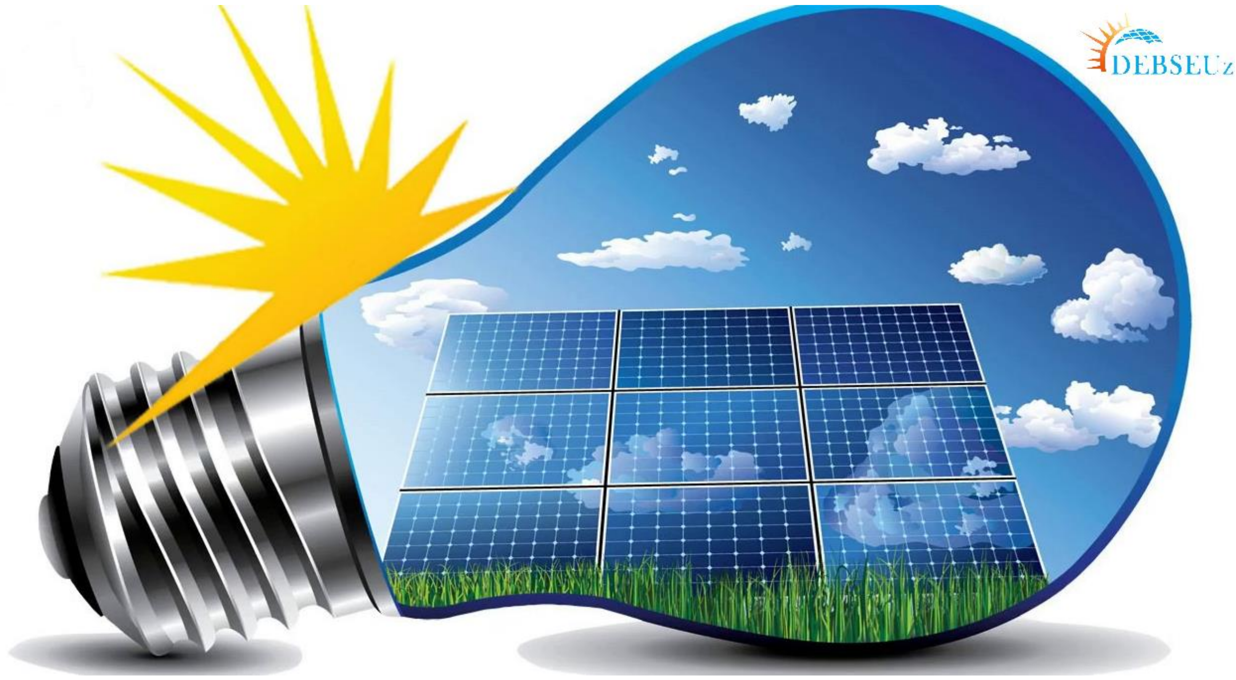
“TIIAME” NATIONAL RESEARCH UNIVERESITY

**D.Kodirov, J. Izzatillaev, I.Siddikov**

# SOLAR ENERGY

**Study guide for students of higher educational institutions**

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**Author: D.Kodirov** – "TIIAME" NRU, head of the department Power supply of renewable energy sources".

**J.Izzatillaev** – "TIIAME" NRU, Associate Professor department of the Power supply of renewable energy sources".

**I.Siddikov** – "TIIAME" NRU, Professor department of the Power supply of renewable energy sources".

**Reviewers:** Academican, DSc. prof. R. Zakhidov-Head of the laboratory Institute of Promlems of Energy

DSc. prof. A. Isakov- "TIIAME" NRU, Dean of the Faculty Energy

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# INTRODUCTION

Mankind of renewable energy sources, large-scale industrial development on the scale of the main reasons I am motivated to engage with:

- the atmosphere in $so_2$ , the increase in the content of arising as a result of climate changes;

- many developed countries, especially the european a strong dependence on the import of fuel;

- there are limited reserves of organic fuels.

Recently, the signing of the Kyoto Protocol by most developed countries of the world has put on the agenda the rapid development of technologies that contribute to the reduction of $CO_2$ emissions into the environment.

The sun drives 99.98% of the world’s energy supply, including thermal, photovoltaic, photochemical, photobiological and hybrid solar, hydro, wind, wave, and biomass energy conversion. It originally grew the biomass thatwe now access as fossil fuels. Other sources include tidal, geothermal andnuclear. The sun’s energy comes from fusion reactions in its core. Thesereactions have been “burning” for 4.5 billion years and are expected tocontinue for another 6.5 billion years. The total power radiated out intospace by the sun is about $3.86\times10^{26}$ W. Since the sun is approximately$1.5\times10^{11}$ m from the earth, and because the earth is about $6.3\times10^{6}$ m inradius, it intercepts only 0.000000045% of this power. This still amounts to massive $1.75\times10^{17}$ W.

The development of this technology and the incentive for them to realize the economic losses associated with not only the threat of climate change, but also of greenhouse gas has become a commodity means that the quota for the waste that has very real value. Organic fuel to reduce costs and $so_2$ one of the technologies that allows the reduction of waste by solar energy hot water supply, heating, air conditioners, and other technological needs of low potential for heat production.

Mankind at the present time consumed by the primary energiyaning more than 40% of this ecome on and the sun in exactly the same area to cover htiyojlarni energiyasi technologies for wide practical use eng mature and economically acceptable.

Also the use of solar heating systems for many countries of the economy that depends on the extraction method is both reduced fuel imports. This task, especially the economy, 50% of minerals energiya to the countries of the european union, which depends on the import of medicines and topical today to come and this dependence 70% can be raised to this esa is a threat to the economic independence of this region.

On average, depending on climatic conditions and the latitude of the area, the solar radiation flux to the Earth's surface reaches 400 to 800 $W/m^2$, almost anywhere (regardless of latitude), about 1000-1200 $W/m^2$. Uzbekistan is a republic where all the gods are good receivers of solar energy and have the ability to produce energy. In hot water and power supply, heating and cooling systems, there is an stigma of achieving 50-70% primary energy source savings through the use of solar energy.

Uzbekistan is a country in Central Asia with a growing demand for electricity. Solar power can play a role in meeting this demand, as the country has abundant solar resources and a strong potential for solar energy generation. The government of Uzbekistan has implemented several initiatives to promote the use of solar power, including the development of large-scale solar power plants and the introduction of incentives for individuals and businesses to install solar panels. Some of the benefits of solar power in Uzbekistan include reduced dependence on fossil fuels, lower greenhouse gas emissions, and improved energy security.

Uzbekistan is actively developing, with the assistance of the World Bank, a targeted program to install two-kilowatt solar panels in 150,000 private houses. Installation work is planned to be carried out in 2021-2023. Also, funds were allocated by local governments for the installation of solar panels in the apartments of low-income families. Because the cost of installing solar panels is high relative to the income of the population, they are not becoming widely popular despite state subsidies.

# CHAPTER 1.
# SOLAR ENERGY AND ITS POTENTIAL ENERGY

**Solar energy** – this is the sun and which is the production of electric energy or water and other substances is a source of energy that can be used for heating. This energy is the conversion of sunlight into electricity (solar panels mode) or through the direct use of gas heating by solar collectors or heat through a fluid is obtained.

Energy of the sun into the atmosphere because it is one of the most environmentally friendly energy sources and does not require extraction does not produce harmful waste. We will use large quantities of energy in our daily life. To spend our lives built on natural resources and energy spending. Figure. 1.1 - where to spend the energy distribution is shown in the picture. The information listed in the picture for the UK, but they "created the world" let's get you to other places too.

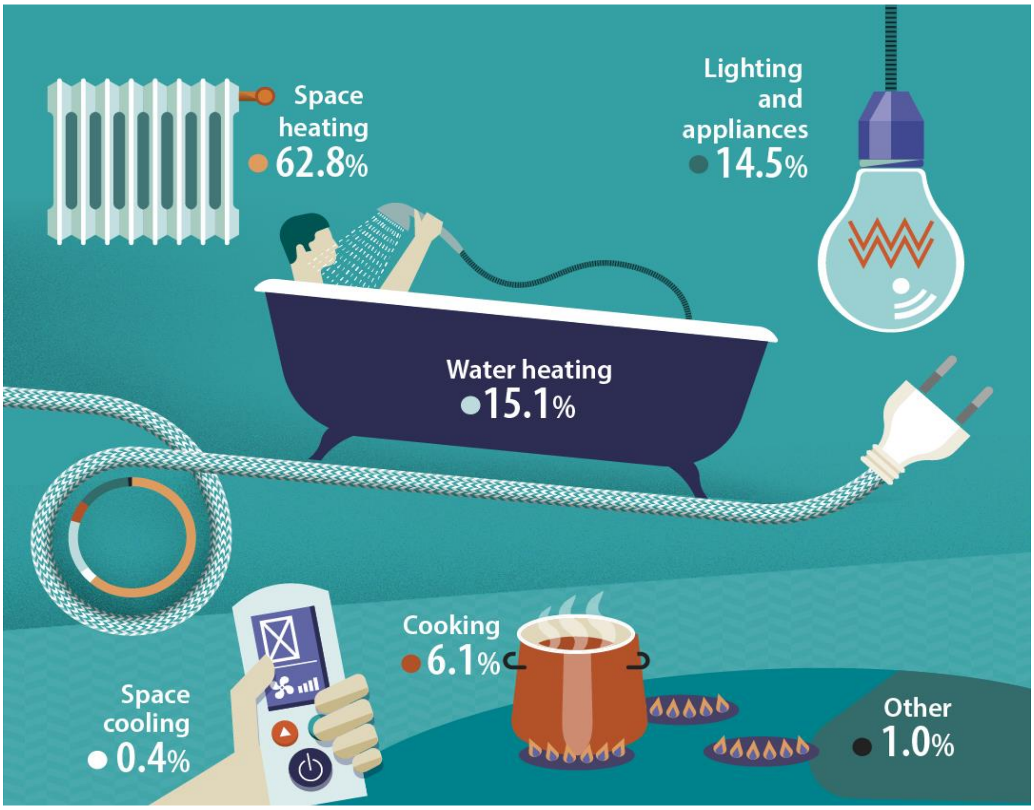



Figure 1.1. Energy consumption in EU households (2020).

Using heat is to spend a large portion of our energy – 58 %, we can see this passive solar projects. We use energy 24% of spending to heat water, using solar energy heating the water in these sources easily with quotes.

So, as we have seen, 82% of the energy we use is related to solar technology. The next 13% of the energy will be spent on providing electricity to our home. The remaining 5% of energy is applied to cooking. The energies that we will thus need are linked to solar technologies. Solar energy is clean, green, Free, better than all, wherever you go there is everywhere for the next five billion years. As a result, you can gain knowledge about methods that approach The Sun in a new way and are favorable for the Earth, not harmful to the environment.

Taking North America as an example, we can fear sufficient reserves of solar energy in Figure 1.2. The bulk of the energy is on the west side, with the rest of the U.S. land also having cost-effective solar power.

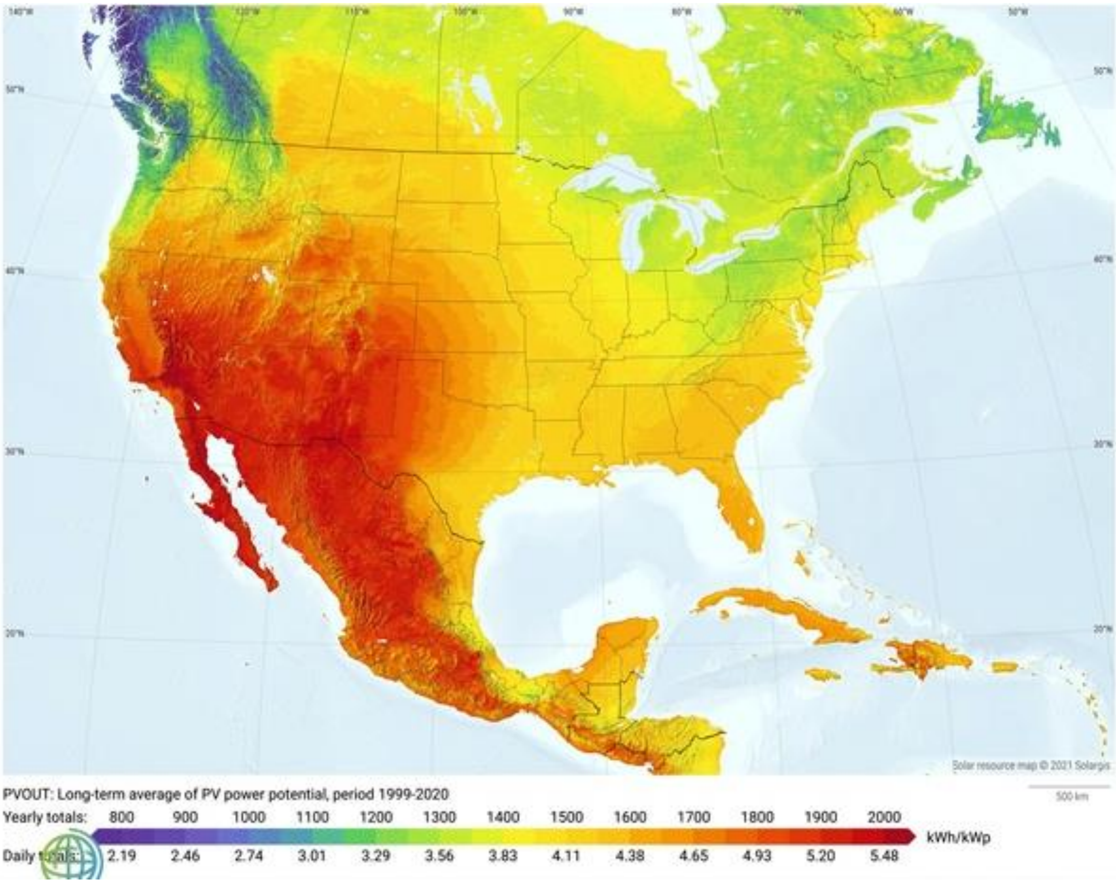



Figure. 1.2. Photovoltaic power production (North America, SolarGis)

In this regard appear to be the kind of primary energy source, the requirements to use the scope to meet the needs within the framework of increasing the initial information about minerals, it is necessary to be able to yonilg'ilar to meditate on. In particular, they exist in very ancient times on the basis of the remains of plants and animals appeared. Minerals in the form of approximately 360 – 286 million years ago paleozoic era of carbon that is a part of the period is important. Which is convenient for you to live this time – the amount of many plants of the world, large qirqquloqlar, as well as the swamp, covered with a forest of plants. The ocean and the sea was full of tiny grass plants consisting of water. Even if the emergence of the period, which dinazavrlar coal carbon in the structure, starting from the main part of chalk mineral resources in the period around 65 million years ago the carbon formed from the remnants of the era.

If the plants die with the passage of time, the stones and the remains of plants which are rich in all the places were covered with carbon. For many years, which is generated due to high temperature and pressure to layers tightened their reason. The issue of fossil fuel. In fig. 1.3 see data restless enough throws! Fossil fuel emission is seen because of the sharp increase in the next hundred years – this large amount of our ecosystem and climate stability noturg'un out our kabonat dioxide will cause you to be mean.

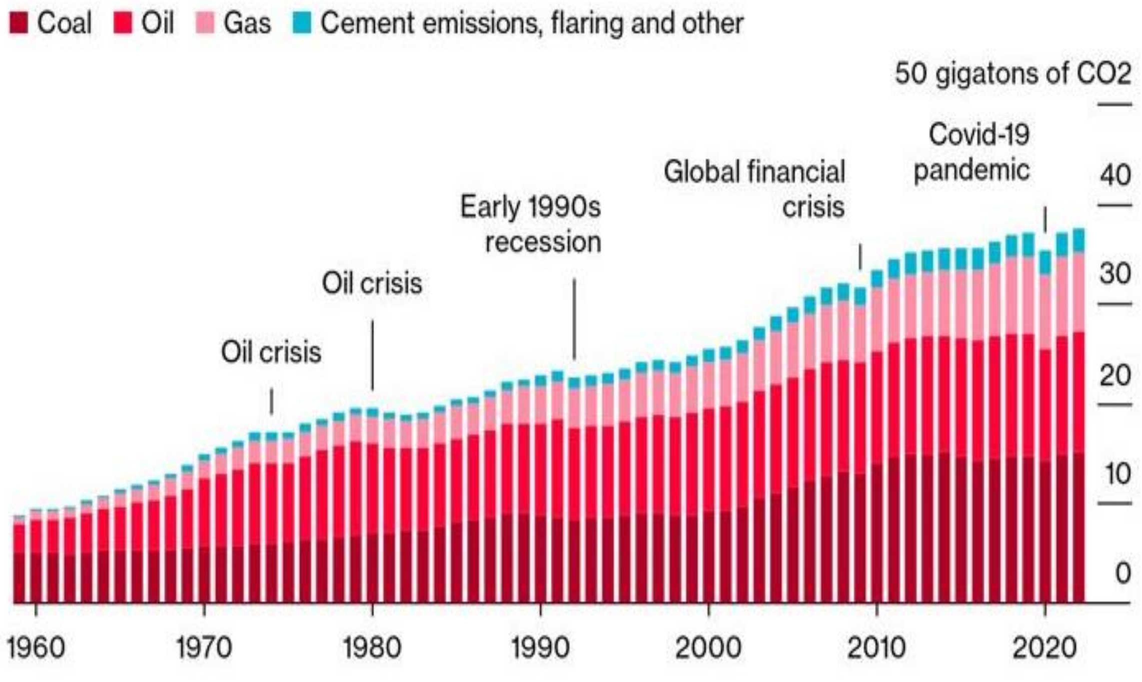



Figure. 1.3. Increasing fossil fuel emissions.

Xubbert of peak oil and peak. In 1956, geophysicist marion king xubbert a lecture at the institute of american made american oil industry. Oil extraction at us at the end of 1960 he and the world is observed to reach a maximum peak in 2000, he said. Actually the beginning of the 1970s American oil extraction, this forecast was bad but the rest of the theory is horrible.

The status of the theory, that is, the curve qo'ng'iroqsimon appearance of fossil fuel production line, the production slowly increased, then a sharp peak is observed when the technology become the main force of production, then increased production against increased spending should work. To reach a plateau and then falls with the costs of extraction increased production – initially slow and will get toned. This figure 1.3 - described in picture.

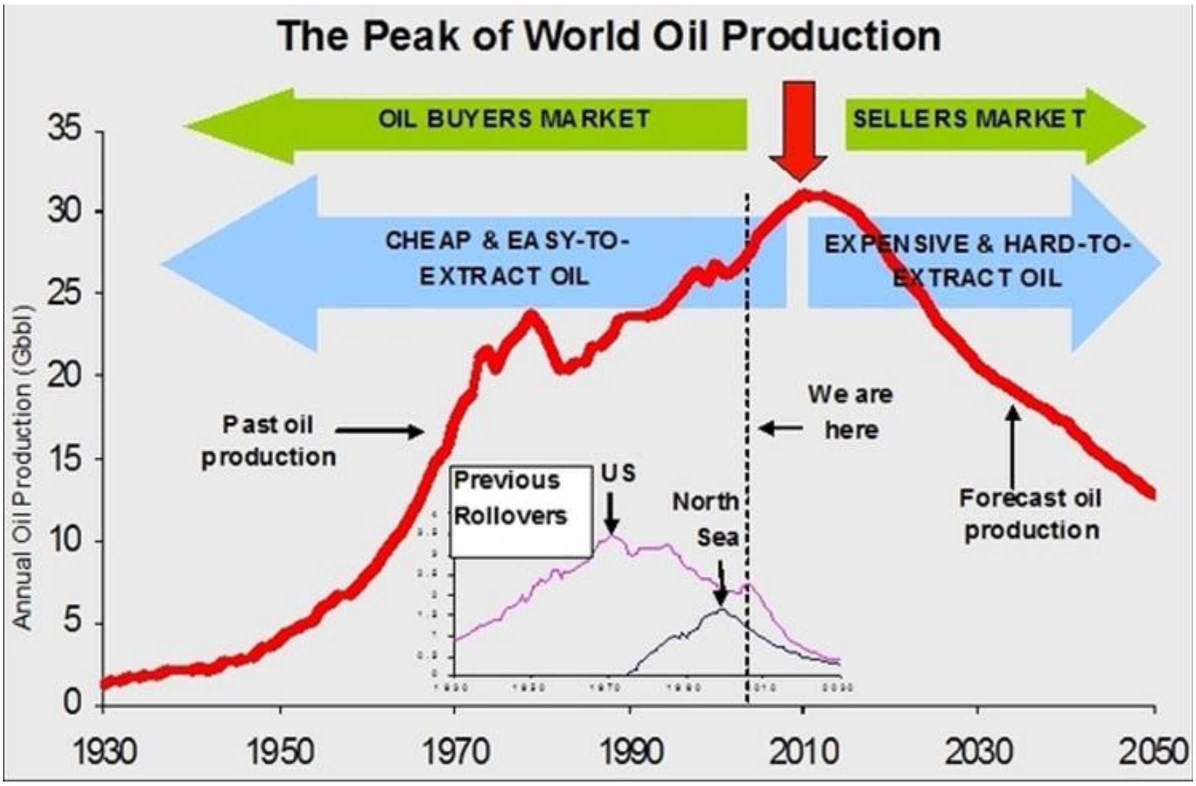



Figure. 1.4. "Peak oil" theory of the image

International energy agency oil information from the vendors to give the biggest in the world than 48 units in 33 of them in the condition is known to lower energy production. Along with the peak oil, coal is also the peak, peak gas, peak uranium there (fig.1.4). All of the source and permanently the last remaining reserves will not continue. Well the sun we will how to use the energy from? We have been thinking about this, there are many types that are linked to the sources in our surroundings qanchasi effects of the sun and the sun works (fig.1.5).

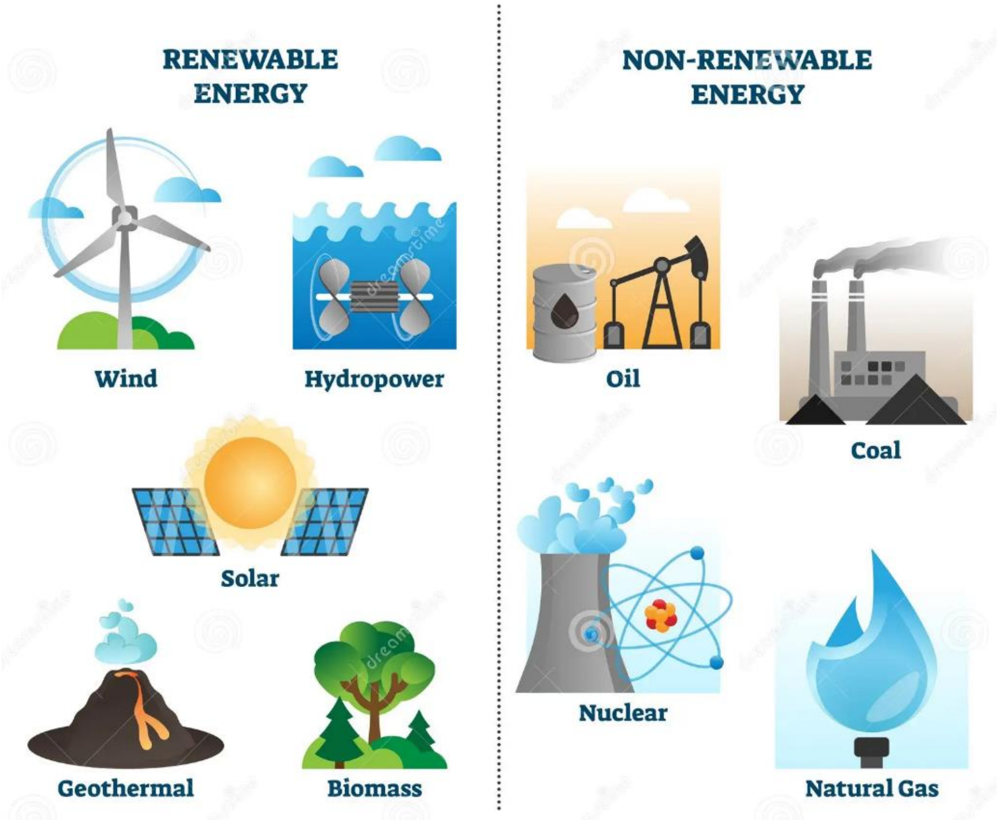



Figure. 1.5. The energy sources.

The U.S. energy supply to see the situation in countries in Western Europe, and so on. Does not have to look at the US's energy supply (fig. 1.6) at the present time the main energy is obtained from fossil fuels. This implies a carbon-intensive economy, that is, imports from other carbon-producing countries, mainly from the Middle East. Unfortunately, this makes the United States dependent on other countries for oil purchases – not a very good political situation. Then we can see hydropower -about 7% of America supplies electricity. Things like aluminum furnaces, which consume a lot of electricity, are mostly built next to a gyroelectric power plant, so they produce relatively cheap energy. Finally, ”others" account for 5% of American electricity production.

The"other" world, solar energy, wind energy, wave energy, water and energy, such as the ascension of the descent at the expense of the facility. This sector fossil fuel savings, which we need in order to stabilize the increase of spending in the sector. Solar energy how can I use it? We have to think about this, all of the energy coming from the sun is transmitted directly or indirectly from one point to another point.

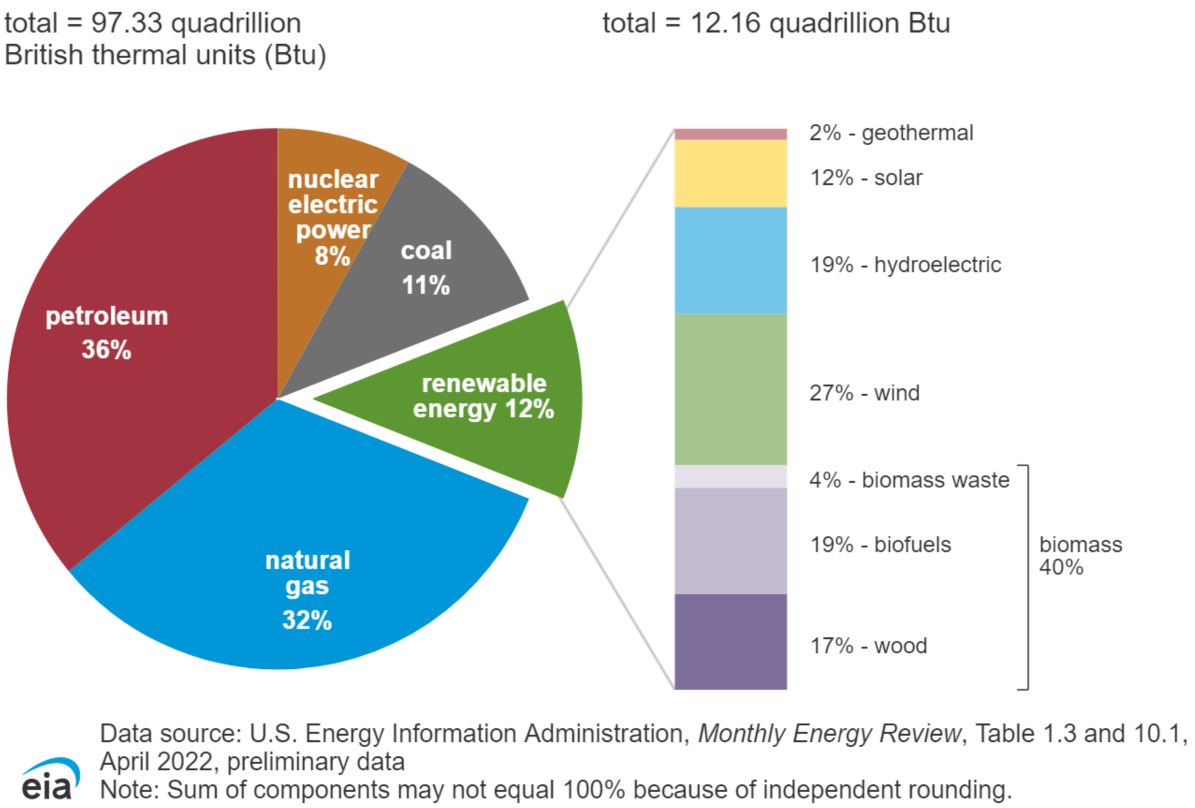



Figure. 1.6. U.S. primary energy consumption by energy source (2021).

**Solar energy –** the sun to provide power devices directly from solar energy term and the majority of the collection and uses of any type may become useful energy. The devices were collected and directly at the solar energy will turn into a useful energy source.

**Wind energy –** the sun that gives heat in our atmosphere in the form of the convective flow, this gradient is certain to be between large and small streams of the drainage area. Move to other place from one place to the air and walk creates the wind, and the sun energy into electrical energy using a wind generator to take large and it can be turned.

**Hydro –** solar performs the hydrological cycle, that is, of heaven, is raised and the water to evaporate in the back ground done in the form of precipitation with rain drops. With the rising of the earth above sea level to higher levels of water it meaning explained! If you collect form water dams in high places, falling through the turbine into electrical energy with the potential energy of the water gravitasion it can be turned.

**Biomass –** to ensure that we can grow, we do not replace fossil fuel savings. The biomass of the trees, is a forest and I used them builds. GDP growth and it is also grown bio-ethanol can convert to, they yonuv is used in place of gasoline in internal engine. Grow all the plants cultivated in the influence of the sun, so they also require completion of the construction of solar energy.

