CZECH
UNIVERSITY
OF LIFE SCIENCES PRAGUE

Master Thesis
Faculty of Engineering

Perspectives of the photovoltaic energy conversion in Armenia

Sona Grigoryan

Supervisor
Prof. Libra Martin

CULS in Prague 2020

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Engineering

DIPLOMA THESIS ASSIGNMENT

Bc. Sona Grigoryan

Agricultural Specialization
Trade and Business Dealing with Machinery

Thesis title

Perspectives of the photovoltaic energy conversion in Armenia

---

Objectives of thesis

To compare locations in Armenia and in the Czech Republic in terms of installation and operation of photovoltaic power plants based on measured data.
Carry out an economic assessment of the efficiency of photovoltaic power plants in Armenia and in the Czech Republic.
Student should make own conclusions on the further perspective of photovoltaic power plants in the locations surveyed.

Methodology

Data will be collected and evaluated from the PV power plant in Prague and from two PV power plants in Armenia. Based on the available data, the economic calculation will be carried out and the efficiency of PV power plants in the examined locations will be assessed.

The proposed extent of the thesis

50

Keywords

PV power plant, photovoltaics, solar energy

Recommended information sources

Fotovoltaika, ILSA, Praha, 2010
Hallyday, D. a kol., Fyzika, VUTIUM, Brno, 2003
M. Koehl, a kol., Modeling of the nominal operating cell temperature based on outdoor weathering, Sol. Energy Mater. Sol. Cells, 95, (2011), 1638–1646 .
Poulek, V. a kol., Influence of increased temperature on energy production of roof integrated PV panels, Energy & Buildings, 166, (2018) 418–425

Expected date of thesis defence

2019/2020 SS – FE

The Diploma Thesis Supervisor

prof. Ing. Martin Libra, CSc.

Supervising department

Katedra fyziky

Electronic approval: 3. 12. 2018
prof. Ing. Martin Libra, CSc.
Vedoucí katedry

Electronic approval: 15. 2. 2019
doc. Ing. Jiří Mašek, Ph.D.
Dean

Prague on 07. 04. 2020

Sworn declaration:

I declare under oath that I have prepared the thesis at hand independently and without the help of others and that I have not used any other sources and recourses than the ones stated. Parts that have been taken literally or correspondingly from published or unpublished texts or other sources have been labeled as such. This work has not been presented to any examination board in the same or similar form before.

I am aware that by consignment my thesis I agree with thesis's discloser according to the law n. 111/1998 about universities.

I am aware that my thesis will be electronically uploaded in the university system and will be available for reading.

I am aware that for my Master's thesis implements the law n. 121/2000 about copyright.

Date

Signature

Contents

Preface:

This thesis is made as a completion of the master education in Engineering. Yours truly has a bachelor degree in Power Engineering from Technical University of Armenia and this thesis is the product of the master period in Czech University of Life Science.

Several persons have contributed academically, practically and with support to this master thesis. I would therefore firstly like to thank my head supervisor Professor Libra Martin for his time, valuable input and support throughout the entire master period.

Finally I would like to thank my family and friends for being helpful and supportive during my time studying.

Abstract:

The aim of my project is to make a comparison of photovoltaic systems in two different countries. Two of them are Armenia and two systems are is Czech Republic. The comparison will be for different installation, construction and operation possibilities of solar systems. Also the aim is to calaculate the economical part of solar systems for both of the countires.

For that we collected the data about solar irradiation from trustworthy sources for photovoltaic systems of Armenia and Czech Republic and after that we count up the production of energy for the duration of one year under several construtions.

By analyzing the results we can mention that photovoltaic system in Armenia have capability to produce more electricity than PV system in Czech Republic and after calculating the time of energy payback for two countries we can mention, that this is also showing the same behavior. In this case PV system in Armenia is showing the time of energy payback approximately 4-5 years and for Czech Republic that time is around 6-7 years but there is need also to say that exists a difference in time of price payback which is connected with the fact, that both countries have different prices for electricity per kWh.

In Armenia people are paying less as compared to Czech Republic for electricity. So the time of price payback is nearly 2-3 years less in Armenia than in Czech Republic.

1.0 Introduction:

A solar photovoltaic (PV) system converts sunlight into electricity (electrical energy). Heat from the Sun can be used in developing technologies such as photovoltaics, solar thermal energy, solar heating, solar engineering and artificial photosynthesis,

It is an important source of renewable energy and its technologies are generally defined as either passive solar or active solar depending on how solar energy is collected and transmitted or transformed into solar power. The use of photovoltaic systems, concentrated solar power and solar water heating to harness the electricity are active solar techniques. Passive solar strategies include the orientation of a building to the Sun, the selection of materials with desirable thermal mass or light-dispersing properties and the construction of spaces that calculate air naturally.

The vast amount of solar energy available makes it an incredibly attractive power source. In its 2000 World Energy Assessment the United Nations Development Program found that the annual solar energy capacity was 1,575–49,837 exajoules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012.

Photovoltaics (PV), also known as solar photovoltaics, has grown over the last two decades from a mere niche market with small scale applications to becoming a common source of electricity. A solar cell is a device that utilizes the photoelectric effect to transform light directly into electricity.

Concentrating Solar Power (CSP) systems use lenses or mirrors and monitoring systems to focus a large area of sunlight on a small beam. The concentrated heat is then used as a source of heat for a conventional power station.

In this diploma thesis I will try to figure out the potentiality of PV systems in both countries by considering that one of them is in Asia, and the second one in Europe so they have totally dissimilar climatic states. In the other words we will try to figure out information about the energy production, the time of energy payback and the time of price payback.

2.0 Goals and objectives, aim:

The main goal of this project is to make an economical calculations for the PV systems in two countries concerning to the price of electric energy. To get that information, we are going to discuss and compare two different cities in Armenia (Asia) which are Yerevan and Gyumri and two different cities in Czech Republic (Europe) which are Prague and Brno.

In the result we are going to get information about the fact how feasible are the PV systems in Armenia and Czech Republic with the periods of energy and price payback.

2.1 Keywords:

PV system, economics, solar energy, payback time

3.0 Current Status

The photovoltaic (PV) effect was discovered by Edmund Becquerel (1852-1908) in 1839, but it was only in 1954 that Bell Laboratories produced expensive, low-efficiency (initially just 4.5%, later 6%) silicon solar cells, which were first used in 1958 to power the Vanguard 1 satallite, four years later in 1962, Telstar 1, the first commercial telecommunications satellite, had PV cells rated at 14 W, and in 1964 the Numbus satellites carried cells capable of 470 W (Smill 2006). Space appilactions, where cost is not a primary consideration, have been thriving for decades, but land-based uses for electricity generation werelimited by high costs, and the industry began to grow only during the late 1990s. In terms of peak power, just 50 GW of PV cells were shipped in 1990, 17 GW in 2010, and about 50 GW in 2015, when the cumulative capacity reached 227 GW. [1]

There are many ways of expressing how much solar energy falls on the earth. Chris Goodall writes in The Switch that the sun supplies enough power in 90 min to meet the world's total energy needs for a year. [2] In more scientific language, the Earth receives 174 $\times 10^{15}$ W [174 PW (petawatts)] of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% of this is reflected back to space, while the rest is absorbed by the oceans and landmasses and things on the earth. At night this 70% absorbed energy is radiated back into space keeping the earth at a constant temperature. The total solar energy absorbed by the Earth's atmosphere, oceans, and land masses is approximately 3.85×10^{24} J a^{-1} [3.85 YJ a^{-1} (yottajoules per annum)]. [3] Photosynthesis captures less than 0.1% of this, approximately 3.0×10^{21} ZJ a^{-1} (zettajoules per annum), in biomass. The total energy consumption in the world today is less than 0.02% of the total solar energy shining on the earth. Most people in the world live in areas with insolation levels of 150–300 W m^{-2} or 3.5–7.0 kW h m^{-2} d^{-1}, where d refers to day. This magnitude of solar energy available makes it an appealing source of electricity. The United Nations Development Programme in its 2000 World Energy Assessment found that the annual potential of solar energy was between 16 000 and 50 000 $\times 10^{18}$ J (16 000– 50 000 EJ). This is many times larger than the total world energy consumption, which was 559.8 EJ in 2012. [4] Solar energy supplied only 0.45% of the total primary energy consumption in 2015. This is far below traditional forms of energy or other renewable forms of energy. [5] Additionally, solar energy produces 1.5% of all the electricity used globally. Therefore, much work has to be done to realize the suggestion of the International Energy Agency (IEA) that the sun could be the largest source of electricity by 2050, ahead of fossil fuels, wind, hydro, geothermal and nuclear. According to a recent report by IEA, solar PV systems could generate up to 16% of the world's electricity by 2050, while solar thermal electricity (STE) from concentrated solar power (CSP) plants could provide an additional 11%; this will require an early and sustained investment in existing and future solar technologies.

3.1 The importance of solar energy:

The importance of the Sun in sustaining life has probably been known to humans in all ancient societies and many of these people, including the Babylonians, ancient Hindus, Persians, and Egyptians worshipped the sun. From written records, the ancient Greeks were the first to use passive solar designs in their homes and no doubt experimented with harnessing the sun's energy in many different ways. There is a story that, Archimedes in the 2nd century BC reflected the sun's rays from shiny bronze shields to a focal point and was thus able to set fire to enemy ships. The Romans continued the tradition of using the sun in their homes and introduced glass, which allowed the sun's heat to be trapped. The Romans even introduced a law that made it an offence to obscure a neighbor's access to sunlight. By contrast, PV technology (the creation of a voltage by shining light on a substance) and the main focus of this book, is a very recent application. Scientists, as early as 1818, noticed that the electrical conductivity of some materials, such as selenium, increased by a few orders of magnitude when exposed to sunlight; however, it was not until the 1950s that scientists working on transistors at the Bell Telephone Laboratories showed that silicon could be used as an effective solar cell. This very soon led to the use of silicon solar cells in spacecraft; and in 1958, Vanguard 1 was the first satellite to use this new invention. This application paved the way for more research into better and cheaper solar cells. The work was further encouraged after the rapid oil price rise in the 1970s. In 1977, the US Government created the National Renewable Energy Laboratory. A further indication of the rapid rise of silicon solar cell technology was the building of the first solar park in 1982 in

California, which could generate 1 MW; this was followed a year later by a larger Californian solar park, which could generate, at full capacity, 5.2 MW. The United States has now built several PV power plants in the range of 250–550 MW. It is amazing to think that just 34 years after the first solar farm was built in California, China has built a solar farm of 850 MW. Furthermore, the solar PV worldwide generating capacity, at the end of 2016, was in excess of 300 GW. To put this into perspective, 1000 MW (1 GW) is the power generated by a traditional fossil-fueled power station. In January 2017, it was reported that Chinese companies plan to spend US$1 billion building a giant solar farm (of 1 GW) on 2500 ha in the Ukraine. [6]

There are two main types of solar power: solar thermal and solar PV. Solar thermal includes domestic hot water systems, cooking, solar-disinfecting water [7], energy storage—molten salts [8], solar power transport, fuel production, and CSP. The latter involves focusing and tracking the sun's rays using mirrors (usually parabolic troughs or dishes) onto a working fluid, which vaporizes and expands and is used to drive a turbine. The temperature of the working fluid can reach 800°C. The great advantage of CSP is that the sun's energy is converted into heat, which can be readily stored. [6] This is not true for PV systems, because electricity is more difficult to store, although battery technology is rapidly improving. It has been estimated that solar energy could be used to supply up to 70% of household hot water in the United Kingdom and in sunnier climates, providing almost all domestic hot water. Today worldwide solar water heaters are responsible for 435 GW [9]. CSP supplies 5.01 GW electricity globally, this being less than 2% of all electricity supplied by solar energy; Spain is the CSP world leader with 2.5 GW investment followed by the United States (1.9 GW) [9].

Solar PV panels produce electricity directly and can be effective in both, direct, or diffuse cloudy solar radiation, although the systems are obvously more efficient in direct sunlight. Electricity is produced as a result of the sun's energy striking a solar panel (at present usually pure silicon), which causes electrons to be released; these in turn then travel through wires. Until recently, the only solar panels (wafers) available were made of pure silicon (99.9999 purity), which is both costly and energy-intensive to manufacture. Recent research into wafer technology has produced a range of new solar wafers, which include materials, such as cadmium telluride interesting alloys of copper indium and gallium and more recently perovskites. Some of these involve elements, which are in short supply; and some involve elements, which are toxic, for example, cadmium. Silicon wafers have improved significantly over the past 2 decades and the efficiency is of the order of 20%. Furthermore, with mass production, the price of silicon wafers has decreased enormously. A recent report by Fraunhofer stated that in Germany, in 1990, the price for a typical rooftop system of 10–100 kW_p PV, was around 14 € $(kW_p)^{-1}$. At the end of 2016, such systems cost about 1.3 € $(kW_p)^{-1}$. The growth in PV manufacturing has been driven by government incentives where, for example, in countries, such as the UK, Germany, Spain, and Australia the cost of electricity and technological innovation is subsidized. Under such schemes a premium tariff is paid for PV-generated electricity that is fed into the grid. This premium can be several times higher than the normal tariff paid for fossil-fuel-generated electricity.

This has led to the establishment of a large number of wind farms, as well as many rooftop PV systems for individual houses. [6]

All substances, solid bodies as well as liquids and gases above the absolute zero temperature, emit energy in the form of electromagnetic waves. The radiation that is important to solar energy applications is that emitted by the sun within the ultraviolet, visible, and infrared regions. Therefore, the radiation wavelength that is important to solar energy applications is between 0.15 and 3.0 μm. The wavelengths in the visible region lie between 0.38 and 0.72 μm. This section initially examines issues related to thermal radiation, which includes basic concepts, radiation from real surfaces, and radiation exchanges between two surfaces. This is followed by the variation of extraterrestrial radiation, atmospheric attenuation, terrestrial irradiation, and total radiation received on sloped surfaces. [10]

Energy that human beings are using on the Earth can be ranged as: (i) renewable energy sources and (ii) nonrenewable energy sources.

1.(i) **Renewable energy sources:** These are the energy sources that are derived from natural sources that replenish themselves over short periods of time. These resources include the Sun, wind, moving water, organic plant and waste material (biomass), and the Earth’s heat (geothermal). These resources are also called nonconventional sources of energy. This renewable energy sources can be used to generate electricity as well as for other applications. For example, biomass may be used as a boiler fuel to generate steam heat; solar energy may be used to heat water or for passive space heating; and landfill methane gas can be used for heating or cooking.

