are also less terrifying outcomes of the analysis, such as decrease of this value in past few years to about 95%. It is caused probably by development of renewable energy and by growth of consciousness regarding scale of natural environment degradation.

The second page of section dedicated to emission of pollutions, contains visualization of the data regarding greenhouse gases emission by different sectors of economy. On this page user can find:

- Share of greenhouse gases emission by sector of economy since 1990 to 2016,
- Total value of greenhouse gases emitted in selected range of time, expressed in tones,
- Value of greenhouse gases emitted by selected sector of economy in selected range of time, expressed in tones,
- Percentage of greenhouse gases emitted by selected sector of economy in selected range of time out of total greenhouse gases emitted in the same range of time.

In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by sector of economy and by range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding greenhouse gases emission is illustrated in figure 61.

From analysis of this page, user can find out that the biggest amount of greenhouse gases, since 1990, has been emitted by sector of energetics in purpose of electricity and heat generation. It is 29% of whole number of emitted pollutions and unfortunately since 1990 annual emission of greenhouse gases from this sector was growing up until 2013. Finally, after over 20 years of constant increase, this value shrinked a little bit in years 2013 – 2016. But it is still not enough to save the environment from degradation and one of the most effective ways of pollutions emission reduction is to use renewable energy sources or nuclear power to produce electricity and heat.

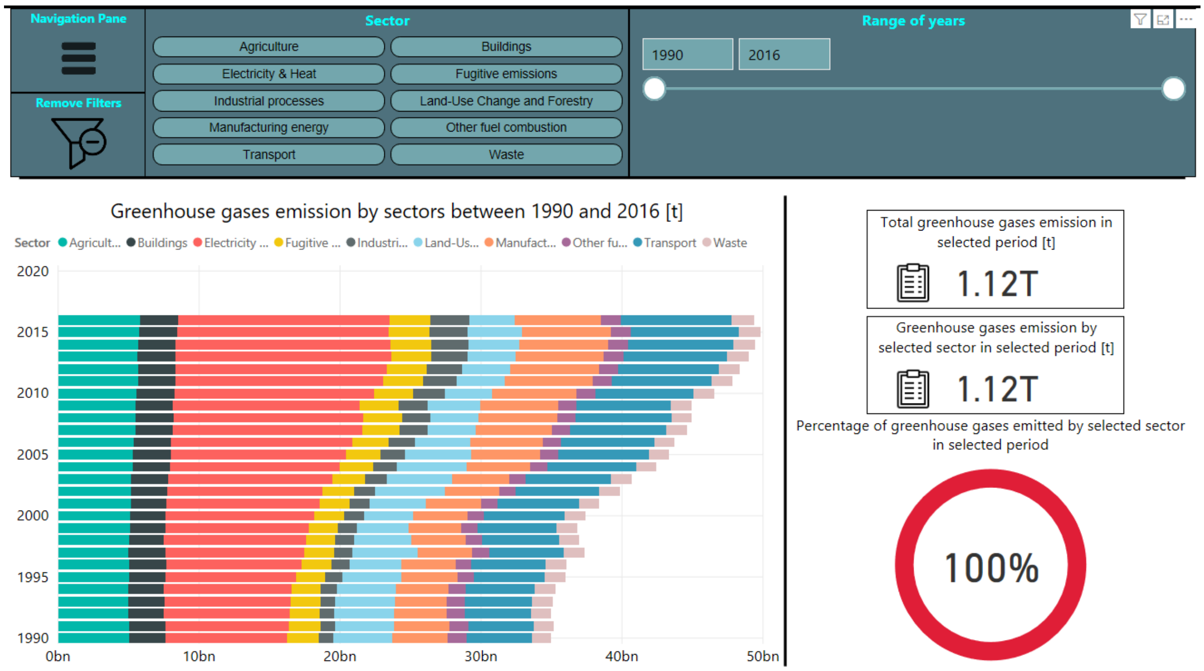


Figure 61. Visualization of the data regarding greenhouse gases emission.

Source: own elaboration

3.4. Nuclear power plants capacity

In this subchapter of the thesis user can find answers for following questions: “Which countries have nuclear power plants?”, “What is the capacity of power plants installed in that countries?” and “Which country has the biggest number of nuclear power plants?”

