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Faculty of Economics and Management

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Bachelor Thesis

Evaluation of Solar Energy Potential in the United States of America

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Faculty of Economics and Management

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Economics Policy and Administration
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Evaluation of Solar Energy Potential in the United States of America

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Objectives of thesis

The aim of this bachelor thesis is to evaluate solar energy potential in the United States of America. In addition to the main aim, partial goals are also expressed. First aim is to conduct literature re-view. Part of the literature review will be dedicated to the development of solar energy and the ad-vantages and disadvantages of solar energy in comparison with traditional energy production and with other alternative energy resources. The second aim is to analyze chosen indicators of solar energy development – generation and installed capacity, levelized cost of electricity, solar PV sys-tem/module prices and energy consumption.

Methodology

The bachelor thesis consist of two parts. First part is theoretical one which is a literature review. Method-ology for this part is based on scientific articles of foreign authors, encyclopedias and open publications of international environmental organizations. The work is a summary of various mate-rials related to impact of solar energy in energy consumption and it potential.

The practical part indicates own calculation and analysis, which have multiple linear regression model, 2 correlation analysis, time series and future forecast of multi module spot prices. I have chosen quantitative research and I am going to proof that the solar energy has a huge potential in development. The solar energy applies not only to economic part, but also to the environmental sphere. As a result of this analysis will be identified the characteristics of solar energy production, installation capacity, energy consumption of solar energy in comparison with other renewable en-ergy resources, module price, levelized cost of electricity and the prospects for further develop-ment. At the end I will summarize data and make a conclusion based on research.

The proposed extent of the thesis

30 – 40 pages

Keywords

solar PV, generation capacity, installed capacity, solar system , solar module, renewable energy resource, levelized cost of electricity , solar energy , emission CO2

Recommended information sources

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Declaration

I declare that I have worked on my bachelor thesis titled "Evaluation of Solar energy Potential in the United States of America" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 12.03.21 _____

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Evaluation of Solar Energy Potential in the United States of America

Abstract

The components of potential development of Solar Energy in USA are being investigated. Analysis of individual components show the level of potential development of Solar energy more deeply. A correlation analysis , multiple linear regression model , time series and future forecast were made. Based on information from previous year, a prediction for multi modules spot prices is made for 2021. Bibliographical research evaluate almost all components of potential development of Solar Energy. All these measurements show the current situation in United States of America. Development of Solar Energy influence on decrease in price on solar system installation, which made renewable energy more affordable. The results of evaluation will be analysed in this work.

Keywords: solar PV, generation capacity, installed capacity, solar system , solar module, renewable energy resource, levelized cost of electricity , solar energy , emission CO_2

Vyhodnocení potenciálu sluneční energie ve Spojených státech amerických

Abstrakt

Bakalářská práce se zabývá zhodnocením potenciálu sluneční energie ve Spojených státech amerických. Analýza jednotlivých komponent ukazuje hlouběji na úroveň potenciálního rozvoje sluneční energie. Byla provedena korelační analýza, mnohonásobný lineární regresní model, časová řada a budoucí předpověď. Na základě informací z předchozího roku je provedena predikce spotových cen více modulů pro rok 2021. Bibliografický výzkum hodnotí téměř všechny složky potenciálního vývoje sluneční energie. Všechna tato měření ukazují aktuální situaci ve Spojených státech amerických. Vývoj vlivu sluneční energie na pokles cen za instalaci solárního systému, díky kterému byla obnovitelná energie dostupnější. V této práci budou analyzovány výsledky hodnocení.

Klíčová slova: solární fotovoltaika, výrobní kapacita, instalovaný výkon, solární systém, solární modul, obnovitelný zdroj energie, srovnatelné náklady na elektřinu, solární energie, emise CO2

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1. Introduction

The environmental problem in the 21st century is more acute than ever. The threat of global warming has united scientists, businessmen and politicians from all over the world in the need to address this problem. The development of alternative energy sources will eliminate the root cause of the problem and extend a comfortable life for the billions of people who inhabit the Earth. The choice of solar energy as the object of research is explained by the widespread use of this type of alternative energy sources. The choice of the country of study, the United States of America, is due to the high degree of development of solar energy in this region, which will allow us to most effectively assess the prospects for the development of solar energy both on the scale of one country and worldwide.

Over the past decade, we have seen a tendency for the falling price of solar electricity in compresence with the non-renewable energy resources, which made fossil-fuel less completive. (Olson, 2019) The installation of solar panels costs lower in comparing to other forms of power generation. Moreover creating electricity from solar panels prevents from greenhouse gas emission, which makes Solar energy one of the most valuable sources. There is no any toxic and detrimental emission released into the air, because of CO2-free.

In this Bachelor Thesis we will answer on such questions as

1. Why USA have ideal conditions for Solar Energy?
2. What is the difference between renewable and non-renewable sources of energy?
3. What is the proportion of Solar energy of the USA in a global context?
4. Why Solar Energy have better future potential than non-renewable sources of energy?

Also the result of the research could be evaluation of Solar Energy Potential in the USA and identify the perspectives of switching from industrial type of energy producing to the renewable type of sources. The theoretical part of the work consists of six parts. The first part presents the history of the development of solar energy in the world. The second part consist of general description of renewable energy resources. In the third of the work, is given a classification of the types of solar energy and a characteristic of each of them. The next part lists the advantages and disadvantages of solar energy. The fifth part focuses on the consequences of carbon dioxide emissions into the atmosphere. The last part contains the socio-

economic aspect of solar energy – solar job growth.

2. Objectives and Methodology

2.1 Objectives

The aim of this bachelor thesis is to evaluate solar energy potential in the United States of America. In addition to the main aim, partial goals are also expressed. First aim is to conduct literature review. Part of the literature review will be dedicated to the development of solar energy and the advantages and disadvantages of solar energy in comparison with traditional energy production and with other alternative energy resources. The second aim is to analyze chosen indicators of solar energy development – generation and installed capacity, levelized cost of electricity, solar PV system/module prices and energy consumption.

2.2 Methodology

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3. Literature Review

3.1 Development of Solar Energy in the world

Solar energy is an almost inexhaustible source of energy that feeds the biosphere for hundreds of millions of years, since the appearance of photosynthetic organisms. (Kostin, 2005) This is also the name of the technology that controls it.

The first efforts to use sunlight for energy production were made by mankind in the nineteenth century. In 1883, American engineer C. Fritts used gold-plated selenium to produce the first solar cell. Research on the use of solar energy became more widespread in the second half of the twentieth century. In 1954, American scientists K. Fuller, D. Chapin and J. Pearson created the first solar battery. (Osipov, 2017) At that time, semiconductor-based solar cells were created for use on spacecraft. Initially, solar panels were expensive and had low efficiency. But for spacecraft, it was possible to afford such an expensive solution. And there was simply no choice on what to power the electrical equipment of satellites and spaceships. (Vasiliev, 2015) On 17th march 1958 the United States launched the first solar–powered satellite «Vanguard 1». Two months later, the USSR also launched a satellite that ran on solar energy. (Osipov, 2017) In the 80s, solar panels stepped into everyday life. The first microcalculators and radios powered by solar energy appeared. However, solar panels could not fully provide power to even such economical devices, they were only switched on in parallel with traditional power sources, thereby increasing their service life. At that time, solar panels could not provide any serious generation of electricity comparable to traditional power plants. And only in the 90-s appeared solar power systems, in which energy was stored in batteries, suitable for mass use. (Vasiliev, 2015)

Among the recent developments in the area of international environmental cooperation should be highlighted the Paris Agreement. It was adopted in 2015 and aims to keep the increase in global average temperature well below 2 °C above pre-industrial levels and make efforts to limit the increase in temperature to 1.5 °C that means the introduction of alternative energy sources. The United States signed the Paris Agreement on April 22, 2016, and on September 3 of the same year sent documents to the UN to the acceptance of the agreement. But it was only acceptance, not the ratification (because the decision was made by President Obama, without the approval of Congress). In 2017, President Donald Trump decided to withdraw from the Paris Agreement

because of too much damage to the national economy. This caused a violent public reaction. In America, heads of states and mayors, universities and companies have announced their climate goals. In the country emerged a new large "We are still in" movement. It brought together 125 cities, 9 states, 183 colleges and universities, 900 business companies-or 120 million American citizens and $ 6 trillion in the national economy. (Chestnoy and Gershinkova, 2017) However, in 2021, with the change of the head of state, the environmental direction also changed. The new president of America, Joe Biden, has already signed a decree on the return to the Paris Agreement.