2.(ii) **Nonrenewable energy sources:** These are the energy sources that are derived from finite and static stocks of energy. It cannot be produced, grown, generated or used on a scale that can sustain its consumption rate. These resources often exist in a fixed amount and are consumed much faster than nature can create them. Examples of these types of resources are fossil fuels such as coal, petroleum, and natural gas and nuclear power (uranium). Due to its exhaustibility in nature, these types of energy resources are sometimes also called conventional sources of energy. [11]

There are 6 sources of energy which people bring into service on the planet. These sources are mentioned below:

(i) the Sun (thermal and electric);
(ii) nuclear energy from nuclear reactions on the Earth;
(iii) chemical energy from reactions among mineral sources;
(iv) the gravitational potential and planetary motion among Sun, Moon and Earth;
(v) fossil fuels such as coal, petroleum products and natural gases (thermal and electric); and
(vi) geothermal energy from cooling, chemical reactions and radioactive decay in the Earth (thermal and electric);

Renewable energy is obtained from sources (i), (ii) and (iii), whereas nonrenewable energy is derived from sources (iv), (v) and (vi). [11]

Solar irradiance is connected with climate conditions and it changes throughout the day and the year, and in different places it is different.

Therefore, one important factor to consider when choosing the best solar panel type for exact situation is the prevailing climate conditions at exact location.

Performance parameters of solar panels are given under STC conditions (25°C cell temperature), and any deviation from those conditions determines the amount of the pertaining losses.

The definition of STC conditions reveals the main factor contributing to the production losses:

- Temperature conditions
- Any deviation in respect to irradiance level of 1000 W/m², corresponding to a common sunny day.

One of the most overlooked parameters is the influence of irradiance levels on solar panel productivity. Usually, the lower the level of irradiance with respect to 1000 W/m², the lower the solar cell efficiency.

We can expect lower irradiance levels early in the morning, on a cloudy day or during winter. Surprisingly, amorphous silicon thin-film solar modules, which are considered a lower grade and a cheaper version of the mono- and polycrystalline solar panels, emonstrate better performance in lower irradiance conditions than more expensive crystalline solar panels.

Therefore, the solar panel type that could be the best fit for exact solar project should always be carefully chosen by weighing the pros against the cons of the aforementioned factors and parameters. [12]

Now information about batteries. Batteries are devices capable of producing and storing DC electricity. In photovoltaic systems, batteries are used to replace the photovoltaic generator:

- At night
- During cloudy weather
- When the PV array is disconnected for repair and maintenance works

A battery cell is a container that is usually filled with a diluted acid used as an electrolyte, with two plates (of positive and negative polarity) immersed into it. Such a battery cell is called a ‘wet cell.’ There are also ‘dry cells’ that do not contain a liquid electrolyte. Battery cells, connected together, form a battery. Batteries, connected together, form a battery bank. The ability of a battery to store DC electricity is called ‘capacity’ and is measured in amperes-hours (Amps-hours, Ah).

After DC electricity is stored in a battery, it can later be rendered as DC voltage. [13]

To truly appreciate PV, it helps to have an understanding of where the technology came from, where it is at now, and where it is going. The operating principles for modern PV cells were first discovered in 1839 by a French physicist named A.E. Becquerel. After that, a number of scientists played with and improved on Becquerel’s original discovery. In the 1950s, Bell Labs created the first piece of PV technology designed for use in space. This technology soon found its way back down to earth for use in telecommunications applications in remote areas. In the 1970s and 1980s, people began using PV modules to charge batteries and then used those batteries to run various lights and appliances in their remote homes. These early PV pioneers helped set the stage for today's PV industry. The first PV cells were not very efficient or widely used outside of space programs. They were also quite costly. Yet over the years, researchers and manufacturing companies increased efficiencies and reliability and managed to drive down costs drastically. All of these contributions have led to the widespread use of solar modules and their availability to you and me. In the following sections, we will describe some common PV applications, a few brief pros and cons of PV systems, and the future of the PV industry. [14]

3.2 PV systems applications

Modern PV systems can be found in a wide variety of applications. They power calculators, pump water, help offset the energy used by floodlights along highways, and, of course, power homes and businesses. For all of us, electricity is available nearly everywhere we go, and PV systems are able to integrate with the existing utility grid. In remote, developing areas, PV systems provide valuable energy for powering lighting systems, running refrigerators, and helping deliver clean drinking water. PV systems have some serious advantages on their side. Producing electricity from the sun has environmental benefits because the power source is an abundant renewable resource that is available every day (even though PV systems are not as effective during cloudy weather, they still produce a little amount of power on those days). PV is also a highly adaptable power source. We can use individual cells to power small electronics and individual panels to power specific loads. You can build small arrays to power homes, or you can build utility-scale projects to send massive amounts of power into the utility grid. And after PV systems are installed, they can provide many years of clean, reliable power at virtually any location on earth. On homes and businesses connected to the utility, PV systems are considered distributed generation, a power source that produces electricity close to the location where the power is used. They are able to offset the requirements on the central power plants sending out the electricity most people use. PV systems are not the right answer for all applications. They have some disadvantages too. For example: The sun is not a continuous power source. At night, the PV modules can not produce power, so in some scenarios, you have to use a method to store the energy for later use (adding cost and complexity to the system design and installation). The amount of area required to produce power is large in comparison to other sources of power. For large-scale projects, significant portions of land or roof space are necessary. Not every homeowner or business owner has access to such space. [14]

During cloudy conditions, nighttime, or when PV modules may be covered or shaded by snow or dust, it helps to have the capability for storing solar electricity that was not under demand in real time when the PV modules were illuminated by the Sun and generating solar electricity. Without storage of the excess solar electricity for use at nighttime, and so forth, one default may be to resort to fossil or biofuel power plants (e.g., natural gas, biogas, combined-cycle) to provide electricity when PV is not producing. Other options could be hydroelectric power plants, geothermal power plants, wind turbines, or fuel cells. Undoubtedly, the topic of solar electricity storage itself requires an entire book to extract any reasonable level of comprehension. Nonetheless, there are two possible ways to store the excess energy generated from solar photovoltaic. The excess PV-generated electricity may be used to operate an electrically powered pump or reversible water turbine that pumps water from a lower elevation lake or reservoir (or even a river) to a higher elevation lake or reservoir, thereby increasing the potential energy of the water. When demand for electricity arises, the water in the upper reservoir is allowed to flow downhill through a water turbine (e.g., Francis or Kaplan turbine) such that the kinetic energy of the flowing water is converted to electricity via a generator (driven by the water turbine) in a process known as hydroelectric pumped storage. It should be pointed out that in many regions of the world where solar photovoltaic modules are, or will be, installed, there simply is no convenient option of using hydroelectric pumped storage to begin with. Also, just because pumped hydro storage could be used, damming rivers to create reservoirs often has a number of adverse consequences (such as displacing people from their homes, submerging historically and architecturally significant sites, or destroying habitat for fish and other wildlife and flora). Moreover, in areas with extensive and extended draught, hydroelectric pumped storage may not be advantageous to begin with. Alternatively, the excess PV-generated energy may be used to charge rechargeable batteries that may then be discharged when electricity is needed. Of course here, as with the precious semiconductor material in the solar photovoltaic cells themselves, attention to raw material abundance and allocation should be taken into consideration upon any decision to scale up the mass production of an enormous quantity of batteries. [15] About this we have mentioned in the chapter 3.1.

Once a curiosity, solar electric systems are becoming commonplace throughout the world. While many solar electric systems are being installed to provide electricity to homes, they are also being installed on schools, small businesses, office buildings, and even skyscrapers, like 4 Times Square in New York City, home of NASDAQ. Many large corporations such as Microsoft, Toyota, and Google have also installed large solar electric systems. More and more electric utilities are installing large PV arrays to supplement conventional sources. Even colleges are getting in on the act. Colorado College installed a large solar system on one of its dormitories. And over the years, several airports have installed large solar arrays to help meet their needs. At Sacramento’s airport, for instance, PVs were built to create parking structures that shade vehicles during the day while also generating electricity. Denver International Airport installed a 2000 kW solar electric system in 2008, and it has greatly expanded its system since then. On a smaller scale, ranchers often install solar electric systems to power electric fences to contain cattle and other livestock. Many have installed small solar systems to pump water for their stock, saving huge amounts of money on installation. Solar electricity is also used to power remote monitoring stations that collect data on rainfall, temperature, and seismic activity. PVs allow scientists to transmit data back to their labs from remote sites, like the tropical rain forests of South America. Stream flow monitors on many rivers and streams throughout the world rely on solar-powered transmitters to beam data to solar-powered satellites. In the United States, this data is then beamed back to Earth to the US Geological Survey, where it is processed and disseminated. Solar electric modules often power lights on buoys, vital for nighttime navigation on large rivers like the Saint Lawrence Seaway. Railroad signals and aircraft warning beacons are also often solar-powered. PV modules are used to boost radio, television, and telephone signals. Signals from these sources are often transmitted over long distances. For successful transmission, however, they must be periodically amplified at relay towers. The towers are often situated in inaccessible locations, far from power lines. Because they are reliable and require little, if any, maintenance, PV systems are ideal for such applications. They make it possible for us to communicate across long distances. Next time during a long-distance telephone call from a phone on a landline, rest assured solar energy is making it possible. While PV systems are becoming very popular in more developed countries, they are also widely used in the developing world. They are for example being installed in remote villages in less developed countries to power lights and computers and the refrigerators and freezers used to store vaccines and other medicine. They are also used to power water pumps. The ultimate in remote and mobile applications, however, has to be the satellite. Virtually all military and telecommunications satellites are powered by solar electricity, as is the International Space Station. [16]

The United States has been promoting solar energy development through a combination of federal tax credits, state-level renewable purchase obligations, and up-front subsidies. It implemented the Solar America Initiative (2007– 2009) aimed at making PV-generated electricity cost-competitive with conventional electricity sources by 2015. Finally, Japan has been promoting solar installations through up-front capital subsidies. In 2009, it introduced a net model FIT scheme, which paid owners of grid-connected solar power systems a premium rate for surplus electricity generated. A number of countries in Asia and the Pacific are confronted with very high costs of energy production. For example, the price of electricity in the smaller islands of Indonesia, Maldives, and the Philippines, as well as Pacific island countries, is exceptionally high due to the distributed nature of the demand. This necessitates the use of diesel-based generators that make power very costly. Solar energy development provides an excellent opportunity to replace expensive fossil fuels in situations where the demand is remote and distributed, and where grid development and centralized generation are not possible. As scale increases, new supply chains and business models will develop, and suppliers will attain the needed critical mass. Subsequently, equipment costs will decline, enhancing the attractiveness of solar energy production and reinforcing the above-mentioned opportunities. [17]

Development of solar photovoltaic systems is vital for the significant uplift of the rural poor in the developing countries, as these systems hold the most promise for supplementing their daily energy needs. Seventy-five percent of India’s population live in villages and 50% of them in inaccessible villages. Most of the energy needs of the rural population for drinking water, irrigation, home electrification, community needs and village industries can be met by photovoltaic systems. Decentralized PV power systems, which have the advantage of being modular, free from pollution and maintenance problems, will be convenient for use in villages, without dependence on outside agencies, for daily power needs. Cost calculations show that even at the present manufacturing cost of Rs 150 (US $20) per peak watt in India, the PV battery charging systems are cost effective for satellite TV-Mass

Education/Entertainment Programme, village telephones and Adult Education Centres. Further, PV power will become cost competitive with diesel power for drinking water supply at a price level of Rs 60 (US $8) per peak watt (targeted price of 1985 in India). Esimates show that there exists a good possibility to realize these cost goals in five years time.

Under the sponsorship of the Department of Science & Technology (DST) of the Government of India, Central Electronics Limited (CEL) has successfully set up an infrastructure for the fabrication of PV cells and modules, and has used these modules to install several PV systems in the past three years. Encouraged by the progress made so far by CEL, and in order to fulfil its objectives of national solar energy programme, the DST has further sponsored CEL to set up a production capacity of 1.2 MW/year of photovoltaic modules/ systems and also to study techno-socio-economic feasibility of such decentralized power systems under actual field conditions. Such an infrastructure is expected to be completed by 1985 at a cost goal of RS 30 (US $4) per peak watt. A socio-economic study of various decentralized PV systems will be carried out in approximately 2000 villages. It is expected that such PV systems will not only provide minimum energy to village population or daily energy needs but will also help in improving living standards, productivity and per-capita income. [18]

Armenia has very high potential for solar energy, many years of Research and Development (R&D) experience in solar thermal and Photovoltaic (PV) applications, but is in the early stage of its broad commercial utilization.

Armenia is rich in solar energy resources, the utilization of which will reduce the need for imports of other energy sources. The average annual solar radiation is approximately 1,720 kWh/m^2 compared to the average annual European solar radiation of 1,000 kWh/m^2. Over a quarter of the territory of the country has solar resources with an intensity of 1,850 kWh/m^2 (according to the Ministry of Energy Infrastructures and Natural Resources of Armenia.