On the next page of the report user can find data regarding another section of the dashboard – nuclear power plants capacity. The visualizations of data show total capacity of nuclear power plants in each country, that has ones and the number of nuclear power plants in selected countries. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by country. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding nuclear power plants capacity is illustrated in figure 62.

Analysis of the data visualized on this page of the report leads to conclusion that there are only 30 countries in the world that have operating nuclear power plants on their territory. Moreover, five first countries from the list with the biggest nuclear capacity, possess more than a half of power plants of this type. Additionally, almost all the countries considered in this visualization are wealthy. So nuclear power, as an expensive energy source, is not good solution that could help poor countries with solving their problems regarding electricity generation in eco-friendly way. For such countries, renewable energy is the best solution.

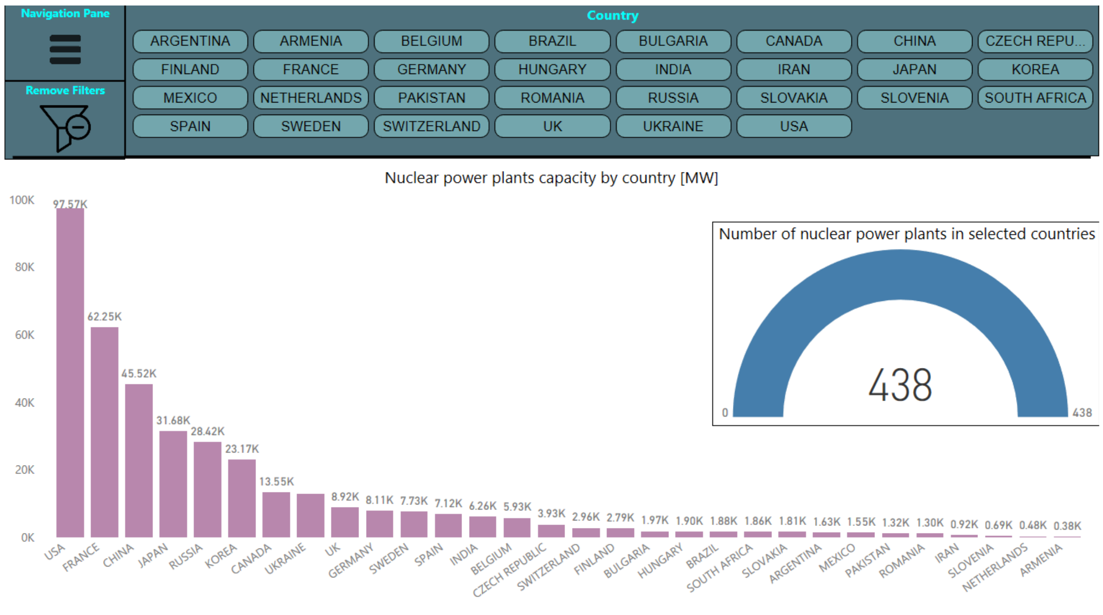


Figure 62. Visualization regarding nuclear power plants capacity.

Source: own elaboration

3.5. Renewable energy sources.

In this subchapter of the thesis user can find answers for questions regarding potential amount of electricity that humanity can generate using renewable energy sources and then he can compare this value with current green electricity generation. Moreover, answers for questions regarding development and current situation of electricity generation with utilization of solar rays, wind and heat of Earth’s core, on each continent, could be found in analysis that has been done in this subchapter. Finally, the answer for the question about amount of money that has been spend on renewable energy sources development is contained here.

The last section of the dashboard begins with the page dedicated to technical potential and current use of renewable energy sources. On this page user can find information regarding:

- Current use of selected renewable energy sources, in terawatt-hours,
- Technical potential of selected renewable energy sources, in terawatt-hours,

- Percentage of used technical potential of selected renewable energy source,
- Share of renewable energy sources current use,
- Share of renewable energy sources technical potential.

In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by source of energy. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding renewable energy sources current use and technical potential is illustrated in figure 63.