The energy sector of the state is now an important characteristic. Scientists classify countries by the level of development of solar energy in them. There are four types of states: countries with a complete solar-energy complex, countries with a fragmented solar-energy complex, countries with a solar-energy complex-transplant, and countries with single imported elements of the solar-energy complex. Countries with a full solar-energy complex play a decisive role in the development of solar energy, they concentrate more than 1/2 of the world's installed capacity of the industry, and the world solar energy for the first time was formed and developed as a modern branch of the world economy since the 70s of the XX century. They concentrate the production capacity for the production of solar installations. These countries form the framework of the territorial structure of the industry in the world. This type of country includes the United States, Germany, Japan, and China. Countries with a fragmented solar energy complex include regions where the solar energy industry shows consistently high growth dynamics in terms of the growth of new heat and electricity capacities, as well as in terms of increasing production capacity to boost the output of solar installations. In countries of this type, not the entire solar energy complex is represented, but only its individual components – national companies partially cover the links for creating added value of various solar installations. These include most European countries, as well as Brazil, Mexico, Turkey, Russia, etc. The category of countries with a solar-energy complex-transplant lagging behind in the development of the industry from the previous ones. Solar energy in these countries began to form under the influence of the presence on their territory of large foreign companies, mainly American, Japanese and German, i.e. companies of countries with a full solar energy complex. The category of countries with a solar-energy complex-transplant lagging behind in the development of the industry from the previous ones. These countries include some North African countries, such as Algeria and Egypt, and Southeast Asia. In countries with single imported elements of the solar energy complex, solar energy is represented by single individual users and companies that purchase equipment in other countries from the largest manufacturers, i.e. they perform the function of retailers, all of which are imported. This type includes Barbados,

Albania, Zimbabwe, Latvia, Lithuania, Estonia, Luxembourg, Malta, Namibia, Uruguay. (Akimova, 2015)

In the history of solar energy development in the United States, there have been both successful and less successful periods. However, the country is now ready to switch to alternative energy sources.

3.2 Types of renewable energy

Alternative energy sources are contrasted with traditional energy as more environmentally friendly and represent a collective concept covering renewable energy sources. They are becoming more and more cost-effective. Alternative energy sources include heat pumps, wind energy, solar energy and tidal energy. (Kostin, 2005)

Renewable energy sources can be used really efficiently. For example, the energy of the currents of the World's oceans is close in magnitude to the energy obtained from the burning of all types of fuel on Earth during the year. River hydropower is the most developed area of renewable energy. It originates from the water wheels and mills used by mankind at the dawn of its development. A distinctive feature of the energy carrier-water, is that it can be used repeatedly, which is the case in the cascades of hydroelectric power plants, but its physical nature remains unchanged, unlike organic types of energy carriers, which as a result of the return of energy change their physical state, forming other substances as a result of combustion. The absence of heating-cooling processes in hydroelectric power plants makes it possible to obtain a high efficiency of converting water energy into electricity, depending mainly on the efficiency of the turbine and generator, the value of which in the best samples exceeds 90%. The next feature of hydroelectric power stations (HPPs) is that the structures and their equipment have been used for 50 years or more. There are hydroelectric power plants that have worked for 100 years. This means that hydroelectric power plants built in the initial economic conditions, having repeatedly paid off, continue to produce the cheapest energy. The most vulnerable aspects of powerful HPPs are land flooding, silting of reservoirs, water blooming in them, changes in the microclimate, as well as relatively high specific capital investments. It is worth noting that the water produced at the HPP can be used for any other purposes in the future. (Nigmatulin, 2020)

Heat pumps operate on the principle of transferring temperature from one source to another. There are two types of such pumps. In heat pumps "air-water" heat source is air, the heat is

transferred to the working body, and then to the water that goes to the heating system of the building for the hot water. An alternative to air heat pumps is water-to-water heat pumps, which operate in a similar manner to air-to-water heat pumps, except that water is used as the heat source. (Kobylkin, Batukhtin and Kubriakov, 2014)

Wind energy is one of the cheapest renewable energy sources. Its resources are extremely large and widespread. Wind farms require certain conditions on the ground where they can be installed. The main indicator that determines the energy value of wind is its average annual speed. In wind energy, areas with an average annual wind speed of less than 5 m/s are considered unsuitable for hosting wind power plants, and those with a speed of more than 8 m/s are considered very good. (Martynova et al., 2018) In 2014, the amount of electricity generated by all wind turbines in the world was 706 terawatt-hours and accounted for 3 % of all electricity produced by mankind. Some countries are particularly intensively developing wind energy. Wind farms are divided into large and small. Large wind farms are included in the overall energy network, while smaller ones are used to supply electricity to remote areas. (Iskenderov, Tagieva and Javadova, 2016)

3.3 Types of Solar Energy

Electricity from solar energy can be obtained in several ways. Stand-alone solar power plants typically use two main technologies. The first is PV (photovoltaic system), the second is Solar thermal. (Akikur, Saidur, Ping and Ullah, 2013)

In PV system, the light incident on the photovoltaic cell is converted directly into DC electricity through photovoltaic solar energy cells, and then is converted by the inverter to alternating current (AC). The use of photovoltaic systems is usually limited to the roofs of residential and commercial real estate, although it is also possible to use them in enterprises of a commercial scale. (Ali Ghazi, 2015) Photovoltaics owes its development to Albert Einstein. He laid the foundations of the general theory of the photoelectric effect. During this time, solar cells have undergone three generations of evolution. Now they are created from high-quality organic elements. (Milichko et al., 2016) Solar Systems-PV can be divided into two types: grid-connected systems and autonomous systems. Grid-connected solar-photovoltaic systems are used more often in a city or urban area. And autonomous solar photovoltaic systems are usually used to supply energy to remote areas. These systems can supply electricity to a single house, but they can also supply an entire locality. (Akikur, Saidur, Ping and Ullah, 2013) Photovoltaic solar

panels can be divided into types depending on the composition. The most popular ones are silicon ones. They are made mainly of 2 types: monocrystalline and polycrystalline. The first ones have the highest efficiency (usually 15% for commercial products, and up to 25 % in the laboratory), but such solar panels are still quite expensive, because they use an ultra-pure semiconductor as the material for the energy converter. Polycrystalline batteries are much cheaper, but due to the existing irregularities of the crystal structure used for energy conversion, their efficiency is slightly lower. Dye-sensitized solar cells convert sunlight into electricity, using a mechanism similar to plant photosynthesis. For this purpose, when light is absorbed by a dye molecule, free electrons are formed in them and they are sequentially transferred to nanostructured titanium oxide. The efficiency of such batteries is relatively low – up to 10 %. Although batteries can also be made of relatively cheap materials of low purity, their problem is the rather high complexity and labor intensity of their production, since the transfer of electrons requires the presence of an electrolyte as the working medium. However, the cost of such solar cells is about 60% less than silicon, so their market share may grow in the future. The third type is polymer batteries. Some organic polymers are used as thin foils, which have the properties of semiconductors necessary for generating electricity. At the same time, they have a fairly low cost, but the efficiency is also low. In addition, they are quite sensitive to the effects of atmospheric gases and humidity. (Vorobev and Vorobev, 2019)

Power plants using solar thermal (is also called concentrated solar power) solar energy is collected using various types of mirrors to heat the working fluid and generate steam (directly or through an intermediate heating stage). This steam is used to turn the turbine and to power generators that produce electricity, as in traditional power plants. Such power plants are divided into four types. The first is a tower-type solar power plant. Here, a field of heliostats (large separate biaxial mirrors) is arranged to direct sunlight to a central receiver mounted on the top of the tower. The second are linear Fresnel reflectors. This is a series of linear mirror strips that collect light to a fixed receiver attached to a linear tower. The third is a parabolic mirror. The system of parabolic mirrors (or solar dishes) consists of a single structure that supports a parabolic dish covered with mirrors that reflect light to a solar radiation receiver located in the focus of the dish. The fourth is a parabolocylindrical solar collector. This is the simplest type of CSP systems, in which the solar collector field consists of rows of elements of parabolocylindrical solar collectors with an integral receiving tube. The collectors are connected to a central motor that follows the movement of the sun. The solar light receiver is a black vacuum glass tube containing a heat carrier – oil or water. (Ali Ghazi, 2015)

Table 1 Stand-alone solar power plants

<table>
<tr><td colspan="8">Stand-alone solar power plants</td></tr>
<tr><td>Main types</td><td colspan="3">Photovoltaics</td><td colspan="4">Solar thermal</td></tr>
<tr><td>Operating principle</td><td colspan="3">Converting light directly into electricity through photovoltaic cells.</td><td colspan="4">Using mirrors to collect the sun's rays and generate the steam that powers the generators.</td></tr>
<tr><td>Practical application</td><td colspan="3">Heating in residential and utility buildings.</td><td colspan="4">Using in production quantities.</td></tr>
<tr><td rowspan="2">Varieties</td><td colspan="2">Grid-connected systems</td><td>Autonomous systems</td><td rowspan="2">Tower-type solar power plant</td><td rowspan="2">Fresnel reflectors</td><td rowspan="2">Parabolic mirror</td><td rowspan="2">Parabolocylindrical solar collector</td></tr>
<tr><td>Silicon</td><td>Dye-sensitized</td><td>Polymer</td></tr>
<tr><td>Characteristics</td><td colspan="2">Using in a city or urban area.</td><td>Using in remote areas and on individual buildings.</td><td>Transmitting solar energy to a receiver located at the top of the tower.</td><td>Long strips of mirrors with a receiver on a linear tower.</td><td>A single design of mirror plates with a receiver in the focus of the plate.</td><td>Rows of elements of parabolocylindrical solar collectors with a liquid-filled glass tube as a receiver.</td></tr>
</table>