3.3 Concentrating Solar Power

Concentrating solar power (CSP) is a complementary technology to the solar photovoltaic process. It uses concentrating collectors to provide high temperature heat to a conventional power cycle. Efficient and low-cost thermal energy storage technologies can be integrated into CSP systems, allowing electricity production according to the demand profile. CSP systems can also avoid ‘shadow plant capacity’ needed to secure generation capacity in periods without sunshine or wind, can provide grid services, and if desired even black start capabilities. It thus supports the penetration of a high share of intermittent renewable sources like wind or PV and avoids a high share of expensive electric storage technology in the grid systems. The first commercial implementation of CSP technology began in 2007 in Spain and the United States. Today, a capacity of 3 GW is in operation and another 2 GW is under construction worldwide. Further developments, in particular in the Middle East and North Africa but also in South Africa, India and China, are under consideration. This chapter summarises the principle, the technical requirements and the different technological concepts of CSP systems. It briefly reports on the state of the art of today’s solar power plants including the current cost of solar electricity. In addition, the most relevant aspects for future cost reductions are highlighted. Furthermore, the worldwide potential impact of this technology, to 2050, is discussed, together with comments on the option of high-voltage direct current transmission allowing electricity to be transported from countries in the Sunbelt to densely populated areas in the developed countries. Concentrating Solar Power systems use high temperature heat from concentrating solar collectors to generate power in a conventional power cycle instead of – or in addition to – burning fossil fuel. Only direct radiation can be concentrated in optical systems. In order to achieve significant concentration factors sun-tracking is required during the day, involving a certain amount of maintenance. Therefore, the concept is most suitable for centralised power production, where maintenance can be performed efficiently, and in areas with high direct solar radiation levels. The concentration of sunlight is achieved by mirrors directing the sunlight onto a heat exchanger (receiver/absorber) where the absorbed energy is transferred to a heat transfer fluid (HTF). Due to their high reflectivity, low cost and excellent outdoor durability glass mirrors have become widely accepted in practice as concentrating collectors. A variety of different CSP concepts exist in which the HTF is either used directly in the power cycle (steam/gas) or circulated in an intermediate secondary cycle (e.g. as thermal oil or molten salt), in which case an additional heat transfer to the power cycle is required. CSP systems can also be distinguished by the arrangement of their concentrator mirrors: line focussing systems like parabolic troughs only require single-axis tracking in order to concentrate the solar radiation onto an absorber tube. In practice concentration factors of up to 100 can be achieved. Point focusing systems like parabolic dish concentrators or central receiver systems using a large number of individually tracking heliostats to concentrate the solar radiation onto a receiver located on the top of a central tower – can achieve concentration factors of several thousand at the expense of two-axis tracking. [19]

With the decreasing cost of PV, it became obvious that CSP could not compete in the markets without its main advantage, i.e., providing power on demand using thermal storage. Today, the majority of new plants are designed with sufficient storage capacities to deliver power during evening and night time, and thus filling the gaps that PV and wind energy may not be able to cover. Storage also has a positive effect on the levelized cost of electricity due to an increased capacity factor which makes the technology more competitive. Most of the new installed commercial power plants use the concept of heat either a synthetic oil or molten salt with the solar field and store part of the energy delivered from the field in a molten salt storage. When using synthetic oil as an HTF part of the energy delivered by the solar field is used to generate steam for the turbine throughout the sunny hours, while the other part is stored after a heat exchange in a molten salt tank allowing power generation during clouds or nights. In tower systems molten salt may directly be used as HTF eliminating the need for the additional heat exchange. The hot salt is directly stored in in tank system. [20]

3.4 Economics:

Economics are an important indicator of how practical a solution will be. Economics, costs and returns on investment will generally dictate which form of power generation people ultimately use. Like it or not, it is the profit driven in charge of power generation, and there is very little we can do. So if a green solution is to be widely utilized by these companies, a strong economic case for such solutions must be made. Additionally, the major energy users in the 21st century will be newly industrializing countries and nations with fast growing economies. Economic prosperity will top their priority list, not the environment. Hence, it is important to have economically feasible and environmentally sustainable energy solutions made available to them. Otherwise they will burn dirty fossil fuels (mainly coal) by default. To the common man, power plants costing more translate into higher electricity bills and if the government is serious about energy subsides, it probably means that you are paying for the subsidies through taxes. In any case, the everyday person should be concerned about the economics and costs of energy choices made because it will eventually affect their bill and tax payments. [21]

Lots of people think that solar power is a 20th century invention.

Few know that the first photovoltaic cells joined the grid on a New York City rooftop in 1881; or that engineers in France used solar power to run steam engines in 1860s; or that in 1901 an ostrich farmer in Southern California used a solar engine with a massive 33-1/2 foot mirrored dish to irrigate 300 acres of trees by pumping 1,400 gallons of water every minute from a reservoir using nothing but the power of the sun. [22]

Solar is no doubt one of the most environmentally friendly power sources we have. It is no surprise why environmentalists and politicians are so excited about it. [21]

Solar is growing fast. In 2014, global solar capacity grew 28.7 percent over the previous year and has more than quadrupled in the past four years. This is an astounding rate of growth: if it were to continue, solar would become the world's dominant source of electricity by 2024. Remarkably in the United States solar power is currently growing faster than coal - not just in percentage terms but in absolute numbers: for 2014, the U.S. increase in coal consumption amounted to 4.6 TWh (terawatt-hour), while solar added 23 TWh.

Even in China, solar is expanding quickly, while coal consumption is hardly growing at all or even starting to taper off (owing to a substantial slowdown in industrial consumption). Solar has spectacular growth is occurring for several reasons, but perhaps the most significant driver has been the fall in prices for new solar capacity as compared to costs for coal and natural gas. The price drop is most apparent in the case of solar: the price of photovoltaic cells has fallen by 99 percent over the past twenty-five years, and the trend continues. In a 2014 report, Deutsche Bank solar industry analyst Vishal Shah forecast that solar will reach “grid parity” in 36 of 50 U.S. states by 2016, and in most of the world by 2017 (grid parity is defined as the point where the price for PV electricity is competitive with the retail price for grid power). The fall in PV prices is being driven by two factors: improvements in technology (both in manufacturing methods and in PV materials), and increased scale of manufacturing. Manufacturing scale improvements have resulted largely from the Chinese government's decision in 2009 to support widespread deployment of PV, which in turn has led to a spate of price cutting across the industry as well as a global flood of cheap panels-though some characterize China's actions as product dumping or unfair competition, with many American and European manufacturers having gone bankrupt due to their inability to match Chinese prices. [23]

For proving the economic feasibility and the need for buying or building a solar panel system, you need to make a techno-economic assessment. Such an evaluation should consider the expected price of the grid electricity in the future within the period of the guaranteed solar electric system lifecycle. The analysis should also account for any potential incomes from other possible investment options. The evaluation should provide you with enough data to compare the overall net income of your investment in a solar photovoltaic system to other alternative options for investing your money, by taking into account:

- The price of the solar hardware,
- The installation costs,
- The annual maintenance cost, and
- The generated 'free' solar energy offsetting these expenses.

By assessing how much you can save from your electricity bills, you can make an informed decision on whether it is worth investing in solar electricity, or your money would be better invested in other financial instruments, i.e., stocks, bonds, real estate, or other. A techno-economic assessment helps you find out the total solar power you need to install, the area you need to mount your solar panels, which solar panels to choose based on the available roof area, and your budget. Once you have chosen the type of solar panels, you should determine how many panels you need and the overall system cost. Then you should get:

- The solar energy production costs,
- How much you can save by installing a photovoltaic system over its guaranteed life cycle, and
- The payback period of your system.

A techno-economic evaluation proves the reason for your solar invested money by considering:

- The startup system cost,

•The annual maintenance cost,

•The cost of solar-generated electricity,

•The rate of rising grid electricity prices and grid electricity cost savings,

•The costs of getting connected to the grid, and

•The payback period of the system. [24]

4.0 Methodology:

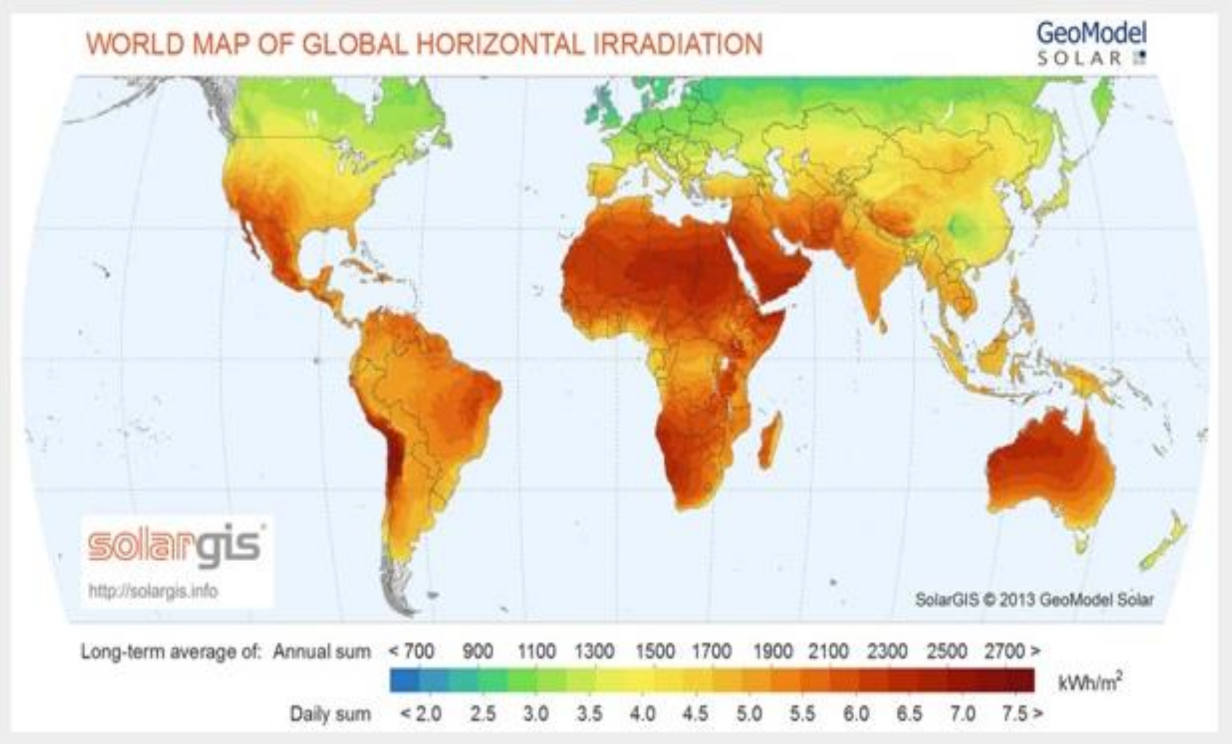
The leading, profitable and beneficial technology such as photovoltaic is used in countries where the average amount of sunny days are higher. World map of global horizontal (Fig. 1) displays the average annual amount of the data collected for several years.

Dark red colors in the map specify those locations which are more appropriate for photovoltaic systems installations. The conflict is in the fact, that without electricity are those areas which have the highest irradiance position and condition. Meanwhile PV is growing in all the countries of Europe, where the isolation situation are not even near to be ideal and there are more suitable energy sources. The key factor why solar is so acceptable and profitable in Europe are the governments encouragements and stimulations, beneficial tarrifs that guaranteed the solar energy's purchasing price for more than 20 years.

It is concentious that a government with a dominance only for several years can make such kind of longterm decision.

It is arguable that a government with an authority for a few years can responsibly make such kind of long term decision.

Fig.1. World map of global horizontal irradiation



Nonetheless, the marketplace of solar power is based in countries with support of governments, discounts, and easy funding options. We need to mention, that EU is still the biggest leader in this region with the help of the most benficial legal permissions and financial incentives. In 2012 the total amount from installed solar photovoltaic generation measurments was 68.64 GW meanwhile in the world total amont of the same year was 120 GW.

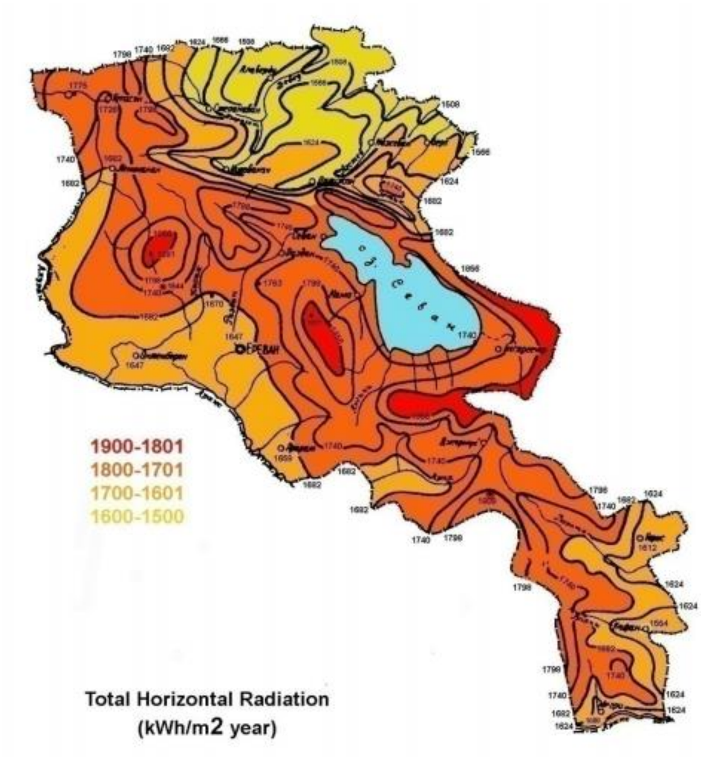
4.1 Armenia:

The Armenian Republic is situated in the South of the Trancaucasus, It borders at the North and East on the Georgian and Azerbaijan and at the East and South - East on Turkey and Iran. The territory of Armenia occupies 29.8 thou. m^2, its population is approximately three mil. people. The capital of Armenia is Yerevan with a population about one mil and the second city is Gyumri with less population. Armenia is a republic distinguished by a developed industry and highly - productive agriculture. The scientists of various institues of the Armenian Academy of Science and other republican research institutes participate in the development of all branched of the modern science, in working out scientific and technical problems brought forward by the national economy of Armenia.

The main power resources of the republic are represented by water power resources and now also by solar power. Potential water power resouces are estimated at 21.8 billion kWh, of which economically profitable for utilization are 6 bllion kWh.

Without a change in the linkage between Gross Domestic Product (GDP) and energy, projections of total world consumption of energy indicate an increase of 49% from 2007 to 2035. The United States Energy Information Administration (EIA) estimates, under their reference case, that the worldwide use of energy will increase 1.4% each year. While projections indicate an increased need for all types of energy, shifting economics may result in a change in the content of the portfolio. Demand for electricity in Armenia has not been growing but is dependent on an old partially disabled nuclear power plant and on increasingly costly imported natural gas. So there is interest in developing indigenous solar and wind resources for energy security and long term economic reasons. The economics of solar PV are continuing to improve. The price of PV modules has been decreasing, following a learning curve of approximately 20% for over 30 years. In 2010, modules were selling for less than $2/watt. As the price is reduced, niche markets (in outer space and off-grid) have expanded into broader markets (rooftop and power plant). Over the past 3 decades, every time the cumulative average PV production doubles, the cost of a PV module is reduced by 20%. PV installations are continuing to grow in both strong and weak global economies. Technical performance of the PV modules is continuing to improve. According to the International Energy Agency (IEA), typical commercial flat-plate module efficiencies are expected to increase from 16% in 2010 to 25% in 2030, with the potential of increasing up to 40% in 2050. Several countries have a long history of supporting the advancement of photovoltaics. The resulting electricity price will be competitive with utility power at $0.05-0.06/kWh. It is estimated that by 2030, 14% of the U.S.'s power will be generated from solar PV. In 2008, about 90% of installations were roof top, residential, commercial and industrial. Flat plate PV integrates well into buildings. The International Energy Agency (IEA) projects that in 2050, residential and commercial rooftop installations will still be about 60% of a much larger market.