During analysis of this page, user may notice that even though hydropower has the lowest technical potential out of all renewable energy sources, recently it is the most exploited renewable energy source. It is used to generate more than 60% of electricity produced by renewables. On the other hand, there is geothermal energy that has almost 70% of all green energy technical potential and is utilized to generate only less than 10% of electricity produced by renewable energy sources. But the most important information that is visible in the report is that humanity is utilizing only 0.32% of renewable energy sources technical potential to produce electricity. It means that there are huge reserves in this branch of energetics and with appropriate efforts people may replace traditional (based on fossil fuels) energy sources with the ones that will allow to prevent environment from degradation.

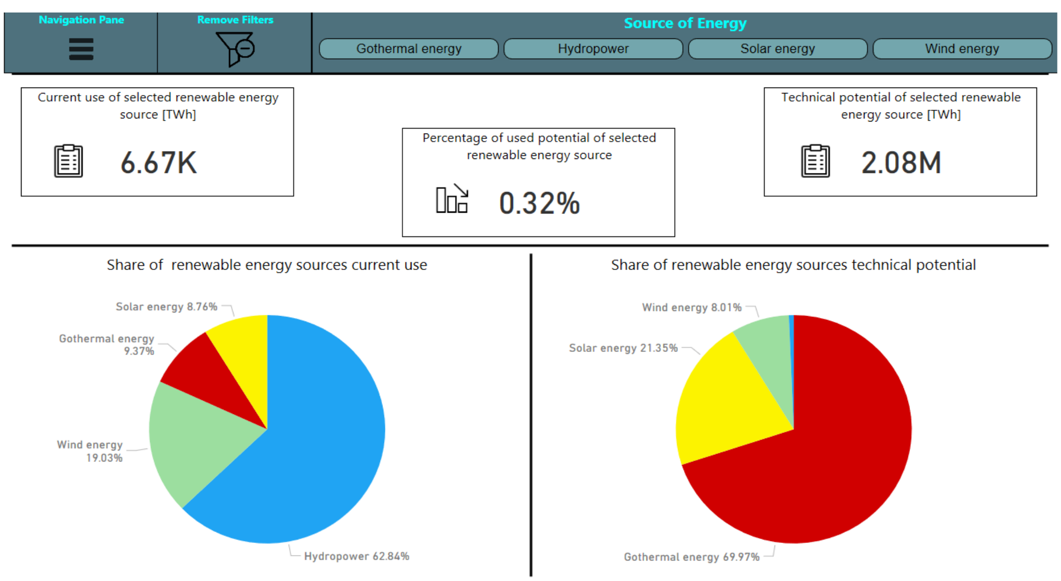


Figure 63. Visualization of the data regarding renewable energy sources current use and technical potential.

Source: own elaboration

The next page of the dashboard contains visualizations of the data regarding electricity generation with utilization of renewable energy sources. There user can find information regarding total value of electricity generated with utilization of renewable energy sources in selected range of years, in terawatt-hours, value of electricity generated with utilization of selected renewable energy source in selected range of years, in terawatt-hours, percentage of electricity generated with utilization of selected renewable energy source in selected range of years and electricity generation with utilization of renewable energy sources since 1965 to 2018. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by source of energy and range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding electricity generation with utilization of renewable energy sources is illustrated in figure 64.

Analysis of the visualization leads to conclusion that throughout almost 35 years since 1965 till 2000, almost only hydropower was utilized to produce electricity on bigger scale. The share of electricity generated by hydropower in that period is equal to 96%. That trend changed a little bit, and through past 20 years significant increase in electricity generation by solar (3% of share since 2000) and wind power (10% of share since 2000) is visible.