In addition to stand-alone power plants, there are hybrid power generation systems consisting of two or more energy sources. Designing hybrid types of solar power plants is much more complicated and risky. The most flexible resource for inclusion in hybrid electric systems is solar energy. Therefore, most hybrid power plants that run on renewable resources are powered by solar energy. (Akikur, Saidur, Ping and Ullah, 2013)

The classification of hybrid power plants is quite extensive. The first type is hybrid solar energy combined with renewable sources. It is the most eco-friendly and the most attractive technology. This includes hybrid solar-wind energy and hybrid solar-hydroelectric energy. Wind is more unpredictable compared to solar energy, but it is still the most common source of electricity in the world after the sun. Due to local features, however, such stations are not always able to independently cover the territory's electricity needs. Water is a resource used not only for energy production, but also for irrigation. Hydroelectric power plants are more cost-effective then the others renewable sources. Large hydroelectric power plants, however, cause environmental damage due to the destruction of lowland, river and grassland ecosystems. Large hydroelectric power plants, however, cause environmental damage due to the destruction of lowland, river and grassland ecosystems, so people try to build mini, micro or pico hydroelectric power plants. Hybrid power plants combining solar and small-scale hydropower can provide cost-effective and environmentally friendly electricity for rural electrification. (Akikur, Saidur, Ping and Ullah, 2013) The problem of power outage can be solved in several ways. For example, it can be solved by buffering intermediate energy storage in an amount sufficient to cover the subsequent peak loads. For this purpose, the hybrid wind-solar system uses multifunctional modules that perform combined functions: conversion, storage and generation of energy. (Dzenzersky et al., 2007)

The next type is hybrid solar energy systems with conventional sources. These are stations that, along with renewable resources, use traditional ones, for example diesel generators. The station combined solar energy with diesel is called hybrid solar-diesel energy station. Combining solar and diesel power is a good solution for remote areas, as it is the most economical and reliable option. This is much more environmentally friendly than traditional energy, but the impact on the environment is still there. In addition, the disadvantages include the instability of prices for diesel fuel. (Akikur, Saidur, Ping and Ullah, 2013)

The latter type is hybrid solar energy systems with two or more sources. It includes hybrid solar-wind-diesel power and hybrid solar-wind-diesel systems with hydroelectric / biomass power. These hybrid systems are the most reliable, but at the same time the most complex to design. Diesel

in the hybrid solar-wind-diesel power system is used mainly to reduce the cost of the station. Hybrid solar-wind-diesel systems have lower maintenance requirements and are therefore very profitable. They are often built in areas with low wind speed and insufficient solar power. hybrid solar-wind-diesel systems with hydroelectric / biomass power stations are the most versatile in terms of location, as they use all types of natural energy. They can be cost-effective, but require serious design calculations.

Table 2 The pros and cons of different types of hybrid stations

Types		Environmental friendliness	Effortlessness in design	Stability of energy supply	Cost-effectiveness
Hybrid solar energy combined with renewable sources	Hybrid solar-wind energy	+	+	-	-
	Hybrid solar-hydroelectric energy	+/-	+	+/-	+/-
Hybrid solar energy systems with conventional sources	Hybrid solar-diesel energy	+/-	+	+	+
Hybrid solar energy systems with two or more sources	Hybrid solar-wind-diesel power	+/-	-	+	+
	Hybrid solar-wind-diesel systems with hydroelectric / biomass power	+/-	-	+	+

The development of solar energy does not stand still, so it is likely that in the near future some types of power plants will disappear, and new ones will come in their place.

3.4 Advantages and disadvantages of solar energy

In 2014, there were enough solar power plants in the world to meet the household needs of almost 70 million people at the average European level of consumption. (Belyaev and Komarova, 2014) And these indicators are growing every year. The development of solar energy raises the question of the advantages and disadvantages of this type of energy production.

There are quite a lot of advantages of using solar power plants. First, the sun will give off energy for several billion more years. At the same time, you do not need to spend significant funds and resources for its production. Second, solar energy generation is a completely eco-friendly process that does not have any risks of environmental pollution. Third advantage is the autonomy of the process. The collection of sunlight and electricity generation takes place with minimal human involvement. The only thing to do is to keep the work surfaces or mirrors clean. Fourth, exhausted solar panels can be recycled and reused in production. (Chaykin, 2018) The use of solar panels in production is becoming increasingly popular. They are almost noiseless, which means that such enterprises can be located in the residential sector. They are quite lightweight, which means they are easy to mount. The solar battery can last quite a long time, since there are no moving parts in the device. (Gorbenko and Makarova, 2013)

A large number of advantages does not negate the fact that there are disadvantages and problems in the development of solar energy. First, for receivers located on the earth's surface, the energy output will depend significantly on the weather. Overcast skies significantly reduce electricity generation for several days. Second problem of using solar energy is that the greatest amount of it comes in the summer, and the greatest energy consumption occurs in the winter. Third important problem of many industrial cities is the effect of the "black sky", when two factors converge over an industrial city — windless weather and humidity. Under these conditions, all emissions from production, car exhaust, along with dust and smoke, accumulate in the air. Due to the "black sky" effect in many industrial cities, heat is dissipated in the atmosphere due to air pollution. The use of solar energy in such conditions is extremely difficult and inefficient. Fourth disadvantage is to accommodate such installations, large areas are required, and in places where solar radiation has a sufficient level. (Chaykin, 2018) Solar panels, however, are not suitable for every production. They are quite large, which means that the enterprise should be rather large for their placement. It is important to keep the solar panels clean, as they are very sensitive to pollution, which greatly affects energy production. (Gorbenko and Makarova, 2013)

Some of the disadvantages of solar energy can be overcome. For example, one of the most effective ways to increase productivity is to use solar tracking systems. The solar radiation coming to the surface of the batteries depends on the climatic conditions and the geographical location of the power plant. (Pilyaeva, 2019) The use of solar tracking systems allows you to reduce the payback period of the system and reduce the cost of electricity produced. The use of these systems will allow the batteries to change the angle depending on the position of the sun, which will increase the amount of power received on the surface of the photovoltaic module. (Kitaeva, Yurchenko, Skorokhodov and Okhozina, 2012)

The problem of unstable energy production is solved by the presence of a solar energy production system in the neighborhood. For example, in the United States, when the government chooses new territories for the construction of industrial solar power plants, it is guided by the fact that they are located close to existing power lines, which will quickly deliver electricity to those cities where it is not enough, thereby contributing to the creation of a system of photovoltaic stations and their integration into a single energy system. (Akimova, 2020)

The figure below shows the location of solar energy facilities in the United States for 2018. The structure of solar energy in the United States is dichotomous. There are two regional poles that generate industry growth: the eastern one, led by the states of New Jersey, North Carolina, and Massachusetts, and the western one, led by California, Nevada, and Arizona.

The debate over the advantages and disadvantages of alternative energy sources is now in full swing. The reason for this is the recent snow storm in Texas (a state where solar and wind energy are actively used). Due to low temperatures, power generation failed and residents of the state were without electricity. Big businessman Bill Gates has expressed his concerns about a complete transition to alternative energy sources. In his opinion, the best option is when 80% of the world's energy is from wind and solar and the remaining 20% comes from nuclear energy. (Maruf, 2021)

It is obvious that the development of solar, as well as other alternative types of energy production, has a number of shortcomings that should be corrected. However, science is actively developing in this direction, and it is quite possible that the list of disadvantages will soon be drastically reduced.

3.5 Emission CO2

Carbon dioxide is one of the greenhouse gases, that absorb and radiate heat. Earth get warmed by sunlight and land and ocean surfaces uninterruptedly radiate heat (thermal infrared energy). The major atmospheric gases (oxygen and nitrogen) are transparent to incoming sunlight to outgoing thermal infrared, so they don't release heat. But carbon dioxide and other greenhouse gases (for example water vapor, methane) are impenetrable to wavelengths of thermal infrared energy. The surface of our planet radiates about 17 percent of incoming solar energy as thermal infrared, but only 12 percent of it escapes to space. The rest — 5-6 percent of it is transferred to the atmosphere and greenhouse gas molecules absorb the energy. Their temperature rises and they radiate the heat in all directions and that warms the surface of the planet. This is called the natural greenhouse effect, which will cause global warming. (Lindsey, 2009)

Global warming is the phenomenon of increasing average air temperatures near the surface of Earth. (Global Warming, 2020) What happens if the planet warms up too much? Arctic sea ice and the Greenland ice will melt and ocean circulation in the Atlantic will divert the Gulf Stream, so it will bring significant cooling to Western Europe. Further, the melting of the ice will lead to an increase of sea level. Large areas will be flooded. Melting glaciers will only accelerate global warming due to methane deposits under the ice, which will heat the air even more. (The Study of Earth as an Integrated System, n.d.)