## §1.1. The physical basis of solar energy

We 92.25 from the Sun$\cdot 10^6$ mile away, in meters or $149{,}6\cdot 10^6$ km distance (fig. 1.7). 299792458 meters per second to imagine such a large distance does not receive light that has passed look it 8,31 minutes, you will need to come to us. In the example of the plane which was flying from america to experience the imaginary can try. It is moving with a speed of 500 miles per hour, in four hours you will need. You move at the speed of light around the earth seven times in the second half across the equator if you want to become. Go the distance now so if you want to move speed 8,31 minutes how long you can imagine that.

It not only away, but it is also very ulkandir. Its diameter 864950 mile; if meter is equal to 1392 million miles if you're running it in standard.

With a fall in the sun too long – it's very great! You may think that you are incomplete has less energy than the fact are incomplete in the coming solar radiation annual global energy the amount of energy from spending 10000 times larger. A square meter per year, an average of 1700 kw·hours of solar energy falls.

The surface of the land covered with a layer of thick black liquid heating for in a mile, if we land on the surface the idea that you will have to collect the energy of falling now it seems absurd as it is not a source. When it comes to solar energy far above the ground in the surrounding atmosphere of 19% will win, and another 35% is swallowed in the cloud. Solar energy will heat up only of the earth on a continuous basis, this technology requires spending yo'qotilayotgan commercial energy into useful energy vain, that is, us we needed it to carry out any useful work.

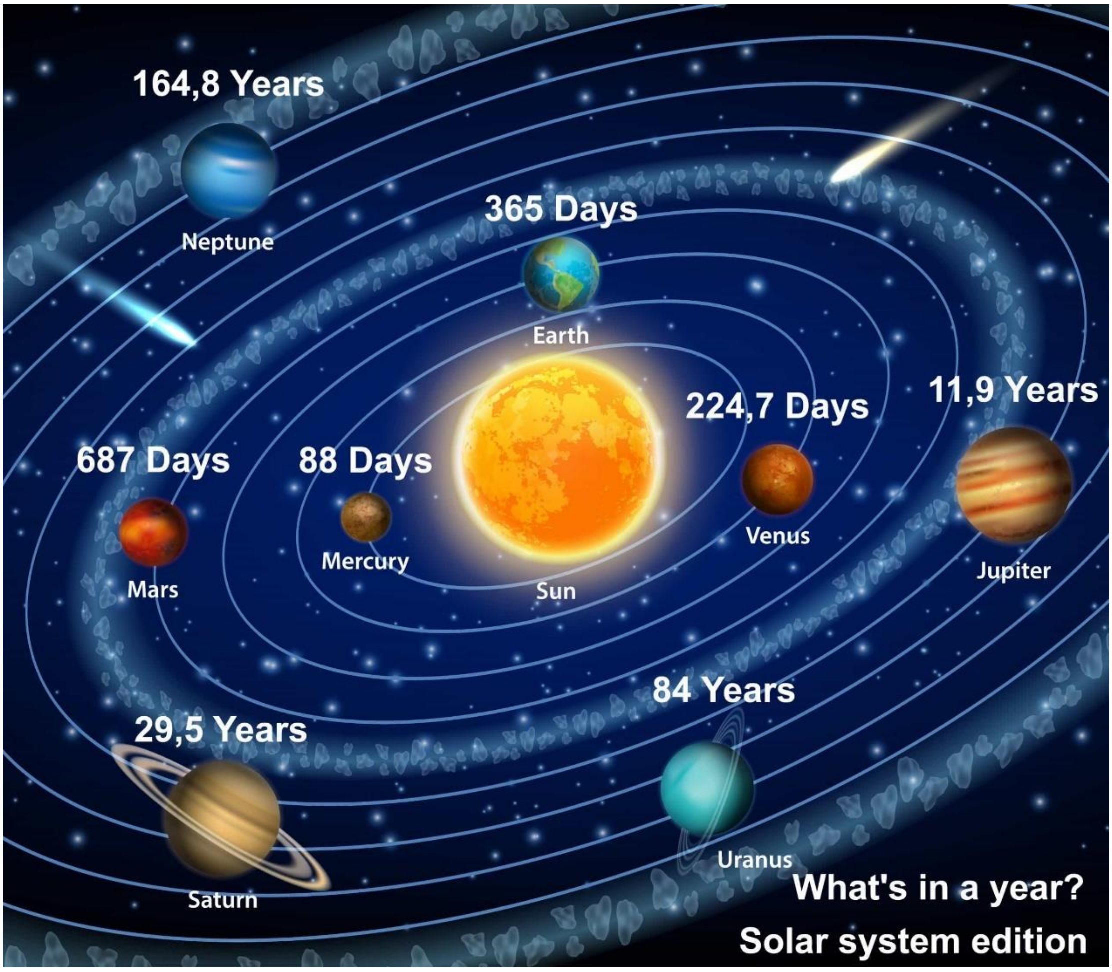



Figure 1.7. Solar system.

The sun termo effective large-core loading also. In the sun every second, minute, hydrogen becomes continuous with geliy sharing applications. What will hinder the sun from the effects of the large amount termoyadro reaction explosion containment? – simple gravitasiya power! As a result of complex reactions, which spread the power which the sun in the night and quite large in size due to the amount of the substance in which is formed as a result of the constant battle between the forces gravitasiya is steady.

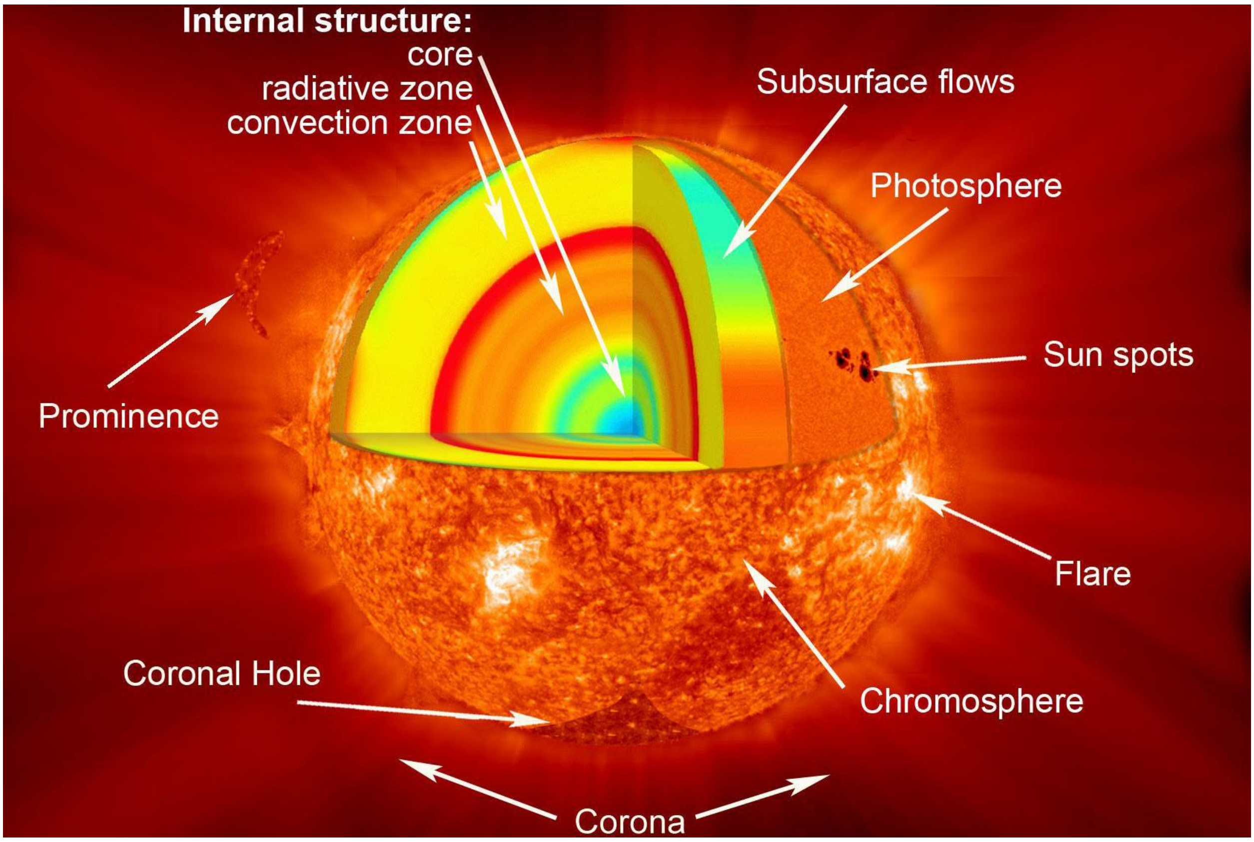


Fig. 1.8. The structure of the Sun (NASA image).

The sun inside all the atoms in a large amount of "contraction" is pulled as a result of each other. At the same time, the effects of nuclear energy and heat formed in the reaction out of all things I will try. We balance our happiness and as a result they will Solar remains constant. Fig.1.8 the structure of the sun - picture quotes – do it we explained that there are a. The core from the center of the sun, radioactive zone, convective zone, fotosfera, there are xromosfera and the crown.

Two of the core of the sun has the texture, creates favorable conditions for the first nuclear reaction – unbelievable Celsius having temperature of 15 million degrees, the second great pressure be trusted. So there termo-nuclear reaction is realized.

One of the pieces will form the core of geliy four hydrogen nuclear reactions at the core.The results from this process are two – foton gamma rays, i.e. large-energy neutron and one of them is known to have mass and charge of the particles of the universe.

**Radiactive zone –** from the core to the next radiactive zone. The reason to call this kind of zone, the radiation it produces. It's less cold, the temperature in degrees radiaktiv zone is in the range of from 1 million to 15 million Celsius (as measured by the thermometer temperature is such that even I don't like). Radiactive zone is basically what is interesting, from this zone to the next zone you will need to pass foton millions of years, so it is also called the convective zone!

**Convective zone –** this zone is different, foton here is moving due to convection in the high – grade physics that size if you want to remember your temperature depending on the pressure side lower and less convection is formed. There are different degrees of this zone is the zone on the border with radiation million. Celsius foreign parts only account for the temperature of 6000 °C (asbestos gloves to hold the thermometer in hohlamaysizmi you now).

**Photosfphere –** called the next area. The visible light of the sun that appear because it yorug'qismi see it here. Fotosfera the temperature of 5500 °C, also huge this temperature. This layer is thin in relation to its thickness 300 mile with the sun.

**Chromosphere –** a few thousand miles thick, evident tumanlik up, the temperature of 6000 °C - 50000 °C varies. This area in the field of the visible spectrum awakening are filled with hydrogen atoms to produce red radiation.

**The crown –** the crown, the atmosphere of the sun from a distance of millions of miles into space stand out. Here the temperature is very hot, that is, Tselsiy million degrees around. Some of the properties of the surface of the sun 1.8 - you can see in the picture, but in the next part of the 1.9 - is described in detail in the picture.

**Features of the sun.** We have considered the internal structure of the sun, and the crown on the surface of the sun us to know what night the process is interesting.

The sun's magnetic field are areas of kovaklar the crown will appear. The sun sends out a large amount of space protuberaneslari of the crown and separate the materials. Keeping the magnetic xalqa protuberaneslarni fozoda will remain. The projection from the surface of the sun crown of the outgoing ruchkasimon qutbli are very small.

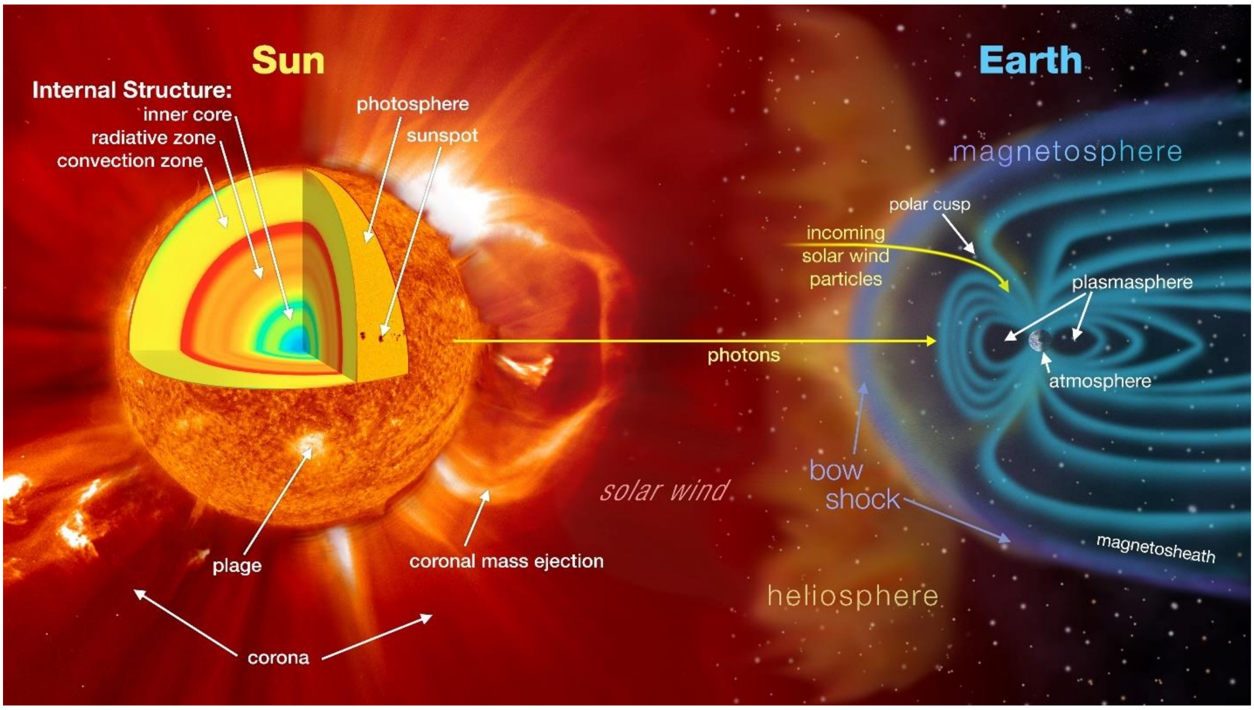


Figure 1.9. Phenomena observed on the surface of the sun (NASA image).

**The earth and the sun.** We have become familiar with the events that occur in the sun, then through the cosmos of solar energy coming out now, you will see how to orbit the earth.

The atmosphere of the earth at any point in the space outside the solar radiation issued by (insolyasiya) is almost stable. While the surface of the land in those instances will change according to any of the following situations:

- Change the state of the space environment of earth,
- The cycle of earth,
- The land of the atmosphere (gases, clouds and dust).

The gases in the atmosphere is relatively steady. In the last year due to the global coverage of the air to decrease the infestation is observed in solid compounds in the atmosphere, fossil fuel waste caused a decrease of solar energy coming from the ground.

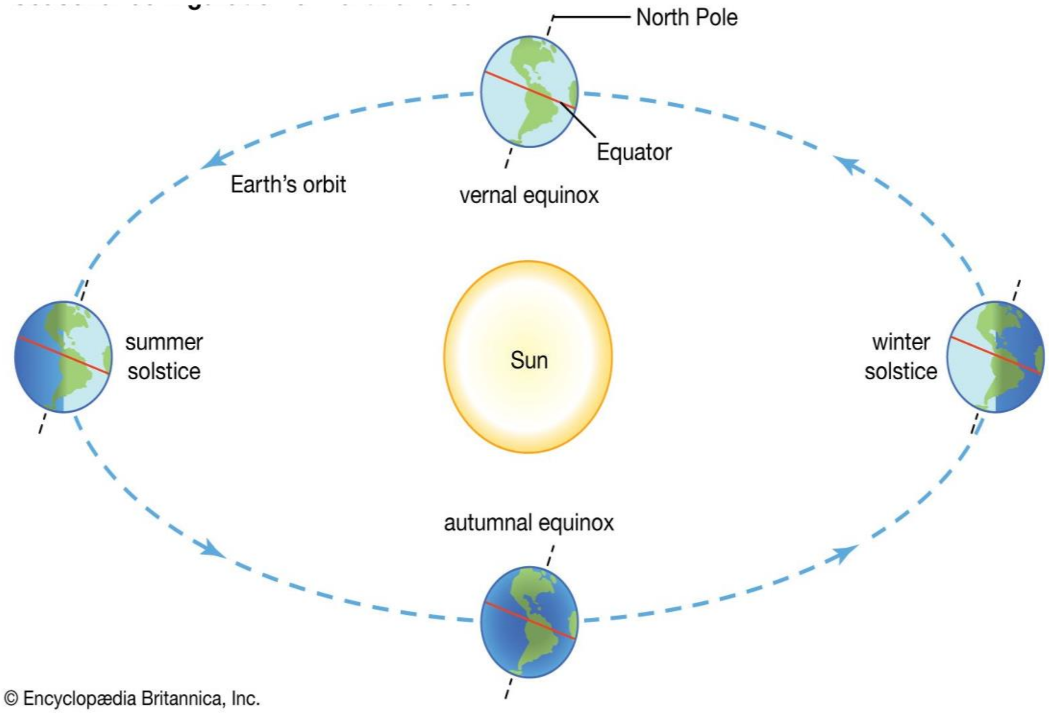



Fig. 1.10. Seasonal configuration of Earth and Sun.

There is much more mobility and the clouds moved from place to place, giving the angle of the shadow. And its orbit about the earth, imagine if we had placed at the angle of the sun compared to the earth turning around its axis, we can see that. Land becomes with the speed of change, the point of the earth's orbit so that you can find some parts more coverage of her route, and vice-versa, because land space is located in. That part of the earth is closer to the sun during the day. This is the reason why the coming seasons – the process 1.10 - described in picture.

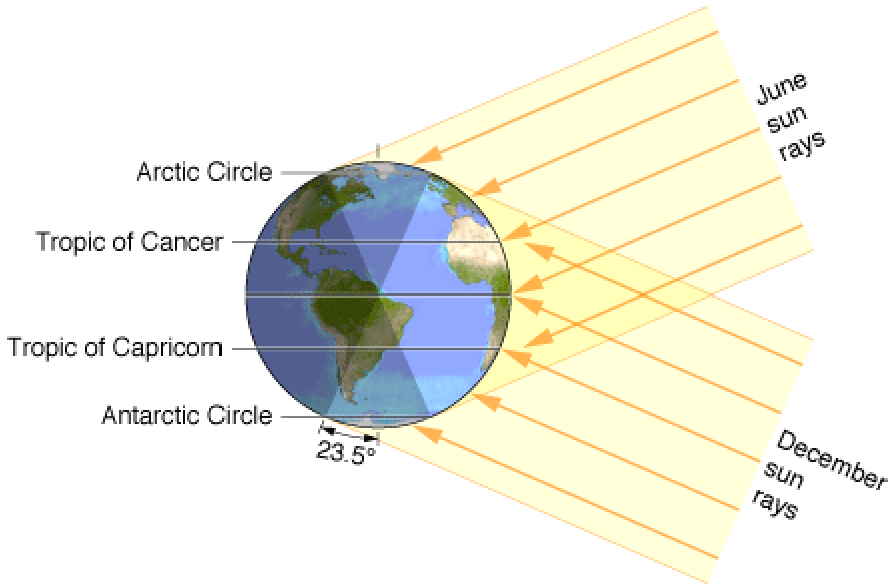



Figure 1.11. A different time of the year to change than the sun of the situation

Since it was the sun see the sky in different parts of our solar who need to track the device. Fig. 1.11 - flat in the picture of the sun collector for efficient use of energy in different time of the year to set how much space you need depending on the situation described.

## §1.2. Meters of solar energy equipment

Solar radiation measuring instruments and is used for different purposes in various fields. They are down to the surface of the land or a certain object, will help you to determine the amount of solar radiation. The areas that may be of wider use of this measurement tool and need the quotes below:

1. Meteorological and iqlimshunoslik: to understand and predict weather conditions, the measurement of solar radiation, as well as for the study of climate change on earth is important.

2. Solar energy: photovoltaic solar collectors and solar stations and calculate the potential productivity for planning the employment of solar radiation you need to know the exact level of the region of interest.

3. Agriculture: the level of light in a certain area of the sun to know to grow crops agronomist and farmers to identify the most suitable, will help you to plan as well as agricultural work.

4. Scientific studies: ecology, biology and other scientific disciplines in the field of the measurement of solar radiation using different ecosystem and the living organism to the effects of the sun light you can learn.

5. Building and architecture: the design of buildings and structures, especially considering the use of natural lighting and energy-saving technologies, the intensity of the light of the sun in different periods of the year and you need to take into account the spread.

Solar radiation measuring instruments can be different, including pirgeliometrlar (for the measurement of direct solar radiation), pirometrlar (total for measurement of solar radiation) and fotometrik is to measure the light intensity in a certain range). These devices will provide specific information that can be used in many areas of human activity.

**Pergeliometr.** Pirgeliometr-this is the surface that is perpendicular to measure the amount of solar radiation that falls on it devices. The principle of its work is to measure the amount of heat based, therefore, the device based on the temperature difference creates thermal batteries voltage electric Zeebek through effects-based. Pirgeliometrning piranometrdan difference is, he is not the scattered light, but the light will measure directly.

Figure. 1.12. Modern pergeliometr

Solar radiation is measured by the amount of energy per unit time per unit area that will fall. Its intensity depends on many variables-in the first place, to place the measure, as well as light enters the atmosphere depends on.

Average square meter of solar radiation in the earth 1366 Watts. Pirgeliometr direct sun measurements to be accurate and it should usually be directed to the source of light moving on the back of the lamp is to install tracking devices.

**Working principle.** The battery light solar Termal eon the other side energiyasiga the ability to convert eha. Voltage of solar radiation to the later standard, converted to the unit of measurement-that is, in watts per square meter. This is the bulk direct lighting is used; the light scattered from the atmosphere of the planet, which is used to measure the light always appear after piranometr learn.

To convert the battery Termal Zeebek effekti this is used for voltage based on the temperature difference allows you to generate, therefore termal not to look at the metal tip of a battery is always the sun, the latter emo she shaded, as a result, they are heated differently. Solar radiation is how high the voltage is so high, this allows you to get accurate results in comparison to the professionals.

**The main types.** In russia, created in the year 1896 angestrem pirgeliometridan are used. The man plates and blackened termojuft associated with them is used, one normal of the plate is heated, and the second emo efrom the vine on the other side. Since it is equal to the temperature, no voltage will not be transferred to the equivalent of solar radiation and temperature to explain the second plate is determined by the amount of flow that should be.

Anelectoral "lapses" tome at shul improved by Charles Abbott pirgeliometri eng is common. It uses the flow of water washed with tarnished from camera. A second camera that the light of the sun does not fall from the eon the other side eis heated with nergiyasi, then out of the water that comes out from the first camera on the temperature of the water is equal to. How to explain to equal the temperature of the flow termojuftlar installed eon the other side energiyasi should measure, and accordingly, researchers intensity of solar radiation can be calculated.

**Areas of use.** Science the deviceis used for iy studies - in particular, can be used to study the changes in solar radiation emitted within a certain time. Now alternative "green" requirements are also in the field of energy, because it is used to determine acceptable locations for the installation of the solar panels. Pirgeliometr conducted by measuring the radiation level of the map on the basis of the average structure is special, they set the best place to find used.

**Actinometr**-the measurement of solar radiation heat capacity of this device. Actinometrlar piranometrlar in meteorology, it is used for measurement of solar radiation as clean and pirgeliometrlar radiometrlar. In 1825 invented by John Xerschel aktinometr the year.

Actinometr-this whole time in the unit or in the system which determine the number of foton light chemical or physical device. This name is ultraviolet and visible wavelength range usually used in the device is applied. For example, iron solution of oxalic aktinometr chemical can be used as bolometrlar, and provide indicators that can be detected foton mutual termoelementlar fotodiodlar associated with the number of physical devices.

Figure. 1.13. His pele-SF 12 actinometr

**The purpose of use. "**Pele his SF-12" aktinometri if it is intended to measure the duration of solar radiation, direct solar radiation level from the nominal limit of 120 W/m$^2$ is higher than the time that is determined.

**Analog output version.** Kanalli eight analog output block to the entrance of aktinometrning electronic access into digital form, this block will be displayed on the display of the signal and at the same time, RS-485 interface to the computer via comes. The data on the computer "pele his Feet" is displayed using the program.

**The digital version is out.** RS-485 interface aktinometrning comes via the digital output directly to the computer, then the data is processed and displayed using software pele his feet.

Instruments which measure the intensity of radiation energy actinometrlar. Nuriy most aktinometrlar the process of turning energy into heat is based on the principle of measuring the effects of heat. Located in a manner perpendicular to the direction of the light radiation the amount of energy in 1 minute 1 $cm^2$ surface was characterized with small absorbed in calories (bald / $cm^2 \cdot min$).

Prior to entry of solar radiation doimiysi the atmosphere of the earth is called the intensity of the sun. Go to the part of the surface of the earth the sun's radiant energy (direct solar radiation), the part that falls into the atmosphere after the spread of solar radiation (scattered radiation) in conjunction with the make up of total solar radiation. Referred to as radiation that is reflected on part of the land is reflected.

## §1.3. The emission spectrum of solar energy

Since time immemorial, the energy from the sun were used by men for their own purposes. 212 bc of us to a place where the light of the sun are concentrated in the synagogue before using qutlug'olov put in dressing. Like the great Greek scholar Archimedes himself is born of unions in the city of the roman keyja protection Sirakuza (blades) going in the same way the movement of shoulders which caused the burning of the sun's rays flow capacity of the atmosphere on the upper border of the land $1{,}78 \cdot 10^{17}$ W while in satx $1.2 \cdot 10^{17}$ W make up.

Ball in the flow of solar radiation incredibly land distribution is uneven. The amount of solar energy 1 $m^2$ surface land for 3000 years $MJ/m^2$ from the northern districts and 8000 $MJ/m^2$ is distributed in the southern districts to heat up (fig. 1.14.).

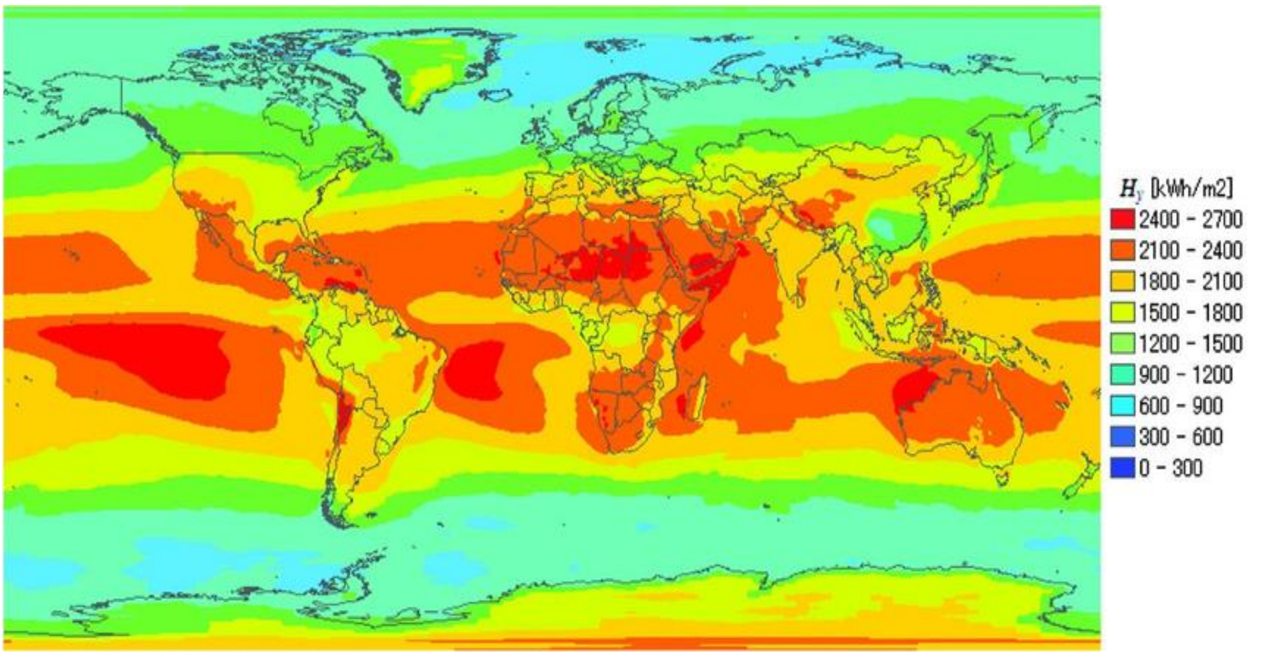
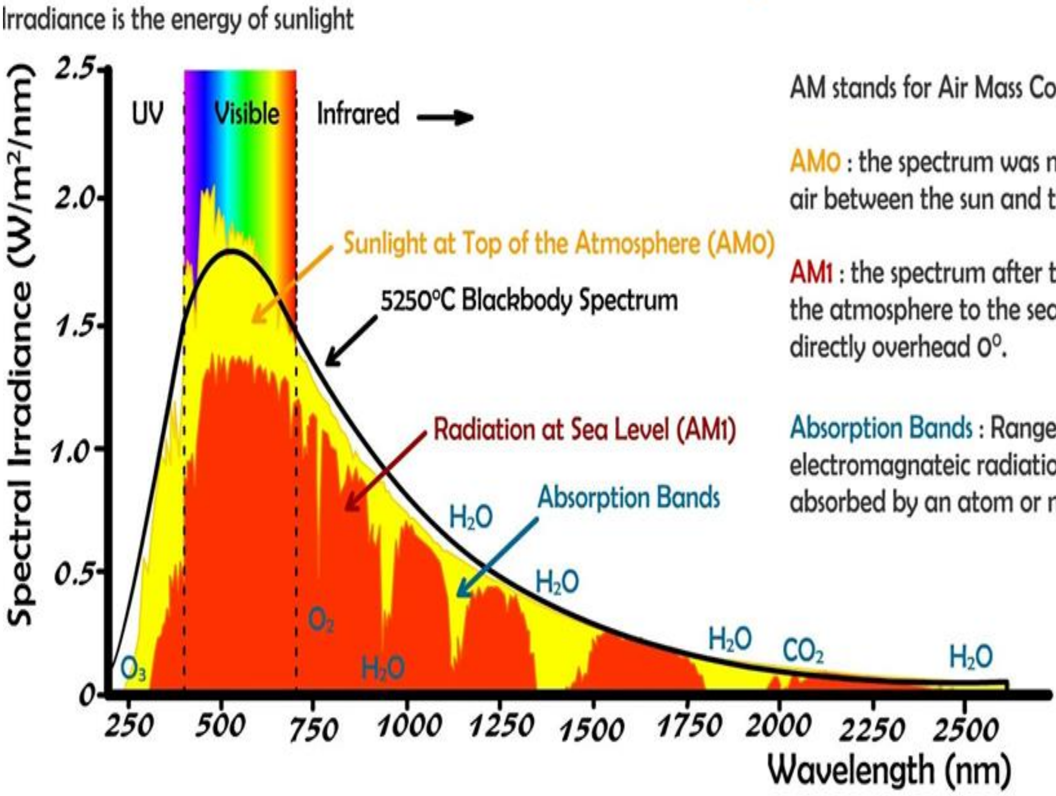



Fig. 1.14. - Global Solar Radiation Map.