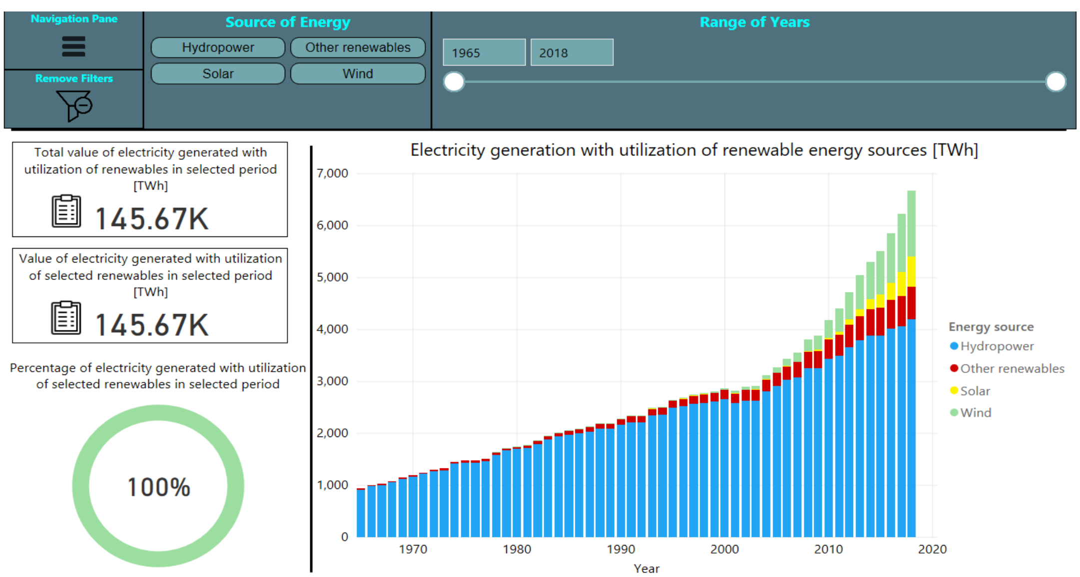


Figure 64. Visualization of the data regarding electricity generation with utilization of renewable energy sources.

Source: own elaboration

After opening of the next page, visualization of the data regarding solar power plants capacity appears. On this page user can find charts that are showing ratio of electricity generation with utilization of solar power plants to solar power plants capacity and solar power plants capacity on each continent in years 1965 – 2017. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by continent and range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding electricity generation with utilization of solar power plants is illustrated in figure 65.

The analysis of visualization leads to conclusion that in these days the biggest solar power capacity is installed in Asia. Also, on this continent value of electricity generated with utilization of solar power plants is the largest. Moreover, capacity of solar power plants grows with the highest pace on this continent. It is also noticeable, that in years 2010 – 2015 solar power capacity installed in Europe increased significantly, but after 2015 development of this technology slowed down. On other continents installed solar capacity is lower, even though there is huge potential to use this technology. It is caused mainly by poverty and tough geopolitical situation. So, there is a lot to do in this branch of energetics to utilize technical potential of solar power on bigger scale.

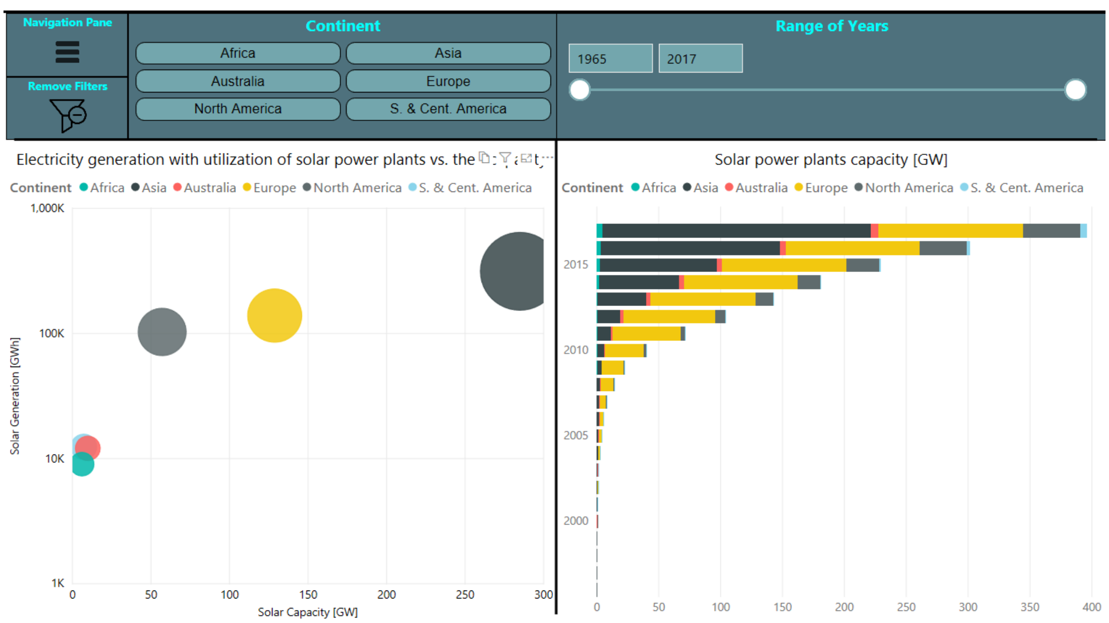


Figure 65. Visualization of data regarding solar power plants capacity.