Generally, carbon dioxide has the biggest impact on climate change. It is for this reason that CO_2 was chosen as the base gas when calculating the global warming potential, which is assumed to be equal to 1. Accordingly, the degree of influence on global warming of other greenhouse gases is compared with the impact of CO_2. It is known that carbon dioxide is formed during a wide variety of processes (for example, fermentation, rotting, respiration), but one of the main sources of carbon dioxide is industrial emissions generated by the combustion of solid, liquid and gaseous fuels. (Gafurov, Osipov, Gatina and Gafurov, 2017)

Carbon dioxide affects three systems at once: the atmosphere, the land, and the ocean. By 1990, anthropogenic CO_2 was added to the already existing natural volume of CO_2, which occupied almost a third of the carbon space and additionally warmed the atmosphere. The land is able to maintain a high degree of reliability of the habitable state of the environment, its biota is not depleted. The amount of energy produced by plants through photosynthesis (with the exception of what they use for respiration) has increased globally by about 6% in the last two decades of the

twentieth century. The ocean, like a sponge, "absorbs" CO_2 from the atmosphere, which is then transformed into carbonic acid and gradually is neutralized. However, the large amount of CO_2 that entered the ocean waters in a short time disturbed the acid-base balance. Such a rate of increase in ocean acidity has not been observed in all historical time. (Fedorov, 2014)

The main reason of carbon dioxide (one of the most long-lived greenhouse gases) increase is the result of human activity since the industrial revolution. (Lan et al., 2020) Renewable energy sources will reduce the amount of greenhouse gas emissions into the atmosphere. The impact from renewable energy sources on the environment is much less than from traditional energy. The use of such resources is beneficial in several directions at once. First, the variable costs of many renewable energy technologies are almost free, since we don't have to pay for wind or for sunshine. Second, it will improve the trade balance. Solar, wind, hydro, geothermal and ocean energy are domestic resources of the country and the development of renewable energy can have a positive impact on the trade balance if the reduction in energy imports is higher than the import of renewable energy technologies. Third, in many countries, the policy of supporting RES provides for a certain degree of localization of project implementation, which should contribute to the development of domestic production, the creation of additional added value and employment in the country. In addition, the use of renewable sources contributes to the expansion of access to energy supply in technologically isolated regions. Currently, more than 1.3 billion people do not have electricity. Autonomous energy systems based on renewable energy sources are alternatives to centralized energy supply in developing regions where access to electricity is difficult or impossible. (Grechukhina and Kiryushin, 2015)

The UN tried to deal with the fight against global warming. In 2016, within the framework of the UN Framework Convention on Climate Change, 176 countries signed the Paris Agreement. The work on this document took a long six years, the success was largely due to the great interest of the world community in the early work to prevent global warming. According to this agreement, countries must make certain changes to their economies, making them cleaner and preventing global warning. A pretentious collective goal is to hold warming well below 2 degrees with efforts to limit warming to 1.5 degrees and to achieve net-zero emissions in the second half of this century. (The Paris Agreement Summery, 2015) However, this agreement did not become absolutely approved. Vladimir Gorbanev, a professor at the Moscow State Institute of International Relations, doubts the effectiveness of the Paris Agreement, because to keep the warming of the air within 2°C, countries need to increase the volume of commitments three times, and to keep the temperature within 1.5°C, as discussed at the Conference, you need to

increase the volume of commitments five times. It seems almost impossible to fulfil such conditions. (Gorbanev, 2018) And he wasn't the only one who expressed doubts about the Paris Agreement. American scientist James Hansen also considered the implementation of the contract impossible. (Milman, 2015) In 2017 the United States (one of the most economically developed countries) withdrew from the Paris Agreement. President Donald Trump has said that the program to reduce greenhouse gas emissions is too expensive for America. (Liptak and Acosta, 2017)

It is clear that carbon dioxide emissions pose a serious threat to our planet. Despite the fact that many countries and international organizations are making efforts to protect the environment, this is still not enough for a save future.

3.6 Solar Job Growth

A new trend in the modern labor market is the development of a policy to promote employment based on the principles of a green economy. A distinctive feature of such a policy is the formation of an environmentally oriented labor market by creating green jobs that contribute to reducing the negative impact on the environment and improving the ecological situation. Attempts to compare and analyze the problems of the labor market and environmental protection have been made since the early 1980s, when it became necessary to fully take into account and evaluate the environmental, economic and social factors of sustainable development. The formation of scientific views and ideas about green employment dates back to the mid-90s of the XX century. Currently, the main factor contributing to economic growth and the creation of new jobs is the activities for improving the environment, preserving natural resources, energy and resource conservation, producing environmentally friendly products, recycling waste, developing organic agriculture, implementing green standards and other areas. Now, an essential aspect of economic behavior when choosing a profession and place of work in the labor market is the consideration of the environmental factor in the employer's activities and his environmental image. (Voikina and Potravny, 2018)

The most promising sector for the development of green jobs is the energy sector. Renewable energy and low-carbon sectors generate significantly more jobs per unit of energy than the fossil fuel-based sector. Reducing the annual growth rate of electricity production by half and achieving 30% renewable in total energy production will create about 2 million workers by 2030 in the

United States. Together, increasing the share of renewable energy sources, improving energy efficiency, and developing low-carbon energy could create more than 4 million jobs by 2030 in the US, with more than 50% of electricity coming from non - fossil fuel sources. (Karlik and Mateos, 2018)

Electricity generation based on renewable resources (mainly solar energy) allows you to create jobs in developing countries, and not only in highly developed ones. The National Ministry of Science and Technology of Republic of China has identified the production of energy from biomass as a priority. The government's policy of supporting solar energy has led to a unique result: three-quarters of the world's solar panels are manufactured in China, providing jobs for many people. India's state strategy in this area is to achieve 40% of electricity generation from renewable sources by 2030, with a separate priority for solar energy and plans to increase investment in this segment to $ 100 billion. The case of India illustrates the unique potential of renewable energy to improve living standards and combat poverty and unemployment. Saudi Arabia, which influences oil prices, plans to provide the national economy with 30% of the electricity generated from renewable energy sources by 2023, and 50% by 2050. Saudi Electricity, together with strategic investor Softbank Group (Japan), plans to create a solar power plant with a gradually increasing capacity of up to 200 GW by 2030, which will create about 100 thousand jobs and save a total of 40 billion US dollars by eliminating the use of energy. (Buchnev, 2018)

Among the common renewable energy technologies, solar photovoltaics creates the largest number of jobs per unit of electricity generation. (Karlik and Mateos, 2018) Over the past forty years, about one million solar converters have been installed on the roofs of US households, and this figure is planned to triple in the next two years. (Buchnev, 2018) Direct and indirect jobs in the solar energy sector worldwide (in 2014) amount to 1360,000 people. Of these, 300,000 in China, 312,000 in the European Union, 112,000 in India, and 90,000 in the United States. (Heale, 2014) The International Renewable Energy Agency presents a review every year «Renewable Energy and Jobs». The latest review, released in September 2020, demonstrates the development of green energy in 2019. This report indicates, among other things, that photovoltaic solar energy remains in the first place. It employs 33% of the total number of people employed in the renewable energy sector. In 2019, 87% of global employment in photovoltaic solar energy was concentrated in the ten countries leading in the deployment and production of equipment in the world. (Vorobev and Vorobev, 2019)

One job in renewable energy leads to 5-6 jobs in related industries. Despite the fact that energy

production is carried out virtually without human intervention, the design, construction and maintenance of solar cells requires the direct participation of workers. (Demin, 2011) Solar energy offers a number of working specialties, including: environmental specialist, electrician, mechanic, welder, specialist in the manufacture and repair of metal products, solar panel and battery installer, assistant installer of solar panels and batteries, roofer. (Voikina and Potravny, 2018)

The fact that the growth of solar and other types of alternative energy helps to solve the problem of unemployment also proves the need to continue the development of this sphere.

4. Practical Part

4.1 Potential of Solar energy in United States of America

Modern renewable energy technologies have the ability to help countries achieve their political goals by: developments in the field of safe, reliable and affordable energy; access to electricity for all without restrictions; reducing cost volatility and promoting social and economic development. The projected reduction in costs for renewable energy production technologies clearly reveals the cost-effectiveness of these energy sources to achieve global goals at present. Signed in Paris in 2015, the COP21 agreement reflects the opportunity to reduce and manage costs in a transition to a sustainable energy future. Effective political support for renewable energy technologies has led to their accelerated development, cost reductions and technology improvements, which have an impact on the power generation sector. This situation is contributing to the transformation of the energy sector with the help of renewable energy technologies.