Fig.2. Global Horizontal in Armenia



Integrating PV into roofs and facades can increase the economies of the system by offsetting the costing of other building materials, assuring that an unobstructed roof or facade is available, load bearing elements of the building a properly designed from the beginning and the buildings electrical system is organized to accommodate solar PV. This approach may allow technical and financial synergies leading to attractive returns. Distributed PV power generation can improve grid reliability.

Having small and large generators dispersed around a geographic region can lead to a stronger power network, making it less susceptible to natural, economic and human risks. In the event a generator is disrupted or a major transmission line fails, many small solar generators can feed power into the distribution system. This may not supply all of the loads but may be able to serve critical loads, keeping vital functions operating until power can be restored. Armenia has a good solar resource, but low electricity prices and relatively higher cost of PV has delayed its deployment (global horizontal in Armenia see in the fig.2). With changes in the regulatory process and allowing a tariff structured for limited technology demonstration projects, groundwork can be laid for the eventual commercial use of this abundant resource in Armenia. [25]

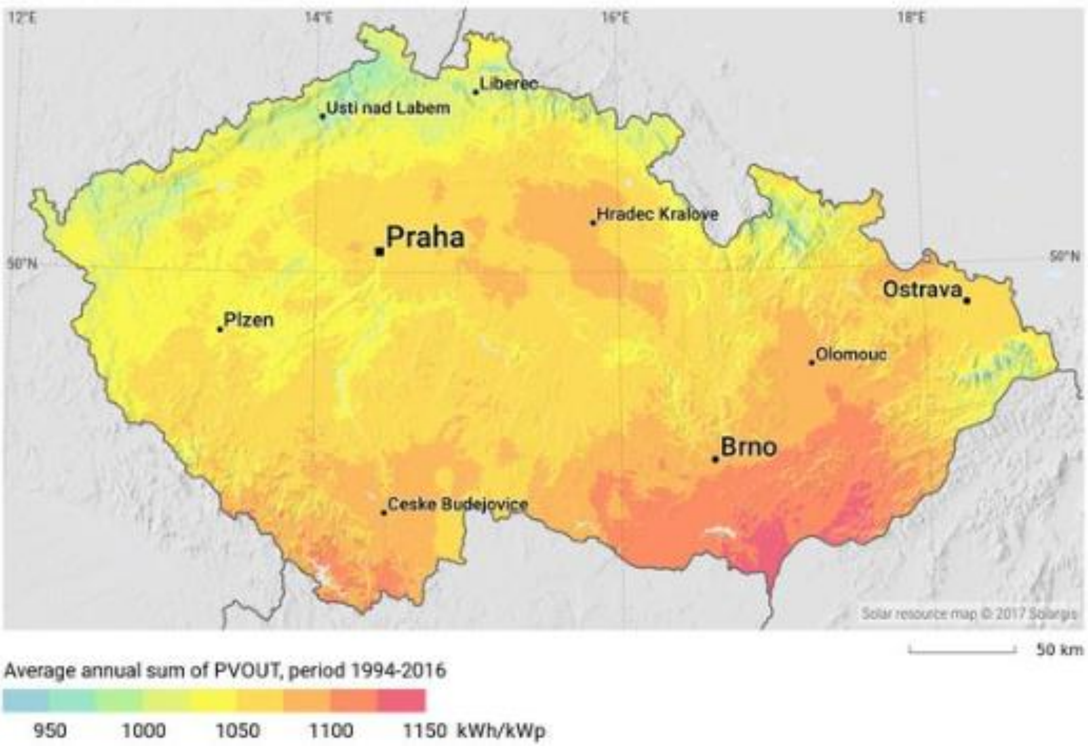
4.2 Czech Republic:

The Czech Republic is a landlocked country in Central Europe bordered by Slovakia to the southeast, Poland to the northeast, Germany to the west and Austria to the south. The Czech Republic has an area of 78,866 km^2 with an oceanic climate and mostly temperate continental climate. Central European republic, with 10.7 million inhabitants. The capital city is Prague, which is also the largest one, with 1.3 million residents. Other major cities are Brno, Ostrava, Olomouc.

The Czech Republic has over 2000 MW of installed PV capacity. Since 2010, additions to the Czech Republic’s solar power sector have been small. The Government's decision to reduce its subsidies by 25% is based on the fact that its national solar target of 1 695 MW was already achieved by the country that year. The Czech Republic was one of the two countries in the European Union to reach its “National renewable energy action

Plan" ten years in advance of the target date. Photovoltaic power potential Czech Republic is shown in the figure 3.

Fig.3. Photovoltaic power potential Czech Republic



The Czech Republic has a potential market of 241 MW annually and therefore should easily achieve 4 000 MW of solar capacity by 2020.

The residential sector counts for over 60% of the installed capacity. In 2012 out of the 113MW of solar capacity added to the national grid, more than 50MW was added in the commercial sector and no large or utility scale plants were added. About 56MW of residential solar was also added to the grid in 2012. In 2011 total installed PV capacity was about 10% of the total, but PV contribution to total electricity generated in the country in the same year was only 3%.

The Czech Republic has a target of generating 13.5% of total electricity by 2020 from renewables.

4.3 Data compilation:

We collect the data[1] concerning to solar irradiation from two cities of Armenia (including Yerevan and Gyumri) and the data about solar irradiation of Prague Czech Republic. We compare the data of Czech Republic and Armenia and draw separate graphs to identify the contrast between two countries.

After that we computed the energy output of 3 kW_p PV system per city with various types of construction including inclined at a fixed optimum angle, fixed flat panel (horizontally) and one at adjusted angle for the duration of year according to winter and summer season by the following formula.

$$E = A * r * H * PR$$

Where:

E is the energy output for a given system (in kWh),

A is solar panel's total area (in m^2),

r is the yield of solar panel (in %),

H is the average solar irradiation on panel during one year, take into concediration, that shadings are not included,

PR is the performance ratio, the coefficient of losses mainly ranges from 0.5 to 0.9 so we pick the 0.75 (we can say, this is a fairly chosen value).

While calculating the energy output of photovoltaic system we consider these losses

Inverter losses = 8%

Temperature losses = 8%

DC cable losses = 2%

AC cable losses = 2%

Shadings = 3 %
Losses due to dust, snow etc. = 2 % [26]

---

[1] *http://www.solarelectricityhandbook.com/solar-irradiance.html*

We calculate the cost of PV system including battery, panel, inverter for two countries. After we figured out the information concerning to the average price of grid connected supply electricity per kWh for both of the countries including Czech Republic and Armenia. Afterwards we do comparison (the cost of PV system with the price of energy output) to determine the money payback period in years. To determine the energy balance period in years we compare the energy input to the photovoltaic system with the energy output. To see the results more evidently we will see the upshot by graphs.

5.0 Results:

We collect the data about solar irradiation for two cities of Czech Republic and Armenia and then we draw table for each of the city specifically (table 1, 2, 3, 4).

Table 1.Solar irradiation in Yerevan for south direction (kWh/m^2*month)

Month	**Horizontally fixed plate**	**At optimal year round angle 50°**	**The angle is adjusted year round**	**Optimal angle for each month (in degrees °)**
Jan	31*2.03=**62.93**	31*3.44=**106.64**	31*3.64=**112.84**	43
Feb	29*2.83=**82.07**	29*4.08=**118.32**	29*4.17=**120.93**	40
Mar	31*3.81=**118.11**	31*4.59=**142.29**	31*4.59=**142.29**	32
Apr	30*4.67=**140.1**	30*4.77=**143.1**	30*4.93=**147.9**	24
May	31*5.64=**174.84**	31*5.21=**161.51**	31*5.59=**173.29**	16
Jun	30*6.69=**200.7**	30*5.87=**176.1**	30*6.72=**201.6**	8
Jul	31*6.69=**207.39**	31*6=**186**	31*6.54=**202.74**	16
Aug	31*6.01=**186.31**	31*5.94=**184.14**	31*6.26=**194.06**	24
Sep	30*4.88=**146.4**	30*5.71=**171.3**	30*5.71=**171.3**	32
Oct	31*3.5=**108.5**	31*4.94=**153.14**	31*5.01=**155.31**	40
Nov	30*2.28=**68.4**	30*3.74=**112.2**	30*3.93=**117.9**	48
Dec	31*1.7=**52.7**	31*2.99=**92.69**	31*3.22=**99.82**	56
TOTAL amount	**1548.45**	**1747.43**	**1839,98**	

Table 2. Solar irradiation in Gyumri for south direction (kWh/m^2*month)

Month	**Horizontally fixed Plate**	**At optimal year round angle 49°**	**The angle is adjusted year round**	**Optimal angle for each month (in degrees °)**
Jan	31*2.12=**65.72**	31*3.72=**115.32**	31*3.97=**123.07**	40
Feb	29*3.02=**84.56**	29*4.5=**130.5**	29*4.62=**133.98**	38
Mar	31*4.02=**124.62**	31*4.94=**153.14**	31*4.94=**153.14**	30
Apr	30*4.8=**144**	30*4.95=**148.5**	30*5.1=**153**	22
May	31*5.61=**173.91**	31*5.2=**161.2**	31*5.58=**172.98**	14
Jun	30*6.85= **205.5**	30*5.96=**178.8**	30*6.86=**205.8**	6
Jul	31*6.81=**211.11**	31*6.13=**190.03**	31*6.67=**206.77**	14
Aug	31*6.14=**190.34**	31*6.1=**189.1**	31*6.42=**199.02**	22
Sep	30*4.97=**149.1**	30*5.87=**176.1**	30*5.87=**176.1**	30
Oct	31*3.5=**108.5**	31*4.99=**154.69**	31*5.07=**157.17**	38
Nov	30*2.32=**69.6**	30*3.86=**115.8**	30*4.07=**122.1**	46
Dec	31*1.74=**53.94**	31*3.14=**97.34**	31*3.41=**105.71**	54
TOTAL amout	**1580.9**	**1810.52**	**1909.14**	

The result of comparing of flat plate solar irradiations for two cities of Armenia (Yerevan, Gyumri) at horizontally fixed plate (fig. 4), at fixed optimal inclination (fig.5) and for the angle, which is adjusted round year (fig. 6) are demonstrated down below. Annual average solar irradiation's comparison for two cities of Armenia is drown in the fig.7.

Fig.4 Comparison of solar irradiation for two cities of Armenia (Yerevan, Gyumri) at horizontally fixed plate

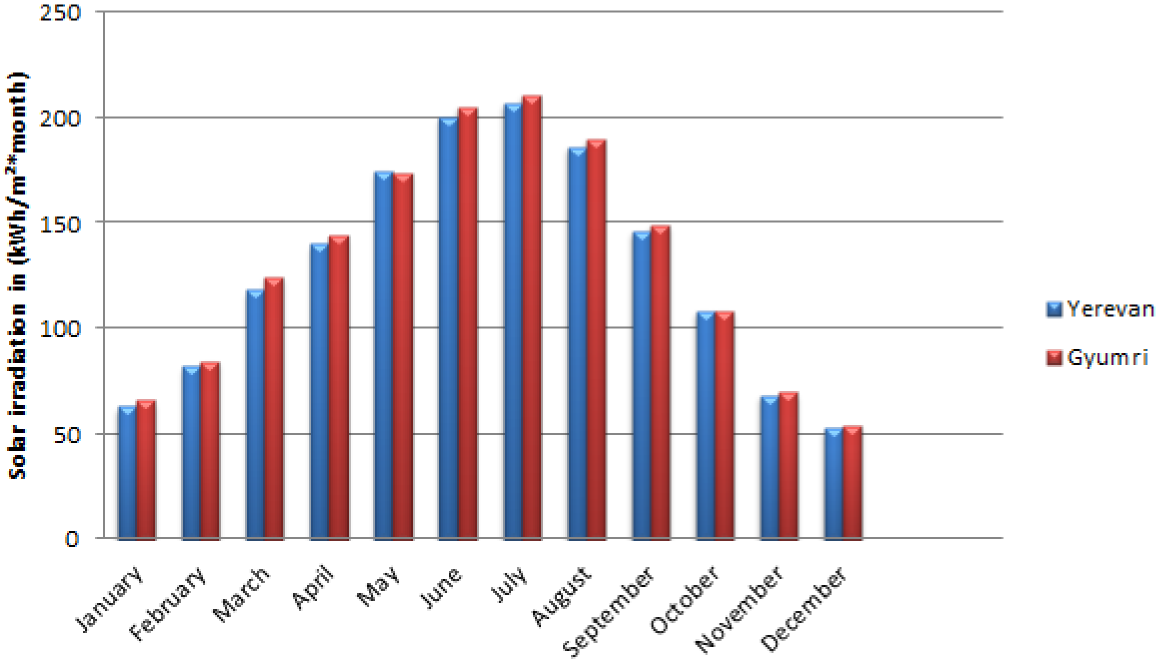


Fig.5. Comparison of solar irradiation at optimal round year angle for two cities of Armenia (Yerevan, Gyumri)

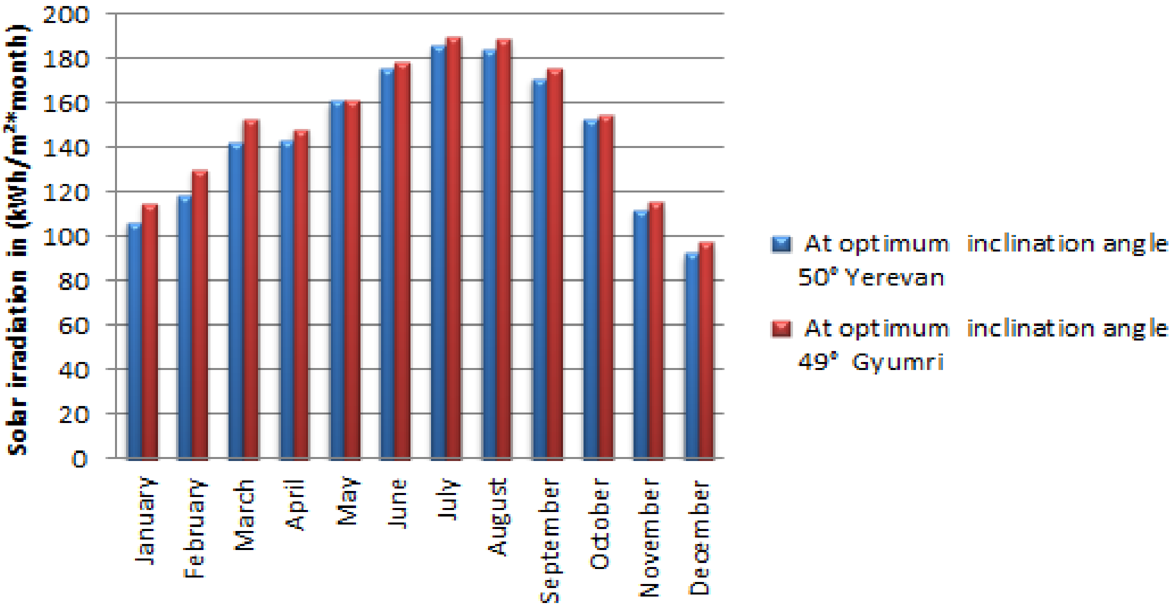


Fig.6. Comparison of solar irradiation for the angle, which is adjusted round year for two cities of Armenia (Yerevan, Gyumri)