Source: own elaboration

The next page of the report is dedicated to electricity generation with utilization of wind turbines. On this page user can find following visualizations: total value of electricity generated with utilization of wind turbines in selected range of time, in terawatt-hours, value of electricity generated with utilization of wind turbines on selected continent in selected range of time, in terawatt-hours, percentage of electricity generated with utilization of wind turbines on selected continent in selected range of time out of total electricity generated with utilization of wind turbines in the same period and value of electricity generated with utilization of wind turbines since 1978 to 2018, in terawatt-hours. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by continent and range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding electricity generation with utilization of wind turbines is illustrated in figure 66.

The main conclusion from analysis of visualizations from this page of the dashboard is that in these days the biggest amount of electricity generation with utilization of wind turbines is in Asia and it is 36% of total electricity generation with utilization of this energy source. Europe is on second place in this rank with result of 31% of total electricity generated with utilization of wind turbines. The significant value of this share, equal to 25%, belongs to North America. What is interesting, for a long time Europe was a sole leader of this rank but in past few years number of wind turbines in Asia increased significantly.

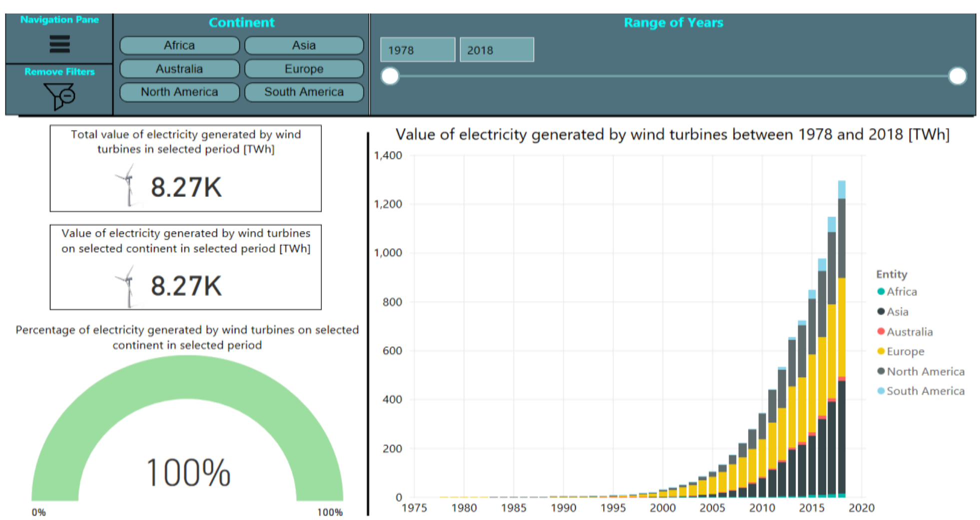


Figure 66. Visualizations of the data regarding electricity generated by wind turbines.

Source: own elaboration

The following page of the report contains visualizations of the data regarding capacity of geothermal power plants. Here user can find information about total capacity of geothermal power plants in selected range of time, capacity of geothermal power plants on selected continent in selected range of time, percentage of geothermal power plants capacity on selected continent in selected range of time out of total geothermal power plants capacity in the same period and geothermal power plants capacity in years 2000 – 2018. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by continent and range of years. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding electricity generation with utilization of geothermal power plants is illustrated in figure 67.

During the analysis of visualizations from this page user may notice that in these days the biggest geothermal capacity is installed in Asia and it is 38% of total geothermal capacity installed in the world. There is also quite big amount of geothermal power plants in North America and their capacity is equal to 33% of global geothermal capacity share. Moreover, user can observe that since 2000 increase of geothermal power plants capacity is quite stable on all continents.