The popular use of renewable energy sources scales up the market for renewable technologies, thus increasing their competitiveness. At the same time, each double total capacity of renewable technologies costs for solar photovoltaic (PV) modules can be reduced from 18% to 22% and 12% for wind indicators. As a result, the cost of equipment for renewable energy technologies is decreasing at the time when technologies become more efficient. The presence of these factors leads to a decrease in the cost of energy obtained from renewable sources. This transformation is now evident in the power generation sector, where significant reductions in the cost of solar PV and wind power contribute to a massive investment in renewable energy.

In the past, huge financial costs have hampered the development of renewable energy sources. Currently, modern technologies for the production of energy from renewable sources are becoming the most competitive in terms of cost, being the most budget option for any energy system that depends on petroleum products (for example, for off-grid electrification in a number of countries). In resource-rich locations, modern energy production technologies are a winning option for centralized power supply and further technology development. However, public discord over renewables often contributes to the degeneration of technology due to a false belief that renewables are not competitive. (The Power to Change: Solar and Wind Cost Reduction Potential to 2025, 2016)

The road to a sustainable energy sector at the lowest cost is accompanied by continuous improvement and development of new technologies, as well as reducing costs through outdated renewable energy technologies. Offshore and onshore wind power, Concentrating Solar Power (CSP) and solar PV systems are now financially attractive technologies with significant cost reduction potential in USA. Reducing the cost of renewable energy technologies until 2025, associated with the recent decline in the cost of solar PV modules and wind turbines. The possibilities of unconditional reduction of financial costs in the future should come from the following sources: balance of system (BoS) - the so-called project balance; optimization of costs for maintenance and operation; lower financing costs. This perspective highlights the significant cost differences between individual technologies in a number of countries. Achieving the goal of reducing financial costs can contribute to a policy shift and be generally unattainable. Solving the many issues of minimum costs and the large number of participants in project costs (from construction to permitting, for example) means reaching out to a range of smaller, segmented markets, excluding large OEMs and project developers. (The Power to Change: Solar and Wind Cost Reduction Potential to 2025, 2016) Objectives of the practical report:

- Provide valid, verified data on U.S energy consumption of non-renewable and renewable energy sources and demonstrate their potential
- Provide up-to-date, realistic and transparent predictions of potential reduction in cost of multi solar module spot prices by the end of 2021
- Provide detailed information of generation and installed capacity of solar energy in the United States of America.
- Compare US commercial and residential levelized cost of electricity and show how the technology influenced on reduction .
- Introduce latest investment in US renewable resources and potential of Solar energy

4.2 Energy consumption

One of the reason why there was a rapid economic growth is a high energy consumption in industrial sectors, which still use fossil fuels as their primary source of energy. Fossil fuels were a leader in the mix of U.S. energy consumption for more than 100 years, but everything can be changed because of renewable sources of energy, which are more environmentally friendly and positively influence on a climate change. Nowadays, the goal of many countries is to substitute non-renewable energy resources by renewable. According to U.S Energy Information Administration, there are following U.S primary energy consumption by major source. (Note:

Petroleum is petroleum products excluding biofuels, which are included in renewables)

Table 3 U.S primary energy consumption by major sources

U.S. primary energy consumption by major sources, 2009-2019 (quadrillion Btu)												
	2009		2010		2011		2012		2013		2014	
Coal	19,691	21,0%	20,834	21,4%	19,658	20,3%	17,378	18,4%	18,039	18,6%	17,998	18,3%
Natural gas	23,416	25,0%	24,575	25,2%	24,955	25,8%	26,089	27,7%	26,805	27,7%	27,383	27,9%
Petroleum	34,779	37,1%	35,324	36,3%	34,627	35,8%	33,839	35,9%	34,398	35,5%	34,657	35,3%
Nuclear	8,335	8,9%	8,434	8,7%	8,269	8,6%	8,062	8,6%	8,244	8,5%	8,338	8,5%
Renewables	7,608	8,1%	8,267	8,5%	9,204	9,5%	8,847	9,4%	9,451	9,7%	9,740	9,9%
Total	93,829		97,434		96,713		94,215		96,937		98,116	
	2015		2016		2017		2018		2019		Sum of annual ↑↓	
Coal	15,549	16,0%	14,226	14,6%	13,837	14,2%	13,252	13,1%	11,315	11,3%	-51,6%	
Natural gas	28,191	29,0%	28,400	29,2%	28,055	28,8%	31,086	30,8%	32,098	32,1%	32,5%	
Petroleum	35,371	36,4%	35,705	36,8%	36,051	37,0%	36,882	36,5%	36,718	36,7%	5,6%	
Nuclear	8,337	8,6%	8,427	8,7%	8,419	8,6%	8,438	8,4%	8,462	8,5%	1,6%	
Renewables	9,721	10,0%	10,363	10,7%	11,077	11,4%	11,301	11,2%	11,460	11,5%	47,7%	
Total	97,169		97,121		97,439		100,959		100,053		6,7%	

Source : EIA, Monthly Energy review, 2020

Since 2009, Coal hold 21% of U.S primary consupmtion, while in 2019 this index is 11%. Over the last decad, Coal have summary of annual decrease for 51,6%, which means that coal consumption have been droped by almost a half comparing with 2009. Surprisingly, Natural gas consumption has been increased by 8,682 quadrillion British thermal units (sum of annual increase is 32.5%). Petroleum and Nuclear consuption have been droped and rised several times over the last decade, but overall they have both increased by 5,6% and 1,6% respectively. Nevertheless, the biggest increase in U.S. primary consumption is by renewables, which had a stable annual growth (total sum of annual increase gives 47,7%). In 2019 happened the historical moment, when renewabls surpassed coal in primary comsuption. By 2019, there are following U.S primary energy consumption by energy source: petroleum – 36,7%; natural gas – 32,1%; coal – 11,3%; renewable energy – 11,5%; nuclear electric power – 8%.

There is more detailed information concerning renewable energy consumption, which have following shares by 2018 from the highest to lowest: solid fuels – 34%; liquid fuels – 27%; hydropower – 15%; wind – 14%; solar PV – 4%; CSP – 2%; geothermal – 2%; biogas – 1%; renewable waste – 1%. (Note: there is only 2017 and 2018 detailed information regarding renewable energy consumption in U.S from IRENA database).

Table 4 Final renewable energy consumption in the USA

Final Renewable Energy Consumption in the United States of America (TJ)						
	2017	Share in %	2018	Share in %	Difference	Difference in %
Hypropower	953836	17%	931411	15%	-22425	-2%
Wind	811522	14%	869421	14%	57899	7%
Solar PV	212599	4%	256079	4%	43480	20%
CSP	88766	2%	116520	2%	27754	31%
Solid Biofuels	1805208	32%	2095998	34%	290790	16%
Liquid Biofuels	1673121	29%	1641471	27%	-31650	-2%
Biogas	49124	1%	47545	1%	-1579	-3%
Geothermal	70181	1%	103106	2%	32925	47%
Renewable Waste	40808	1%	40669	1%	-139	0%
Total	5705163	100%	6102220	100%	397057	7%

Source: IRENA Renewable Energy Balances Database

Due to the following graph, we can compare renewable energy consumption in 2017 and 2018 in the United States of America. It is cleanly seen that the share of solar PV and CSP have only 4% and 2% respectively of overall energy consumption, but they both have the biggest increase from the previous year after geothermal, while the hydropower, liquid biofuels and biogas have a small decrease in consumption for the same period of time.

4.3 Generation Capacity in US and the World

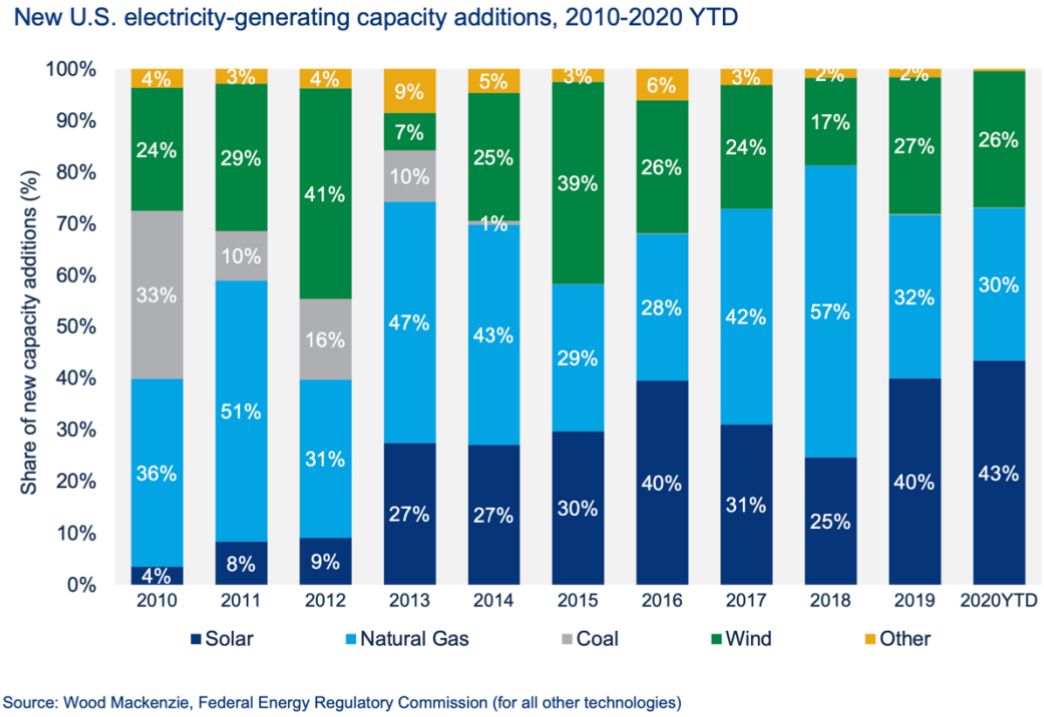
Nowadays the capacity of renewable sources of energy becoming more and more popular, because of economical and environmental aspects. Renewable energy such as wind and solar PV increasing their effectiveness annually. Due to development of technology, solar utility-scale power generation capacity became more cheaper than it was several years ago.