Solar energy flow density $Q_0$ on the upper border of the atmosphere perpendicular to the light they 1353 W/m$^2$ is equal to the amount of the sun doimiysi average energy $e_0$ in the hour of 1 1 m$^2$ the occurrence of 4871 kJ/s·m$^2$ anaqlangan be. The annual average density of flow of sunlight 210-250 W/m$^2$ and subtropical desert land, and in 130-220 W/m$^2$ zone central russia comes on. Solar energy is steep density of 1 kW/m$^2$ reaches. 1.15-in the picture it going on the distribution of the atmosphere, the light of the sun sun rays spektori upper limit of the atmosphere on the border of up and concentration are shown in relation to sea level.

The upper limit of the atmosphere earth in the rays of the sun to the absolute temperature of a black body in as the year comes on the scattered light and ultraviolet radiation 5900 k (the wave length of x=0.2-0.4 mkm), see light $\lambda$=0.4-0,78 mkm and infra red rays (they wave length) will consist of. maximum efficiency of light of the sun (fasting) 0,5 mkm wavelength intensive.




1.15-picture. Solar raduiation spectrum.

In the past a part of the land of the sun light from the atmosphere and spread around the molecules of the air, steam and water projects easy is to win. And dust particles as well as spending. This qo'yosh to weaken the power of the light falling on diffuziyalangan members (who spread) radiation leads. A part of energy particles dissolve and the sun is going back to space, stability gazlashgan to swallow.

Diffuse (spread) the view of the main flow of light energy to reach the surface of the earth, the sun, the fall in the overall flow of solar radiation scattered in geographic and climatic factors related to the amount of light varies during the year. For example, its size Kiev 0,39 in June, in December 0,75. In Moscow 0,54-0.8; while in Tashkent 0,19-0,5; in Ashgabat 0,3-0,5.

The solar potential can be characterized by the average annual magnitude of solar radiation falling on a 1m$^2$ horizontal surface. In Commonwealth of independent countries fields, the annual flow of solar radiation varies widely. 1m2 horizontal surface in the northern islets and in the north-eastern Siberian territory during the year 550...830 kW/s, 1,100-1,300 kW/h in Ukraine, Moldavia, Volga Region, Siberia and the Far East, 1,400-1,600 kW/h in the Caucasus and Central Asia, with 2,000 kW/h and more in the steppe steppes of Uzbekistan. The number of annual sunshine hours is 3000 in Turkmenistan, 2815 in Uzbekistan and Tajikistan-2880, 2575 in Kazakhstan and Kyrgyzstan-2695, 2125 in Armenia, Georgia and Azerbayjan-2520, in Ukraine and Moldavia 2005-2080 (figure 10.3).

The duration of sunlight in Central Asia is 16 h in June and 8-10 h in December. In these regions, 300 sunny days are counted, and the duration of sunlight is 2500-3100 h/year, 320 in the summer months-400 h/month. While solar energy light fall is observed during an open day, the amount of solar enrgia at the beginning and end of the day is not large in the plane perpendicular to the Rays.

An hour after sunrise, its energy will be 400 kcal/m$^2$. in half a day, it reaches a maximum volume of 800 kcal/m$^2$/hour (Table.1.1).

Table 1.1

| **The months** | **Daily, W·h/ (m$^2$·daily)** | **Hours W·h/(m$^2$·h)** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **12** | **11,13** | **10,14** | **9,15** | **8,16** | **7,17** | **6,18** |
| January-December | 2860 | 710 | 670 | 630 | 540 | 310 | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| February November | 3245 | 750 | 740 | 690 | 605 | 460 | - | - |
| March October | 3920 | 780 | 770 | 730 | 670 | 650 | 320 | - |
| April, September | 4411 | 800 | 790 | 765 | 730 | 640 | 546 | 170 |
| May, August | 4640 | 800 | 79+0 | 765 | 730 | 670 | 545 | 340 |
| June, July | 4760 | 785 | 780 | 770 | 730 | 670 | 585 | 440 |

The level of solar radiation in cloudy days $l_P$ at uneven and weak. Reduced to such a huge outpouring of solar energy in the day the clouds that blocked the sun is able to zone depends on the size of (fig. 1.16).

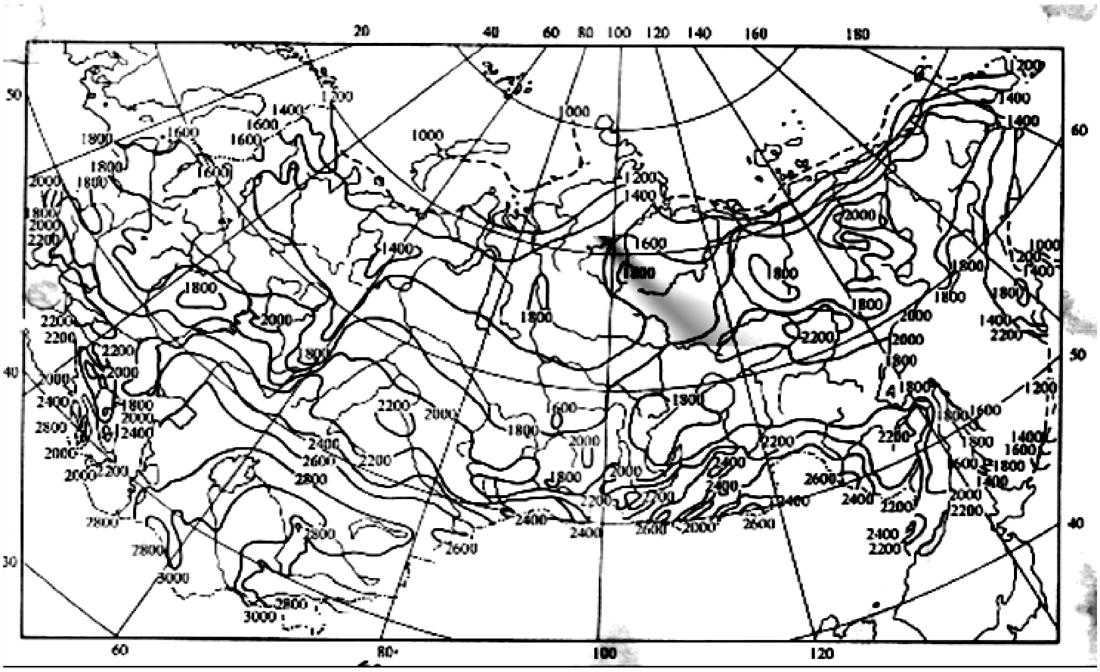



Fig 1.16. Annual radiating of the sun (hour).

Scan cloudy days only diffuse (scattered) from solar radiation can be used. Such a condition approximate the appearance of the graphics of the light of the sun for 1.17 flat in a picture, but the absolute index've radiation is small.

We can see from our daily example, that the solar irradiance available during the brighter sunnier and longer summer days is greater than that of the shorter, duller winter days as we would expect. So the peak sun hours available during the summer is clearly longer than the winter period allowing a PV panel to operate at its peak rated output longer.

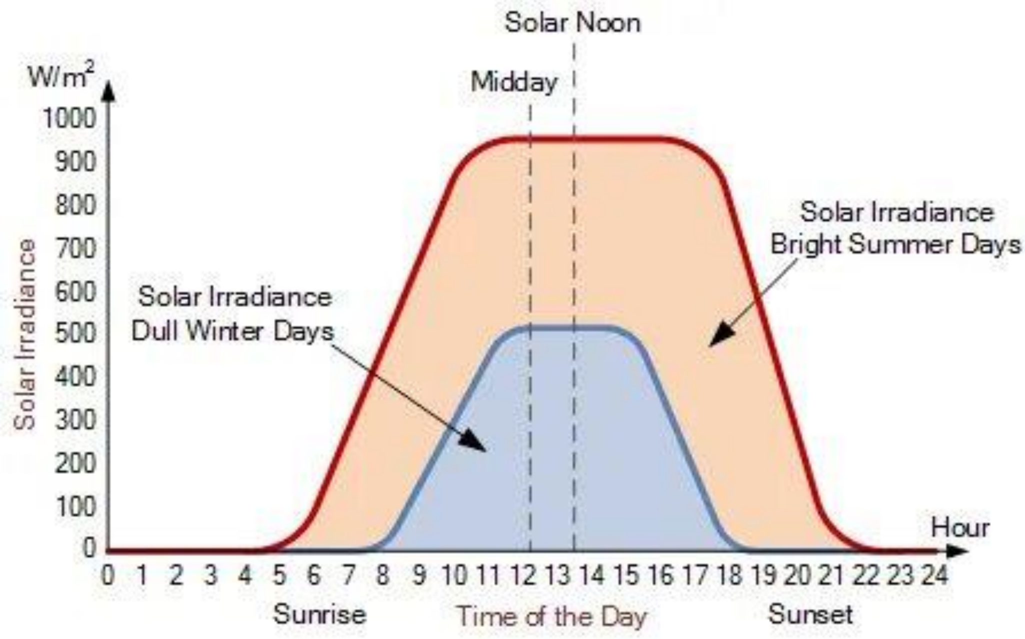



Figure 1.17. Graph of Solar Irradiation During the Day.

So for example, if the average solar energy which falls on a surface during the summer months is 800 W/m$^2$ and is available for a full 8 hours per day, the daily amount of solar irradiance received during the summer months will be:

$$800 \text{ W/m}^2 \text{ x } 8 \text{ hours} = 6400 \text{ Wh/m}^2 \text{ or } 6.4 \text{ kWh/m}^2$$

Thus from above, we can see that if 1 kWh/m$^2$ is equal to one Peak Sun Hour (PSH), then 6.4 kWh/m$^2$ is equal to 6.4 peak sun hours, or 6.4 PSH.

Now if we assume that during the winter months the average solar energy available drops by half, that is to 400 W/m$^2$ and is only available for half as many hours, that is 4 hours compared to the summer months, then the amount of solar irradiance received during the winter months would be:

$$400 \text{ W/m}^2 \text{ x } 4 \text{ hours} = 1600 \text{ Wh/m}^2 \text{ or } 1.6 \text{ kWh/m}^2\text{=1.6 PSH}$$

Then we can see from this very simple example that the amount of solar energy collected during the sunnier summer months is four times greater at 6.4 kWh/m$^2$, than the solar energy collected during the duller winter months at only 1.6 kWh/m2. Again according to NASA, the worldwide daily average value of solar irradiance across the whole planet over one day is approximately equal to 5.0 kWh/$m^2$ or 5 peak sun hours (PSH).

## §1.4. Using the sun's energy, economic, energy and environmental significance

The use of renewable sources, the importance of evaluating certain sense is here the organic fuel reserves that would be the end of them in all spheres and therefore spend together with increased rates of alternative energy sources, search for the necessity of saving fuel and energy resources as well as exercising it is necessary to take into account the order of hard.

A number of scientific and technical and how much of the problem is proven to be at this level there are directions raqobatlashgan take off. The future from the standpoint of economic efficiency in a certain stage of development, providing direction pleasing to see most right now, there is a need to develop all dimensions of looking for new sources of energy. At this level of energy is associated with it or to take off one of the ways social and economic problems which are local energy resources (infrastructure developed in the heart of coal, gas, oil reserves are small and acute, as well as mastering the scale of renewable energy sources that are available on the territory of uzbekistan is the use of environmentally safe.

The concept consists of the following energy forms of renewable energy sources: sun, geotermal, wind, sea waves, energy, flow, strait and the ocean, biomass energy, hydro, and other renewable energy with low potential heat energy of "new" types. RESs are traditionally divided into two groups:

- The usual: using the hydraulic energy into electrical energy which with a capacity of more than 30 mW gidroelektrostantsiyalar, burn with the usual methods (wood, peat and other types of fuel used to heat the oven to get geotermal energy and biomass energy.
- Offbeat: solar energy, wind energy, the waves of the sea, streams, bo'g'oz energy, and energy into hydraulic energy, which is used by the type mikrogHPPs

small, the usual methods of biomass energy heat energy which'liq be used to get hot with low potential of renewable energy and other "new" types.

The potential reserves of renewable energy sources are divided into gross, technical and economic. The gross potential of renewable energy sources is the average annual amount of energy contained in a given type of renewable energy sources when they are fully converted into usable energy.

The technical potential of renewable energy sources is a part of the gross potential, the conversion of which into useful energy is possible at a given level of development of technical means while observing the requirements of environmental protection.

The main components of renewable energy sources in Uzbekistan are: solar, hydraulic, wind and geothermal energy, as well as biomass energy. According to the results of research carried out by Uzbek scientists, the technical potential of renewable energy sources in Uzbekistan is 270 million tons of reference fuel, which is more than three times the annual need for energy resources.

Table 1.2. Potential im mln. t.o.e./year

| **RE type** | **In Uzbekistan** | | **In the world** |
|---|---|---|---|
| | **Gross** | **Technical** | **Gross** |
| **Solar** | 76459,5 | 265,1 | $131x10^6$ |
| **Wind** | 3,33 | 0,64 | $2x10^6$ |
| **Hydraulic** | 3,43 | 0,39 | $7x10^6$ |
| **Biomass** | 13,8 | 2,92 | $0,1x10^6$ |
| **Total** | 76480,0 | 269,05 | $1401x10^6$ |

Higher and secondary special education of our republic, organizations and businesses with the project inquiries, based on the results of research work about the potential of renewable energy sources installed in Uzbekistan general and technical oriented data summarize the scale of the use of raw materials and fuel resources, renewable energy sources, the share of electric energy from heat and gradually decrease as a result of the use and consumption of primary energy in the production of our republic also meet the needs of transportation printsipial-technical shows the possibility. The evaluation of the potential reserves of RES shows them in the republic of very good (fig.1.18).

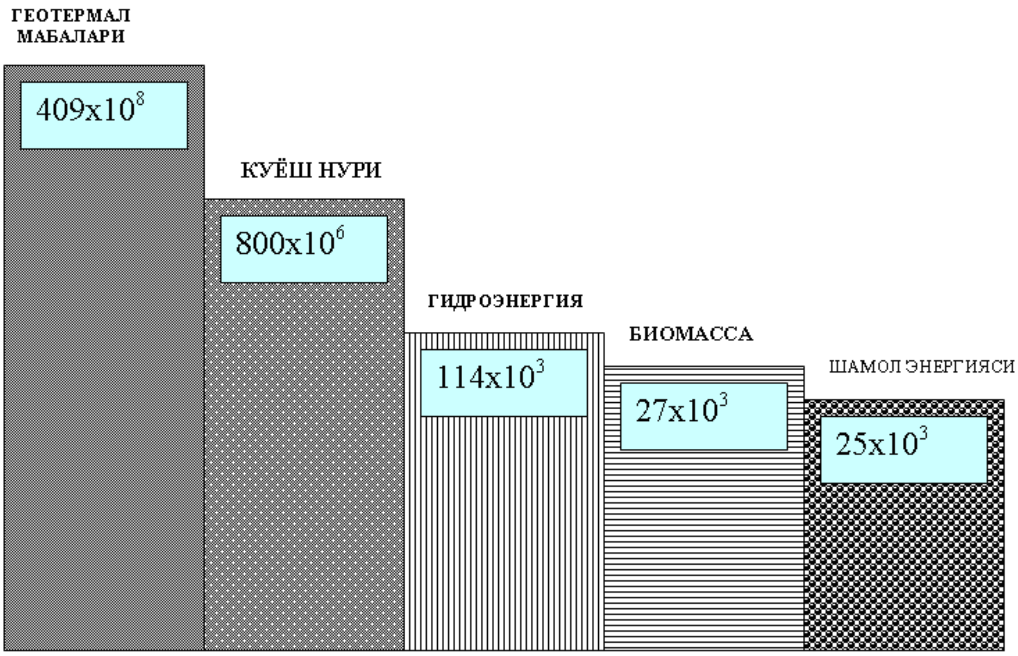



Figure. 1.18. Potential energy reserves of renewable energy sources in Uzbekistan (mil. kw hours/year)

The territory of the republic of the light of the sun, the small rivers, the flow of the wind and other sources of energy who arrived the year valli potential of Uzbekistan, 55-60 mln. tons of conditional fuel to the price of fuel and energy resources annual term hydrocarbon reserves of raw materials from the needs of many in a few times and than the time.

Gross resources or in other words, the theoretical basis on renewable energy sources among the leading geotermal energy. However, relatively low temperatures (70-80 $^0$C), and large depth of water minerallanishi artezian to lay hinders the production of electrical energy from a technical perspective they use. Therefore, if you consider technical potentsiallar performed, then solar energy is leading. The price of energy and limits the wide use of solar energy which produce it.

Therefore, from within all types of renewable energy sources, hydropower, which has a very high economic potential and currently consumes 14.4 billion kWh, will discover practical content. Currently, 4 to 6.5 billion kWh is used. Unused reserves are included in a group of small to medium-sized Gess, characterized by their relatively small pressures, and as a result are targeted at low-power hydroelectric power stations routed along the entire watercourse, including irrigation and drainage channels.

The overall increase in energy resource prices will set the stage for the competitiveness of small and medium-sized HPP electricity. Experiments have shown that different views of microHPP show effectiveness in use. The complex use of water flow energy helps to solve the problem of providing energy to consumers who are low-power by absolute energy consumption magnitude, but released very efficiently by production results. This primarily applies to the mountainous districts of settlements and arable pastures.

In centralized energy supply districts, the use of locally autonomous energy sources allows the energy market to create a competing environment. Along with the energy of small and medium-sized watercourses, unconventional energy sources (wind, solar, biogas energy) can also participate in such competition. According to preliminary calculations, the total use of primary energy in terms of the absolute value of the potential of small and medium water flows, local and non-traditional energy sources is from 1 to 1.5%.

### §1.5. Legal procedure for the use of solar energy

The development of the use of renewable energy sources will reduce fossil, fuel consumption and improve environmental conditions and climate, establish new types of economic activity enterprises and create additional jobs. In addition, the use of RES in territories makes it possible to quickly increase the quality level of the electrical energy system and introduce them with etap. Reduces the cost and risk of invincibility. It is difficult to apply them to a wide scale without creating a privilege for the development of qtems. This was understood by the all countries, which are reducing their technology and success in the process. Relying on the experience of these countries, the following preference forms (forms) can be cited for the use of RES.

- To increase material support for scientific research and experimental design work as well as to lower the cost of energy generated by RES-based devices;

- RES-based equipment and device manufacturing network to attract state invetection;

- Introduction of the use of a privilege for the population on credit to the purchase of energy devices according to the use of RESs;

- Receive benefits in the taxation system for energy producers and energy consumers from devices RESs

- Reduce or cancel import and export customs discount on only RES or component devices and devices;

- Installation of taxes on fossil fuels taking into account $CO_2$ gas;

- The application of RESs to create an environmentally friendly environment in the zones of the exhibition areas, where most residents relax and claim;

Development and introduction of specialist training courses and programs in the higher education system, etc. Many countries have been working for a long time on the introduction of RES into life using a different form of benefits, as well as developing measures for the application of more new technologies. Sustainable energy policy in Uzbekistan is carried out on the basis of regulatory documents and guidelines in the market economy. These documents regulate the energy market between economic facilities and government bodies. For this purpose, regulatory acts are being created and improved. The mechanisms and regulations that trigger energy development are adopted through separate regulatory solutions and by the laws of the president of the Republic of Uzbekistan and decisions of the Cabinet of Ministers. In Uzbekistan, the laws of "Rational use of energy" adopted on May 7, 1997 establish certain benefits for legal and physical persons, which include the use of energy consumption, the use of secondary energoresources, the use of RESs and domestic fuel types.

In such cases, it is envisaged that the Energy Fund will help for them. Benefits are made in the following cases: 1) when obtaining customs deduction and tax on foreign special equipment, tools and materials, if this item and equipment significantly increases the efficiency of energy use; 2) experience and production of energy-efficient equipment in financing scientific research and experimental constructivism work between the fields; 3) from the decision of the Cabinet of Ministers of the Republic of Uzbekistan dated December 28, 1995 №476 "Development of small hydropower" in the preferential allocation of state credit in financing the implementation of targeted (program) programs by national regional and networks, the projects carried out in the field of rational use of energy provide for the construction of many small The basics of using RESs are constantly improving.

## Questions about Chapter 1:

1. Do you think about the sun and its energy potential?
2. The structure and properties of the sun?
3. What do you know about the types and spectrum of solar radiation?
4. What are the tools and equipment that measure modern solar radiation and explain their function?
5. What can you say about the energy, economic and environmental importance of using solar energy?

# CHAPTER 2.
# DEVICES AND METHODS FOR OBTAINING THERMAL ENERGY FROM SOLAR ENERGY

In the conditions of the climate of Uzbekistan, the extraction of thermal energy from solar energy is intended to meet the demand for hot water and heating supplies of buildings and structures based on these solar energy devices. This chapter focuses on the devices that convert solar energy into thermal energy and the systems on which they are based.

## §2.1. The recipient of thermal energy from solar energy history of the development of devices

The widespread use of solar energy in heat supply goes back to the distant past. Below are the stages of development of this line.

1. Ancient civilizations: the use of solar energy began in ancient civilizations. For example, the ancient Greeks and Romans built their houses in such a way that they use sunlight and heat as efficiently as possible. The architects directed the buildings to the south so that the rooms were warmer during the cold months due to the sun's Rays.

2. $19^{th}$ century: in the 1860s, the French inventor Augustin Mouchot created the first solar machine to use mirrors to direct sunlight and heat water-vapor deposition. This was one of the first examples of practical use of solar energy.

3. 1940s: the development of the first modern solar water collector for solar heating occurred in the 1940s. These devices began to be used for heating water at home, which significantly improved the possibilities of independent energy preparation.

4. 1970s: the energy crisis of the 1970s spurred the rapid development of renewable energy technologies, including solar heat supply. Many governments

have begun to introduce incentives and subsidies to support research and development in the field.

5. 1980-2000: with the advent of more efficient and affordable photovoltaic technologies, the growth of solar energy accelerated. Solar heating systems have become common and economically viable for private households and businesses.

6. 21st century: with the development of nanotechnology, improved materials and energy storage methods, solar heat supply continues to improve. Modern systems not only heat water efficiently, but also support the operation of heating systems and can be combined with other types of renewable energy for maximum efficiency and stability.

Thus, the solar heat supply has gone a long way, from primitive architectural solutions to high-tech systems that play a key role in the transition to renewable energy sources.

## §2.2. History of solar collectors

The technology of solar collectors cannot be called super new. The fact that the first model of the solar collector was created from glass, wooden box and an inner warming layer was created by the swesarian scientist Gorasiy Sossyur in the 18th century. The scientist noted at this time that this construction was "small, cheap and simple." The first in practice to use such a device for water heating began in Southern California in the late 19th century. Various firms began to produce simple solar collectors mounted in a wooden box, in the form of a black buck for water, and oriented to the sun with one side covered with glass. In this case, the water would have to cool down during the night and wait for it to heat up the next day.

In 1909, in California, William Beale created a prototope of a modern flat collector mounted separately from the buck for water and transmitting heat through a heat-exchanging contour. The industry of solar collectors developed primarily in the United States of California, Florida, until the late 1940s, and then the cost of electricity and gas in water heating decreased, so that the production of solar collectors ceased. The second prospect of solar collectors was that during the oil crisis of the 1970s, prices rose very high. As a result, mass production of solar collectors began in many countries, which continued especially in the United States, Japan, Australia and the Mediterranean. Israel began to experience energy shortages starting in the 1950s. The energy shortage was such that in the evening, there was a ban on heating water at night by Israel legislation. At this time, the production of water heating solar systems developed in the country.

By 1967, 20% of the country's population had switched to using solar collectors. At the time of the energy crisis in the 1970s, parliament passed legislation that new houses under construction should be provided with water heating solar systems. By now, as a result, about 85% of homes in Israel are served by solar collectors.

The energy generated by them accounts for 3% of the country's energy consumption and is estimated to be 2 million per year. the barrel saves oil. With the rise in the cost of energy resources in the 2000s, a new stage in production began and the use of solar collectors expanded. In early 2010, the capacity of solar collectors installed on our planet increased by 150 GW (in addition to solar systems that heat air collectors and pools).

### § 2.3. Application and use of solar energy in agriculture

For the maintenance of mechanisms and machines in the peasant enema from electricity, heating air and water, steaming, in technological needs, raising water and lighting, etc.k. used. Autonomous power supply of peasant enemas should provide the possibility of operation of entire machines and equipment complexes. Therefore, it is necessary to select such types of agricultural energy consumers so that they can be used in the production of low-volume rural agriculture in terms of its energy consumption, productivity and other technical characteristics.

It is only possible to determine the necessary power of an autonomous energy source by drawing up a time-based graph of energy consumption based on the accepted technology of rural agricultural work, or electricity between technological operations consumed by the entire peasant or company Agriculture (fig. 2.2).

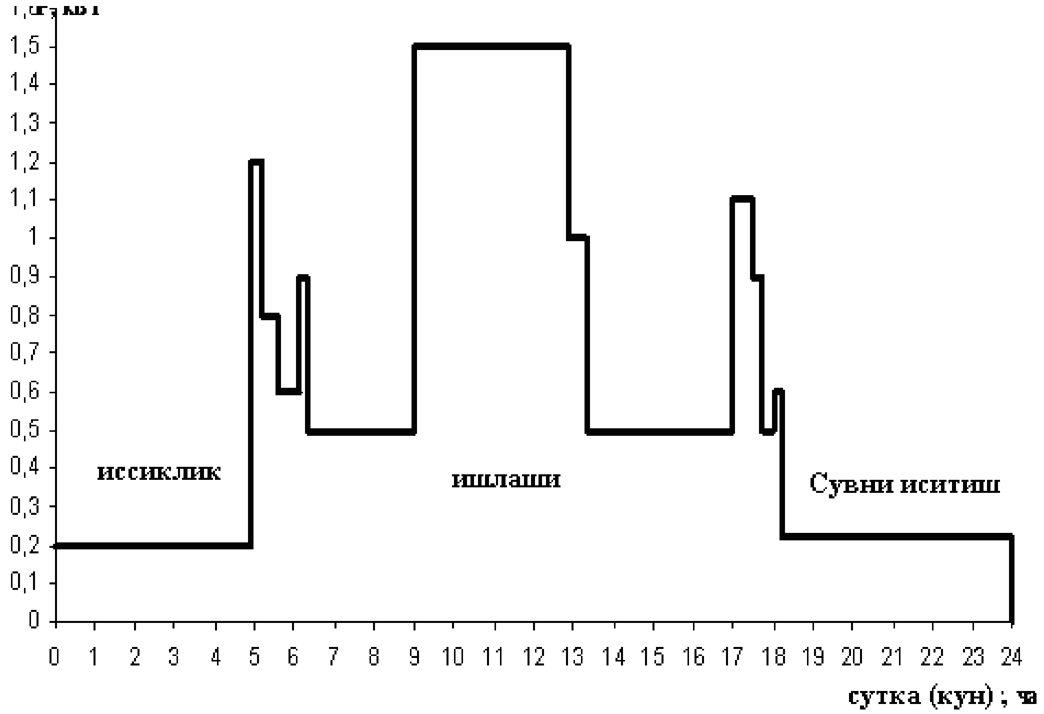



Figure 2.2. Distribution of electrical energy to the electrical equipment of the farmer's enema during the day.

**Water heating.** Household electric water heater is more convenient for residential use in houses that do not have a centralized hot water supply, as well as for housing conditions designed to provide hot water to residents of buildings where it is not advisable to use gas and similar apparatus, which are designed for heating and storing hot water at large intervals. Such a water heater is in the form of a heat-repellent metal buck, in which an electric heater element and a device that adjusts or limits the temperature of the water are located. Bak capacity is usually chosen based on the Daily need for hot water. For example, for kitchen needs (mainly for washing dishes), the capacity of the water heater is 7-10 l, and for the shower and bathroom- 80-150 l. The water in the tank is heated by electric heating elements as a result of natural convection. The heating speed depends on the size of the buck and the capacity of the heaters. For household extensions, water heaters with a unified capacity of uns series, 10 l (for the kitchen) and 40, 60 and 100 l (for the shower and hammam) are produced. These water heaters have a single, 125 kW heating element installed for the entire series, which connects the 220 V voltage to the network. In terms of savings, electric heaters of the EVAN type are of interest. The EVAN 5/1, 25 type water heater is a low pressure battery type instrument. It provides a family of 2-4 people with hot water for all their needs. The fact that the time of heating the water from 15 to 85 $^{0}$C is more than 20 minutes allows you to adjust the water temperature.