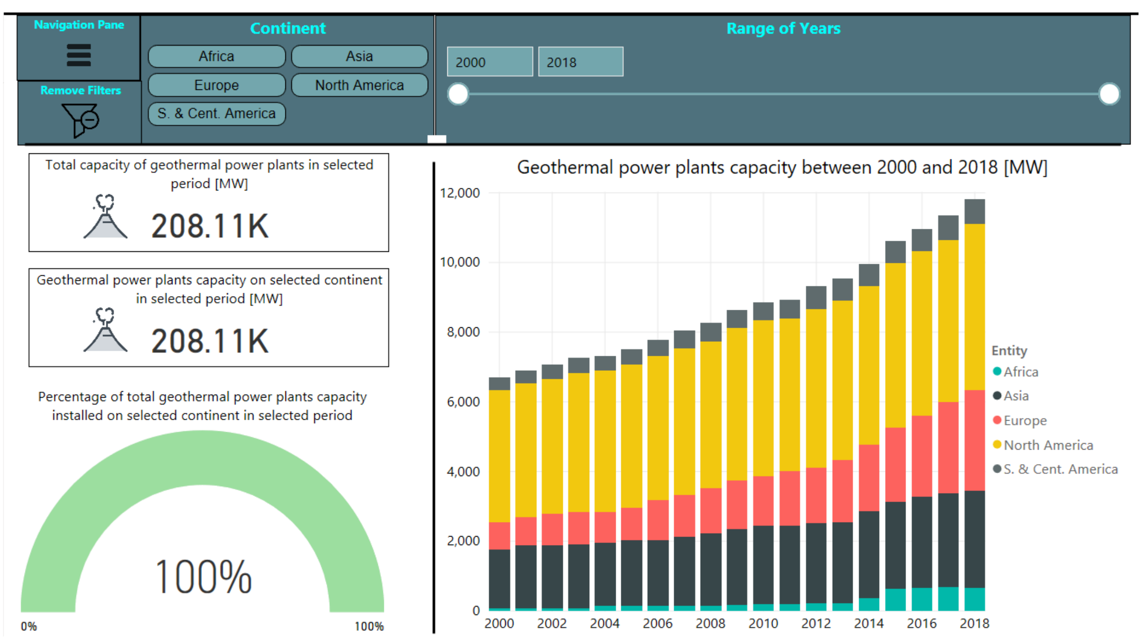


Figure 67. Visualization of the data regarding electricity generation with utilization of geothermal energy sources.

Source: own elaboration

The last page of the report contains data regarding worldwide investments in renewable energy sources. On this page user can find information about how much money was invested in renewable energy sources since 2004 to 2016. In the top of the page filtration pane is available. Filters that are contained there enable user to filter the visualization by source of energy. To remove filters, user needs to click ***Remove Filters*** button. To change the page, user must click ***Navigation Pane*** button and select the title of page that he wants to open in pop-up window. The visualization of data regarding worldwide investments in renewable energy sources is illustrated in figure 68.

From the analysis of the chart from this page user can conclude that amount of money that has been invested in renewable energy sources was raising from year to year since 2004 till 2011, then this value was decreasing for the next two years, to grow up again in years 2014 – 2015. In the last year considered in this visualization amount of money invested in green energy decreased again. The vast majority of the money allocated to develop renewable energy sources has been invested in solar and wind energetics solutions and for both of these branches it is value that exceeded 100 billion dollars in past few years.