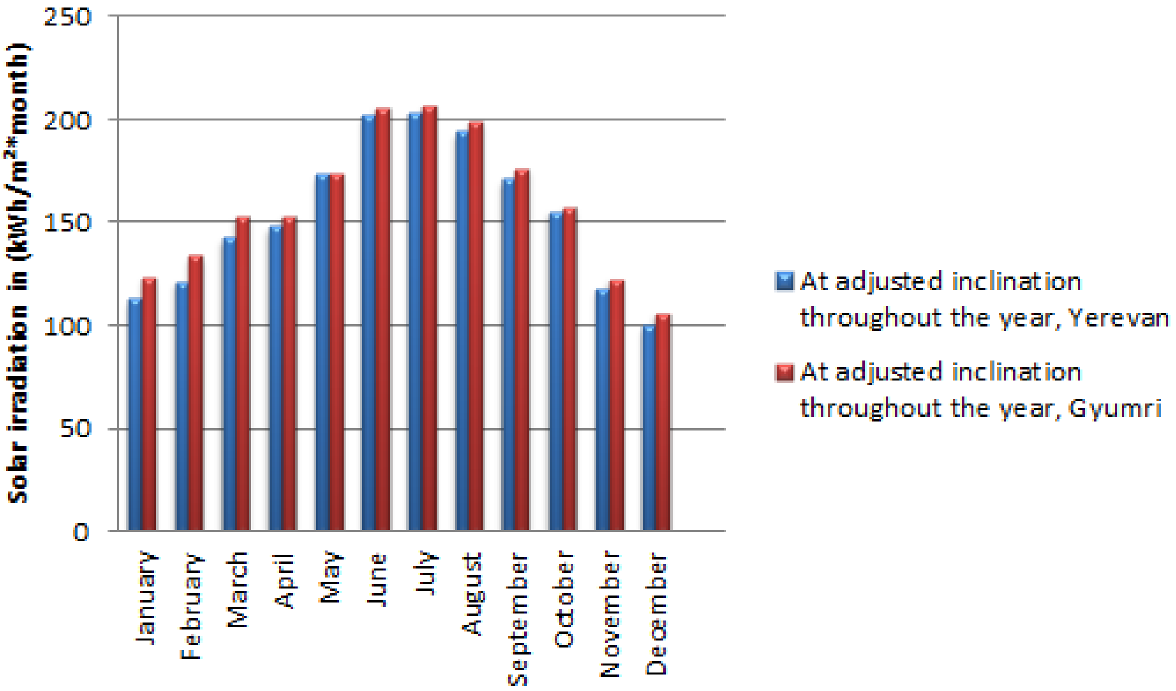


Fig.7. Annual average solar irradiation's comparison of for two cities of Armenia

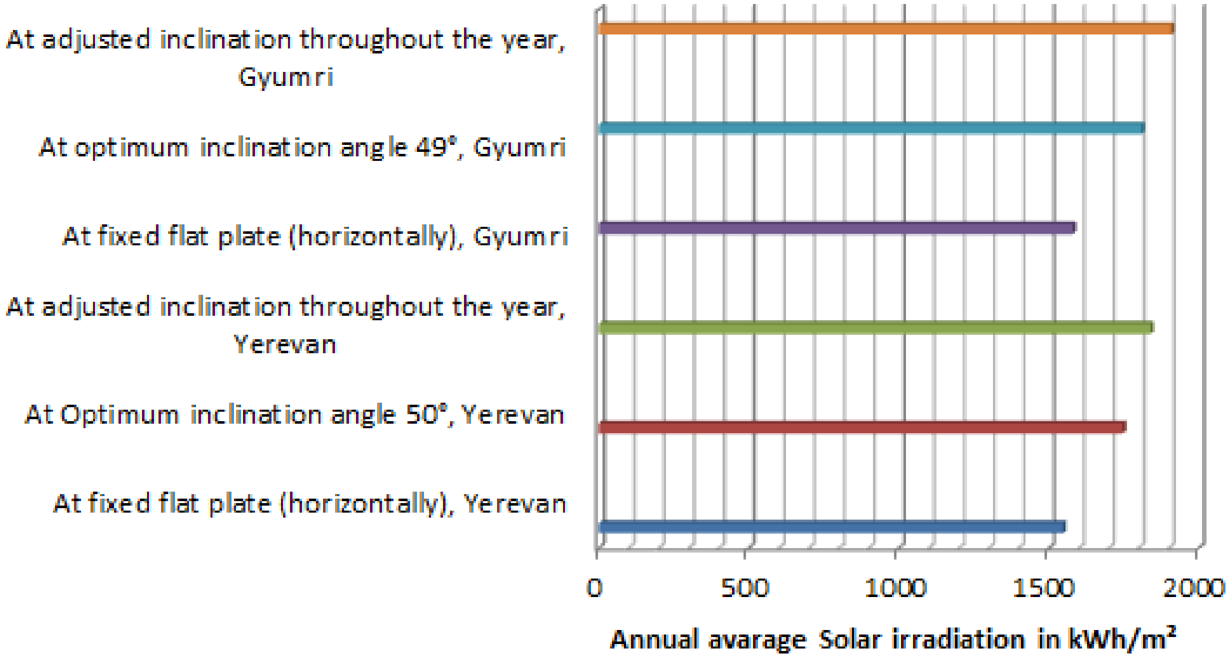


Table 3. Solar irradiation in Prague for south direction (kWh/m^2*month)

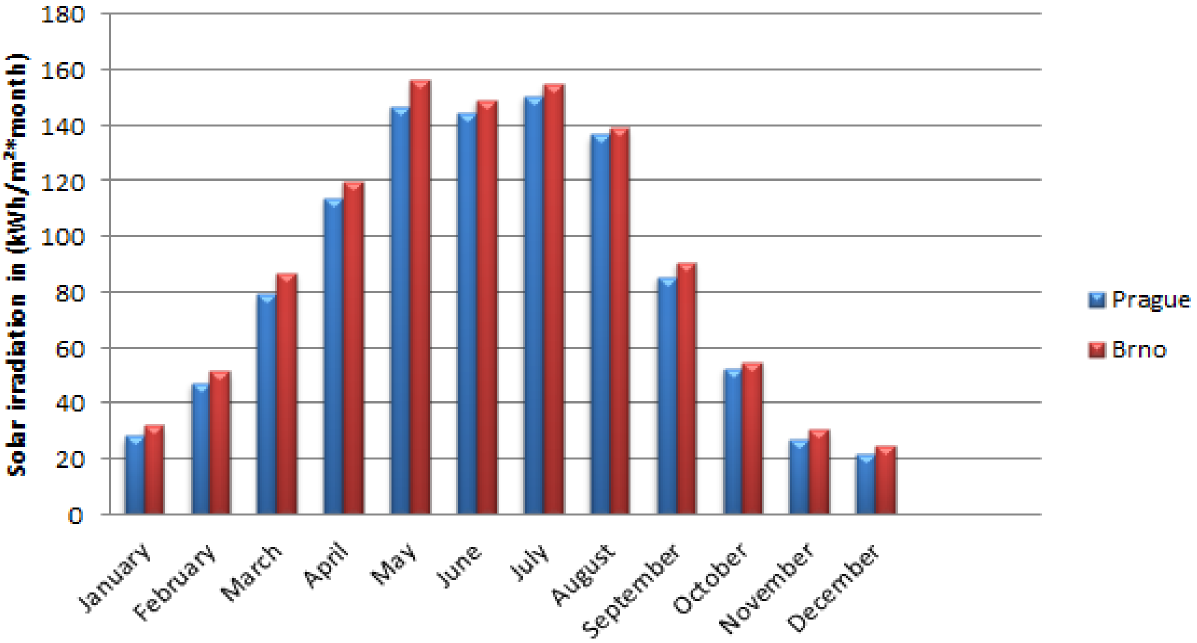
Month	**Horizontally fixed flat plate**	**At optimal year round angle 35°**	**The angle is adjusted year round**	**Optimal angle for each month (degrees °)**
Jan	31*0.92=**28.52**	31*1.58=**48.98**	31*1.62=**50.22**	66
Feb	29*1.7=**47.6**	29*2.56=**71.68**	29*2.58=**72.24**	58
Mar	31*2.56=**79.36**	31*3.09=**95.79**	31*3.09=**95.79**	50
Apr	30*3.81=**114.3**	30*3.93=**117.9**	30*4.12=**123.6**	42
May	31*4.74=**146.94**	31*4.3=**133.3**	31*4.66=**144.46**	34
Jun	30*4.81=**144.3**	30*4.15=1**24.5**	30*4.86=**145.8**	26
Jul	31*4.86=**150.66**	31*4.28=**132.68**	31*4.69=**145.39**	34
Aug	31*4.42=**137.02**	31*4.38=**135.78**	31*4.69=**145.39**	42
Sep	30*2.86=**85.8**	30*3.28=**98.4**	30*3.28=**98.4**	50
Oct	31*1.7=**52.7**	31*2.38=**73.78**	31*2.38=**73.718**	58
Nov	30*0.91=**27.3**	30*1.42=**42.6**	30*1.43=**42.9**	66
Dec	31*0.7=**21.7**	31*1.23=**38.13**	31*1.27=**39.37**	74
TOTAL amount	**1036.2**	**1113.52**	**1177.34**	

Table 4. Solar irradiation in Brno for south direction (kWh/m^2*month)

Month	**Horizontally fixed flat plate**	**At optimal year round angle 35°**	**The angle is adjusted year round**	**Optimal angle for each month (degrees °)**
Jan	31*1.04=**32.24**	31*1.78=**55.18**	31*1.83=**56.73**	65
Feb	29*1.85=**51.8**	29*2.78=**77.84**	29*2.8=**78.4**	57
Mar	31*2.81=**87.11**	31*3.42=**106.02**	31*3.42=**106.02**	49
Apr	30*4.01=**120.3**	30*4.15=**124.5**	30*4.35=**130.5**	41
May	31*5.05=**156.55**	31*4.61=**142.91**	31*4.98=**154.38**	33
Jun	30*4.98=**149.4**	30*4.3=**129**	30*5.03=**150.9**	26
Jul	31*5=**155**	31*4.41=**136.71**	31*4.83=**149.73**	33
Aug	31*4.49=**139.19**	31*4.45=**137.95**	31*4.76=**147.56**	41

Sep	30*3.03=**90.9**	30*3.48=**104.4**	30*3.48=**104.4**	49
Oct	31*1.78=**55.18**	31*2.47=**76.57**	31*2.47=**76.57**	57
Nov	30*1.02=**30.6**	30*1.59=**47.7**	30*1.61=**48.3**	65
Dec	31*0.81=**25.11**	31*1.41=**43.71**	31*1.46=**45.26**	72
TOTAL amount	**1093.38**	**1182.49**	**1248.75**	

Fig.8 Comparison of solar irradiation for two cities of Czech Replubic (Prague, Brno) at horizontally fixed plate



The result of comparing of flat plate solar irradiations for two cities of Czech Republic (Prague, Brno) at horizontally fixed plate (fig. 8), at fixed optimal inclination (fig.9) and for the angle, which is adjusted round year (fig. 10) are demonstrated down below. Annual average solar irradiation's comparison for two cities of Czech Republic is drown in the fig.10.

Fig. 9 Comparison of solar irradiation at optimal round year angle for two cities of Czech Republic (Prague, Brno)

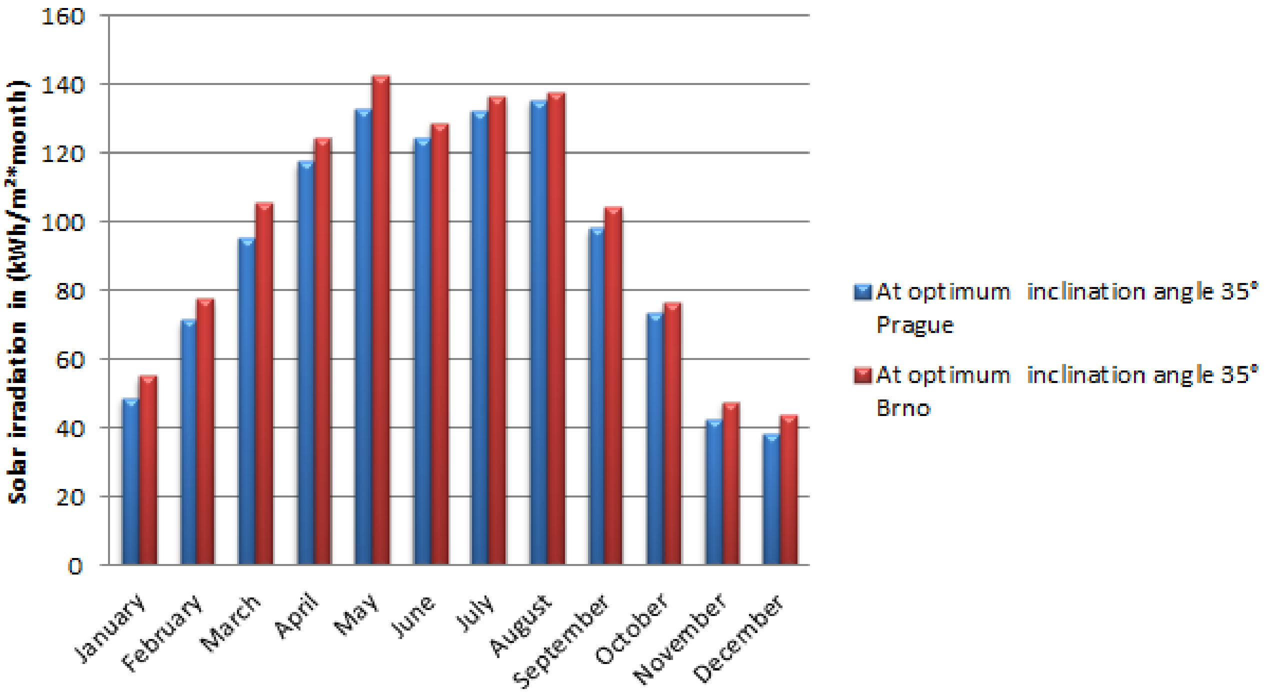


Fig.10. Comparison of solar irradiation for the angle, which is adjusted round year for two cities of Czech Republic (Prague, Brno)