Table 2.1

| **Technical dates** | |
|---|---|
| Power, kW | 6 |
| Capacity, l | 12 |
| Heated water temperature, $^{0}$C | - |
| For technological needs | 75 |
| For Heating | until 90 |
| Weight, kg | 12 |

To heat a large amount of water, for example, for a company enema, it is advisable to take heat accumulator electric heaters with a capacity of Evan-100 or EVAO-100 types. This water heater heats 100 l of water to a temperature of 850s, then turns off automatically. Due to the special heat storage insulation, the water stays warm for a long time and can be used for various extents. EVAN Power is 1.25 kW, heating continuity is close to 8 hours. It is deliberately made, to activate this heater in the evening when there is an excess of electricity on the network. With an even larger volume of heated water, the flowing type EVNU-6 provides a universal electric water heater, is designed for heating water in technological hot water supply and heating systems of manufacturers and household buildings on small farms and private enemas (Table 2.1).

### § 2.4. Solar water heater collectors and their types

Solar collectors absorb solar radiation energy and convert it into ambient thermal energy (usually water or air) and are used for heating and hot water supply. There are three different types of solar collectors:

- flat

- vacuum

- cumulative concentrators.

The most common liquid flat collector in the world will consist of a heat-absorbing panel (absorber) and channels (tubes)attached to it for heat carrier circulation. The upper part of the absorber, which absorbs solar radiation, has transparent insulation. All of this structure is attached to the body, and the back and sides are covered with thermal insulation material. A solar collector is a device designed to collect solar energy and convert it into heat or electricity. Depending on the design and application, there are different types of solar collectors.

Let's look at some of them as well as the effectiveness and principle of operation:

**1. Thermal solar collectors**: flat collectors: this is the most common type of thermal solar collectors. They consist of a flat surface covered with transparent material through which sunlight passes and is absorbed by the absorber, which converts it into heat. The efficiency of such collectors is usually from 40% to 80%, depending on the design and technical characteristics. Vacuum tube collectors: vacuum tube collectors generally have higher efficiency compared to flat collectors. They consist of glass tubes containing a vacuum-enclosed absorber to reduce heat loss. The efficiency of vacuum tube collectors can exceed 80%.

**2. Photovoltaic (solar) panels:** photovoltaic panels convert sunlight directly into electricity using the photovoltaic effect. The efficiency of photovoltaic panels is usually between 15% and 22% for silicon panels, but there are more efficient technologies that can be higher than 25%, such as crystalline or perovskite solar panels.

**3. Concentrated solar collectors:** these collectors use lenses or mirrors to concentrate sunlight on a small absorber, allowing for increased temperature and improved conversion efficiency. The efficiency of concentrated solar collectors can be very high, which exceeds 30-40%. The performance and efficiency of solar collectors can vary significantly depending on many factors, including the intensity of solar radiation, temperature conditions, specifications, and operating conditions. However, a properly designed and installed solar collector can significantly save energy and reduce the cost of heating or generating electricity.

The process of work of solar collectors. The solar water heating device is composed of a solar collector, a heat exchanger contour and a heat accumulator (water tank). Through the solar collector, the heat carrier (liquid, propylene glycol,) acts circulatory. In the solar collector, the heat carrier heats up at the expense of solar energy and gives its heat to the water through the heat exchanger installed in the bak-battery. Hot water is stored in the Bak-battery until it is used, so it is necessary that it has good thermal insulation. In the first contour, where the solar collector is located, there may be a natural and forced circulation of the heat carrier. An electric heater-doubler can be installed on the Bak-battery.

When the water temperature in the Bak-accumulator drops below the norm (in cloudy weather, the hour of solar radiation decreases in the winter season), the heater-doubler will automatically add and heat the water to a given temperature.

The main structural element of solar equipment is the collector, in which the capture of solar energy, its replacement by heat and heating the water to air or any other heat carrier is carried out. Two types of solar collectors are distinguished, flat and focusing.

In flat collectors, solar energy is swallowed without concentration, and in the foci – with concentration, that is, with an increase in the density of the incoming radiation flow, the most common type of collectors in low-cost Helio equipment is the flat collector of solar energy collectors (SEC). Its operation is based on the principle of "hot crate", which is easy to imagine if we remember that a closed car cabin heats up in the sun, and it serves as a kind of cover for it to the bright rays of transparent mirror surfaces. To prepare a flat cage, first of all, a light-absorbing surface with a reliable connection of a pipe or a series of channels is necessary for the heating heat carrier to be discharged. The sum of a flat light-absorbing surface and heat-carrying tubes (channels) forms a constructive single element, the absorber. In order for solar energy to be well absorbed, the surface above the absorber must be painted black, and the decrease in heat losses to space with a special absorbent coating is achieved by using thermal gezolation, which closes the lower surface of the absorber, as well as transparent insulation of Light located at a certain distance from it above the absorber. All transparent insulation compaction is covered with glass. Thus a liquid heating flat collector is formed, the general view of which is shown in figure 2.1.

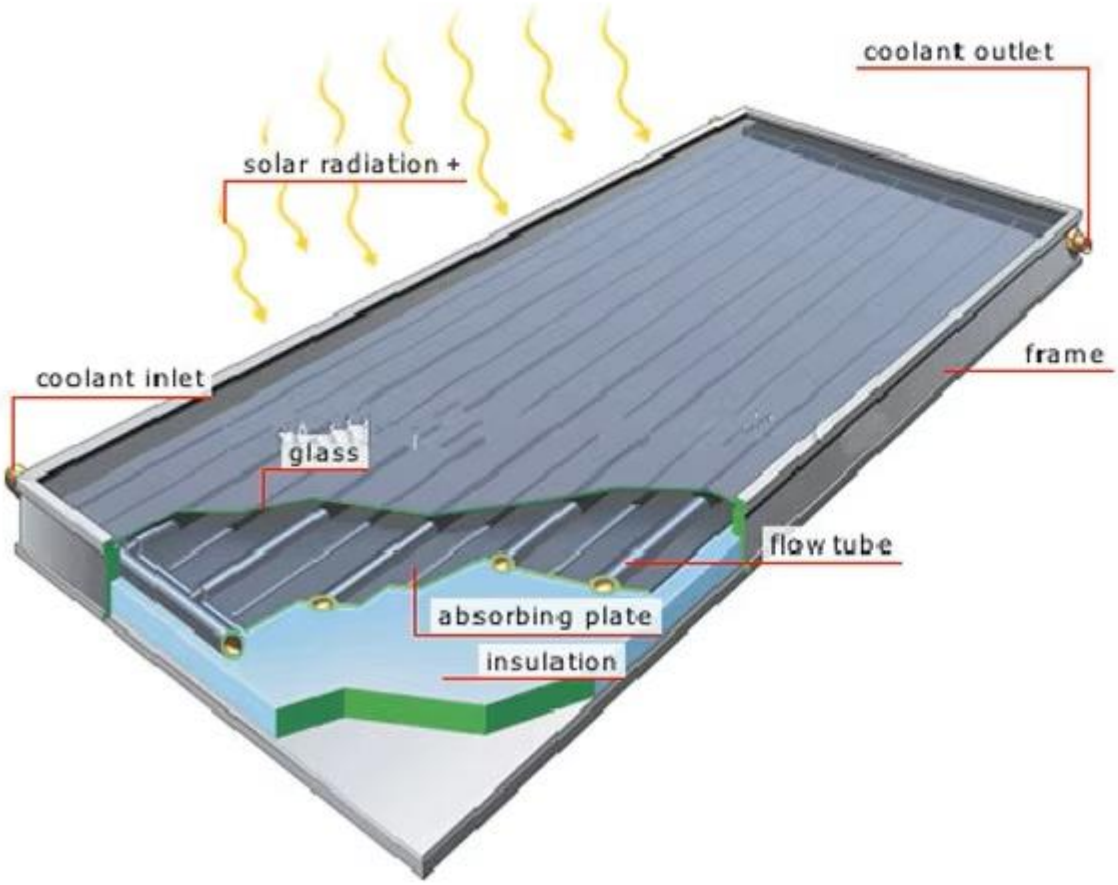



**Figure 2.1. Constructive elements of the solar energy flat collector.**

The principled advantages of a flat Jack over other types of collectors include its ability to retain the correct (luminous) and also scattering solar energy, and as a result – the possibility of its stationary installation without the need to observe it from behind the sun. Solar energy flat collector absorber is usually made of metal with high thermal conductivity, in particular steel, aluminum and even copper.

Transparent insulation is in the form of one or two layers of glass or polymer plinth. A combination of the outer floor of the bottle and the inner floor of the polymer plenka can be used. In the case of low heating temperature of the heat carrier (up to 30 $^{o}$C), the collector may not have transparent insulation at all.

The Collector body can be made of galvanized iron, aluminum, wood, plastic. Various materials can be used as thermal insulation: mineral cotton, penopolyurethane and etc.

- conductive property of transparent collector surface coatings;

- absorption capacity of collector surface relative to sunlight;

- the optical code of the collector or the quoted absorption capacity of the Collector surface (more than 0.85);

- absorption panel efficiency coefficient (heating fluid, material and panel thickness of channel sizes) flow rate and properties of the fluid in the collector, in modern constructions the F value is equal to 1 (more than 0.9);

- the density of thermal energy losses of the collector is determined by two factors: cooling the panel in the environment using convection and radiating heat from the surface.

The average temperature of the collector panel is T or the average liquid temperature is almost equal to the temperature of the hot liquid at the outlet from the collector, such as Tg, determined by the collector structure and description, as well as the intensity of the falling light T, the temperature of the cold liquid at the inlet is TX, and the exemplary consumption of liquid per unit working surface of the collector is determined by G, kg/(m2C), liquid heating technology.

Where $C_P$, J(kg / s) is the comparative heat capacity of a liquid. Here, using (I), we achieve the connection with fluid consumption with the arrival of energy fluid charor and environmental flow in the fixed energy flow. Fluid consumption decreases when it raises its temperature at discharge. The difference between the maximum dissolved liquid heating temperature $T_m$ and the ambient temperature corresponding to the absence of liquid flow (P=0) is equal to the following.

## § 2.5. Solar collectors and heat exchangers in them install and configure devices.

Solar collectors absorb solar radiation energy to convert it into ambient thermal energy (usually water or air) and are used for heating and hot water supply. There are different types of solar collectors: through the use of flat, vacuum and concentrators. The most common liquid flat collector will consist of a heat-absorbing panel (absorber) and channels (tubes) attached to it for heat carrier circulation. The upper part of the absorber, which absorbs solar radiation, has transparent insulation. All of this structure is attached to the body, and the back and sides are covered with thermal insulation material. Solar energy flat collector absorber is usually made of metal with high thermal conductivity, in particular steel, aluminum and Hatto copper. Transparent insulation is in the form of one or two layers of glass or polymer plinth. A combination of the outer floor of the bottle and the inner floor of the polymer tape can be used. In the case of low heating temperature of the heat carrier (up to 30 $^{o}$C), the collector may not have transparent insulation at all.

The collector body can be made of galvanized iron, aluminum, wood, plastic. Various materials can be used as thermal insulation: mineral cotton, penopolyurethane and etc. The useful power P=W/m$^2$ carried over the collector unit surface can be quoted with the following expression:

Where ν=W/m$^2$ is the cumulative radiation intensity in the collector plane;

a. conductive property of transparent collector surface coatings;

b. absorption capacity of collector surface relative to sunlight;

c. the optical code of the collector or the quoted absorption capacity of the collector surface (more than 0.85);

d. the coefficient of efficiency of the absorbing panel (heating fluid, material and panel thickness of the dimensions of the channels) is the flow rate and peculiarities of the fluid in the collector, in modern constructions the value F is equal to 1 (more than 0.9);

e. the density of the losses of thermal energy of the collector is determined by two factors: cooling the panel in the environment by convection and radiating heat from the surface.

Air collectors refer to the use of solar energy and use air as a heat carrier. Currently, they are distributed in the USA, to a lesser extent in the central parts of Europe. In very rare cases, Air collectors are used for water heating. The largest aerial solar collector is located in Europe near Leipzig in the city of oshas, with an area of 1,175 $m^2$. It is designed for heating a warehouse of finished products and building materials. It is advisable to use air collectors to obtain hot air (not hot water). Samples for the use of air collectors:

1. Buildings with an air heating system, such as gyms, warehouses, cexes, buildings with a high level of external air intake and residential houses. In part, after the standard introduction into low energy consumption in western Europe, the proportion in heat consumption to air heating in the ventilation system has become more important than the total consumption of heat. The system used in combination with controlled ventilation and an air collector can cover a significant part of the required heat. With the help of Air solar collectors, it is definitely impossible to fully provide heat in the winter seasons, the reason for this is the unfavorable relationship between the amount of solar energy falling and the amount of heat required for heating.

2. Buildings for drying agricultural and industrial products, as well as cereals, seeds, medicinal and medicinal plants, wood and building materials. The drying potential of the air solar collector is about 0.2 to 0.7 kg of water evaporation per hour per 1 $m^2$ collector surface.

3. In solar cooling systems. That being said, air collectors are less common than liquid-powered collectors, but they have significant advantages over liquid-heat-carrying collectors:

- air collectors do not freeze in winter;
- heat carriers will not be at risk of leakage when overheating in the summer;
- there are very few problems with carrosia;

- air collectors are less demanding on materials, much cheaper;

- heat exchanger when using directly heated air in collectors, there will be no heat loss;

- fire safety.

Thanks to these achievements, they are always suitable for individual constructions, can be easily assembled during installation, require little output. Also air collectors are effective for heating production buildings, garages, small buildings that took home.

In combination with this, air collectors have the following disadvantages:

- air holes can shorten the useful area in the building;

- effective heat accumulation cannot be achieved in them;

- due to the low density of heat carrier air, the thermal production efficiency of the system is low compared to collectors working in liquid;

- usually during the operation of air collectors, a large amount of electricity is used to drive air;

- the useful working coefficient of the air collector is smaller than that of the liquid collector, which is determined depending on the physical properties of the air.

Air collectors are mainly made in flat appearance. They are made up of thermal insulation material, absorber, upper transparent coating and casing, which are located in the lower and side wall body. When choosing various components, body and other materials, taking into account the resistance to atmospheric and other influences, Basic Rules such as fluid collectors are observed.

Air collectors are divided into 2 classes, depending on the absorber structure: - in the form of an absorber with an air-conducting matrix (figure 2.4; - in the form of an airtight flat absorber (from the back) (figure 2.5).

An air collector with an air permeable Matrix absorber (in the future, briefly speaking of a matrix absorber) is made up of a porous material with open pores (here the term "matrix" is used). For example, it can be penoplast plates that are placed as an air filter on the air cylinder, or black porous material used in weaving. Solar radiation is not only on the surface of the absorber layer. maybe it is also swallowed in its interior. With a transparent coating, a slit with a variable width is placed in the middle of the absorber, which serves to transfer air to the absorber. The air also absorbs heat during the filtration process through the absorber.

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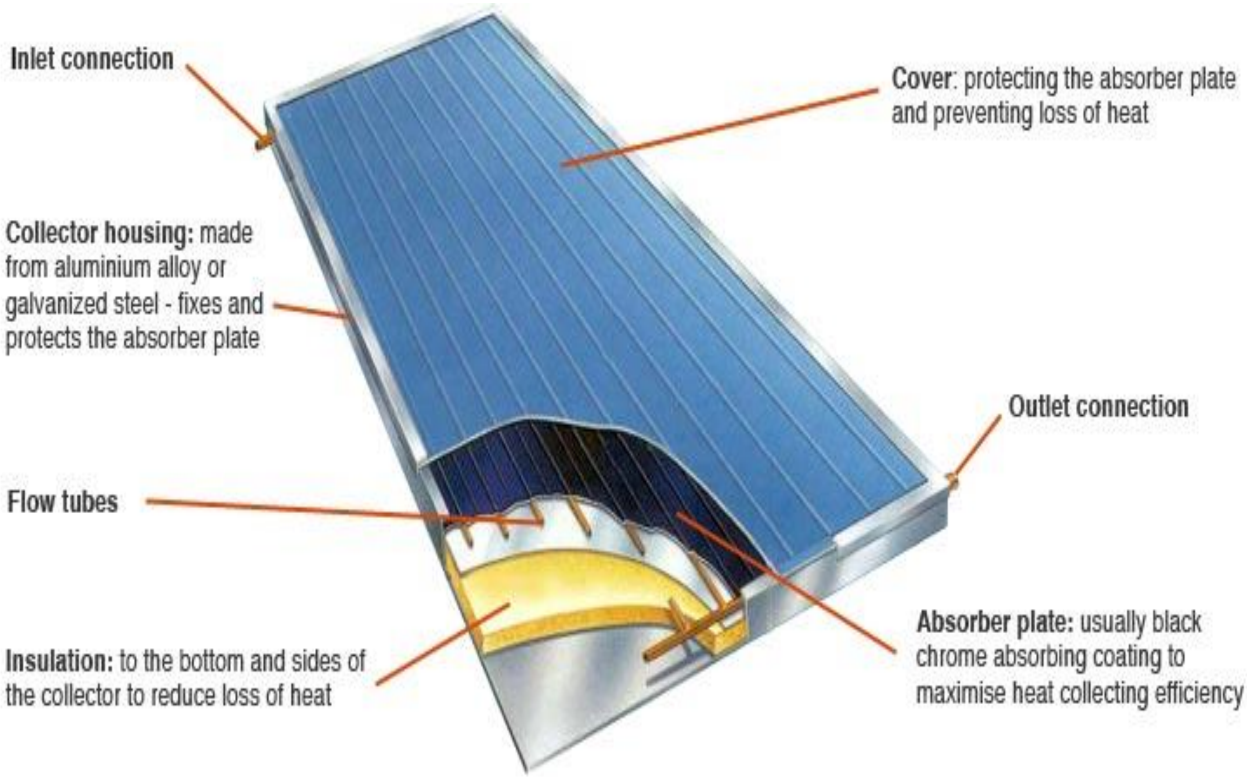



Figure 2.4. Matrix absorber solar air collector

As shown in Figure 2.5, air travels parallel to the absorber, or along the two surfaces of the absorber, or along its back. Heat is supplied to the air by convection along the absorber wall or by the method of thermal conductivity. A collector with an absorber with an air-conducting matrix is usually more efficient when a collector is used to heat the outside air. The fact is that when the outside air is at low temperature, the high transparent coating is cold, when using a structure with an air-permeable absorber moving air across the surface of the two absorbers, the heat transmission through the transparent coating is high.

In this case, if under normal conditions it is required to heat the air to a high temperature, first of all, a structure in which there is air movement from the back of an airtight absorber structure is preferred. The heated air will not come into contact with a transparent top coating at cold temperatures, the coefficient of heat transfer will be small. It is necessary to consider the good transfer of heat from the absorber to the heat carrier, and when designing air collectors in relation to liquid collectors, it is necessary to consider the sufficiently high efficiency coefficient of the absorber. The thermal conductivity of air is 24 times smaller than that of water.

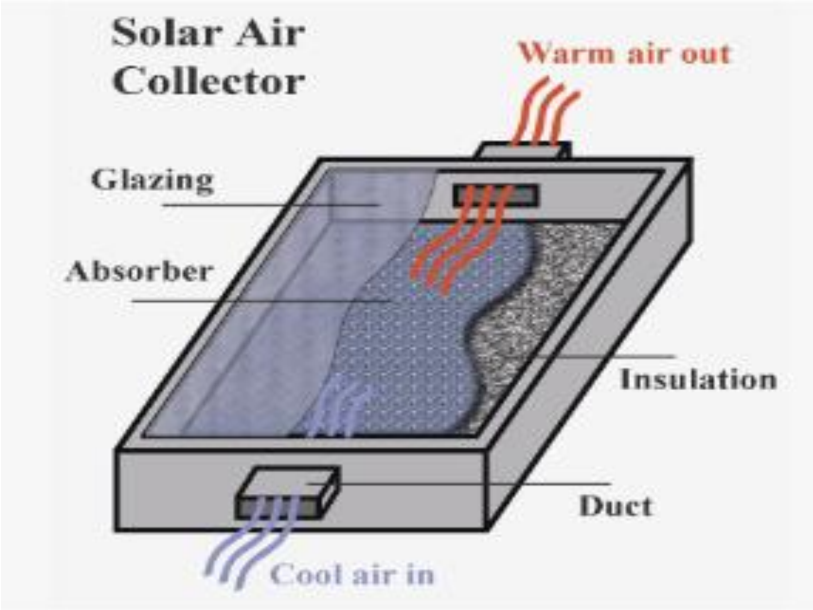



Figure 2.5. Solar air collector with airtight absorber

Therefore, for heat exchange, it is necessary to form a large surface and create an air flow of a narrow transverse cross-section. At the same time, it is necessary to consider the electrical energy output and hydraulic resistance that will be spent on the work of the fans that provide the movement of the heat carrier. With an increase in the average speed of air in the channel, hydraulic resistance also increases rapidly. In general, the coefficient of heat transfer from the absorber to the air increases slowly. It is necessary to optimize air ducts in concrete structures in the collector. The goal of optimization is to increase the possibility of forming a large surface contact with the absorber so that the pressure of excess air does not fall during effective heat transfer.

Also currently, an air photoengineering device (PV-T collector) design is also created on the basis of a combination of air collectors with photoelectric batteries. Solar elements are usually cooled by forming a natural convection or forced air circulation to cool the photoelectric modules installed on the facades and roofs of the building at the back (fig. 2.6).

Fig. 2.6. Air photosensitivity devices created by SolarWall company

SolarVenti offered a similar design to the world market in 2001. The structure was developed by the company and was automatic ventilation of dacha-type houses by cooling photovoltaic modules. Some of SolarWall's back-to-back developments have also evolved to find their place in the trade. The heat separating from the rear of the photoelectric modules is directed to the heat supply of the building using ventilation or conditioning.

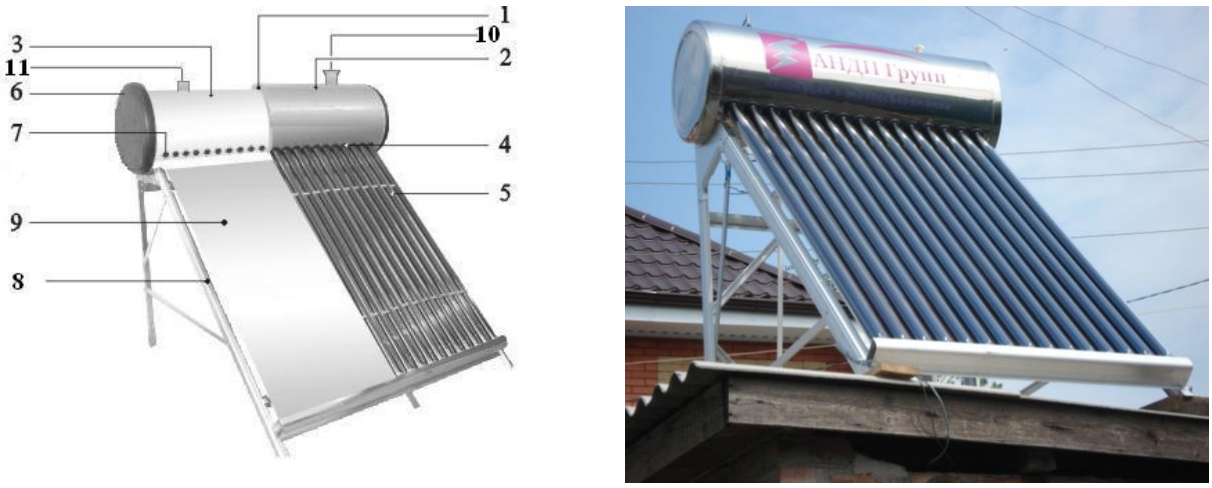



Fig 2.7. Installation of solar water heater collectors.
1-water tank; 2 – buckning plaster; 3 – buckning plaster; 4 – external fastener; 5 – vacuum tubular plaster; 6 – suv uchun tank plaster; 7 – rubber plaster Plaster; 8 – steel or stainless steel with galvanic coating; 9 –an option or the installation plates – torsion; 10 – emergency air valve; 11 – sensor controller.

The solar water heater collector, developed at the firm Andi Grupp, does not take much time to Install, Install and assemble in houses and field yards, especially since special knowledge and skills are not required. The device's writ will show the installation procedures and the processes of assembling the device in a pictorial way to carry out the installation process.

Two people will definitely be needed when assembling, installing, installing a solar water heater device. It takes about 2-3 hours to assemble, install, launch one device. In addition to the necessary instruments, liquid soap and sponges are definitely used. The construction of the base frame is carried out in accordance with the picture in the writ. Bolts and gags of certain sizes are used when assembling the boating equipment of the rama carcass.

### § 2.6. Solar water purifier devices and their energy analysis

A solar water purifier is a device that uses solar energy to purify salt or contaminated water as well as to prepare a suitable source for consumption. Its energy characteristics include:

**Solar radiation energy:** the solar flue device uses solar radiation as an energy source. For this purpose, solar panels are usually used that convert sunlight into electricity.

**Energy efficiency:** the efficiency of a solar chute device depends on several factors, including the efficiency of solar panels, energy conversion efficiency, the efficiency of the chilling process, etc. Optimizing all of these factors can increase the energy efficiency of the system.

**Spraying process:** Solar spraying device can use various water purification methods such as reverse osmosis, evaporation-condensation, etc. Each of these methods has its own energy requirements and characteristics.

**Energy storage:** an important aspect of the energy performance of a solar suction device is the ability to store solar energy for use during periods of lack of sunlight, such as at night or on cloudy days. Batteries or other energy storage systems can be used for this. Application scale and production performance: the energy characteristics of a solar flue device can also depend on its scope and operation. Larger devices can provide more fresh water, but more solar panels and other equipment may be required to provide the necessary energy.

Figure 2.8. Water-repellent device using solar energy

Solar water purifiers are a promising solution to ensure the use of clean drinking water in remote and remote areas where the use of electricity is limited. They allow the use of a renewable energy source to solve the problem of water supply and at the same time reduce the negative impact on the environment. Types of solar water repellent devices. There are several types of solar water purifier devices, each of which uses different technologies and methods to purify water. Some of them are listed in the sheep:

**1. Evaporation-condensation-based solar water fresheners**: these devices use solar energy to evaporate contaminated or saline water and then condense the Steam back into the water. They usually consist of solar collectors, a steam generator and a capacitor. The water evaporates under the influence of solar heat, and then condensates on the surface of the steam-heated capacitor, forming desalinated water.

**2. Reverse osmosis-based solar water purifier devices:** these devices use solar energy to drive pumps and other equipment needed for the reverse osmosis process. In the reverse osmosis process, salt water passes through a semi-permeable membrane, which captures salts and other impurities, leaving desalinated water.

**3. Solar water purifier devices based on embodied solar radiation:** these devices use solar mirrors or lenses to collect solar radiation on the working surface where the desalination process takes place. It can be evaporation, condensation or other processes based on the thermal effects of solar radiation.

**4. Vacuum distillation-based solar water purifier devices:** these devices use solar energy to heat contaminated or saline water, then the water evaporates and condenses in special capacitors to form desalinated water. The vacuum helps to lower the boiling point, which allows the process to be carried out at low temperatures and low power consumption. These different solar desalination plants have their own advantages and limitations and the choice of a particular installation may depend on local climatic conditions, available resources, and water desalination needs.

## § 2.7. Solar-based drying devices

Solar dryers are devices that use solar energy to dry a wide variety of materials, such as fruits, vegetables, grains, wood, grass, and other biomass. Their effectiveness can be influenced by the following factors:

**1. Design efficiency:** the design of the drying device plays an important role in its efficiency. Effective drying devices should be designed to maximize the use of solar radiation and ensure good air circulation inside.

**2. Materials and insulation:** the use of materials with good thermal insulation can reduce heat loss and increase the efficiency of the drying process. It is also important that drying devices are built from weather-resistant materials.

**3. Moisture control:** effective sun drying devices should be able to control moisture inside plants. This can be achieved with ventilation holes or special devices for moisture regulation.

**4. Size and scale**: the correct size of the drying device should match the size of the dried material and the needs of the user. Installation that is too large or too small can be ineffective.

**5. Climatic conditions:** the effectiveness of solar drying devices depends on the climatic conditions in the region in which they are used. In areas with Sunny and hot climates, they can be more effective than in cold and humid areas. In general, properly designed and used solar drying devices are a very effective means of drying various materials, helping to save energy and reduce dependence on traditional energy sources (figure 2.9).