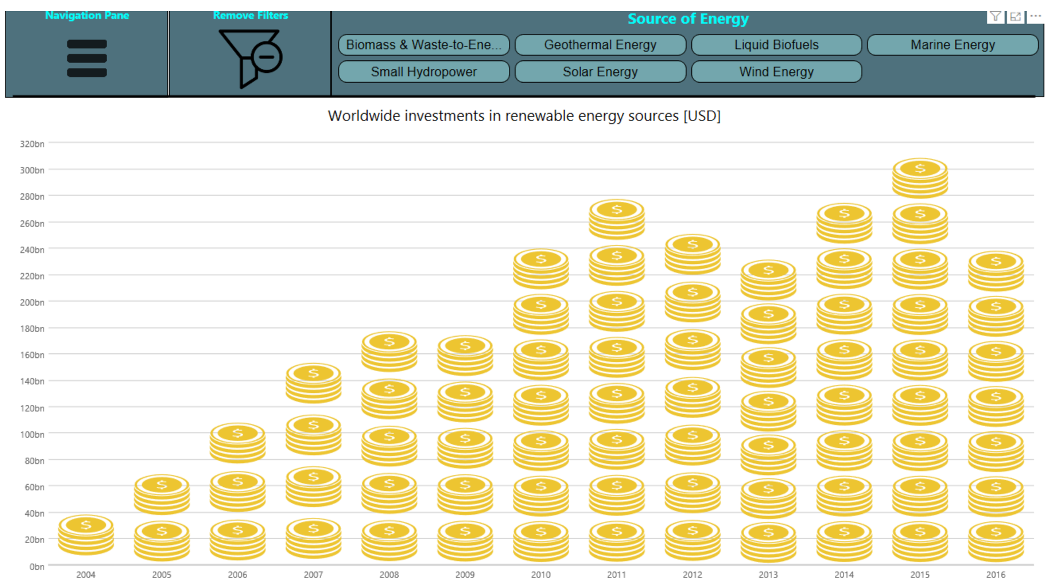


Figure 68. Visualization of the data regarding worldwide investments in renewable energy sources.

Source: own elaboration

Conclusions

The theoretical chapters of this thesis lead to conclusion that there is huge variety of methods that allows to generate electricity on commercial scale without making a damage to natural environment. Science is on such advanced level, that even in places that seems to be very unpleasant to utilize renewable sources, it possible to do it in efficient way. Moreover, there are a lot of researches in the branch of energetics, what allows to believe that in the future people will have technical solutions that will make electricity generation even less harmful for environment and more effective in terms of costs.

Unfortunately, the fact that the technologies that allows to utilize renewable energy sources exist, does not mean that they are commonly used. Based on the report prepared for this thesis, it can be stated that **71%** of electricity is generated with utilization of fossil fuels, **11%** with utilization of nuclear power plants and only **18%** with utilization of renewable energy sources. It is appalling statistic, especially considering the fact that **34 billion tons** of carbon dioxide (95% of total CO_2 annual emission) and **4 billion tons** of other greenhouse gases (73% of other greenhouse gases annual emission) is emitted during one year of utilization of fossil fuels.

There is a question, whether humanity is able to generate enough electricity to fulfill all needs, without using fossil fuels. The answer to this question is also present in the Power BI report prepared for this thesis. In the visualization regarding technical potential of renewable energy sources, value of this potential can be found, and this value is equal to **2.08 million TWh**. This number is over 85 times bigger than total annual electricity generation. But on the same page of the report, the statistic regarding percentage of current use of technical potential can be found and this statistic says that only **0.32%** of renewables total capacity is utilized by people in electricity generation purposes. So, there is enough capacity to fulfill energetic needs of whole humanity but there is long way to achieve it.

Currently **6.67 thousand TWh** of electric energy is generated annually by renewable energy sources and even though hydropower has the lowest technical potential, **63%** of mentioned value is generated by this source. Only **19%** of this value is produced with utilization of the wind turbines and just **9%** using solar power plants. Geothermal energy, despite its enormous technical potential, has less than **9%** of share. It is caused by technological demands connected with electricity generation using this source.

Statistics and numbers mentioned above are proving that mankind still has a lot to do in terms of renewable energy sources development. That is why the last visualization of the Power BI report was dedicated to show the investments in renewable energy sources. It is very good trend that governments spend hundred billions of dollars each year to build power plants that are utilizing different renewable energy sources, to develop existing methods of electricity generation from renewables and to find new ones. Hopefully in the future world will be better place thanks to the renewable energy sources.

The aim of this thesis was to study present-day methods of energy generation that utilizes renewable sources, to show global investments in this sector of energetics and to present level of their development on each continent. Moreover, the issue of natural environment degradation due to conventional energy sources usage was raised in this thesis and analysis of the dashboard leads to conclusion that it is obvious that further exploitation of fossil fuels on the same level will be extremely harmful our environment. The opportunity to avoid that situation is to utilize renewable energy sources on wider scale. However to achieve the goal of saving our planet, incessant researches in this field and investments in renewables development are essential.

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