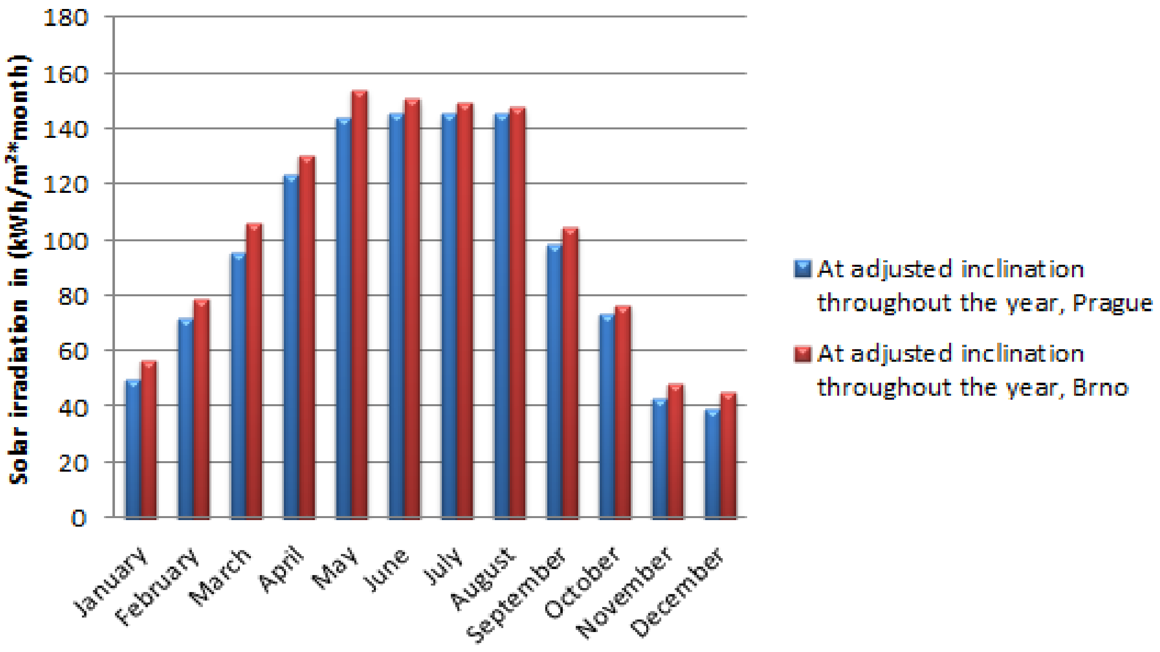
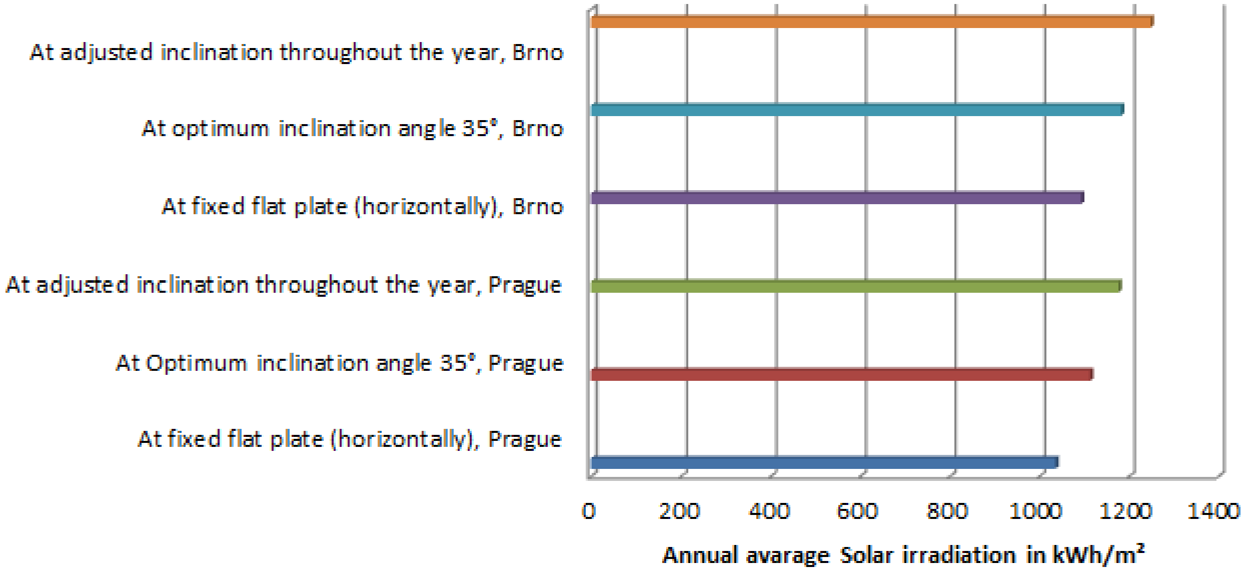


Fig.11. Annual average solar irradiation's comparison of for two cities of Czech Republic



5.1 Production of energy:

3 kW_p photovoltaic (PV) system's energy output for Yerevan (table 5) and for Gyumri (table 6) are shown down below.

Table 5. 3 kW_p *photovoltaic (PV) system's energy output for Yerevan* (kWh/month)

Month	**Horizontally fixed flat plate**	**At optimal year round angle 50°**	**The angle is adjusted year round**
Jan	141.6	239.9	253.9
Feb	184.7	266.2	272.1
Mar	265.7	320.2	320.2
Apr	315.2	322	332.8
May	393.4	363.4	390
Jun	451.6	396.2	453.6
Jul	466.6	418.5	456.2
Aug	419.2	414.3	436.6
Sep	329.4	385.4	385.4
Oct	244.1	344.6	349.4

Nov	153.9	252.5	265.3
Dec	118.6	208.6	224.6
TOTAL amount	3484	3932	4140

Fig. 12. 3 kW_P *photovoltaic (PV) system's electricity production for Yerevan*

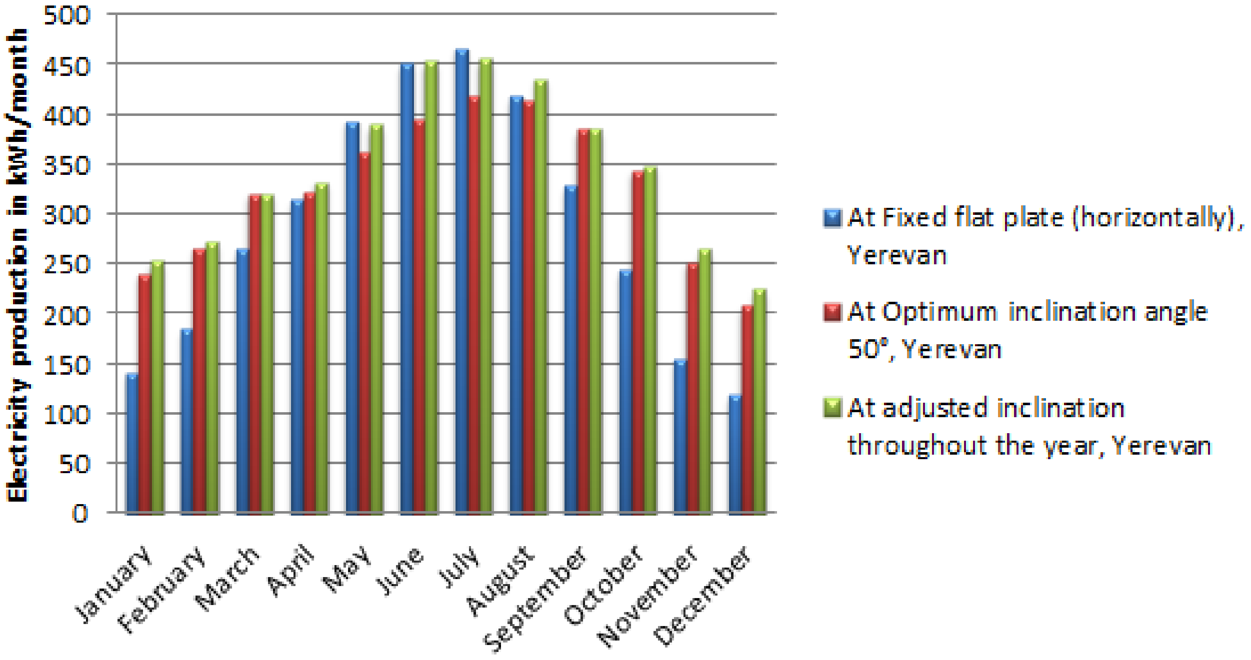


Table 6. 3 kW_P *photovoltaic (PV) system's energy output for Gyumri* (kWh/month)

Month	**Horizontally fixed flat plate**	**At optimal year round angle 49°**	**The angle is adjusted year round**
Jan	147.9	259.5	276.9
Feb	190.3	293.6	301.5
Mar	280.4	344.6	344.6
Apr	324	334.1	344.3
May	391.3	362.7	389.2
Jun	462.4	402.3	463.1
Jul	475	427.6	465.2
Aug	428.3	425.5	447.8
Sep	335.5	396.2	396.2

Oct	244.1	348.1	353.6
Nov	156.6	260.6	274.7
Dec	121.4	219	237.8
TOTAL amount	3557	4073.7	4294.9

Fig. 13. 3 kW$_P$ *photovoltaic (PV) system's electricity production for Gyumri*

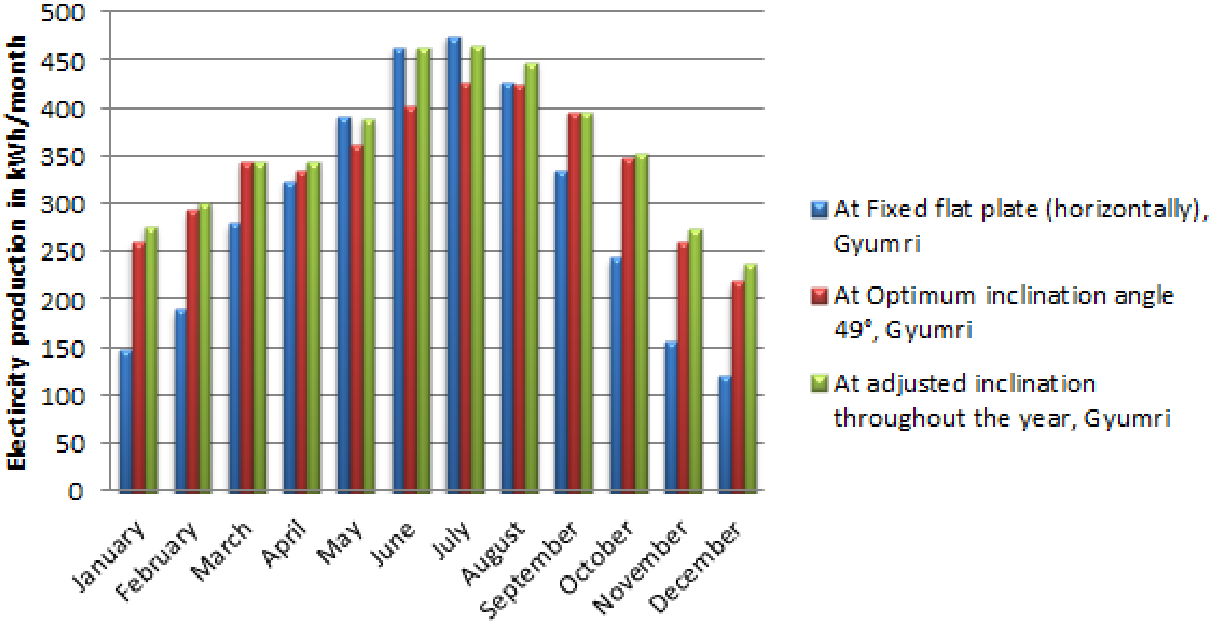
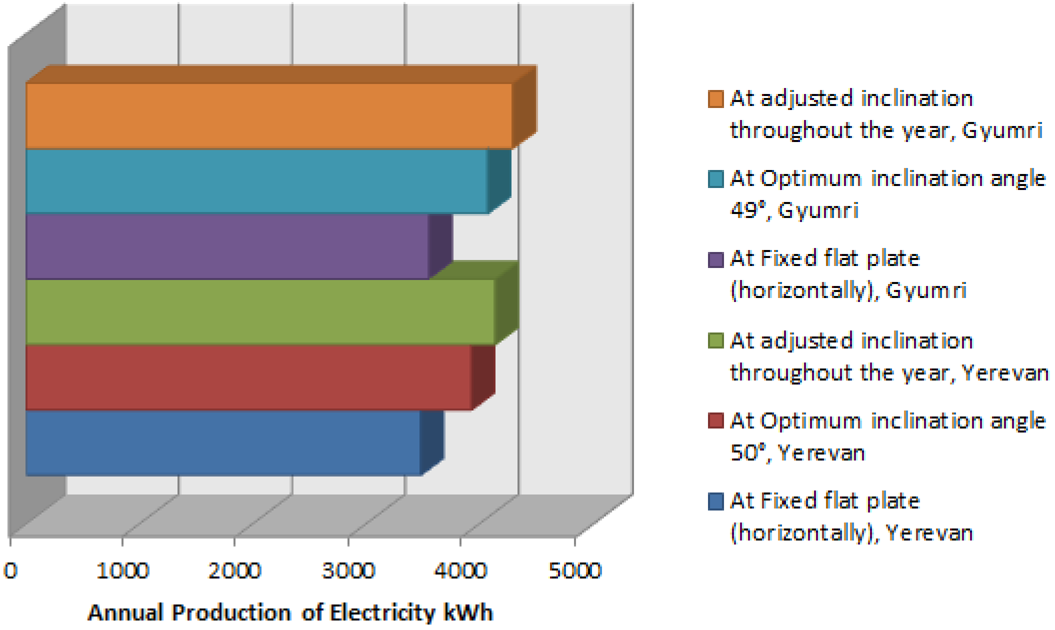


Fig. 14. Production of electricity by 3 kW$_P$ *photovoltaic system throughout the year in two cities of Armenia*



Information about the electricity production of 3 kW_p photovoltaic (PV) system in Yerevan is demonstrated in the fig. 12, Gyumri's results are in the fig. 13. Production of electricity by 3 kW_p photovoltaic system throughout the year in two cities of Armenia is drown in the fig. 14.