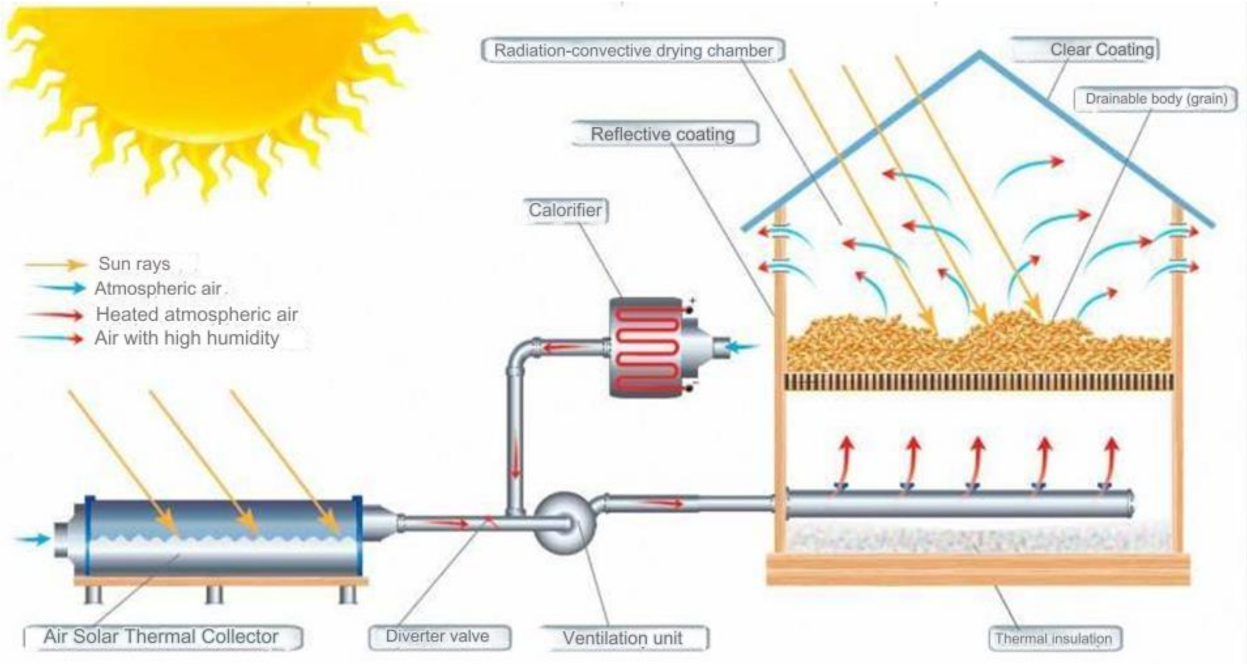



Figure 2.9. Functional scheme of solar convective dryer

Methodology for calculating the effectiveness of solar drying devices. The calculation of the effectiveness of solar dryers involves assessing several basic parameters that affect their performance and ability to dry materials. Here, the method of calculating efficiency includes the following parametardar:

**1. Determining the performance of a solar collector:** the first step is to determine the performance of a solar collector. This includes measuring or evaluating the collector area, its orientation, inclination, and the efficiency of collecting sunlight.

**2. Heat flow measurement:** it is necessary to measure or evaluate the heat flow entering the surface of the solar collector. This is an important parameter that determines the amount of heat that can be used to dry materials.

**3. Determination of the heat transfer coefficient:** the heat transfer coefficient between the collector and the dried material must also be taken into account. This coefficient depends on the material of the solar collector, the type of drying chamber and other factors.

**4. Calculation of drying volume and drying time:** knowing the coefficient of heat flow and heat transfer, it is possible to calculate the drying volume and the time required to dry a certain amount of material.

**5. Assessment of the energy consumed by the system:** when calculating the total energy efficiency of a solar dryer, the energy consumed by the system (such as a fan for air circulation) must also be taken into account.

**6. Comparison with other drying methods:** finally, the effectiveness of a solar drying device can be compared with other drying methods, such as natural or mechanical ventilation, to determine its advantages and disadvantages. The calculation of the effectiveness of solar dryers helps to optimize their design and production process, and helps to make sound decisions when choosing drying methods for certain materials and working conditions.

## Questions about Chapter 2:

1. List the devices that receive thermal energy from solar energy?
2. How many types of solar collectors are divided?
3. Structural arrangement of solar collectors?
4. The main differences of solar water and air heating collectors?
5. The principle of operation of solar water impeller devices?
6. List the possibilities for controlling heat flow in solar greenhouses?

**:**

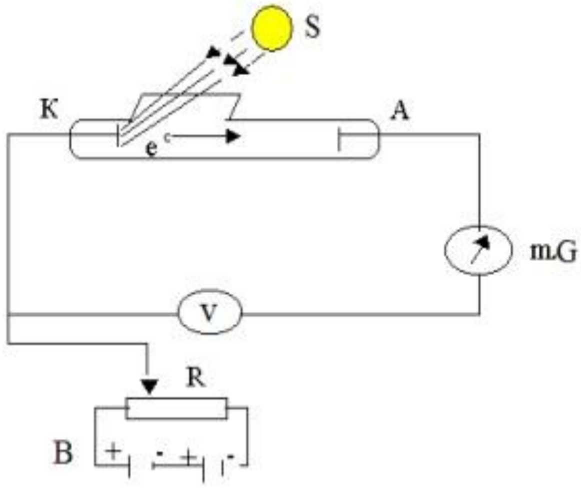
# CHAPTER 3. METHODS OF OBTAINING ELECTRICITY FROM SOLAR ENERGY, DEVICES AND SYSTEMS.

## § 3.1. About history

The history of solar panels is complex, so there is no simple answer to the question of who exactly invented these devices. Instead, many scientists and innovators have completed each other's discoveries. In 1839, French physicist Edmond Becquerel discovered the photoelectric effect. He created a cell made of metal electrodes and found that it produces more energy when exposed to sunlight. Because of this discovery, Willoughby Smith discovered in 1873 that selenium could be used as a photocondector. Then in 1883, Charles Fritz created the first solar cells from Selenium based on Smith's discovery. They were similar to those used today, the only difference being that modern manufacturers use silicon instead of selenium. Finally, in 1954, Daryl Chapin, Calvin Fuller, and Gerald Pearson created the first silicon solar cell at Bell Labs.

### § 3.1.1. Physical properties of sunlight and the phenomenon of photoeffect and its discovery

Photoeffect is the electron separation from an object when exposed to light. The first to experience the phenomenon was in 1887, when G.Gers observed, and he was observed in the experiment by the Russian scientist A.Stoletov checked. In 1898, Lenard and Thomson determined that the particle separating from the cathode as a result of photoeffect was an Electron based on the particles flowing in the magnetic field. To study the phenomenon of photoeffect, a glass container with air absorption, a cathode and anode plates inside it are taken (figure 3.1). As a result of the experiments carried out, the volt - Ampere characteristic in Figure 3.2 was obtained.



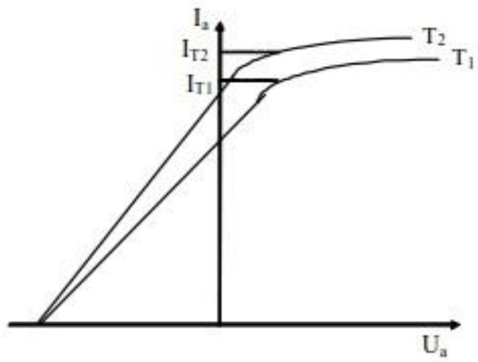




Fig 3.1.    Fig 3.2.

There are 4 Basic Laws of photoefect:

**1.** While the spectral composition of light falling on a particular photocathode is constant, the saturation value of the phototoc is exactly proportional to the light flux.

**2.** The maximum value of the initial velocities of photoelectrons separating from a particular photocatode does not depend on the intensity of the light. When the wavelength of light changes, the maximum velocities of the photoelectrons also change.

**3.** For each photocathode, there is some "red border", from which a photoeffect does not occur under the influence of light with a larger wavelength. Its value is absolutely independent of the intensity of light, it depends only on the chemical nature of the photocatode material and the state of its surface.

**4.** No significant time elapses between the fall of light on the photocathode and the formation of photoelectrons.

The 1$^{st}$ Law of photoeffect can be explained on the basis of Wave Theory. But wave theory fails to explain laws 2 - 3 and 4. The laws of the photoeffect experiment cannot be explained on the side of classical physics. Classical theory is completely impotent in explaining this phenomenon. Well, why classical theory cannot afford to explain the photoeffect process, after all, even from its point of view, this phenomenon is permissible. A qualitative explanation of photoeffect on the basis of wave theory seems to be possible in one view. According to Maxwell's theory of electromagnetic waves, thermal radiation is electromagnetic radiation – light with a full length in the field visible to the human eye, and its structure is constructed from electric and magnetic fields. The square of the amplitude of the electric field of radiation characterizes the intensity of light. Therefore, the amplitude of the falling electromagnetic radiation forces electrons on the metal surface to vibrate, if with a period of Hussite oscillation of the Electron, a resonance occurs when the oscillation period of the falling wave corresponds, the vibrational amplitude of the electron increases sharply, and as a result it leaves the metal surface and leaves the arrangement. By the way, if such a landscape is appropriate, then the kinetic energy of electrons separated from the metal surface should be a link to the intensity of the incident light.If the intensity of the falling light increases, the kinetic energy of electrons separating from the metal surface in accordance with it should also increase. Unfortunately, the result of experiments made in large numbers shows that in a photoeffect, the kinetic energy of electrons separated from the metal surface is not a mutlaco bond to the intensity of the falling light, whether we illuminate the metal surface with the monochromatic radiation of a 1-watt bulb or a 1000-watt bulb, to which, anyway, the kinetic energy of its electrons

It was very surprising that the kinetic energy of electrons separating from the metal surface does not have a link to the intensity of the radiation of the falling light. Eskperiment high Judge. This result of the eskperiment was the first problem of photoeffect, and it rejected the direct light wave theory. For this reason, this result was also a problem of classical physics. According to the classical theory, when the intensity of light radiation falling on a metal surface is very weak, then electrons should not be separated from the metal surface at all or separated late. To explain this point, take the following example. Let the surface of the potassium Metal be illuminated by light radiation with an axial density of $E_0=10^{-5}$ W/m$^2$. Energy equal to $3.6\cdot10^{-19}$ W·h is needed to separate electrons from the potassium atom. In order for this energy to accumulate on the metal surface, it is necessary to continuously illuminate the potassium for about 6 days. In other words, after illuminating the metal surface with 6 days of light, the electrons must begin to separate.

The results of the experiment were completely contrary to this view. Indeed, even when the intensity of light is very weak, i.e. radiation falling at a frequency $\nu>\nu_0$ ($\nu_0$-threshold frequency) will instantly knock electrons out of the ($\sim10^{-7}$ s) metal surface. Photoeffect-instant process. The circuit is instantaneous from the metal surface. This law of photoeffect was the second problem of classical physics. The fact that electrons separating from the metal surface only have a link to the frequency of falling radiation was a third problem for classical physics. Because in the arsenal of classical physics there was not a single idea of the dependence of energy on frequency. These three problems made photoeffect question the theory of classical physics. It was absolutely impossible to explain the phenomenon of photoeffect, standing within the framework of the imagination of classical physics. To explain this phenomenon, a new imagination, a new idea, new concepts are needed.

The first to note that the photoeffect phenomenon can be explained based on the Planck hypothesis is A.Einstein's mind did. Based on the opinions expressed, Einstein fully explained the phenomenon of photoeffect. The photon theory of light confirmed that the photoeffect is a corpuscular phenomenon, a quantum phenomenon in modern language. Solar elements (photoelement) are prepared mainly on the basis of semiconductor materials. Therefore, knowledge of the optical and photoelectric properties of the solar element assumes the structure of semiconductor materials to study their difference from metals and dielectric materials and properties that are directly fundamental to semiconductor materials. Let us consider the formation of solid bodies from the point of view of electron theory on the example of semiconductor materials. In the process of solid formation, the convergence of atoms relative to each other goes so far that the result is a generalization of electrons in the outer shell.

Instead of individual individual orbits of individual electrons in an atom, generalized collective orbits are formed, and the shells in an atom merge into spheres, and they remain generally crystal-specific. The nature of the movement of electrons changes in absolute terms, electrons located at a certain atom and at a certain energy level are able to move to another neighboring atom at that energy level without changing their energy, and consequently, free displacement of electrons in the crystal is observed. The inner shells of all atoms in the isolation state of the crystal will be filled with electrons. Only in the area where the valence electrons, consisting of some of the highest levels, are located, will the levels not be fully occupied. The electrical conductivity, optical and other properties of the crystal are determined mainly by the energetic distance to the filling level of the valence field and from it to the field above it, and it is called the conduction field. At the expense of heat and optical excitation, electrons can pass through the valence field into the conduction field and participate in the conduction of electric current. The displacement of electrons to the empty positions formed in the valence field produces the movement of positive charges opposite it, and these charges are called pits.

As dielectrics, the valence sphere is filled and the next conduction from this sphere is said to be substances with a relatively large energy distance to the sphere. Metals, on the other hand, have a different structure. In them, the valence domain will be partially filled, or it will have entered the next domain – the conductance domain. A widely abandoned silicon-based solar power structure is generated from a close junction of the opposite type of *p* - and *n*-material. The semiconductor is *p* - and *n*-type within the material.

The transition area between the materials (the boundary God) is called electron-hole or *p*-*n* transition. In the case of thermodynamic equilibrium, the Fermi level, which determines the equilibrium state of electrons and holes, must be in the same position in the material. This condition creates a dual charge layer in the *p*-*n* transition region and is called a volumetric charge layer, giving it a matching electrostatic potential.

Optical radiation incident on the *p*-*n* Ridge surface produces electron-hole pairs whose concentration decreases perpendicular to the *p*-*n* transition direction from the surface to the material. If the distance from the surface to the *p*-*n* transition is smaller than the beam's entry depth (1/ά), electron-hole pairs are also generated inside the *p-n* transition. If the *p-n* transition is at a distance of or less than the diffusing longitudinal distance from where the pair is formed, the charges can be separated by the diffusion process by reaching the *p-n* transition and being exposed to an electric field. Electrons move to the electron-boron part of the *p-n* transition (n-part), holes move to the r-part. In electrodes (contacts) connecting external *p* - and *n*-fields, a subtraction of potentials is formed, resulting in an electric current starting to flow through the connected load resistance. non-primary charge carriers that diffuse into the *p-n* transition are split in two, as they are a potential barrier. Overproduced (separated by means of a barrier) and stacked, electrons in the *n*-field and holes in the *p*-field compensate for the existing volumetric charge in the *p-n* transition, that is, forming an electric field opposite to the existing electric field.

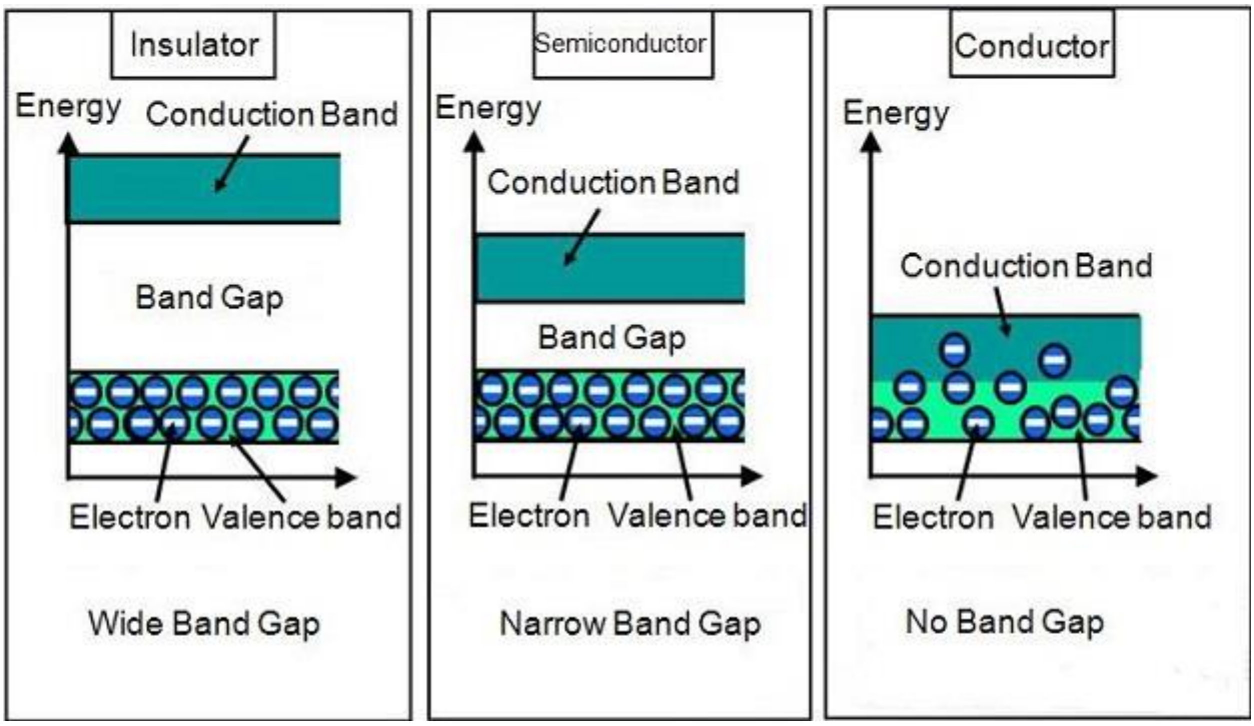



Figure 3.3. Structural scheme of zones in semiconductors

Due to illumination, a change in the existing potential barrier in the non-illuminated P-n transition occurs along with the formation of a subtraction of potentials in the external electrodes. The resulting photo-EYUK reduces the potential barrier value that it has. This in turn ensures the emergence of opposite currents, that is, the electron from the electron part generates the flow of electrons, and the r-part the flow of holes. These currents are nearly equal to the current in the right junction as a result of the effect of the electrical voltage applied to the P-n transition. The accumulation of excess (relative to equilibrium) charges from the time the illumination process begins (in the n-field of electrons and in the r-field of holes) reduces the potential barrier height, or in other words the electrostatic potential (See Figure 3.3). This in turn increases the current Force flowing from the external load and ensures that the flow of electrons and holes generating opposite currents passes through the P-n transition. A stationary equilibrium is formed when the number of excess pairs produced by light is equal to the number of pairs leaving through a p-n transition or external load. This usually occurs over a thousandth of a second of the lighting process.

The study of solar energy short-circuit Isc, the density of the incoming optical radiation and the spectral composition provides an opportunity to generate an idea of the efficiency of the conversion process of each individual radiant quantum into electrical energy that is taking place within the element structure. For SE, the following equation can be given for the case where the known light flux density is falling.

$$I_{sca}(\lambda) = I_{scc}(\lambda)/[1-r(\lambda)] \tag{3.1}$$

where Iscc(λ) and Isca(λ) is the value of the Solar Energy short circuit current, for the incident and absorbed radiation of a given intensity, r(λ) is the coefficient of primary return. The three mentioned magnitudes are true for the case where Ham has the same wavelength. In order to analyze and assess the quality of solar energy, it is extremely important that its spectral characteristic of the ICZ current is calculated for each quantum beam absorbed. This magnitude is called the effective quantum output of the solar element and is denoted by Qeff. If $N_o$ -number of Quanta falling on the unit surface of a non – semiconductor material surface, then

$$Q_{eff}= I_{sc}/ N_o \tag{3.2}$$

is, where the Isc electron is measured in seconds, and the Qeff electron must be obtained in quantum (photons). The solar energy effective quantum output is a two-parameter link that

$$Q_{эфф} = \beta\gamma \tag{3.3}$$

β is the quantum output of an internal photoeffect. This magnitude indicates the electron-hole pairs that form within the semiconductor during photoionization for each absorbed quantum. γ-p-n is the summing (summing) coefficient of the transition potential barrier of the current carriers, or, in other words, the separation coefficient of the current carriers is also called. This coefficient shows how much of the total pairs formed using optical radiation are involved in short circuit current. An external measuring instrument shows that for the connected case, if β=1, each quantum can form a single pair.

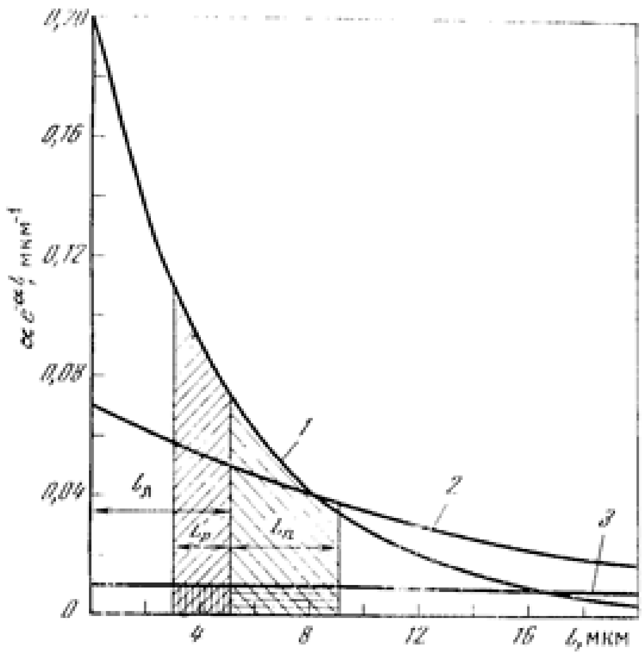



Figure 3.4. The distribution of electron-hole pairs formed for the case where the silicon-based p-n of radiation with different wavelengths falls perpendicular to the transition.

1- λ =0,619 mkm, α=2000 $cm^{-1}$; 2- λ =0,81 мmkm, α=700 $cm^{-1}$; 3- λ =0,92 mkm, α=90 $cm^{-1}$.

Optical radiation, which has different wavelengths, can penetrate different depths in the material (the ability of quanta to penetrate depth depends on their energy). Electron-hole pairs formed at the expense of the quanta absorbed in semiconductor materials form a spatial distribution in the material (See Figure 3.4). The further fate of the resulting pairs depends on the length of the diffusion path of the semiconductor materials. If this parameter size is sufficient, then the excess non-primary charge carriers generated by radiation can only be separated by its electric field by coming to a P-n transition due to the diffusion process. An important role in the process of rotating optical radiation is played by the electron diffusion path length( lp ) and the p-n transition depth (ℓ), since the pairs that are forming and need to be separated depend on them.

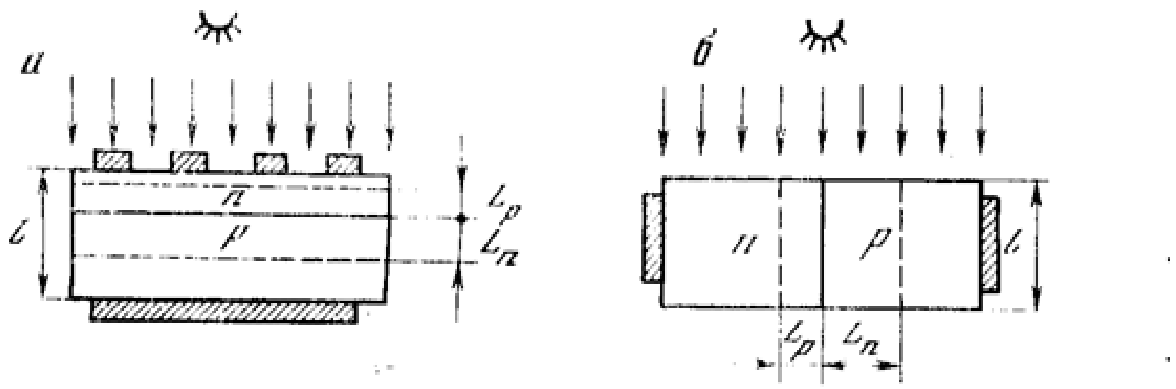


Figure 3.5. In a semiconductor crystal, p-n is the incidence of optical radiation for the (a) perpendicular and (b) parallel p-n transition plane, depending on the location schemes of the transitions. Diffusion lengths of non – primary charge carriers in LN, Lp - p–, and p - fields; ℓ – the input limit of radiation in a semiconductor; and bartered fields - the appearance of metal contacts in p-and n-fields.

Depending on the direction of the optical radiation falling on the semiconductor material, there are two varieties of the p-n transition structure, and we will consider them for the case presented in Figure 3.5 below.

**Case 1.** Where the P-n transition to the direction of optical radiation is perpendicular. A semiconductor with an optical radiation thickness of l penetrates the entire end of the material.

**Case 2.** Where the P-n transition to the optical radiation direction is parallel. The Radiation Falls on a structure with a width equal to D. For perpendicular and parallel P-n transitions, the summation (concentration) coefficient (efficiency) is determined by the following relations.

$$\gamma = ( L_{п} + L_{p}) / \ell \ (6) \text{ and } \gamma == ( L_{п} + L_{p})/d \qquad (3.4)$$

here, $L_p$ is the length of the diffusion path of the holes. At first glance, the parallel arrangement of the p-n transition appears to be preferable, since their distribution relative to the semiconductor material thickness and the p-n transition is important to assemble and separate the resulting pairs of charges to their fullness. The uniform formation of pairs within a semiconductor with respect to material depth is crucial to their separation process through a p-n transition-side diffusion event. Therefore, in solar panels with multiple p-n transitions (photovolts-consisting of multiple micro PVP), their p-n transitions are placed parallel to the falling optical radiation. In the long-wave section of optical radiation, this structure will have a high efficiency of Assembly of charge carriers, as well as make it possible to obtain a large amount of photo- power-conducting power from one unit of surface. However, one of the main problems was the theoretical and practical determination of the magnitude of the recombination event relative to perpendicular p-n transitions in micro PVP with relatively small-dimensional parallel-lying p-n transitions. Therefore, for this type of SE, in order to increase the spectral efficiency of short-wave Rays on the surface focused on solar radiation, it is advisable to form an additional thin layer with an inverse-type conductivity, in which additional inputs are included. That is, it is desirable to return again to the element of the partially perpendicular construction.

The concentration of electron-hole pairs (M) formed in p-n transition PVP located in parallel varies from the material surface to the inside. For a p-n transition SE construction located perpendicular, however, most of the resulting pairs for both the n-type material and the p-type form near the p-n transition. The electron-hole pairs that form are determined at unit depth by the following equation.

$$M = N_o \alpha \exp(-\alpha\ell) \qquad (3.5)$$

where, $N_o$ is the number of quanta falling on a unit surface. The number of pairs, decreasing inward.

Their number can be determined α (E) in an area that can be swallowed in a semiconductor material. The result of such computations for silicon is given in Figure 3.6 below for wavelengths with several values. vertical lines delimiting the areas of diffusion lengths of charge carriers in an n-and p-type material make it possible to evaluate the process of concentrating charge carriers for a case where the p-n transition is perpendicular. The ordinates of the lines are proportional to α exp(-α.), while the abssissas indicate the depth of inward entry from the illuminated surface of the semiconductor material. Surfaces bounded by lines between axes – equal to the flow of descending quanta, surfaces bounded by ordinates $\ell = \ell d\ \ell n$ and $(\ell d + \ell n)$ – indicate a short circuit current. Thus, the ratio of the barbed surface to the total surface gives the assembly efficiency based on the expression (for β=1) determining the internal photoeffect quantum output.

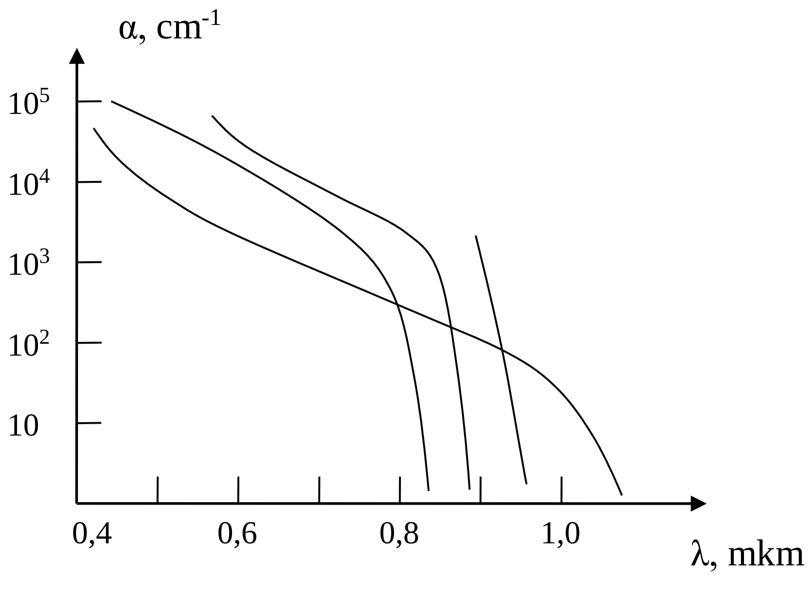



Figure 3.6. Change in absorption rate in energy for certain semiconductor materials.1 – Si, 2 – CdTe, 3 – GaAs, 4 – InP.

If the valence domain of a substance is not fully occupied, but the energy distance to the conduction domain is relatively small (less than 2 eV), such substances are called semiconductors. Semiconductor properties-in particular electrical conductivity-will depend on the external environment, especially temperature. The increase in temperature (T) leads to an exponential increase in current carriers in the transition of the amount of electrons to the valence V conductance field, and an increase in electrical conductivity $(\sigma)$.

$$\sigma = A\exp\left(-E_g / 2kT\right) \qquad (3.6)$$

based on the equation leads to the change of where k is the Bolsman constant, a constant magnitude that characterizes the substance A.

The electrical conductivity of metals is determined by the temperature dependence of electron reactivity due to the fact that the concentration of free electrons is constant, and gradually decreases with increasing temperature.

Logarithm of the above equation yields the following expression.

$$\ln\sigma = \ln A - E_g / 2kT \qquad (3.7)$$

This equation can be graphically shown in semi-logarithmic coordinates. The resulting straight line and its angle tangent φ determine the width of the forbidden sphere $E_g = 2kT\varphi$, which is the main parameter of the semiconductor materials. It should be noted that an oblique straight line, that is, a change in electrical conductivity depending on the logarithmic $1/T$, looks like this only for materials with a private conductivity, free of pure inputs.

In input semiconductors $\ln\sigma$, the connection $1/T$ of from is complex, and it can consist of two oblique straight lines and is adjacent to each other through a horizontal section. Using the oblique straight line tangent generated from the equation $\ln\sigma = \ln A - E_g / 2kT$ obtained by measurement under low temperature conditions, it is possible to determine the state of the energetic levels of the inputs located in the Forbidden field. In cases obtained under high temperature conditions, however, it is possible to determine the magnitude of the forbidden domain of semiconductor materials, i.e. Eg.