In 2019 we can strongly agree that solar and wind power technologies faces the record of the most lowest cost prices. Every second out of five utility scale solar PV cost less the cheapest new fossil fuels. (Renewable Power Generation Costs in 2019, 2020)

According to Wood Mackenzie we can observe total dominance from renewable sources of energy in electricity-generated capacity additions from 2014. During 2017-2018 we can notice a huge impact of Natural Gas which were 42% and 57% respectively. From 2019 main renewable electricity sources share more or less divided the capacity equally with a 10% advantage of solar

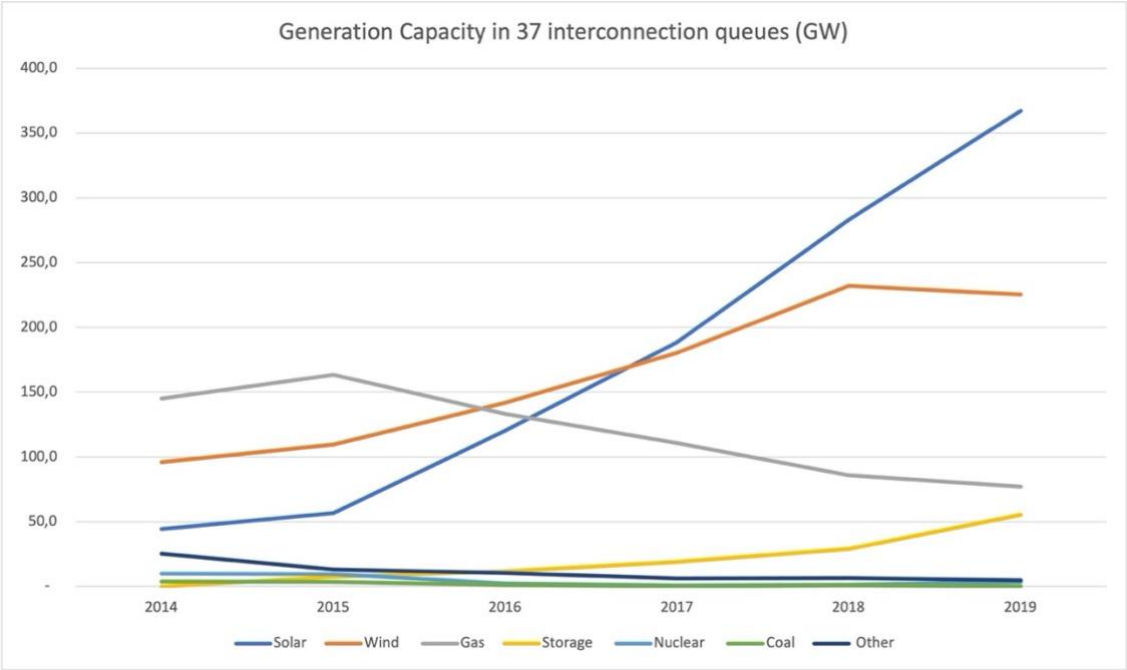
energy. This shows that during the last decade RSE , especially solar energy , mainly substituted coal electricity-generating capacity , which already indicates less than 1%.

Figure 1 U.S. electricity-generating capacity additions



In addition to more detailed analysis, turn to Lawrence Berkeley National Laboratory which provide generation capacity in 37 selected interconnection queues from 2014 to 2019. It is essential to mentioned that collected information provides hybrid generator types (for example Solar PV+ storage , wind + storage and etc.), which means that this data might be undercounted. All of the above only confirms the tendency that fossil fuels have tangible decrease in GW across the US. Gas have fall from 145,1 GW in 2014 to 77,2 GW in year of 2019, while Solar generation capacity have huge increase by the average 55% annually. On the graph below, we obviously notice that the wind capacity has been increased 2,3 times , while the solar capacity has been increased 8,4 times during the same time period of time (from 2014 to 2019).

Figure 2 Generation Capacity in 37 interconnection queues



Source: Lawrence Berkeley National Laboratory

West (non-ISO) is the fastest growing region in Solar generation capacity, including all generator types such as stand-alone and hybrid prior ; stand-alone and hybrid new. By the end of 2019, West (non-ISO) continues to hold a leading position in Solar generation capacity that equals 75,1 GW which is almost 21% of all 37 interconnected queues. The highest percentage of proposed generators hybridizing in 2019 is in California (CAISO) which are 50% for Wind and 67% for Solar. (Bolinger, Seel, Robson and Warner, 2020)

According to IRENA Capacity and Generation database, Germany was a long-term leader in the world for electricity generation of solar energy since 2006 until 2014. China became the first country which was able to surpass Germany on these indicators in 2015. In general, China, Germany and the United States had almost the same indexes in terms of electricity generation in 2015, but after that China become a dominator among everyone. By 2018, China has double difference from the second place, which is United States of America.

4.4 Solar PV system/module growth in USA

According to U.S. Solar Market Insight, we can observe an annual constant growth of total installation in average rate of 43% over the last decade. In 2020 there are more than 88,9 GW of

solar energy installed in USA, which provides electricity to more than 16 million homes across America due to the availability of small private rooftop system or communal utility-scale solar panels. (United States Surpasses 2 Million Solar Installations | SEIA, 2020)

The downward trend in the cost of solar PV modules during 2019 is a historically significant factor in increasing competitiveness. Over the ten years, from December 2009 to December 2019, the cost of crystalline silicon modules in Europe dropped by 87% -92%. The weighted average cost reduction over this period was approximately 90%. From December 2018 to December 2019, the cost of core modular technologies dropped by 14%, reaching $ 0.27 per watt. Costs for the various module types as of December 2019 ranged from US $ 0.21 per watt to US $ 0.38 per watt.

Costs for double-sided modules in December 2019 were 56% higher than the "main" category, and 18% higher than the more expensive mono-face option. Data for 2019 revealed high module costs in the assessed markets. Compared to 2018, the range of costs narrowed both in terms of US $ per watt from US $ 0.52 per watt to US $ 0.32 per watt, and in the ratio of the highest costs to the lowest in the assessed markets (from 2.89 times to 2.35 times). Between 2018 and 2019, the overall cost reduction in the assessed markets ranged from 4% to 30%. Solar PV modules based on the above and other similar types of cell architecture (called double-sided contact cell concepts) made up 60% of the market in 2019 and will continue to dominate in the coming years. That’s why the high efficiency of solar PV modules leads to a reduction in power for a given area. (Renewable Power Generation Costs in 2019, 2020)

Due to the fact that solar PV multi modules prices have decreasing every year, here is a time series for modeling current situation with the price and make a forecast model to understand how prices will be for the end of 2021. All the data presented are taken from GTM and SEIA report and measured in U.S dollar per peak watt. As we can see, there is an obvious tendency in decreasing in module prices every quarter since Q1 2014, but at the beginning of 2017 had reverse course from 0,39 USD/W to 0,48 USD/W by the end of 2017. This happened due to the fact that in 2016 have double difference from 2015 in number of installation of solar PV systems, that’s why solar modules price have been increased because of higher demand and lower supply. Nevertheless, at the end of 2017, everything went back, and prices continue falling. Unfortunately, there is no available open data about multi module prices for Q3 and Q4 of 2020, that’s why it is essential to predict them as well as for the end of 2021.

On the grounds of linear regression model, it is possible to predict what multi modules price will

be from Q3 2020 to Q4 2021. To built multiple linear regression model, we should make following Microsoft Excel file. In order to make future forecast using multiple linear regression equation, we should provide current forecast, to understand the tendency. It's necessary to take coded time from 1 to 26 instead of years (2014 -2020) or quarter (1-4) , because that shows timeline, which is more accurate and easy-to-use in forecast.