Table 7. 3 kW_p *photovoltaic system's energy output for Prague* (kWh/month)

Month	**Horizontally fixed flat plate**	**At optimal year round angle 35°**	**The angle is adjusted year round**
Jan	64.2	110.2	113
Feb	107	161.3	162.5
Mar	178.6	215.5	215.5
Apr	257.2	265.3	278.1
May	330.6	299.9	325
Jun	324.7	280.1	328.1
Jul	339	298.5	327.1
Aug	308.3	305.5	327.1
Sep	193.1	221.4	221.4
Oct	118.6	166	166
Nov	61.4	95.9	96.53
Dec	48.8	85.8	88.6
TOTAL amount	2331.5	2505.4	2649

Fig15. 3 kW$_P$ *photovoltaic (PV) system's electricity production for Prague*

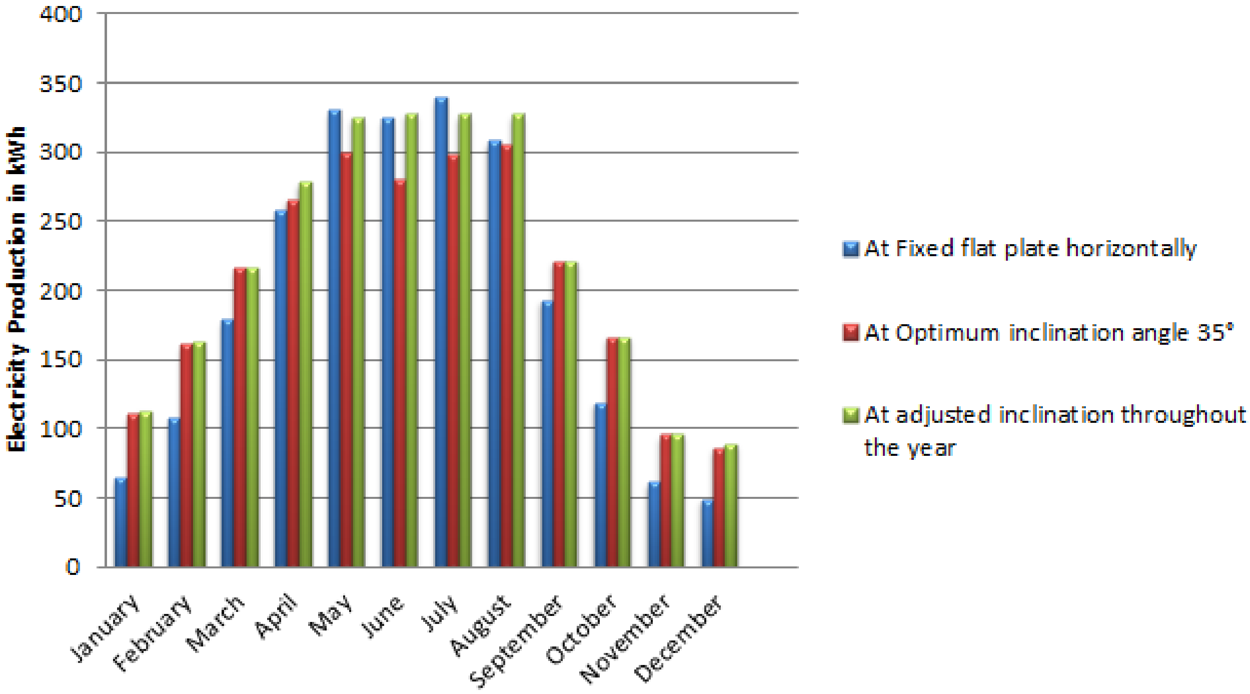


Table 8. 3 kW$_P$ *photovoltaic (PV) system's energy output for Brno* (kWh/month)

Month	**Horizontally fixed flat plate**	**At optimal year round angle 35°**	**The angle is adjusted year round**
January	72.5	124.2	127.6
February	116.6	175.1	176.4
March	196	238.6	238.6
April	270.7	280.1	293.6
May	352.2	321.6	347.4
June	336.2	290.3	339.5
July	348.8	307.6	336.9
August	313.2	310.4	332
September	204.5	234.9	234.9
October	124.2	172.3	172.3
November	68.9	107.3	108.7

December	56.5	98.4	101.8
TOTAL amount	2460	2660.6	2809.7

Fig.16. 3 kW$_P$ *photovoltaic (PV) system's electricity production for Brno*

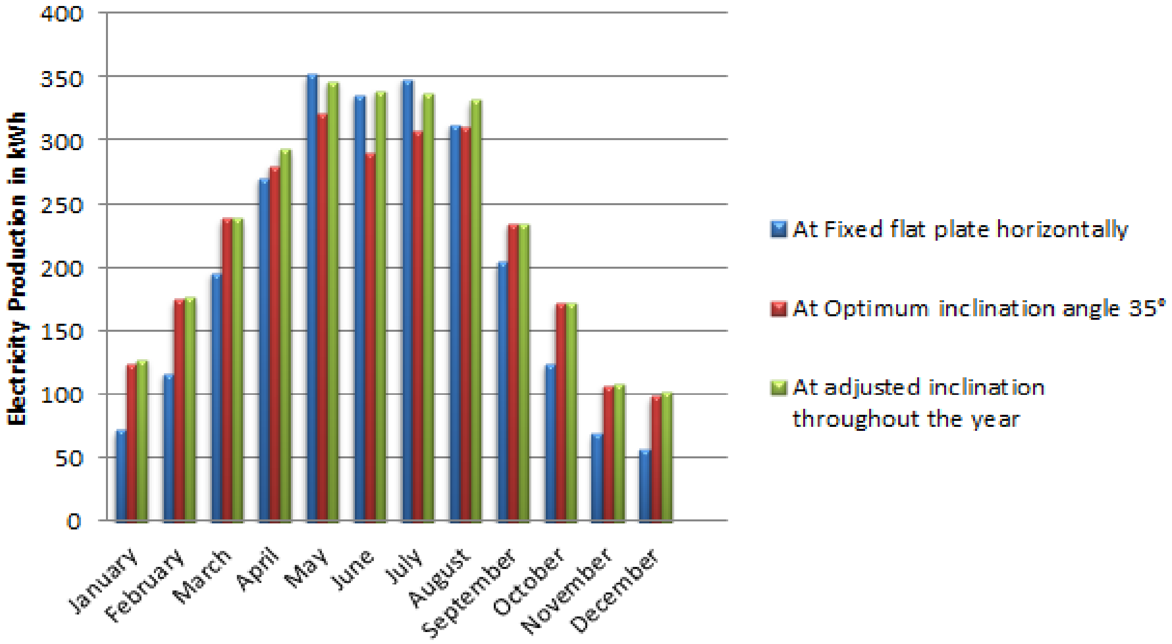
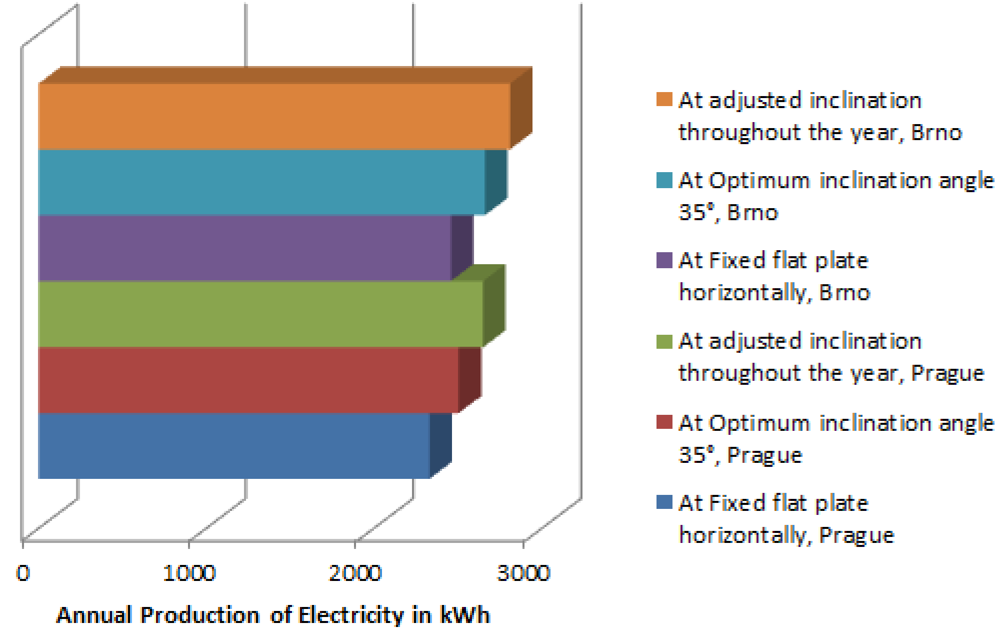


Fig.17. Production of electricity by 3 kW$_P$ *photovoltaic system throughout the year in two cities of Czech Republic*



3 kW_p photovoltaic system's energy output for Prague (table 7) and for Brno (table 8) are shown above. Information about the electricity production of 3 kW_p photovoltaic (PV) system in Prague is demonstrated in the fig. 15, Brno's results are in the fig. 16. Production of electricity by 3 kW_p photovoltaic system throughout the year in two cities of Czech Republic is drown in the fig. 17.

If we are going to discuss the energy production graphs of the 3 kW_p photovoltaic system for each month, then we will get as a result, that maximum energy output in Armenia is around 475 kWh under all consruction conditions during summer months June and July. About Czech Republic's energy output we can mention from the results, that the maximum production is approximately 350 kWh during summer season. However, the lowest energy production for all construction conditions in any month in Armenia is nearly 115kWh. In spite of that fact, for all construction conditions in Czech Republic the lowest enerhy output exceeds 48 kWh.

The average energy output at adjusted inclination in Armenia is around 350 kWh and 200-250 kWh for Czech Republic. Take into consideration, that this is the best construction case for two countries. We discussed the production of energy yearly. From the graph we can freely notice that the maximum energy production in Armenian two cities is around 4000 kWh/year meanwhile in Czech Republic it is exceeding 2600 kWh/year for Prague and 2800 kWh/year for Brno. This is by *32.5%* less than the annual energy production of Armenia, so this demonstrates that by same photovoltaic system there is a huge difference in energy output in two countries.

5.2 Energy Payback Period:

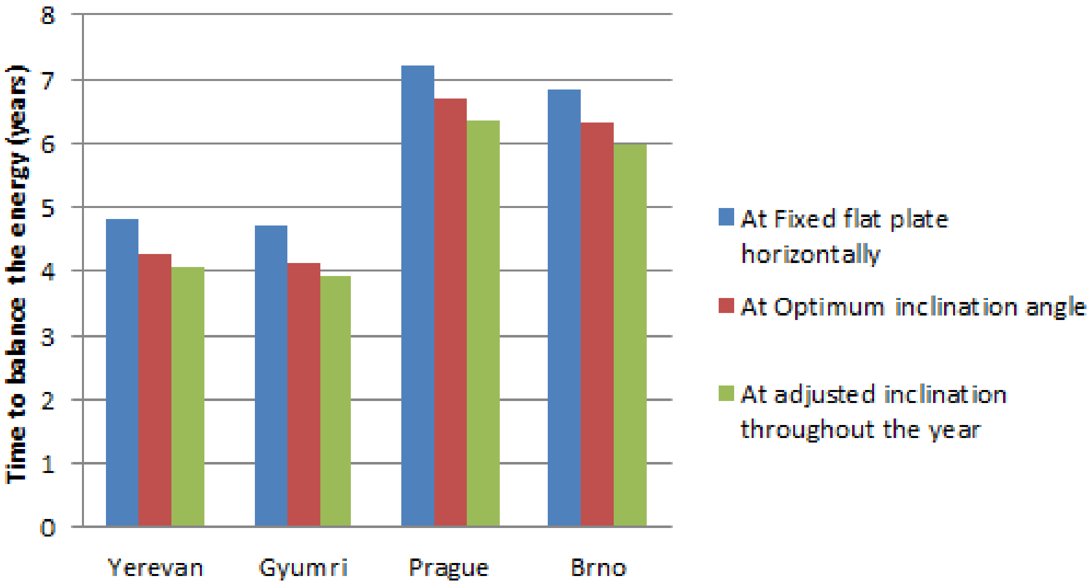
For manufacturing polycrystalline silicon based photovoltaic panels with the highest output of 3 kW_p balance of energy around 16800 kWh is needed. [27]From that amount 8229 kWh is neccesery for manufacturing procedure and 8571 kWh is needed for material depletion. After calculating the energy which is required to balance this (upwards mentioned) energy we measured how fiar is the beneficialness and opportuneness of 3 kW_p PV system and counted the time in years. The result is demonstrated in the table 9. The following table characterize the required time, which is needed to balance energy consumption and this for all already mentioned consturstion cases.

Table 9. Time necessary to balance the energy consumed for the time of production in years

Cities	**Horizontally fixed flat plate**	**At optimal year round angle**	**The angle is adjusted year round**
Yerevan	4.8	4.3	4.1
Gyumri	4.7	4.1	3.9
Prague	7.2	6.7	6.3
Brno	6.8	6.3	6

The comparison of time necessary to balance the energy consumed for the time of production for different cities of Armenia and Czech Republic is drown down below in the fig. 18.

Fig18. Comparison of time necessary to balance the energy consumed for the time of production for different cities of Armenia and Czech Republic



From the fig. 18 we can easily see that period which is required to balance the energy consumed for both cities of Czech Republic ranges from 6 years to 7 (in some cases even more than 7years) meanwhile for the cities of Armenia the amount is around 4-5 years.

5.3 Price payback Period:

In Armenia[1] the cost[2] of 3 kW_p PV system is about 4576 US $ including battery, inverter and the panels. Although in Czech Republic that price is nearly 9153 US $. Electricity price by grid supply is around 0.224 US $[3] in Czech Republic (per kWh) and 0.084 US $[3] for Armenia (per kWh).