In the preparation of the solar element, the processes of interaction of solar radiation with a semiconductor material, absorption and emission of photon energy in electrons in the material are important.

In quantum mechanics, elementary particles, including electrons, are also seen as having wave properties. Therefore, in addition to energy (E) and impuls (*P*), their wavelength repeatability $\nu$ and wave vector $K = P / h$, (h–Planck constant) are also used in the study of elementary particle motion. Where $E = h\nu$ and $P = h / \lambda$ is equal to. The domain structure of the crystal can be illustrated by E – K diagrams. Here, the energy is shown in electron-volts (eV) in parts of the wave vector K – crystal lattice constant. At the same time, the direction of the crystal lattice is indicated using indicators on the K-axis. By means of the e-k diagram, it is possible to determine whether Inter-field transitions are "correct" or "non-correct" in the semiconductor material and including the transition.

The magnitude of the Eg determined from the measurement of optical absorption will often depend on the concentration of free charge carriers in the semiconductor material, the temperature, and the presence of the energy levels of the inputs in the Forbidden field. If the states at the bottom of the conductance domain and above the valence domain are filled with charge carriers, then Eg for krishmali semiconductor materials can be greater than its corresponding value to the pure private material. If the field generated by the inputs merges with the nearest allowed field limit (e.g., the observed case when multiple inputs are introduced), then the $E_g$ decreases. This reduction in $E_g$ affects the primary absorption threshold.

In a semiconductor material, the absorption coefficient is usually determined by decreasing the wave energy e times at a distance, and is found from it.

$$N = N_0 \exp(-\alpha\lambda) \qquad (3.8)$$

Where N is the density of the flow of photons entering the depth in the semiconductor material, $N_0$ is the density of the flow of photons crossing the surface of the material.

The absorption coefficient $\alpha$ of the material is connected by $\alpha$ $\alpha = 4\pi K / \lambda$ elationship with the absorption index K. Thus, it is possible to find the values of K and $\lambda$ for that substance by changing the intensity of optical radiation passing through samples of semiconductor material with known and precise thickness.

For some semiconductor materials for which solar elements are made, figure 3.6 presents the change $\alpha$ of energy of. From the picture it can be seen that the absorption index of the spectral characteristic of the given semiconductor differs greatly from each other in materials, and this difference is largely due to their field structure and the nature of optical transitions. CdTe, GaAs, InP materials contain optical transitions of a direct field nature, rapidly rising to levels with the appearance of photons with energies greater than $Eg$ in the radiation spectrum $10^4 - 10^5 cm$.

In silicon materials, however, the absorption process is from 1.1 eV through improper energetic transitions, and this also requires the participation of light quantum and Lattice oscillations quantum-photons. Therefore, the absorption rate $\alpha$ gradually increases. Only after the energy of the photons reaches 2.5 eV, the field-field transitions become direct transitions, and the absorption goes sharply behind.

The spectral characteristic of the absorption coefficient shows that using silicon material, it is possible to convert a very large part of the solar spectrum into electric current. For example, for extraterrestrial solar radiation (AM 0) this is 74%. Where as only 63% solar radiation can be converted to electricity if a GaaS semiconductor is obtained as a material. However, since the value of is not large at the basic absorption limit of" irregular " optical transitions, the thickness of the silicon solar element should not be less than 250 μm for the entire quoted solar spectrum to be absorbed. Whereas, for the same conditions, GaAs is enough that the thickness of the material is 2-5 μm. Therefore, it is necessary to constantly take into account that these properties of spectral characteristic are important in the development of a highly efficient and thin-layer solar element.

If the photons falling on the semiconductor surface are low in energy and cannot release electrons from the valence sphere into the conduction sphere as a result of absorption, the electron under the influence of radiation can move into areas that are not allowed inside the Crystal. For this case, the spectral characteristic of absorption can be felt in the long-wave portion following the main absorption limit.

Such absorption is called the absorption of free charge carriers, and this process will depend on the concentration of such charge carriers. Since free charge carriers depend on the concentration of inputs that can be light ionization, absorption will also depend directly on it. studies of such long-wave absorption properties in semiconductor materials have identified several types of absorption. Including absorption in spatial lattice vibrations, absorption in inputs, absorption in excitons. The exciton is a coupled electron-hole pair that does not change the concentration of charge carriers. Because inside a crystal is not a separate electron or hole motion, but a bound state motion.

Absorption spectra provide the necessary all-round useful information about the crystal structure. In particular, the degree of legalization allows you to determine the activation energy of the inputs and their energy levels located in the prohibited zone. For example, on the basis of absorption spectra, it is possible to determine whether there is oxygen in ыilicon (9 μm). In the long-wave area of the spectrum, the reflection coefficient p, with an increase in such inputs, is observed to increase sharply. Lighting. As sources of power supply, heating lamps, fluorescent and gaseous lamps are used in the village enema. That said, there will be a big difference in their efficiency between individual light sources, that is, in the length of light measured in Lux corresponding to Watt power (Table 3.1 ):

Table 3.1 Lighting devices

| **Name of lamp** | **Power, W** |
|---|---|
| Heating lamp | 12 |
| Halogen lamp | 22 |
| Fluorescent lamp | 55 |
| High pressure mercury lamp | 55 |
| High pressure halogen lamp | 80 |
| High pressure sodium lamp | 95 |

Incandescent lamps are traditional and widely used light sources. In household lighting devices, heating lamps with a power of 15 W to 300 W are used, designed for a voltage of 220 V or 127 V. There are more perfect light sources that are widely used-fluorescent lamps that have a light transmission 4-5 times higher than a heating lamp and a service life 5-8 times larger. Thus, the light transmission of a 20 W fluorescent lamp is equal to the light transmission of a 150 W incandescent lamp.

**Autonomous power supply of electrical household appliances.** In autonomous power engineering, it is necessary to focus on the main reach to the economy of the work of electrical household appliances. On the one hand, the energetic description of electrical appliances is one of the indicators that determine the degree of improvement of household appliances. On the other hand, it clarifies the power and cost descriptions of another autonomous energy source.

In table 3.2 lists standard and sufficient complete electrical equipment for household equipment of peasant enemas, indicating periodicity and standard average daily working time. We bring some recommendations on the choice of an energy-saving household electrical appliance and give a qualitative assessment of energy consumption from it.

The electric plate usually has an alternating connector that provides one to seven heating steps. The power of one comforal electric plate is 0.8-2.6 kW, and two comforal electric plates – 1.8-3 kW. Electric tiles with tubular concourse are more efficient and more perfect: such concourses are long-resistant, while their spiral shape ensures good contact with the bottom of the container.

The microwave is more economical and is used for quick food preparation, for heating ready-made dishes and for defrosting products. The principle of heating with ultra-high frequency electromagnetic waves, which is used in the microwave, not only ensures the high taste-giving quality of the dish, but also keeps vitamins in full. Energy consumption ranges from 0.5 to 2.0 kW, depending on the size of the camera. These ovens, whose good energy compatibility with small-capacity renewable energy sources, unconventional for Uzbek cuisine, are considered very promising.

A sink boiler is a typically tubular electrical heating element designed to boil a small amount of water. Boilers with a capacity of 0.3 to 2 kW are produced. A glass of water from 20 to 90 $^oC$ 0.3 kW power cookers 5 min. during, while 7 *l* of water is

30 min in a 2 kW boiler. heated at. These boilers have a high efficiency factor (98%) specificity, which indicates a minimum electrical energy consumption compared to other types of water-boiling electrical appliances.

Table 3.2

| **№** | **Electrical equipment name** | **Daily working hours** | **Working order** | **Power, kW** / **Consumption power kWh** | **Brand** |
|---|---|---|---|---|---|
| 1. | Electric plate | 3,0 | periodic | 1,0/3,0 | Different |
| 2. | Microwave | 0,5 | periodic | 0,8/0,4 | Samsung |
| 3. | Refrigerators | - | During the day sometimes | 0,05/1,1 | ММ-163/16 |
| 4. | Washing machine | - | Episodic, 100 hours a year | 0,25/- | «Malyutka-2» |
| 5. | Air condition DEWOO | 3,0 | 3 months in summer, depending on the season | 0,52/1,56 | ДЭУ-052С |
| 6. | Watch TV | - | 18-00, 24-00 | 0,05/0,3 | Different types |
| 7. | Video recorders, tape recorders, radios and electric razors | 10,0 | During the day | 0,02/0,2 | Different types |
| 8. | Vacuum cleaner | - | Episodic | 0,7/- | «Ракета-600» |
| 9. | Juicer | - | Episodic | 0,2/- | Differen |
| 10. | Iron | - | periodic 50 h year | 1,0/- | Differen |
| 11. | Electromechanical typewriter | - | Episodic | 0,035/- | «Yantar» |
| 12. | Computer | - | periodic | 0,1/- | Different |
| 13. | Electric razors | 0,1 | Daily | 0,3/0,03 | Different |

A sink boiler is a typically tubular electrical heating element designed to boil a small amount of water. Boilers with a capacity of 0.3 to 2 kW are produced. A glass of water from 20 to 90 $^oC$ 0.3 kW power cookers 5 min. during, while 7 *l* of water is 30 min in a 2 kW boiler. heated at. These boilers have a high efficiency factor (98%)

specificity, which indicates a minimum electrical energy consumption compared to other types of water-boiling electrical appliances. Refrigerant is an energy-consuming device. Since refrigerators are always connected to the network, they are used if the electric plates consume energy: the compressor refrigerant (depending on the size) is 250-450 kW.s, and the absorption cooler-500-1400 kW.s per year, the more energy it consumes, the more (even more) energy it consumes. Depending on the capacity consumed, modern types of refrigerators differ little from each other. The economy of the refrigerator has a working order, which depends more on the periodicity of its use and compliance with the rules of use. This thing is also true for refrigerators, the most optimal of which is MM-163/16 and similar refrigerators, which provide a freezing temperature of up to 20 kg with a loading volume of up to 18 $^{o}$C .

Washing machines perform the most laborious processes in the House enema. From the point of view of electricity consumption, the connection and disconnection are automatic machines that are carried out according to a strict program. At the same time, there is a need for a small amount of laundry. For these purposes, the House should have a washing machine with a small gabarite. Light named "Malyutka" takes up little space, washes quickly and cleanly, and energy will not need more than a 200 W light bulb. One loading capacity of the "dwarf" machine is 2 kg of dry laundry.

Household condiments serve to automatically maintain temperature and humidity in indoor buildings. With cooled air, a large number of condisioners are produced, designed to provide premises with a capacity of 25; 30; 35 $m^2$ and more surface. In terms of air exchange, their productivity is 700, 750, respectively; 1000 $m^3$/h and more the consumption capacity of the Dewoo firm in the more perfect capacitors is 500 W and more.

The power of the remaining electric pribors is either very small, or their operating order is episodic, which consumes little energy throughout the year, making them secondary to the choice of power descriptions.

### § 3.1.2. Volt-Ampere classification of semiconductor materials and solar photovoltaic panels

The planar construction of solar elements (where optical radiation falls perpendicular to the surface of the structure) is the main construction in solar energy technology and their practical use. In this case, solar energy was developed on the basis of various semiconductor materials. Based on the above analyzes, highly efficient optimized constructions have been developed. But for any material, it was determined that the above basic requirements for them should be maintained. To increase $U$ and $I_{sc}$, it is definitely desirable to increase the diffusion length on both sides of the r-n transition. To do this, it is necessary to choose the necessary material and try not to reduce the diffusion length in the process of technological preparation of the p-n transition. It is necessary to take it into account if its decline is clear. If there is no possibility to increase the $L_d$ on the frontal surface, then the frontal surface thickness must be obtained following Lp>>ℓ. On this basis, the choice of base parameters is necessary.

In the early periods of the creation of solar elements, a semiconductor material with a width of 2 eV of the prohibited area was obtained as the optimal material, comparing it to the maximum of the spectrum of solar radiation. It was later discovered that for increasing the number of photoactive quanta and for the growth of short circuit current, the value of the Forbidden field width $E_g$ should be less than 2 eV. But for this case, it is clear that the value of the photo-power-conducting power (P.C.P.) being generated will decrease relatively, since the potential barrier value in the *p-n* transition will decrease. Later, when the possibility of using varizon (materials with the possibility of changing the value of the prohibited area) semiconductor materials in the preparation of solar energy, 2 variations of their implementation were proposed:

1. Application of indirect heterotakes.

2. Applying a semiconductor layer whose value of the forbidden sphere is greater than the value of the forbidden sphere of the base material as a broad sphere.

There are two conflicting views on the effect of the material to be applied as a base on the properties of SE. SE P.C.P. in order to justify the serious dependence on the width of the forbidden area of the base material, it is necessary to analyze the element Volt-Ampere characteristic (VAC) and study the effect of the spectrum of optical radiation falling on it.

1956 y the theoretical calculation required above for the spectrum of solar radiation in ground conditions was performed by Lofersky. For SE made of different optimized material, the value of optical and photoelectric losses was evaluated. The results of such samples are shown in Figure 3.7 below.

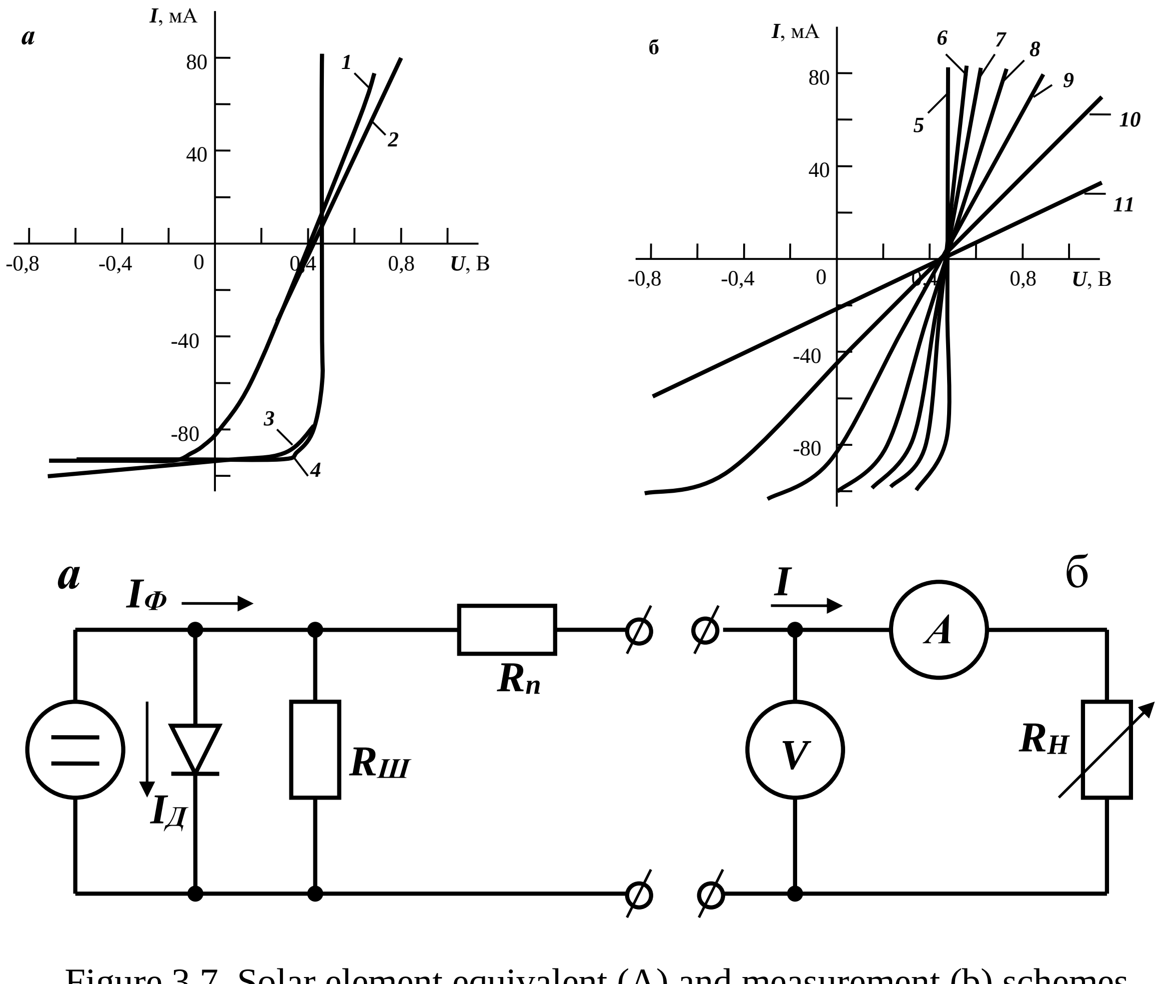



Figure 3.7. Solar element equivalent (A) and measurement (b) schemes

Considered the main characteristic of solar elements, Volt-Ampere characteristic and spectral sensitivity are links to optical and electrophysical properties of semiconductor materials. SE VAC differs from the VAC of a P-n transition semiconductor diode by the emergence of a new If term. If is a current that is a generation in the solar element when exposed to optical radiation. If there is a current flowing through the Id – diode and a current flowing through the I – external load, then,

$$I_ф = I_d + I \quad (3.9)$$

$$I_d = I_o(\exp (qU/kT) – 1) \quad (3.10)$$

The characteristic of the diode in the dark, the saturation current in the reverse direction of the $I_o$ – p-n transition, q - is the electron charge, T - is the absolute temperature, k - is the Bolsman constant, U - is the voltage.

For an open chain holi whose resistance is infinite, i.e. at I=0, it follows from the above equation.

$$U_{xx} = \ln(I_ф/I_o +1) kT/q \quad (3.11)$$

Fig. 3.7 is *a*. At different values of Rp and Rsh, the representations of SE VAC (a) and the values of $R_p$ at $R_{sh}= \infty$ are (b); R $_п$=5 Ом, $R_ш$ = 100 Ом; 2 - R $_п$=5 Ом, $R_ш = \infty$; 3- R $_п$= 0, $R_ш$ = 100 Ом; 4- R $_п$= 0, $R_ш = \infty$; 5- 11 - R $_п$= 0; 1; 2; 3,5; 5; 10; ва 20 Ом

In practice, the organizers of sequence resistance in solar elements are the resistance of the layers that make up these contacts, the resistance of the individual p- and n-fields, the resistance of the transition areas between the metal-semiconductor, the RSH shunt resistance in the ham, etc. Given these resistances, as well as recombinational losses in the p-n transition, VAC can be expressed in a more complex way, i.e.

$$L_n (I + I_ф)/I_o – (U – IR/I_o R_ш + 1) = q/AkT(U – I_{rn}) \quad (3.12)$$

The included coefficient A indicates the degree of affinity of the current instrument with respect to the ideal instrument. This equation can be written close to practice as follows.

$$I = I_ф + I_o (\exp q(U + IR) /AkT – 1 - U + IR/R_ш \quad (3.13)$$

Based on this equation, it is possible to create an equivalent and measuring scheme of the solar element. The power P obtained from the unit surface of the solar element can be estimated from the following equation.

$$P = (I_н U_н) = \xi I_{кз} U_{xx} \qquad (3.14)$$

here, ξ-Volt-Ampere shows the fill factor of the characteristic, that is, to what extent the VAC form is close to the rectangle. The filling coefficient is 0.8 and greater in modern PVP (silicon and gallium arsenide-based elements). Consider the effect of sequence and shunt resistance from figure 3.8 to VAC. From the picture it can be seen that the reduction of shunt resistance Rsh from infinity to 100 Ohms has almost no effect on the VAC form, and including the output power of SE to Pv. Whereas the change in sequence resistance Rp from 1 Ohm to 5 Ohm causes a sharp deterioration in the VAX shape and the output power Pv is relatively reduced.

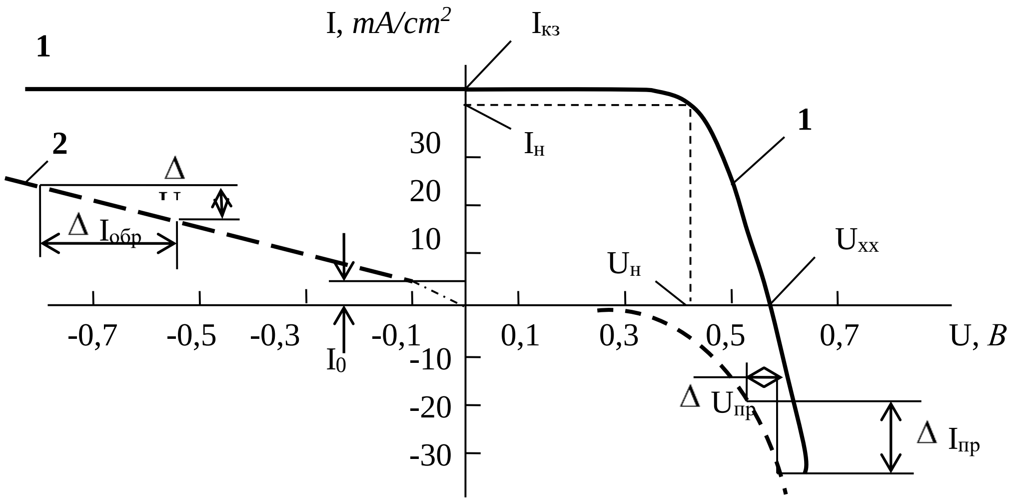



Figure 3.8. A typical volt-Ampere characteristic of modern silicon-based SE measured for solar radiation in an extraterrestrial state.

1-light-induced; 2-Dark States

The properties of SE VAC in light and dark can be more accurately analyzed. Usually, depending on the voltage level, the transition mechanism of the reverse saturation current passing through the *p-n* transition changes. This current usually consists of the sum of two currents, namely

$$I = I_{o1} [( qU/kT) - 1] + I_{o2} [( \exp qU/kT) - 1] – I_ф \qquad (3.15)$$

here, $I_{o1}$ is the current flowing through a thin p-n transition by means of a diffusion mechanism, while $I_{o2}$ is the reverse saturation current for the recombination event in the *p-n* transition area for the case where A=2 is equal to.

Based on the VAC of solar elements measured in darkness and light, some of its parameters can be determined, which include $I_o$, $R_P$, $R_{SH}$ and A. Figure 3.8 below shows the typical VAC for AM 0 conditions and the element VAC obtained in darkness. Part of the VAC obtained under light conditions in the first quadrant, and its continuation in the pusher quadrant is straight-line. The slope of this straight line to the axis of the currents determines the sequence resistance of SE.

$$R_{п} = \Delta U_{пр}/\Delta i_{пр} \qquad (3.16)$$

here, a change in the $\Delta U_{пр}/\Delta i_{пр}$ value in the area close to $U_{sf}$ is obtained. The part of the quoted characteristic in the first quadrant and its continuation in the second quadrant is a straight line. Its deviation from the axis of voltages determines the value of the shunt resistance $R_{sh}$ in SE, i.e.

$$R_{ш} = \Delta U'_{пр}/\ \Delta I'_{пр} \qquad (3.17)$$

here, the values of $\Delta U_{пр}$ and $\Delta I_{пр}$ are obtained, the change in the area close to the short-circuit current Isc.

Since the short circuit of the VAC obtained in light makes it difficult to change the slope of the straight line around the Isc, the shunt resistance $R_{SH}$ is determined from the slope of the VAC obtained in darkness (second quadrant barcode line), i.e.

$$Rsh = \Delta U_{обр}/\ \Delta I_{обр} \qquad (3.18)$$

With the help of the characteristic obtained in the dark, it is possible to determine the reverse saturation current $I_o$. The solar element *p-n* transition will be connected in the correct direction in the operating mode, i.e., the formation of unbalanced charge carriers from both sides to the *p-n* transition as a result of the effect of optical radiation, indicating that the *p-n* transition is connected in the right direction. Therefore, it is advisable to find the inverse saturation current Io and the idealization coefficient A from the VAC measured in darkness or light in the right direction. The diode equation with respect to VAC obtained in darkness can be written differently as:

$$L_n (I_д + I_o) = \ln I_o + qU/AkT \quad (3.19)$$

This equation can be used under conditions $Id>>I_o$ where the value of the current is large for the calculation, and the inverse saturation current can be used for the moment that passes through the p-n transition based on the recombination mechanism. Based on the VAC (for large currents and voltages) of SE measured in the right direction, the function $\ln I_o=f(U)$ can be plotted. The tangent of this equation slope will be equal to *q/AkT*.The cross section he cuts on the ordinate axis gives the value of ln, $I_o$.

There is another way to determine the value of $I_o$ and $A$ under conditions close to the Real operation of SE. To do this, the VAC of SE is measured using an imitator at least at two different values of the light flux density. For the process of sequence resistance decreasing voltages for $R_n$ and recombination in the *p-n* transition domain, we cite the above equation, namely

$$I = I_o[\exp\{q(U-IR_п)/AkT\} - 1] – I_ф \quad (3.20)$$

Since salt is I= 0, $U=U_{id}$ in operation mode, one can take $R_p=0$ and then $I_f=I_{sc}$. Then

$$L_п (I_{кз} + I_o) = \ln I_o + qU_{xx}/AkT \quad (3.21)$$

using the standard of solar energy to apply this equation, the linear values of the equation $I_{sc}$ =(Eg) are found corresponding to the current density of each new optical radiation, from which $I_{sc}$ and $U_{id}$ are determined. The value of q/AkT is determined by the angle of the tangent, and the value of lnIo is determined by the cross section that it cuts off from the ordinate axis.

## § 3.2. Understanding the features of solar photovoltaic panels and their use, as well as the important conditions for installing solar panels

**Conversion of solar energy into electrical energy**. Obviously, electricity is considered some of the most convenient types of energy for use. The bulk of this energy is produced in electromagnetic generators that are driven in the Earth's sphere using one type or another of heat machines. And now we will look at ways to get electricity under the influence of solar radiation and increase its effectiveness. We know that in a semiconductor material, due to the fact that electrons occupy new permissible levels of the energy zone, in order for a current to form, they need to receive additional energy. Electrons in the filled or valence zone cannot move into the conduction zone through the forbidden zone until they receive sufficient energy. In order for them to move to the Forbidden zone, natural semiconductor electrons such as silicon or germanium will have to obtain 1 eV of energy. Light photons have such energy. The process of operation of semiconductor photoelectric generators (solar cells) consists of: by absorbing photons of solar radiation, electrons gain additional energy and begin to shift into the conduction zone.

The energy of each electron increases in accordance with the value of the Forbidden zone width. Usually the electron is in this case at very small time intervals. It then recombines with the ion, while the energy released from this amplifies or re-irradiates the crystal lattice oscillation. It is known that the increased oscillation of Lattice ions leads to an increase in temperature in solid bodies. That's exactly what it is for us. In a photoelectric generator, electrons excited by the action of light pass through a semiconductor material and have time to give their excess energy to a useful load without wasting it on other interactions. By preventing solar energy from turning into heat, we hope to be free from certain thermodynamic limitations, but nature puts new contradictions in front of us. The Photon Energy is connected to the frequency as follows:

$$E = h\nu = \frac{h\upsilon}{\lambda} \qquad (3.22)$$

Given that solar radiation wavelengths lie in an area around 1 μm, this relationship can be written in a simpler way:

$$E = \frac{1.24}{\lambda} \qquad (3.23)$$

Energy is measured in eV, wavelength in *mkm*s. From equation (3.23) it follows that as the wavelength increases, the energy of photons of solar radiation changes (decreases). There is such a wavelength at which the electrons they excite go through the forbidden zone when there is not enough Photon Energy in reality. For example at room temperature, silicon has a photon energy of about 1.1 μm wavelength with a forbidden zone width of about 1.1 eV. About 20% of the solar radiation to the sea level of the Earth's surface corresponds to the long-wave part. In this way they fall from the sphere of motion of silicon-based devices. The shortwave part of the radiation cannot be fully used either. While electrons are only shifted to allowable levels, the excited state is maintained more by only electrons whose energy is close to the width of the Forbidden zone. When irradiating a material with high-energy photons, the excess energy of the electrons quickly becomes a waste to amplify the vibrations of the lattice, that is, to gain its inner enrgia. Thus, when radiating silicon with photons of 0.6 μm wavelength (corresponding to about 2.0 eV of energy), electrons can "absorb" only 1.1 eV of energy, while the rest of the energy becomes a futile expenditure to achieve the temperature of the material.

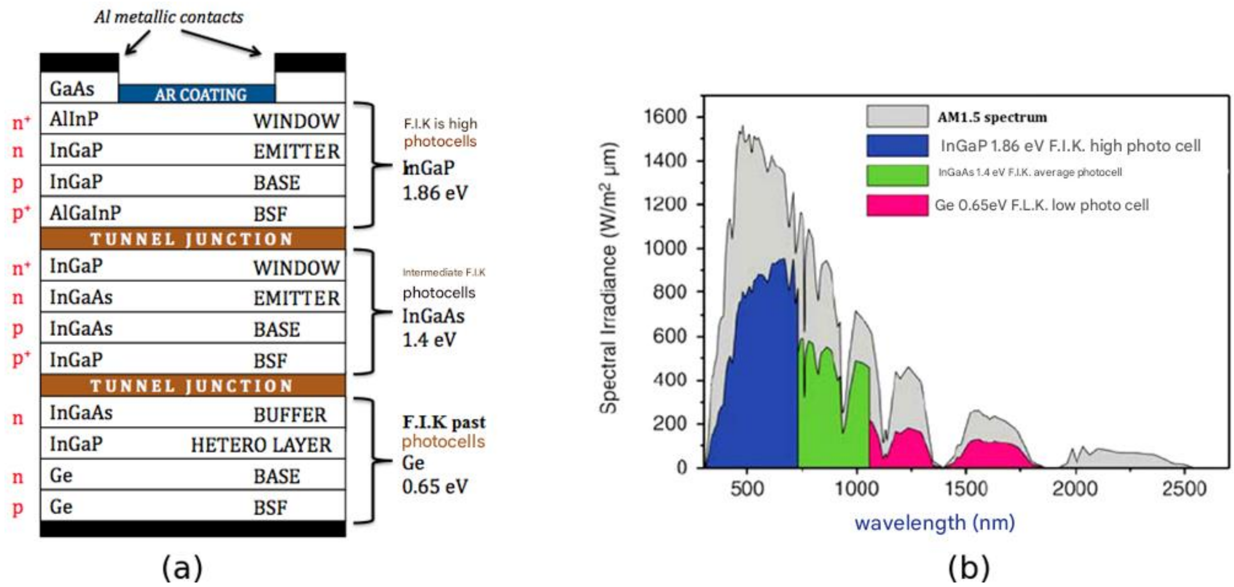



Figure 3.9. Spectral distribution of solar radiation energy.