Table 5 Matrix Creation

Year	Quarter	Price	Coded Time	Quarter 1	Quarter 2	Quarter 3	Quarter 4
2014	1	0,73	1	1	0	0	0
2014	2	0,73	2	0	1	0	0
2014	3	0,75	3	0	0	1	0
2014	4	0,73	4	0	0	0	1
2015	1	0,72	5	1	0	0	0
2015	2	0,68	6	0	1	0	0
2015	3	0,67	7	0	0	1	0
2015	4	0,65	8	0	0	0	1
2016	1	0,63	9	1	0	0	0
2016	2	0,59	10	0	1	0	0
2016	3	0,49	11	0	0	1	0
2016	4	0,39	12	0	0	0	1
2017	1	0,38	13	1	0	0	0
2017	2	0,4	14	0	1	0	0
2017	3	0,45	15	0	0	1	0
2017	4	0,48	16	0	0	0	1
2018	1	0,47	17	1	0	0	0
2018	2	0,42	18	0	1	0	0
2018	3	0,34	19	0	0	1	0
2018	4	0,34	20	0	0	0	1
2019	1	0,33	21	1	0	0	0
2019	2	0,32	22	0	1	0	0
2019	3	0,29	23	0	0	1	0
2019	4	0,22	24	0	0	0	1
2020	1	0,21	25	1	0	0	0
2020	2	0,19	26	0	1	0	0

Source: Own calculations with data from GTM/SEIA, 2018

To make regression analysis in excel, it's essential to take spot prices as X and coded time including quarter 1,2,3 as Y. Once we made regression analysis, we get several basic matric such as Multiple R, R-Square, Adjusted R-Square and Standard Error.

Table 6 Regression Statistics

Regression Statistics	
Multiple R	0,963210745
R-Square	0,927774938
Adjusted R-Square	0,914017784
Standard Error	0,053565038
Observations	26

Multiple R- is an absolute value of correlation coefficient between 2 variables. In our case r= 0,976, which means that there is a strong relationship between variables X and Y. R-squared is a coefficient of determination, which equals 0,9275, that helps to measure how close the data from the regression trend line. In this particular case, R-squared indicates 92,75% that the regression model explains all the variability of the response data around it's mean. Due to the fact that we have multiple linear regression model, we have to take in consideration Adjusted R-Square instead of R-Square, which indicated 91,4% of variability respond. The Standard Error reflects the average error of regression model. In other words, it shows how wrong our model can be if we are making predictions, which equals 0,0536. Nevertheless, to make a prediction, it have to be a statistically significant model.

Table 7 Regression model coefficients

	Coefficients	*P-value*
Intercept	0,790	0,0000000000000000095
Coded Time	-0,023	0,000000000000194737
Quarter 1	0,004	0,884511512
Quarter 2	0,007	0,806790677
Quarter 3	0,007	0,823161649

Significance F	0,00000000001115

In addition to understand significant level of the regression model, it should be noted the significance F metric above. If F-value is less than $\alpha = 0,05$ (confident interval is 95%), than our model is significant. In our case we have F-value (0,00000000001115) less than $\alpha = 0,05$, which means that our multiple linear regression model is statistically significant. In fact, there is a P-value marked with yellow color, due to the fact that there is statistically significant relationship between dependent variable X (Price) and independent variable Y (coded time), which is $0,000000000000194737 < \alpha = 0,05$. Finally, here is a basic formula for making multiple linear regression equation, where the c is an intercept ; b_1 = coded time; b_2 = quarter 1;

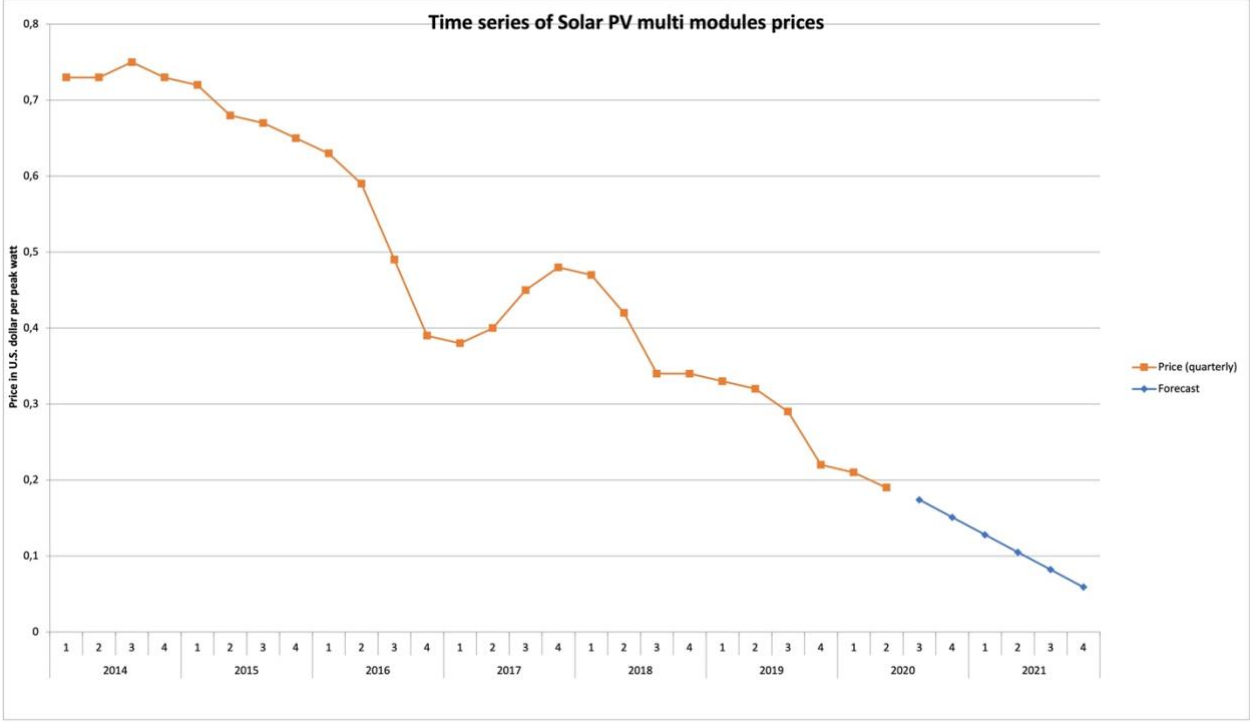
b_3 = quarter 2 ; b_4 = quarter 3.

$$y = c + b_1x_1 + b_2x_2 + .. + b_nx_n$$

$$y = 0{,}790 - 0{,}023x_1 + 0{,}007x_2 + 0{,}007x_3 + 0{,}007x_4$$

As mentioned earlier, we take current forecast coded time from 1 to 26 for years 2014 -2020, but in order to make future forecast from Q3 2020 – Q4 2021, it is necessary to prolong time code from 27 to 32. This number is held in formula as x_1 , while the others x_2 , x_3 , x_4 are 1 or 0. There are following predictions for 2020 - 2021: Q3 2020 – 0,176 USD/W; Q4 2020 – 0,146 USD/W; Q1 2021 – 0,128 USD/W ; Q2 2021 – 0,108 USD/W ; Q3 2021 – 0,084 USD/W ; Q4 2021 – 0,054 USD/W. Overall, now we can built a time series of Solar multi modules spot price graph, which will show how price was decreasing from 2014 and present future forecast.

Figure 3 Time series of Solar PV multi modules prices

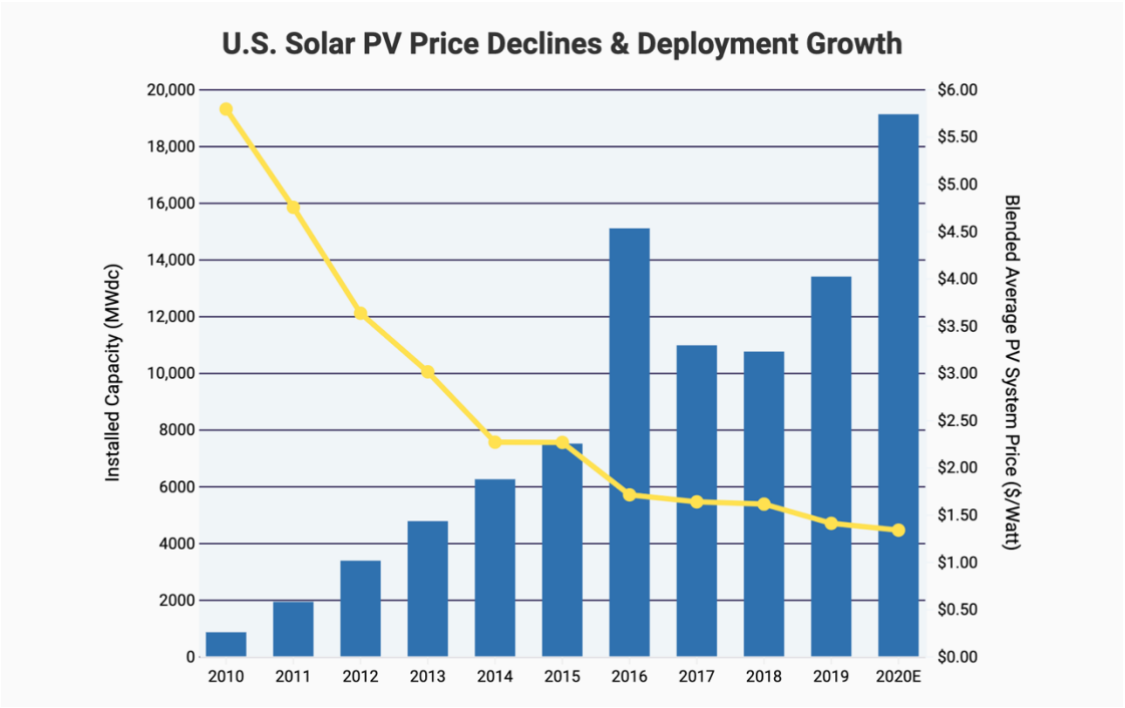


4.5 Installed capacity in U.S.

According to IRENA Capacity and Generation Database, European Union had a leadership in installed capacity of solar energy until 2014, when China started to drive tremendous growth in

solar energy. During 2014 till 2019 China had increase of installed capacity in average by 50% annually, while the United States of America had increase in average by 30% annually during the same period of time.