For upwards mentioned cities of Czech Republic and Armenia we counted the price payback period (in years) and the price comaback per year (in $) for various construction cases (table 10). This computation relies on the present tariff of electricity, which is offered in each country individually.

Table 10. Price payback period (years)

	Price comeback per year ($)			**Price payback period (years)**		
City	**Horizontally fixed flat plate**	**At optimal year round angle**	**The angle is adjusted year round**	**Horizontally fixed flat plate**	**At optimal year round angle**	**The angle is adjusted year round**
Yerevan	292.65	330.26	347.75	15.64	13.86	13.16
Gyumri	298.79	342.19	360.77	15.31	13.37	12.68
Prague	522.25	561.22	593.39	17.52	16.31	15.42
Brno	551.06	595.97	629.37	16.61	15.36	14.54

As we can notice, in spite of Czech Republic's and Armenia's irradiation throughout the year is very different there is only a slight gap in price payback period for two countries. This happened, because in present situation, electricity price in Armenia is less, compared to the price in Czech Republic.

---

[1]- *https://solaron.am/*
[2] - *As of Feb 25th, 2020 conversion rate.*
[3] - *https://www.globalpetrolprices.com/*

If we hold in mind that the average life duration of PV panel is around 25 years, that is trustworthy period, then we are able to say that the photovoltaic panel has the possibility in the future in case of a fossil fuels' shortage to deliver cheaper electricity.

It is typical to count photovoltaic system's lifetime of 20–30years, but anyways, it is considered that the other components of the system like batteries, inverters, etc., are expected to be replaced during this system's lifetime. [28]

5.4 Discussion:

As the results show Armenia is rich with energy but price payback period is comparatively high, which is simply conneceted with the fact, that electricity prices are low compared to Czech Republic tariffs and that in Armenia panels' prices are high (for Armenians, compared to the average salary in Armenia).

The Government of Czech Republic has made significant and major work to get the required level of renewable energy production. One of the steps was to provide an information to the residents about the worth and advantages of renewable energy, about long-term benefits of it and the second step was the suggestion of profitable tariffs.

However, Armenia still is far from accepting renewable energy's specialty and all the benefits. The key fact about Czech Republic success in this field is connected with the beneficial and profitable policy, which must be welcomed in Armenia as well to make the people in Armenia more interested in using renewable energy.

The Government of Armenia can successfully increase the development of renewable energy because…

- Needed regulatory, institutional and legal framework is ready,
- Economical market is interested and capable in lending for RE investments
- Private sector is interested to invest in RE sector
- The development of RE is reqired by strong ecological society
- The scientific community interested in solar and geothermal technologies

In the table 11 down below is the SWOT analysis for renewable energy development in Armenia.

Table 11. SWOT for renewable energy development in Armenia

S STRENGHTS	**W** WEAKNESSES	**O** OPPORTUNITIES	**T** THREATS
✓ RE resources	✓ Small market	✓ Resource assessment using public funds	✓ Technology price
✓ Strong interest of private sector	✓Lack of professionals	✓ Sound banking services	✓ Regulatory policy changes
✓Regulatory framework	✓ Lack of concessional funding	✓ Guaranteed off-take by utility for 20 years	✓ Technology price
✓ Human resources	✓ High prices	✓ Increase in end user tariff	✓Regulatory policy changes

6.0 Conclusion:

The aim of this project was to make a comparison of photovoltaic systems in two different countries. The comparison is done for different construction, installation and operation possibilities of solar systems. Another aim was to calaculate the economical part of solar systems for both of the countires.

For that we collected the data about solar irradiation from reliable sources for photovoltaic systems of Armenia and Czech Republic and after that we count up the production of energy for the duration of one year under several construtions.

From our research, calculations and obtained results it is obvious that Armenia has more potentioal in solar energy contrasted with Czech Republic. Electricity production of PV system in Czech Republic is lower as compared to Armenia and energy payback period is higher than in Armenia. We took into consideration the facts mentioned above and so we can clearly see that for photovoltaic technology’s adoption Armenia is more beneficial and profitable than Czech Republic. Talking of the difference in the price payback interval we can note that in Armenia it is around 12-15 years whereas for Czech Republic it is approximately 14-17 years.

We need to remember that inflation is not taken info account during all the calculations and research as it is the key component in predicting the profitability of photovoltaic system. The price of electricity has been raised during last 5-6 years for 2-3 times which is because in Armenia the people are more dependent on fossil fuel electricity generation, which is very expensive and by prediction the price will increase more. So after that the benefits of photovoltaic systems will be more evident and the people will understand the value and profit of renewable energy.

By collecting and analyzing all the results we can note that photovoltaic system in Armenia have capability to produce more electricity than PV system in Czech Republic.

7.0 References:

[1] SMIL, Vaclav. *Energy and civilization: a history*. Cambridge, MA: First MIT Press paperback, 2018. ISBN 9780262035774.

[2] C., Googall. *The switch: How solar, storage and new tech means cheap power for all* [online]. London, United Kingdom: Profile books, 2016 [cit. 2020-04-17]. Dostupné z: https://profilebooks.com/the-switch.html

[3] O., Morton. *A New Day Dawning?: Silicon Valley Sunrise* [online]. Nature, 2006 [cit. 2020-04-17]. DOI: https://doi.org/10.1038/443019a. Dostupné z: https://www.nature.com/articles/443019a

[4] UNITED NATIONS DEVELOPMENT PROGRAMME, ONE UNITED NATIONS PLAZA a BUREAU FOR DEVELOPMENT POLICY. *World Energy Assessment* [online]. One United Nations Plaza, NY: New York, 1001 [cit. 2020-04-17].

[5] *World Energy resources 2016: World Energy Council 2016 report*. United Kingdom: Corn- hill, 2016, (33), 62-64.

[6] BENDA, Vítězslav. *A comprehensive guide to solar energy systems: with special focus on photovoltaic systems*. Editor T. M. LETCHER, editor Vasilis M. FTHENAKIS. London: Academic Press, an imprint of Elsevier, 2018. ISBN 978-0-12-811479-7.

[7] L., Chong, Po-Chun H. a Hongtao Y. Rapid water disinfection using vertically aligned MoS2 nanofilms and visible light. *Nat Nanotechnol*. 2016, , 1098-1104. DOI: 10.1038/nnano.2016.138.

[8] JA, Noël. *Storing energy: with special reference to renewable energy sources* [online]. Letcher TM. Oxford: Elsevier Science, 2016 [cit. 2020-04-17]. Dostupné z: https://ru.scribd.com/read/308245884/Storing-Energy-with-Special-Reference-to-Renewable-Energy-Sources

[9] *REN21*. Renewables 2016: Global Status Report. Paris: REN21 Secretariat, 2016. ISBN 978-3-9818107-0-7.

[10] A. KALOGIROU, Soteris. *Solar Energy Engineering: Processes and Systems* [online]. Academic Press, 2013 [cit. 2020-04-17]. ISBN 9780123972569. Dostupné z: https://ru.scribd.com/book/282548111/Solar-Energy-Engineering-Processes-and-Systems

[11] NATH TIWARI, Gopal a Rajeev KUMAR MISHRA. *Advanced Renewable Energy Sources* [online]. Royal Society of Chemistry, 2015 [cit. 2020-04-17]. ISBN 9781782625780. Dostupné z: https://ru.scribd.com/book/289453978/Advanced-Renewable-Energy-Sources

[12] MSE, Lacho a Dimi MSE. *The Truth About Solar Panels The Book That Solar Manufacturers, Vendors,*

Installers And DIY Scammers Don't Want You To Read [online]. Digital Publishing Ltd, 2015 [cit. 2020-04-17]. ISBN 9786197258035. Dostupné z: https://ru.scribd.com/read/274344013/The-Truth-About-Solar-Panels-The-Book-That-Solar-Manufacturers-Vendors-Installers-And-DIY-Scammers-Don-t-Want-You-To-Read

[13] MSE, Dimi a Lacho MSE. *The Ultimate Solar Power Design Guide Less Theory More Practice* [online]. Digital Publishing Ltd, 2015 [cit. 2020-04-17]. ISBN 9786197258066. Dostupné z: https://ru.scribd.com/read/282490664/The-Ultimate-Solar-Power-Design-Guide-Less-Theory-More-Practice

[14] MAYFIELD, Ryan. *Photovoltaic Design and Installation For Dummies* [online]. Wiley, 2010 [cit. 2020-04-17]. ISBN 9780470912737. Dostupné z: https://ru.scribd.com/read/37142416/Photovoltaic-Design-and-Installation-For-Dummies

[15] P. KIRK, Alexander. *Solar Photovoltaic Cells: Photons to Electricity* [online]. Academic Press, 2014 [cit. 2020-04-17]. ISBN 9780128026038. Dostupné z: https://ru.scribd.com/read/282667507/Solar-Photovoltaic-Cells-Photons-to-Electricity

[16] CHIRAS, Dan. *Power from the Sun - 2nd Edition: A Practical Guide to Solar Electricity - Revised 2nd Edition* [online]. New Society Publishers, 2016 [cit. 2020-04-17]. ISBN 9781550926248. Dostupné z: https://ru.scribd.com/read/358298238/Power-from-the-Sun-2nd-Edition-A-Practical-Guide-to-Solar-Electricity-Revised-2nd-Edition

[17] *Asia Solar Energy Initiative: A Primer* [online]. Asian Development Bank, 2011 [cit. 2020-04-12]. ISBN 9789290923145. Dostupné z: https://ru.scribd.com/book/363887569/Asia-Solar-Energy-Initiative-A-Primer

[18] M.F., Jenzen a Swartman R.K. *Solar Energy Conversion II: Selected Lectures from the 1980 International Symposium on Solar Energy Utilization, London, Ontario, Canada August 10-24, 1980Solar Energy Conversion II: Selected Lectures from the 1980 International Symposium on Solar Energy Utilization, London, Ontario, Canada August 10-24, 1980* [online]. Elsevier Science, 2013 [cit. 2020-04-12]. ISBN 9781483155906. Dostupné z: https://ru.scribd.com/book/282587390/Solar-Energy-Conversion-II-Selected-Lectures-from-the-1980-International-Symposium-on-Solar-Energy-Utilization-London-Ontario-Canada-August-10-24

[19] M. TREVOR, Letcher. *Future Energy: Improved, Sustainable and Clean Options for our Planet* [online]. Elsevier Science, 2013 [cit. 2020-04-12]. ISBN 9780080994222. Dostupné z: https://ru.scribd.com/book/282574242/Future-Energy-Improved-Sustainable-and-Clean-Options-for-our-Planet

[20] HELLER, Peter. *The Performance of Concentrated Solar Power (CSP) Systems: Analysis, Measurement and Assessment* [online]. Elsevier Science, 2017 [cit. 2020-04-12]. ISBN 9780081004487. Dostupné z:

https://ru.scribd.com/book/348598849/The-Performance-of-Concentrated-Solar-Power-CSP-Systems-Analysis-Measurement-and-Assessment

[21] ONG, Theodore. *Solar Power: Economic Disaster* [online]. Efficate Books at Smashwords, 2014 [cit. 2020-04-12]. ISBN 9781310168291. Dostupné z: https://ru.scribd.com/read/216441093/Solar-Power-Economic-Disaster

[22] PERLIN, John. *Let It Shine: The 6,000-Year Story of Solar Energy* [online]. New World Library, 2013 [cit. 2020-04-12]. ISBN 9781608681334. Dostupné z: https://ru.scribd.com/book/157283381/Let-It-Shine-The-6-000-Year-Story-of-Solar-Energy

[23] HEINBERG, Richard a David FRIDLEY. *Our Renewable Future: Laying the Path for One Hundred PercClean Energy* [online]. Island Press, 2016 [cit. 2020-04-12]. ISBN 9781610917803. Dostupné z: https://ru.scribd.com/book/313987095/Our-Renewable-Future-Laying-the-Path-for-One-Hundred-PercClean-Energy

[24] MSE, Lacho a Dimi MSE. *Top 40 Costly Mistakes Solar Newbies Make Your Smart Guide to Solar Powered Home and Business* [online]. Digital Publishing Ltd, 2019 [cit. 2020-04-12]. ISBN 9786197258141. Dostupné z: https://ru.scribd.com/book/408187188/Top-40-Costly-Mistakes-Solar-Newbies-Make-Your-Smart-Guide-to-Solar-Powered-Home-and-Business

[25] HOVHANNISYAN, Laert a Norayr HARUTYUNYAN. *Cogeneration systems: Manual*. Yerevan: Engineer "Ճարտարագետ", 2015. ISBN 9789939721835.. [translated].

[26] AKHTAR, Ali. *Project of photovoltaic power plant and economical calculations* [online]. Prague, 2014 [cit. 2020-04-13]. Dostupné z: https://is.czu.cz/auth/lide/clovek.pl?id=52798;zalozka=13;studium=149020;zp=45178. Master Thesis. Czech University of life sciences Prague. Vedoucí práce Libra Martin.

[27] LIBRA, Martin a Vladislav POULEK. *Photovoltaics: theory and practice of solar energy utilization*. Prague: ISLA, 2010. ISBN 978-80-904311-2-6.

[28] PEARSALL, Nicola. *The Performance of Photovoltaic (PV) Systems: Modelling, Measurement and Assessment*. Elsevier Science. UK: Woodhead Publishing, 2016. ISBN 9781782423546.

[29] *Photovoltaic power potential in Czech Republic* [online]. b.r. [cit. 2020-04-15]. Dostupné z: https://solargis.com/

[30] TACISPROJECT. *Support to the Energy Policy of Armenia* [online]. EUROPAID, 2007 [cit. 2020-04-15]. Dostupné z: http://www.renewableenergyarmenia.am/images/Re_sources/3_l _.2.a._solar_ potential_fig_l.jpg

List of Figures:

List of Tables:

Abbreviations:

AC	Alternating Current
PW	Petawatts
YJ	Yottajoules
ZJ	Zettajoules
IEA	International Energy Agency
DC	Direct Current
STE	Solar Thermal Electicity
CSP	Concentrated Solar Power
DST	Department of Science and Technology
CEL	Central Electronics Limited
EU	European Union
GDP	Gross domestic product
HTF	Heat Transfer Fluid
TWh	Terawatt-hours
GW	Gigawatt
kWh	Kilowatt hour
kW_p	Kilowatt pick
MW	Megawatt
PV	Photovoltaics
RE	Renewable Energy