Now let's evaluate the maximum effectiveness of converting solar energy into electricity using an ideal photovoltaic generator. This effectiveness will be partially dependent on the distribution of the energy of the solar radiation Spectra, which varies depending on the meteorological conditions and latitude of the location as shown in Figure 3.9. Table 3.3 lists the results obtained under cloud-free conditions in the tropics as examples.

Maximum efficiency of solar energy re-conversion in Silicon (marginal wave length equal to 1.1 μm).

Table 3.3

| Wavelength range, mkm. | Solar energy contribution corresponding to the range, **%**. | Solar energy contribution used in the range | The total amount of solar energy used is the energy contribution,%. |
|---|---|---|---|
| Less than 0.3 | 0 | - | - |
| 0,3 – 0,5 | 17 | 0,36 | 6 |
| 0,5 – 0,7 | 28 | 0,55 | 15 |
| 0,7 – 0,9 | 20 | 0,73 | 15 |
| 0,9 – 1,1 | 13 | 0,91 | 12 |
| More than 1.1 | 22 | 0 | 0 |
| Total | 100 | | 48 |

From equation (3.22), it follows that if the energy of a photon with wavelength $\lambda$ is equal to *1.24/*$\lambda$, when the energy corresponding exactly to the width of the Forbidden Zone has photons with wavelength $\lambda_T$, the value of the useful energy radiated by photons of wavelength $\lambda$ is determined by the relation $\lambda/\lambda_T$. Photons with wavelengths greater than the boundary wavelength cannot excite electrons at all.

Calculations for different boundary wavelengths show that Silicon ($\lambda_T$ =1.1 μm) is the preferred material for photoelectric generators, although at some wavelengths $\lambda_T$ close to its maximum CPP. even if it reaches only 45%. Consequently, CPP of such photoelectric devices no more than 45%. Unfortunately, in real devices CPP. it will be even less. To explain this, we need to carefully consider the process of obtaining energy using electrons excited by the action of solar radiation. At the next point, we will cite some explanations, although briefly as a complement to the previously presented ideas about the properties and conductivity of semiconductors.

The above-mentioned laws show that the efficiency of each process depends on the optical and electrophysical properties of the semiconductor material (on the return of light on the surface of the structure to the quantum output of the photoionization phenomenon, on the length of the diffusion path $L_n$ of non-primary charge carriers, on the spectral state of the main absorption limit, etc.), on the characteristic, depends on the geometric factor (the relationship between the length of the diffusion path of some material and some thickness, i.e., $L_n$ and *l*), as well as the degree of legibility of the semiconductor material in the n- and p-fields.

Furthermore sequence resistance is necessary to determine the effect of $R_N$ on the VAC form and power P. In turn, the value of the sequence resistance is also determined by the resistors of the parts that make it up and the geometric arrangement of the contact layers. As a result of bringing conflicting requirements to compromise Technical Solutions, a design of solar elements with a p-n transition located perpendicular to the radiation of the falling light was selected. In modern times, with some additions (introduction of a pulling electric field, obtaining isotype barriers to the back contact, replacement of the entire coated contact with a mesh contact, texturing the surface surface, forming reflective coatings on the back), the above construction has been preserved.

In order to improve the efficiency of the solar element, radiation-protective coating, temperature-controlling and surface-clarifying coatings are formed on its frontal light-receiving side. In the process of operation of the solar element, these coatings increase the amount of radiation entering the material, reduce excess heat at the expense of irradiation. In addition, coatings protect them from radiation in unfavorable climatic conditions on Earth and in the universe. The solar element is made from a thin layer of silicon with a surface focused on frontal, optical radiation, usually containing phosphorus atoms, and legalizes it up to $10^{20}$ $cm^3$ and even more.

And to the base of the element there is an input of $10^{15}$-$10^{16}$ $cm^3$ degrees, which occupies up to 5-7% of the frontal surface of the solar elements focused on optical radiation, is covered by a mesh contact of various topologies. non-primary charge carriers being separated from the *p-n* transition by means of an electric field must move to the outer loop. While on the semiconductor material frontal surface (n-type coating) charges move along the coating, at the base of the solar element (p-type material) their motion is in perpendicular yunalish. The diffusion path of non – primary charge carriers in the ultra-legulated frontal layer is 0.2-0.6 μm in length.

And at the element base, this magnitude will go up to 100-250 μm, and the values of themnng will depend on the concentration of charges and the mode of technological operas performed during the preparation of solar elements.

That being said, during the technological operas performed in the process of preparing solar elements, its initial parameters change as a result of the appearance of uncontrollable inputs and recombination centers that are not needed in the semiconductor material. Therefore, it is advisable to re-measure the parameters of the semiconductor material by various means at the end of the process of preparation of solar elements.

The relatively low diffusion length value in the flattened frontal layer requires the p-n transition to be shallower (in modern solar elements, the frontal layer thickness is taken to be 0.3 – 0.5 μm). However, in order to use the bulk of solar radiation falling into the solar element, that is, to be executed $h\nu = E_g$, it is required that the base thickness of the solar element be no less than 200 μm. Along with the fact that silicon plates of such thickness are suitable for relatively mechanical processing, up to 93-95% of radiation can be absorbed in them. The resistance of the base area is of little value, since the current passes perpendicular to the thick base.

The first layer of the omic contact to be prepared is made of aluminum. Since aluminum is an inlet in the R-material, it gives Silicon good omic contact and is then coated with Ti, Pd, Ag or Ni and the desired mesh contact alloy. The resistance of the frontal n-layer of the solar element is relatively large and can go up to 50-100 mk. To overcome such resistance, layers are passed one after the other from the material indicated above. It is required to prevent electrical perforation of the frontal thin layer during the transfer of technological processes.

Scientific research shows that if the contact material to the frontal thin layer is initially taken as a coating to the entire surface, and then performed by chemically absorbing a certain-shaped image with the means of a photolithographic process, many micro-perforated grooves will appear on the frontal surface. This, in turn, reduces shunt resistance by increasing the inverse saturation current I0. It is therefore required that the frontal contact topology be conducted through a mask or the photolithographic process before the contact is obtained.

When the layer resistance of the frontal surface of the solar element with a surface of 2x2 $cm^2$ is from 50 to 100 *Om·sm*, a collector (collector) path of one unit width of 0.5-1 mm is passed to it, and from 6 to 12 sidewalks with a width of 0.05-0.1 mm protruding from it. As a result, it will be possible to reduce the sequence resistance $R_n$ to 0.15-0.2 Om. However, when shallow p-n transitions are prepared (example, l=0.15-0.4), the frontal layer resistance can increase to 500 *Om·sm*, then in the solar element with a surface of 4 $cm^2$, the number of satellites is increased to 60. The width of the aisles is 15-20 μm, and the contact thickness is brought to 3-5 μm by means of electrochemical re-growing. If the calculation book becomes clear and the technological processes are performed perfectly, the VAC of the solar element will improve dramatically.

**Choosing the slope angle of the photoelectric battery installation to increase the efficiency of use:** the greatest efficiency of solar energy achieves solar radiation in photoelectric batteries when the surface of the panel is set in a perpendicular position. To orient the photoelectric panel relative to The Sun, an automatic solar monitoring device is usually installed, which attaches to its composition a servomotor and control unit that consumes electricity. The cost of the tracking system is expensive enough to require additional outputs when unloading into operation. Therefore, at present, photovoltaic batteries are installed on the territory of Uzbekistan without surveillance systems. To increase the efficiency of a photovoltaic battery, in fact, it will be necessary to install them at a certain angle to The Sun every month. In connection with this, in a simple way, it will be necessary to determine the optimal slope angle with respect to the horizon in order to install the photoelectric battery at a certain slope angle with respect to The Sun.

In the following scientific works (M.N. Tursunov, V.G. Discin and I. A. Yuldoshev) developed a methodology in the Visual Basic program for calculating the angle of incidence of solar radiation. Horizontal and vertical measurement drawings for determining the orientation of the optimal angle of the photoelectric module in installation are made of an experimental device mounted at right angles to a square-shaped foil plate.

The illumination of the photovoltaic battery at maximum is installed in a good place that is, at an angle of slope towards the south. It is also necessary to take into account the change in the state of the seasonal sun, taking into account the incidence of solar radiation on the surface area of the device. For each latitude, the photoelectric battery is available for the optimal slope angle of the device, and only in regions located close to the equator, photoelectric batteries are located horizontally.

Usually the angle of inclination of the photoelectric battery is changed 3 times a year in a fixed position in the base structure (figure 3.10). Even if the photovoltaic battery is installed on a flat surface, the most important thing is to keep them rising at a certain distance from the ground level. This is done in order to form a spatial free air circulation made under the device.

It is necessary that the distance between the plane and the photoelectric battery is ≥more than 5 cm, otherwise the photoelectric battery will strongly overheat and weaken the production of electrical energy during the charging process to the battery. The base structure is also necessary to be stable to adverse weather conditions: strong wind speeds, large amounts of precipitation, and carrozia properties.

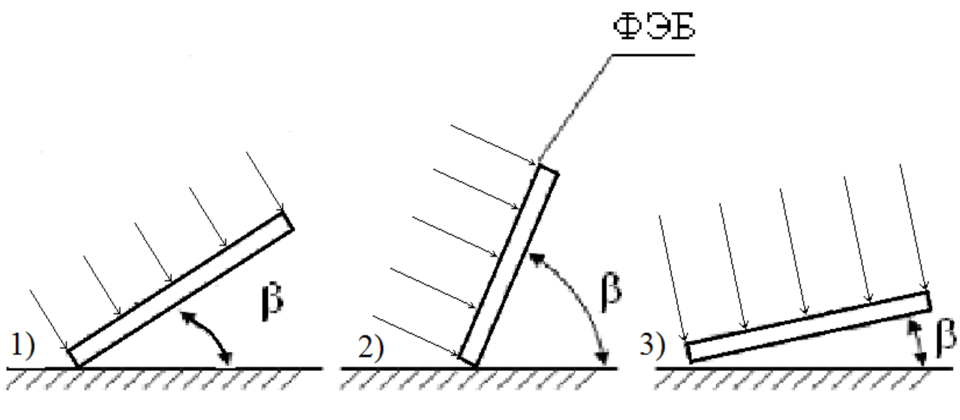



Figure 3.10. Spring and summer equinox (1), winter period (2) and Summer season (3) slope angle of photovoltaic battery installation

The photoelectric battery is oriented once a month according to the slope angle of the receiving surface and is determined from the following formula:

$$\beta_{г.н} = \phi - \delta_м \qquad (3.24)$$

The deviatio this is the geographical latitude of the territory, $^0$; $\delta_l$ - the angle of inclination of the sun for a given month, $^0$;.

n of the sun is determined by the following expression in Cooper's formula:

$$\delta = 23{,}45\, sin\left(360\frac{284+n}{365}\right) \qquad (3.25)$$

Where n is the ordinal number of the day of the year, which is calculated from January 1. as *n*, the average number of lunar days is usually taken for the months I-XII of the year.

(3.25) according to the expression Feb for the city of Tashkent account work for installation at an optimal angle is presented in Table 3.4. The geographical latitude of Tashkent City is 41°15'52".

Table 3.4.

| **Months** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| In relation to the horizontal slope, the photovoltaic battery is the optimal mounting angle (grad.) | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 57 | 49 | 41 | 33 | 25 | 18 | 25 | 33 | 41 | 49 | 57 | 64 |

Accounting work has shown that the optimal slope angle for spring and autumn equinoxes depends on the geographic latitude of the area. But in the process of photovoltaic battery exploitation, the difficulties of changing the orientation of the slope angle by months are engraved. Thus, the choice of the slope angle of the photovoltaic battery is carried out depending on seasonal changes (winter, spring, summer and autumn).

Knowing the amount of solar insolation in a given geographical area, we find the minimum solar radiation energy for December and January. The Sun deviation for these two months (according to the Analemma indicator) ranges from 17.5$^0$ to -

$23.5^0$. The magnitude of the average deviation angle is determined by the average arithmetic cosines of these angles:

$$\cos\delta_{cp.} = \frac{\cos(-17,5^0)+\cos(-23,5^0)}{2} \qquad (3)$$

from here $\cos\delta_{avr.}=-20,7^0$. Then the optimal slope angle for the winter season in Tashkent is as follows:

$$\beta_{г.н} = 41^0 - (-20,7^0) = 61,7^0 \qquad (3.26)$$

We will continue the accounting work for the summer season (June, July):

$cos\,\delta_{avr.} = \frac{cos(23,5^0)+cos(18,5^0)}{2}$; (5), from here $\cos\delta_{avr.}=21,1^0$. The optimal slope angle for the summer season is equal to;

$$\beta_{ã.í} = 41^0 - 21,1^0 = 19,9^0 \qquad (3.27)$$

Below is a table for installing a photovoltaic battery at an angle relative to the horizon in accordance with the seasons of the Year in the conditions of the city of Tashkent.

Table 3.4

| Optimal slope angle of photoelectric battery installation in relation to the horizontal plane by seasons of the year | | |
|---|---|---|
| Winter | Spring and Autum | Summer |
| $\sim62^0$ | $\sim41^0$ | $\sim20^0$ |

The optimal slope angle of photovoltaic battery installation has also been determined for the rest of Uzbekistan. For example, the results for the Samarkand region are presented in Table 3.5. The geographical latitude of Samarkand region is 39°39'15".

Table 3.5

| **Month** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The horizontal position relative to the photovoltaic battery is optimal for operation in a tower (deg.) | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 56 | 48 | 39 | 32 | 24 | 16 | 24 | 32 | 39 | 48 | 56 | 64 |

Results for Andijan region are given in Table 3.6. The geographical latitude of Andijan region is 40°46'55".

Table 3.6

| Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The horizontal position relative to the photovoltaic battery is optimal for operation in a tower (deg.) | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 57 | 49 | 40 | 33 | 25 | 18 | 25 | 33 | 40 | 49 | 57 | 64 |

Results for Bukhara region are given in Table 3.7. The geographical latitude of Bukhara region is 39°46'28".

Table 3.7

| Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The horizontal position relative to the photovoltaic battery is optimal for operation in a tower (deg.) | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 56 | 48 | 39 | 32 | 24 | 16 | 24 | 32 | 39 | 48 | 56 | 64 |

The results for the conditions of the city of Karshi are given in Table 3.8. The geographical latitude of Karshi is 38°51'38".

Table 3.8

| Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The horizontal position relative to the photovoltaic battery is optimal for operation in a tower (deg.) | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 55 | 47 | 38 | 31 | 23 | 16 | 23 | 31 | 38 | 47 | 55 | 62 |

The results for the conditions of the city of Karshi are given in Table 3.9. The geographical latitude of Urgench 41°32'59".

Table 3.9

| Month |
|---|
| The horizontal position relative to the photovoltaic battery is optimal for operation in a tower (deg.) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 58 | 50 | 41 | 34 | 26 | 18 | 26 | 34 | 41 | 50 | 58 | 66 |

Taking into account the geographical width of the territory for other regions of Uzbekistan (3) by the formula, the slope of the installation of the photovoltaic battery in relation to the horizontal plane can be calculated. orientation along the slope angle of the photoelectric battery leads to two positive efficiencies:

- photoelectric battery production capacity increases as a result of perpendicular solar radiation fall on the frontal surface of the module;

- with the rise in photovoltaic battery capacity, the battery charging time is reduced due to the increase in the charging current of the batteries.

## § 3.3. Technology for the preparation of solar photovoltaic panels

Solar photovoltaic panels are made up of solar photoelements. We will definitely have to produce enough and a large number of solar panels if we want to generate large amounts of electricity. Photoelements of solar photovoltaic modules are polycrystalline rectangular or Square and monocrystalline photoelements are pseudocwadrate (figure 3.11).

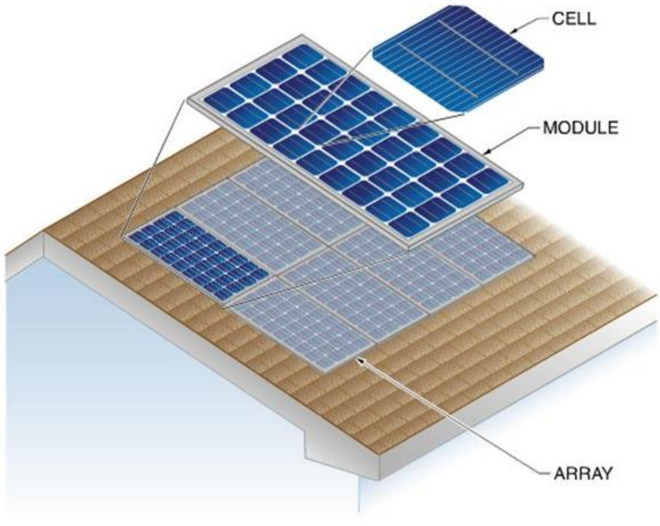



Figure 3.11. Components of a solar photovoltaic station

According to the production of solar panels (photovoltaic module or solar module), there are many sizes and many types. The most common type of photovoltaic module is power (40÷260 W at minimum power when sunlight is low and maximum power when sunlight is at optimal angle in clear Ham). These solar modules range in size from 0.4 to 2.5 m$^2$.

Solar modules are available for sale in a wide range of sizes depending on production capacity. It can be called solar panels (PV panels) or by connection (arrays). In terms of the difference in power in their production 10, 20, 30, 40, 50, 100 and is produced up to 400 W.

15-23% of the solar modules at the present time have a C.E. connected to the electrical energy grid, which is the distribution of electrical energy produced by solar elements in Transformers with the energy generated in the world.

To date, a lot of research has been carried out in scientific research laboratories around the world for the production of solar panels with a C.E. of up to 45% based on new materials. Of course, the cost in the production of solar elements is very necessary. On a large scale for the production of thin-layer solar elements on the basis of a number of new technologies, the work on the cheapening of solar panels and modules was launched.

Figure 3.12. The position of the solar module device installed on the roof of the House

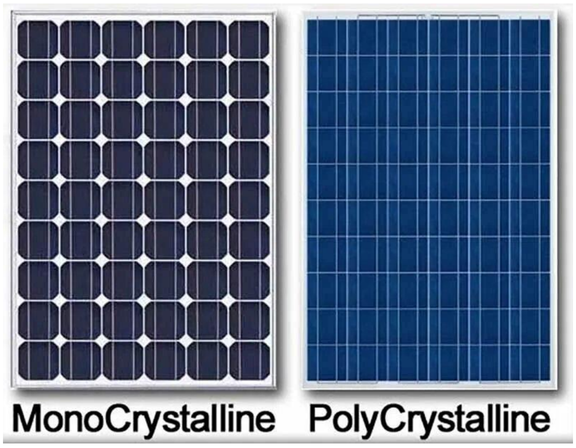



Figure 3.13. Mono and polycrystalline silicon-based solar elements

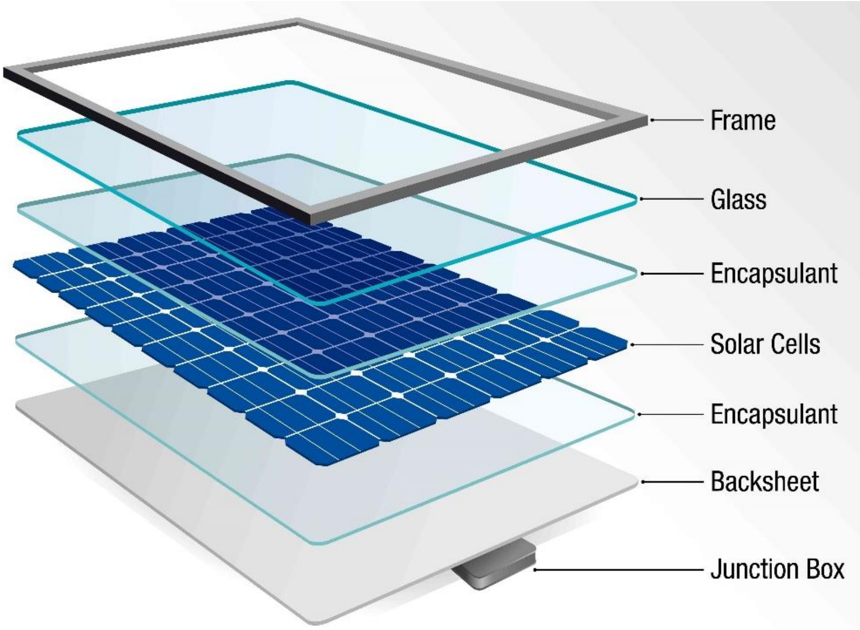



Figure 3.14. Parts of solar panel

Silicon crystal in the solar module can be multi-layered. The image above shows a solar panel of several layers. Hermetic materials will be needed for the working solar panel, in a position that does not change the resistance to external influences during the year in the open air. When wet air or water enters the solar module, at the expense of oxidation of the solar contacts, there is a state of erosion and erosion in them, which leads to a malfunction of the solar module. A very simple and high-quality hermetic film is EVA (ethylene vinyl acetate). Unfortunately this causes photoelectric modules to lose their transparency over time.

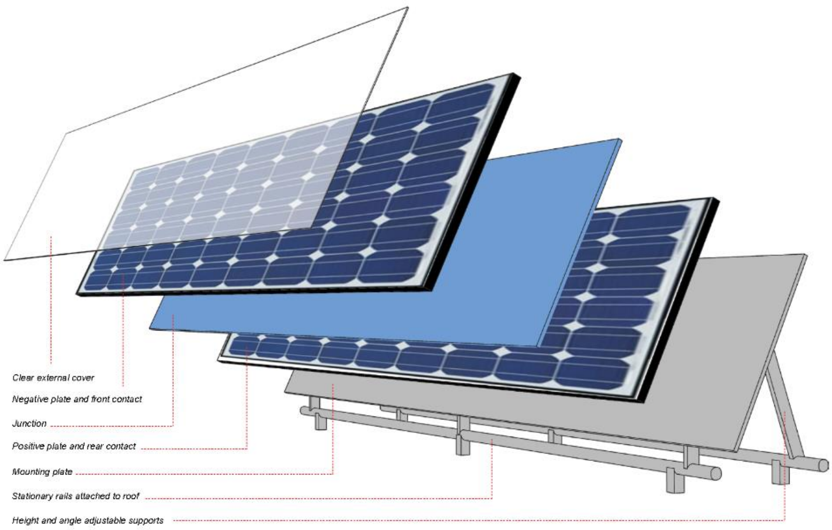


Figure 3.15.

Currently, there is considerable scientific research on the search for a material that can replace this hermetic material, but not so long ago, EVA (ethylene vinyl acetate) was used in the production of a hermetic material that can replace it. At the end of the panel in the form of a solar module, aluminum is installed in the profile. The photoelectric generator is in the form of a panel, in which a double hermetization (lamination) plenc with a back side on a glass plate is applied to the solar photoelement through metal (nickel) plates, in which the electric energy from photoelements (-) and (+) charges are generalized. The lower hermetization film serves to homoze the inner layers. Through the internal structure of the body, the photoelectric module is integrated into the body. In the interior of the module body, a cover block with an electrical contact is installed at the base of the panel to connect the modules together.

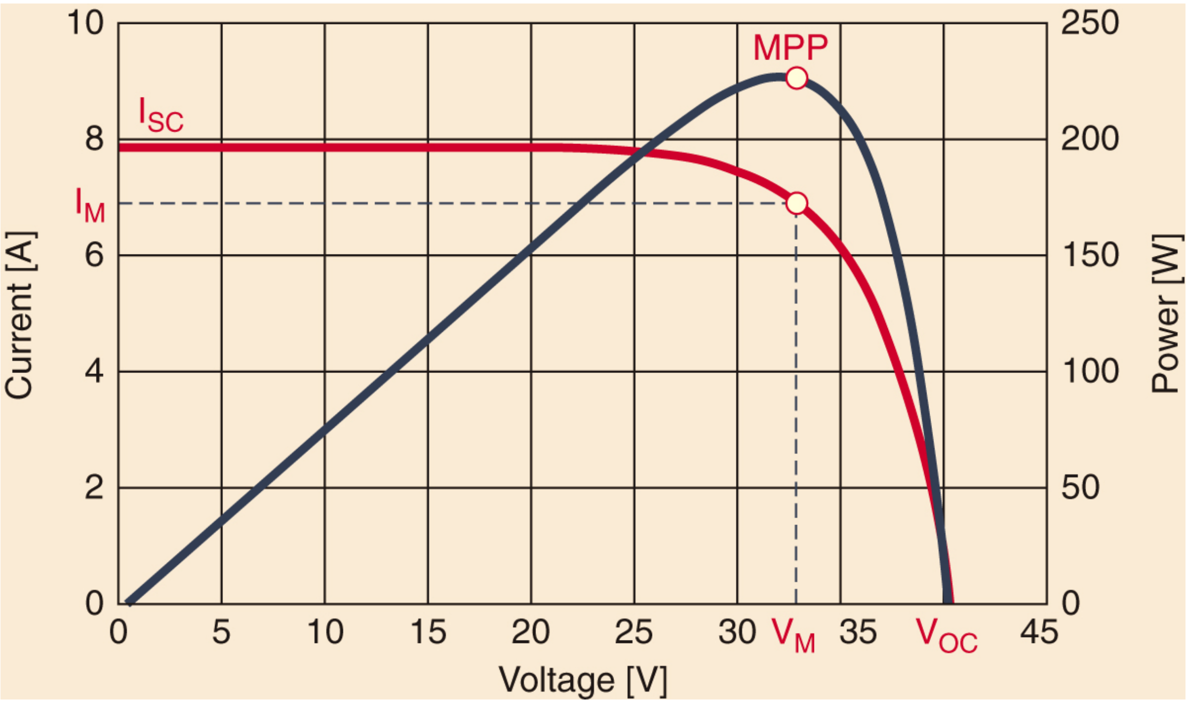



Figure 3.16. Solar panel VAC

Volt-Ampere and volt - Watt classification of the solar module. We can obtain the working State Volt Ampere classification (VAC) of the solar module at combined current strength and voltages. Currently, a unique single point of the solar module in the working State is selected. This point is not chosen according to the module, but when choosing a solar module, the electrical classification of the circuit (solar battery) is studied.

In a solar photovoltaic module where the current force is 0, the voltage reaches its maximum value, giving this position $V_i$ is called idling voltage. In contrast with the solar photoelectric module where the voltage is 0, the current force reaches its maximum value, to this position $I_{s.c}$. is called short circuit current. At this point, the wattage of the solar module is 0. From a practical jack, this works with a combination of current strength and voltage when sufficient power is accumulated in the system. The combination at maximum power (TMM or MPP) is called. Respectively, the naminal voltage and current strength ($U_n$ and $I_n$) are determined. Of course through these parameters it is possible to determine the total power and C.E. of the solar module.

Currently,it is advisable to work directly on the solar module, together at the specified voltage with the battery battery. We need to make their exact account books for battery batteries in all parts of the world. For example solar modules can have voltages from 10 V to 14.5 V but have a fixed voltage value of 12 V. If you need 24 V, we can of course make the voltage 24 V with a sequential connection. Accordingly, its performance parameters should be at an acceptable level to the consumer. This makes it possible to compensate for voltage transmission in the photoelectric module and maintain a full charge on the battery.

People usually have a simple question, "Why can't a solar photovoltaic panel be made to give 12 V". If you want to provide the module with the necessary voltage for the battery charge of accumulation, we will find out that this happens only in the ideal case and in an open air with a low temperature. Usually such processes do not occur under real conditions.

Therefore, when the solar photovoltaic module overheats under the influence of solar radiation, when the surface area is pollinated and there is not enough illumination, it is necessary that the accumulation is higher than the voltage to charge the battery. It should be said that despite the cold weather in the open sun, solar photovoltaic panels work perfectly. Under normal conditions, when C.E. 18-19% solar photovoltaic panels heat up to 40-45 $^0$C, their power is reduced by 15-17%.

It is known that accumulations with a voltage of 12 V to charge the battery, it is necessary to give it a voltage of 14.5 V (up to 15 V at low temperatures). Under real conditions, the nominal voltage of the solar photovoltaic module will be less than 17 V.

First of all, this is due to the fact that the temperature of the solar photovoltaic module heats up under the influence of sunlight, and when the module temperature rises from 25 $^0$C to each degree of Celsius, it decreases from -2.3 mV, that is, the temperature coefficient by Voltage is $\frac{dU}{dT} \approx -2{,}3\ \frac{mV}{C}$

Secondly, is the loss of voltage in the connecting cables.

Thirdly, the concentration of dust and aerosol in the atmosphere also seriously affects the salt walking voltage and current strength magnitudes of the solar photovoltaic module. According to the research of scientists, a high indicator of dust concentration negatively affects the efficiency of the solar photovoltaic module and other heliostructures, it can reduce the C.E. of the device by 40-50%.