Figure 4 Solar PV Price Declines & Deployment Growth



Source 2: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight 2020 Q4

It is generally agreed today that solar PV modules have been decreased in cost, which means that it directly connected with the price for Solar PV system. As we can observe in the graph above, there is a repeating pattern in case of reduction the cost over the last decade. At the beginning of 2010 the price for PV system were 5,79 $USD, while in 2020 the price was 1,33 $USD, which is more than 4 times less in only the last decade. During 2010-2014 we may notice a huge jump in price, which was reduced in average by 26,5% annually. Nevertheless, the tendency did not counties as fast as it was until 2016, because the price almost reaches its maximum minimum, that's why it falling in price slower than it was from 2010-2014.

In addition, it is necessary to mentioned relationship between capacity installed and blended average PV solar systems prices. In this case, we will turn to such a statistical analysis as correlation, which equals -08588. We should mention that if correlation coefficient is closer to 1 or -1, the higher dependence between 2 variables. In our case, we have negative perfect correlation (inverse correlation), that can be translated as: the more installation we made, the less price of solar system will be. It can be easily explained by the fact that technology is

permanently improving every year because of increasing in demand.

It is not a secret that high popularization of clean energy in U.S is a consequence of the growth of solar energy in commerce sector. Over the last decade, corporate solar deployment was 15 times worse than nowadays. Slightly less than a half of all corporate solar installation was during 2016 until the end of 2019. Large companies report that COVID-19 did not influenced on delays in installations. It's important to mentioned that all presented data affects only 70% of all commercial solar capacity in USA by the end of 2019. (Solar Means Business | 2019 Repor t | Solar Energy Industries Association, 2019)

Table 8 Corporate solar installations

Top 10 Rankings	
Company	Installed Capacity (MWh)
1. Apple	398,3
2.Amazon	369
3. Walmart	331
4. Target	284,8
5. Google	245,3
6. Kaiser Permanente	181,8
7. Switch	179
8. Prologis	133,7
9. Facebook	119,5
10. Solvay	81,4

Source: SEIA Means of Business 2019

According to SEIA report, Apple take leadership in corporate solar installation for the 2 year in a row since 2018 and have been installed capacity in 398,3 MW. Apple believes that by the end of 2030 their company will manufacturing all products from 75% of renewable energy, meaning they will be eco-friendly, because their plan to become carbon neutral. Nevertheless, to reduce remaining 25% of their footprint, they will develop innovative solutions by 2030. Apple already in cooperation with 70 suppliers who uses 100% renewable sources of energy, which saves 14,3 million metric tons of CO2 emission annually. (Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030, 2020) Walmart take a leadership in numbers of installations, making 331 GW (increased by 120+ GW in 2019). Facebook jumped from 27th to 9th place in just 1 year, making 119,5 GW in 2019, when in 2018 they

produce less than 20 GW. (Solar Means Business | 2019 Report | Solar Energy Industries Association, 2019)

In the process of gaining experience by project developers and development in the supply chain structure markets, there was a decrease in costs, which led to: an increase in the number of markets where PV systems achieve a competitive cost structure; falling global weighted average total installation costs, which occurred in major global markets including United States of America, C hina, India and others. (Renewable Power Generation Costs in 2019, 2020)

4.6 Levelized cost of Electricity (LCOE) and Investment

Due to the fact that we had multi module prices by quarter 1-4, it is necessary to calculate average price for each year , in order to make correlation coefficient to find out relationship between weighted average LCOE and multi modules. There are following multi module average price: 1) 2014 – 0,735 USD/W ; 2) 2015 – 0,680 USD/W ; 3) 2016 – 0,525 USD/W ; 4) 2017 – 0,428 USD/W ; 5) 2018 – 0,393 USD/W ; 6) 2019 – 0,290 USD/W.

Table 9 Residential and commercial sector solar PV LCOE

Residential and commercial sector solar PV levelised cost of electricity											
Secor	Market	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
		2019 USD/kWh									
Residental	California	0,306	0,290	0,253	0,222	0,210	0,213	0,207	0,187	0,179	0,171
	Other US States	0,304	0,280	0,230	0,202	0,203	0,202	0,178	0,162	0,157	0,155
Commercial	Arizona	0,279	0,249	0,222	0,180	0,152	0,162	0,147	0,135	0,120	0,112
	California	0,259	0,251	0,203	0,191	0,156	0,152	0,157	0,150	0,138	0,134
	Massachusetts	0,433	0,397	0,320	0,277	0,264	0,247	0,242	0,210	0,206	0,186
	New York	0,439	0,397	0,337	0,268	0,243	0,227	0,213	0,189	0,181	0,171
Weighted-averege in US		0,202	0,2417	0,2123	0,2161	0,151	0,144	0,134	0,099	0,079	0,067
		Multi modules averege price				0,735	0,680	0,525	0,428	0,393	0,290

Source: IRENA Renewable Cost Database

If we will compare residential LCOE between California and other US states , we will found that the average price over the last decade across the U.S is cheaper than in California (0,207 and 0,224 respectively). In commercial sector, the most friendly market is Arizona with 0,176 USD/kW on average over the last decade. In order to make corelation coefficients, we have to multiply weighted-average LCOE by 1000, because we need to convert kW into W. After that, we have recourse to correlation analysis in Microsoft Excel, which gave us a result of 0,951. This means

that there is a strong positive relationship between decrease in multi modules price and decrease in average solar PV LCOE. This can be explained by the fact that over the last decade was a rapid development of technology , because of huge investments in Solar industry.

It's not a secret, that Solar PV industry developed because of big investment in renewable energy. According to IRENA CPI global finance report , United States have invested around 56 and 69 billions $USD in 2017 and 2018 respectively, which is 2 times more than it was in 2015-2016. Overall, during 2017 and 2018, the United States invested more in renewable energy than the rest of the world on average rate of 19% of global investment. Thanks to FAS, there are following federal investment in renewable energy from 2011-2021: 1) Solar Energy Technology Office (SETO) has total invested 2582,8 millions $USD (average 234,8) ; 2) Water Power Technology Office (WPTO) has total invested 816,8 millions $USD (average 74,3); 3) Wind Energy Technology Office (WETO) has total invested 945,2 millions $USD (average 85,9). That's why, higher investment is one of reason for the rapid growing rate of Solar energy over the last decade.

5. Conclusion

The aim of my bachelor thesis was to evaluate the solar potential in the United States of America. In literature review I focused on development of solar energy in general and what advantages solar energy has comparing with other renewable energy resources. All types of renewable energy resources have a rapid development in U.S. over the last 20 years, but solar energy shows the fastest growing industry in context with others. There is a tendency where non-renewable resources is quietly substituted by renewable resources and it's potential only growing. USA is one of the countries, which aims to achieve net-zero emissions, economywide, by no later than 2050.

In practical part I focused on analysis of several indicators, which positively influenced on solar energy development. Solar energy primary consumption already overtook the coal in 2019. Number of generation and installed capacity increasing every year, due to the decreasing in cost of solar PV systems and their components. Recent cost reductions are associated with streamlining the module manufacturing process and efficiency gains associated with the wider adoption of new types of cell architectures. Cost savings in solar PV module production have also been achieved by reducing the use of diamond wire cut materials, improving production processes, lowering labor costs and increasing the efficiency of modules. Levelized cost of electricity reduction directly connected with solar industry technology development and annual corporate and government investments.

Based on my research and predictions people can understand, how solar energy development influence on U.S. economy and environment. U.S. government with Joe Biden plan to build a modern, sustainable infrastructure and an equitable clean energy future with a $2 trillion accelerated investment, which they plan to deploy those resources over Joe Biden first term. Nevertheless, Fossil fuels are still in use in United States and the World, but America made a huge step into eco-friendly future , where solar energy will revel its potential.

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