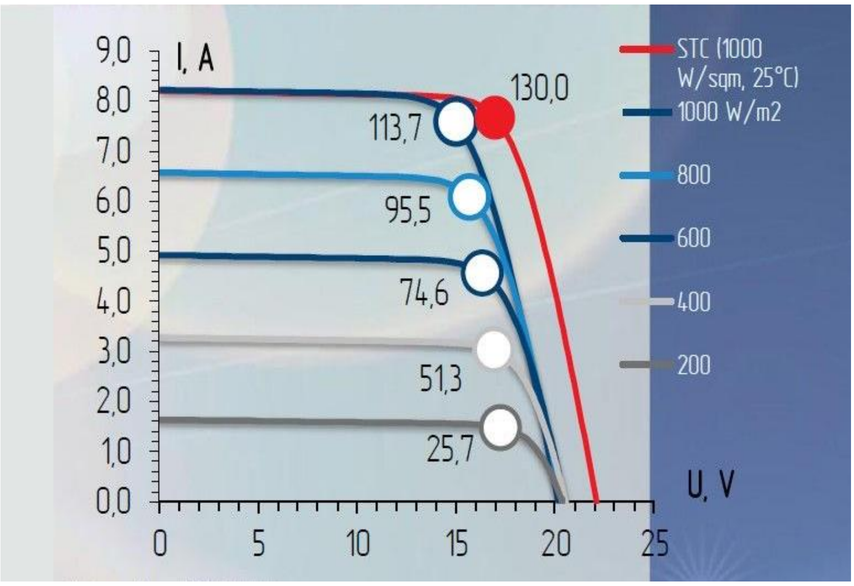



Figure 3.17. The luminance dependence of the photoelectric module of the monocrystalline type with a power of 130 W VAC.

The power of the solar photovoltaic panel changes in the correct proportion to the illumination. At a certain exact illumination, that is, at very low values, the solar photoelectricity module ceases to provide electrical energy. The luminance ranges from about 150–200 $W/m^2$ for crystal type, i.e. silicon photoelectric modules, to around 100 $W/m^2$ for amorphous silicon modules.

Also, the power of the solar photovoltaic modules will depend on the temperature of the external environment, as we stated above. For silicon solar photoelectric modules of the polycrystalline and monocrystalline types, the temperature coefficient per C.E. is -0.45%. For solar photovoltaic modules of the amorphous type, this indicator is 2 times smaller, and in recent years the temperature coefficient by power is positive in the developments of three-pass amorphous solar photovoltaic modules.

In the photovoltaic module passport, the following parameters ($U_{i.}$, $I_{s.c}$, MPP, $V_n$, $I_n$). A new generation of solar charge controllers and voltage inverters maintain a maximum power point (MPP) to provide a module efficient display during Operation. They hold the current strength and voltage values to the maximum at this maximum point. Thus MPPT controllers help increase current by reducing voltage. Maximum-point power monitoring provides a 15-30% increase in electrical energy production in the solar photovoltaic module.

1) Photovoltaic batteries or solar cells are complex devices, consisting of a SE connected in a certain order and an eluting basis on which these elements are placed. These may also include separator diodes. The PB structure should be resistant to shaking and attempts and easy to operate. It is advisable to take full advantage of the potential capabilities of PVs to create the technology of PB preparation. To do this, it is necessary that the PB preparation technology allows you to maximize the reduction of battery power losses. In PBs, the power loss is dual, which are optical and electrical losses.

2) **Electrical losses.** Electrical losses are mainly due to the precise measurement of SE parameters and their precise sorting according to their

parameters. Sorting by parameters should be carried out close to the optimal points of the electrical load.

3) **Optical losses.** Optical losses are in the fact that not all reach the PVP of this falling sunlight. In particular, this loss consists of losses in the hermetization of the qb Si (non-uniformity of the hermetic material and defects caused by the technological process) and in the light-conducting coating (mirror or plastic substance) falling on the frontal surface. The main technological processes in the preparation of solar cells are as follows: - Sort PVP by appropriate parameters, - switching elements to obtain a given voltage and current strength, - Preparation of bodies of PBs, - to place the switched elements in the battery and hermetize it, - Measuring and sorting PBs by parameters.

4) **Switching PVP.** To obtain the required voltage and current strength, PVP are switched in parallel, in Series or in complex.

Generally speaking, the electrical power of a PB si must be equal to the sum of the power of a SE lari in a battery. If this is not the case, then it is necessary to find a way to reduce losses. The current of PB Si is determined by the sum of the current of the parallel connected elements in the battery, while the voltage is determined by the sum of the voltages of the elements connected in series. Below are the calculation formulas.

$$U_{sb} = N_{ser}U_{se}, \quad (3.28)$$

$$I_{sb} = N_{par}I_{se}, \quad (3.29)$$

$$P_{sb} = N_{\Sigma}P_{se}, \quad (3.30)$$

$$P_{\kappa sb} = U_{sb}I_{sb}, \quad (3.31)$$

$$P_{sb} = U_{se}I_{se}, \quad (3.32)$$

$$N_{\Sigma} = N_{ser}N_{par} \quad (3.33)$$

where $U_{sb}$ and $U_{se}$ are the SB and SE voltages respectively, $N_{ser}$ and $N_{par}$ are the number of consecutive and parallel connected elements respectively, $P_{sb}$ and $P_{se}$ are the SB and SE capacities respectively.

Example: In a given load SE with the following parameters, the voltage drop at $U_{load}$ = 0.4 V the maximum current strength is I=0.5 A. Of these SB, 100 are connected in series and 300 are connected in parallel. What are the parameters of the prepared PB?

$$I_{sb}=100\cdot 0,5=50\ A,\ U_{sb}=300\cdot 0,4=120\ V\ \text{and}\ P_{pb}=50\cdot 120=6000\ W.$$

Depending on the operating conditions and power of photoelectric devices, they can be conditionally divided into two groups:

1. Displacement, lift (Assembly) solar cells and photoelectric devices. Such devices serve to provide autonomous power to low-power consumers, located mainly away from centralized conventional power networks.

2. Photovoltaic stations (PVS). These devices autonomously provide electricity to electricity consumers who are used in production, business affairs and living. For the first group, Consumers can mainly be this lifting radio - TV equipment, lifting refrigerators, low-power lighting and other living equipment. In the second case, it can be applied to agricultural facilities, medical networks, water discharge on individual farms, irrigation, lighting and other agricultural work, which are located mainly away from centralized power networks.

In the production and use of PBs and PVS, some of the conditions listed below should be taken into account. In particular, the conditions of use (highlands, plains, etc.in terms of geographical structure), the intensity of light fall (daily, weekly, monthly, annual), The amount of moisture and dust in the air, the maximum and minimum values of the annual temperature, the geographic width of the territory, the morphology of the local area, etc. are taken into account.

The composition of the photovoltaic device can be different depending on the operating conditions and consumer demand. For maximum power in general, it includes a battery control system (controller) with a photoelectric block, a battery, a consumer, a current converter (inverter) with a constant current of variable voltage

220 V and a frequency of 50 Hz, a control unit that monitors the position of the photoelectric device depending on the course of the sun, etc.

## § 3.4. Preparation of the base structure for the solar photovoltaic device

**Base structure:** supporting structures for solar panels serve as an important part of solar photovoltaic systems. It provides the necessary consistency for all systems and the right slope angle for the solar panel. The combination of the solar panel with the base structure should withstand different wind speeds and other environmental influences.

**Construction and installation of solar photovoltaic stations:** for large photovoltaic systems, there are different types of structures that can be prepared from small nushas to industrial-grade replicas. Such a structure is made of metal or synthetic material. There are different types of base structures depending on the state at the time of installation of photoelectric systems. For grid-connected systems, there are types of base structures at a small angle on the flat or roof, as well as for house facades. Grid-connected systems can also be an element of a building structure (integrated solar systems). The construction and installation of solar photovoltaic stations is carried out with the help of qualified, experienced specialists and technicians, each of whom must have a specialty in their direction:

Work on the design of the installation area, geodetic field specialists.

1. Ground installation work of metal structures.
2. Installation of solar modules, inverters and other electrical circuits and their connection.
3. Passing cable lines, mounting cable – conductor devices, connecting them to the transformer substation.

Above 3.18 and figures 3.19 show signs from the construction of a solar photovoltaic station with a capacity of 130 kW, built in the Pop District of Namangan. This station was built as part of the implementation of the Memorandum of cooperation between the Ministry of economy of the Republic of Uzbekistan and the Ministry of Trade, Industry and energy of the Republic of Korea.

Equipment from “Hanhwa”, “JSPV”, “S-Energy” and “TopSum” were installed at the photovoltaic station. The commissioning of a photovoltaic station in this test procedure creates the following possibilities:

- Increase the strength of electricity supply to the population of the Kandigon neighborhood;

Figure 3.18. Installation of the frame part of the solar photovoltaic station

Figure 3.19. Installation of solar panels by engineers at a solar photovoltaic station

- Providing Korea's solar modules with information to be used to conduct inspections of promising and comprehensive projects for the development of solar energy in the Republic by field testing of its practical productivity;

- Testing the productivity of solar modules produced in Korea in the natural conditions of Uzbekistan;

- To assist Korean technologies in the construction and development of solar photovoltaic stations in the Republic of Uzbekistan and to assist in the training of national specialists in the field of solar energy.

In the process of installing solar panels, specialists are required to study one by one, since the location of the solar power plant being created involves complex processes in the selection, Assembly and design of the most convenient devices. In the first place, the capacity of the solar photovoltaic station in the project is determined. This allows us to calculate the required number of solar modules, determine the area of the area, and then experts will offer you an optimal drawing of the magnifying system. Of course, in the presented drawing, the orientation of the photovoltaic station must be selected, allowing you to obtain the maximum amount of electrical energy at low output.

Figure 3.20. One-axis tracker solar power station

There are two main manifestations of the base system: **static and dynamic**. To the main elements of the static system, it is made of high-quality aluminum profile in the magnifying system, steel, the base elements of which are covered with spirit silence. The characteristic of a static system is that the slope angle of the modules oriented relative to the sun cannot be changed. Logically, it is necessary that the solar modules are maximally illuminated during the daylight hours and orientated towards the south. In the construction of solar photovoltaic stations, trees, electricity and telephone should be far from cable lines, television antennas. It should be said that the presence of a temporary shade dressing, ambient light dust and bird droppings negatively affect the electrophysical parameters of photoelectric modules in other such cases. Also another case, it is worth paying attention to the distance between the photoelectric panels, since they do not shade each other and reduce the incidence of failure by touching each other when ground shaking occurs.

We briefly talk about more static systems: modules can be placed on the table gorizantally and vertically (1-5) from a number of rows. Depending on the weight of the structure and several other classifications, the table (carcass) can be one or two supports. The system in which the structure is fixed is attached to the ground in two ways: 1) attaching to the installation site directly through the pile. 2) attaching the area of the place under installation through a concrete screed.

These parameters are determined first of all, depending on the geodesy and geology of the soil and the capacity of the station in the project. A dynamic system- such a system is called a visual (tracker), that is, an "observer device" in Uzbek. Its operation process is quite simple, and the device is designed to increase the C.E. to monitor the sun to the maximum. There are two types of them, the first with one axis and the second with two axes.

Figure 3.21. Two-axis tracker solar power station

A one-shot tracker changes its position with respect to only one bullet. Usually such a tracker is similar in appearance to a static structure, and when viewed with attention, this structure is provided with an actuator, the device changes the angle of the slope. The actuator, in turn, consists of a motor – reducer and a plug. The stock moves the table up or down by attaching it to itself. A single-axis tracker changes its angle relative to the sun a number of times in a year. This is managed through software that makes changes from 2 to 20 per year.

A two-axis tracker is a complex engineering structure that is oriented in two different planes. The contrast of the two-axis tracker, the one-axis tracker, is that the maximum collection of sunlight during the day until sunrise and sunset, rotating the table at an unrestricted 1,800 angles. It also has a safe mode in a horizontal position, which is also considered durable when strong winds blow. They automatically control the system, which is designed to receive the maximum amount of sunlight. The efficiency of such a system is 30-40% higher than that of a static system. It is 15% higher than the one-support system.

## § 3.5. Methods for obtaining electricity from solar energy

Methods for obtaining electricity from solar radiation:

**1. Photovoltaics** is the conversion of photons directly into electrical energy using photoelements. The appearance of electric current in an illuminated electrolyte was first observed in 1839 by Alexander Edmon Becquerel. However, the first photovoltaic solar cell was discovered only 44 years later by the American engineer created by C. Fritts. That is why exactly 1883 is considered the year of the beginning of the solar energy era.

The main laws describing photovoltaic processes could be established in the XIX-early XX centuries. At the end of the XIX century A.G. Stoletov's works established an empirical relationship between the amount of phototoc and the flow of light incident on the sample (known as the 1st Law of photoeffect). And in 1905 Albert Einstein developed the foundations of the general theory of photoeffect, for which he was awarded the Nobel Prize in Physics in 1921.

A.Einstein's theoretical work made it possible to conduct targeted research on the creation of effective solar cells and laid the groundwork for the creation of a new direction in science-solar photovoltaics.

**2. Heliothermic energy** is the heating of a surface that absorbs sunlight, and the subsequent dissipation and use of heat (directing solar radiation into a container of water or salt for later heating, hot water supply, or the use of heated water in steam generators). As a special type of heliothermal energy stations, it is customary to distinguish between concentrated — type solar systems (CSP-Concentrated Solar Power). In these devices, the energy of sunlight using lenses and a mirrors system is focused on concentrated light. This beam is used as a thermal energy source to heat a working fluid that is spent on generating electricity, similar to conventional thermal power plants, or stored to conserve energy.

The conversion of solar energy into electricity is carried out using heat machines:

- Stirling engine;
- gas turbine;
- thermal air power plants (conversion of solar energy into the energy of the air flow directed to the turbogenerator).

**3. Solar aerostat power plants** (generating water vapor inside an aerostat balloon by heating an aerostat surface covered by a selective absorbing coating with sunlight). The advantage is that the steam reserve in the cylinder is enough for the power plant to work in the dark and in adverse weather conditions.

### § 3.5.1. Polycrystalline silicon photoelectric panels

Polycrystalline solar panels are a type of photovoltaic panel used to convert solar radiation into electricity. They are made from silicon crystals with different crystal lattice directions. Polycrystalline panels are usually blue due to the peculiarities of the crystalline structure of Silicon. The main advantages of polycrystalline panels:

**1. Low production cost:** polycrystalline panels are cheaper to manufacture than monocrystals, which makes them more convenient for a wide range of consumers.

**2. High temperature resistance:** they generally hold their performance better at higher temperatures compared to Monocrystalline panels. However, they also have disadvantages, including:

**1. Lower efficiency factor:** polycrystalline panels usually have a rate of conversion of solar energy into electricity compared to single crystal panels.

**2. Low efficiency in low light conditions:** polycrystalline panels can produce less energy in low sunlight, such as on cloudy days or in the early morning and evening hours.

The choice between polycrystalline and Monocrystalline panels depends on the specific conditions of the project, budget and performance requirements. The energy performance of polycrystalline solar panels can vary depending on the manufacturer, panel model, specifications and operating conditions. However, the main indicators that are usually considered when assessing the efficiency and performance of polycrystalline solar panels:

**1. Power:** this is the main measure of solar panel performance, measured in Watts (W) or kilowatts (kW). Polycrystalline panels can typically have a power of several watts to several hundred watts per panel, depending on size and design.

**2. Efficiency (energy conversion coefficient):** this is the ratio of the maximum output power of the panel to the input solar energy. Typically, polycrystalline panels have an efficiency of 15% to 20%, but there are more efficient models with higher efficiency indicators.

**3. Temperature coefficient:** this is a parameter that shows how temperature changes affect the performance of the panel. The temperature coefficient for polycrystalline panels is usually from -0.4% to -0.5% in Celsius.

**4. Guaranteed service life:** manufacturers usually provide warranty for their panels, which indicates the service life and expected performance during this period. Typically, the guaranteed service life is from 20 to 25 years.

**5. Power tolerance:** this is the deviation range of the actual panel power from the declared value. Typically, the strength tolerance is ± 3% or 5%. These indicators are important in the selection and installation of solar panels, since they determine their performance, reliability and economic efficiency.

### § 3.5.2. Monocrystalline silicon photoelectric panels

Monocrystalline solar panels are also a type of photovoltaic panel used to convert solar radiation into electricity. They are made from one silicon crystal with the same crystal lattice structure. Some features of monocrystalline solar panels:

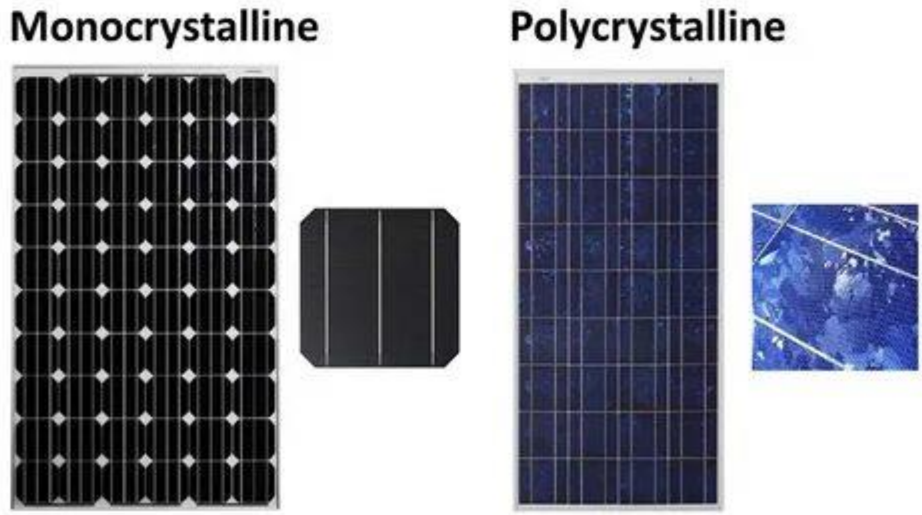
**1. High conversion rate:** Monocrystalline panels usually have a rate of conversion of solar energy into electricity compared to polycrystalline panels. This means that they can generate more energy per unit area.

**2. Better low-light performance:** Monocrystalline panels are generally more efficient in low-light environments, such as cloudy days or early morning and evening hours, than polycrystalline panels.

**3. Small size:** due to its high efficiency, monocrystalline panels are usually smaller at the same power output, which can be important if the installation area is limited.

**4. High production cost:** however, the process of manufacturing Monocrystalline panels is much more complex and expensive, which makes them more expensive than polycrystalline panels.

**5. High temperature resistance:** they usually maintain their performance better at high temperatures.




**3.27-расм. Монокристал кремнийли фотоэлектрик панел.**

The energy performance of monocrystalline solar panels can vary significantly depending on the manufacturer, panel model, specifications and operating conditions. The main indicators that are usually considered when assessing the efficiency and performance of monocrystalline solar panels:

**1. Power:** monocrystalline solar panels usually have a high conversion rate of solar energy to electricity, which gives high power per unit area. Panel power is measured in Watts (W) or kilowatts (kW).

**2. Efficiency (energy conversion factor):** typically, monocrystalline solar panels have high efficiency, which can range from 18% to 24% or higher, depending on the particular model and manufacturer.

**3. Temperature coefficient:** this is a parameter that shows how temperature changes affect the performance of the panel. Typically, the temperature coefficient for monocrystalline panels ranges from -0.3% to -0.4% in Celsius.

**4. Guaranteed service life:** Manufacturers usually provide warranty for monocrystalline panels, indicating service life and expected performance during this period. Typically, the guaranteed service life is from 20 to 25 years.

**5. Power tolerance:** this is the deviation range of the actual panel power from the declared value. Typically, the strength tolerance is ± 3% or 5%.

### § 3.5.3. Amorphous silicon photovoltaic panels

Amorphous silicon solar panels (also known as amorphous crystalline solar panels) are a type of thin film solar panels. Unlike traditional crystalline solar panels made of monocrystalline or polycrystalline silicon, amorphous solar panels are created from amorphous (non-crystalline) silicon or other amorphous semiconductors.

Main features of amorphous silicon solar panels:

**1. Thin film:** amorphous solar panels have a thin layer of semiconductor material, which makes them lightweight and flexible. This allows them to be applied in a variety of applications, including architectural elements and integrations to wearable devices.

**2. Production:** amorphous solar panels are generally cheaper to manufacture than traditional crystal panels. They can be produced using thin film laying processes such as vacuum spraying or melting techniques, which makes the manufacturing process easy and cost-effective.

**3. Efficiency:** Amorphous solar panels usually have a rate of conversion of solar energy into electricity compared to conventional crystal panels. However, they can have advantages in low light conditions, such as cloudy days or early morning and evening hours.

**4. Temperature change resistance:** amorphous solar panels generally have better resistance to temperature changes and can perform better at higher temperatures than other solar panels.

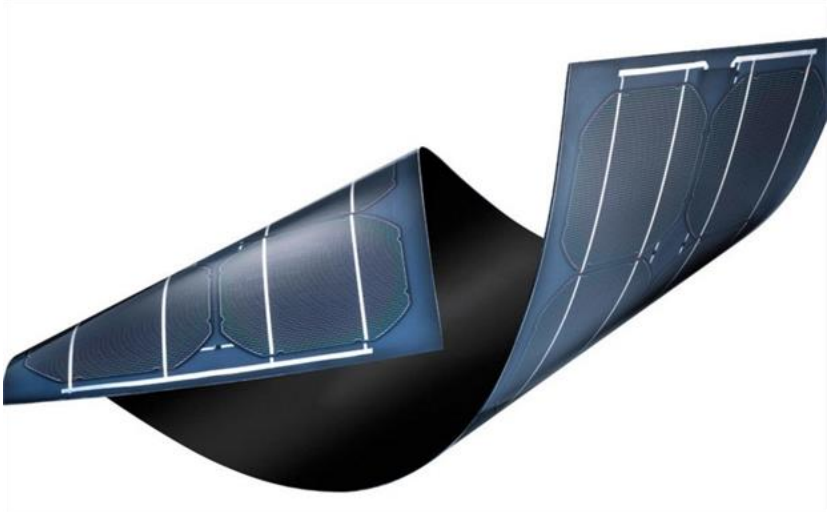


Figure 3.28. Photovoltaic panel made of amorphous silicon.

While amorphous solar panels may have some efficiency limitations compared to conventional crystal panels, their flexibility and low production cost make them an attractive option for specific applications. The energy performance of amorphous solar panels can vary depending on the particular manufacturer, panel model, specifications, and operating conditions. Some of the main indicators that are usually considered when assessing the efficiency and performance of amorphous solar panels:

**1. Power:** the power of amorphous solar panels is measured in Watts (W) or kilowatts (kW), and they indicate the amount of electricity they can generate under certain light conditions.

**2. Efficiency (energy conversion coefficient):** this is the ratio of the maximum output power of the panel to the input solar energy. Typically, the efficiency of amorphous solar panels ranges from 5% to 10%, but there are more efficient models.

**3. Temperature coefficient:** this is a parameter that shows how temperature changes affect the performance of the panel. Typically, the temperature coefficient for amorphous solar panels is about -0.2% per Celsius.

**4. Guaranteed service life:** manufacturers usually provide warranty for their panels (this indicates the service life and expected performance during this period). Typically, a guaranteed service life can range from 10 to 25 years.

**5. Power tolerance:** this is the deviation range of the actual panel power from the declared value. Typically, the strength tolerance is ± 3% or 5%.

## § 3.5.4. Comparative analysis of the effectiveness of monocrystalline, polycrystalline and amorphous solar panels

A comparative analysis of the performance of monocrystalline, polycrystalline and amorphous solar panels will help determine which type of panel is best suited to the specific project environment. Let's consider the main features of each panel type:

**Monocrystalline solar panels (advantages):**

-High conversion rate: Monocrystalline panels usually have one of the highest conversion rates of solar energy to electricity (typically 18% to 24%).

-Low light efficiency: they have good performance even at low light levels.

-Long service life: Monocrystalline panels usually have a guaranteed service life of 20 to 25 years.

**Monocrystalline solar panels (disadvantages):**

-High cost: Monocrystalline panels are usually more expensive to manufacture, which is reflected in their high cost.

-Shade sensitivity: they are sensitive to shade, even partial shades can reduce their performance.

**Polycrystalline solar panels (advantages):**

- Cheaper price: polycrystalline panels are cheaper to manufacture, which makes them even cheaper.

- High temperature resistance: they maintain their performance better at high temperatures.

**Polycrystalline solar panels (disadvantages):**

- The conversion rate is slightly lower: usually, the conversion rate of polycrystalline panels is slightly lower than that of monocrystalline panels.

- Low efficiency under low light conditions: they can produce less energy when the light level is low.

**Amorphous solar panels(advantages):**

- Flexible and lightweight: amorphous panels can be lighter and more flexible, allowing them to be used in a wide variety of applications.

- Low production cost: amorphous panels are cheaper to manufacture than crystal panels.

**Amorphous solar panels (disadvantages):**

- Low conversion rate: the efficiency of amorphous panels is usually low, which means low productivity compared to crystal panels.

- Short service life: the guaranteed service life of amorphous panels is usually shorter.

### § 3.5.5. Thin film solar cells: types and their effectiveness

**Thin-film solar cells** are a type of solar cell made by depositing one or more thin layers (thin films or TFs) of photovoltaic material onto a substrate, such as glass, plastic or metal. Thin-film solar cells are typically a few nanometers (nm) to a few microns (μm) thick–much thinner than the wafers used in conventional crystalline silicon (c-Si) based solar cells, which can be up to 200 μm thick. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous thin-film silicon (a-Si, TF-Si).

Solar cells are often classified into so-called generations based on the active (sunlight-absorbing) layers used to produce them, with the most well-established or *first-generation* solar cells being made of single- or multi-crystalline silicon. This is the dominant technology currently used in most solar PV systems. Most thin-film solar cells are classified as *second generation*, made using thin layers of well-studied materials like amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium gallium selenide (CIGS), or gallium arsenide (GaAs). Solar cells made with newer, less established materials are classified as *third-generation* or emerging solar cells. This includes some innovative thin-film technologies, such as perovskite, dye-sensitized, quantum dot, organic, and CZTS thin-film solar cells.

Thin-film cells have several advantages over first-generation silicon solar cells, including being lighter and more flexible due to their thin construction. This makes them suitable for use in building-integrated photovoltaics and as semi-transparent, photovoltaic glazing material that can be laminated onto windows. Other commercial applications use rigid thin film solar panels (interleaved between two panes of glass) in some of the world's largest photovoltaic power stations. Additionally, the materials used in thin-film solar cells are typically produced using simple and scalable methods more cost-effective than first-generation cells, leading to lower environmental impacts like greenhouse gas (GHG) emissions in many cases. Thin-film cells also typically out perform renewable and non-renewable sources for electricity generation in terms of human toxicity and heavy-metal emissions.

Despite initial challenges with efficient light conversion, especially among third-generation PV materials, as of 2023 some thin-film solar cells have reached efficiencies of up to 29.1% for single-junction thin-film GaAs cells, exceeding the maximum of 26.1% efficiency for standard single-junction first-generation solar cells. Multi-junction concentrator cells incorporating thin-film technologies have reached efficiencies of up to 47.6% as of 2023.

Still, many thin-film technologies have been found to have shorter operational lifetimes and larger degradation rates than first-generation cells in accelerated life testing, which has contributed to their somewhat limited deployment. Globally, the PV marketshare of thin-film technologies remains around 5% as of 2023. However, thin-film technology has become considerably more popular in the United States, where CdTe cells alone accounted for nearly 30% of new utility-scale deployment in 2022.

The efficiency of thin film solar cells can vary depending on various factors, including production technology, material quality and operating conditions.

### § 3.5.6. Gresel element

Thin-film solar cells are a type of solar panel that uses thin films of semiconductor materials to convert solar radiation into electricity.

The most common types of thin film solar cells and their effectiveness:

**1. Amorphous silicon (a-Si) solar elements:** efficiency: the efficiency of amorphous silicon solar cells is usually about 6-12%, which is often lower than that of crystalline solar panels. However, amorphous solar cells have other advantages such as flexibility and low production costs.

**2. CIGS (copper-indium-gallium-selenium) solar elements:** efficiency: CIGS solar elements have a high efficiency potential, usually between 10% and 20%. This makes them one of the most effective thin-film solar cells. However, the specific efficiency may vary depending on the production technology and other factors.

**3. CdTe (cadmium-tellurium) solar elements:** efficiency: CdTe solar elements have good efficiency, often rated between 9% and 18%. This makes them one of the most used thin film solar cells on the market.

**4. Perovskite solar elements: efficiency:** perovskite solar elements is a relatively high technology that has demonstrated very high efficiency capabilities. The efficiency of such solar cells can exceed 25%, which makes them one of the most effective solar cells at the moment. However, their commercial implementation is still in the process of development.

A perovskite solar cell (PSC) is a type of solar cell that includes a perovskite-structured compound, most commonly a hybrid organic–inorganic lead or tin halide-based material as the light-harvesting active layer. Perovskite materials, such as methylammonium lead halides and all-inorganic cesium lead halide, are cheap to produce and simple to manufacture.

Solar-cell efficiencies of laboratory-scale devices using these materials have increased from 3.8% in 2009 to 25.7% in 2021 in single-junction architectures and, in silicon-based tandem cells, to 29.8%, exceeding the maximum efficiency achieved in single-junction silicon solar cells. Perovskite solar cells have therefore been the fastest-advancing solar technology as of 2016. With the potential of achieving even higher efficiencies and very low production costs, perovskite solar cells have become commercially attractive. Core problems and research subjects include their short- and long-term stability.

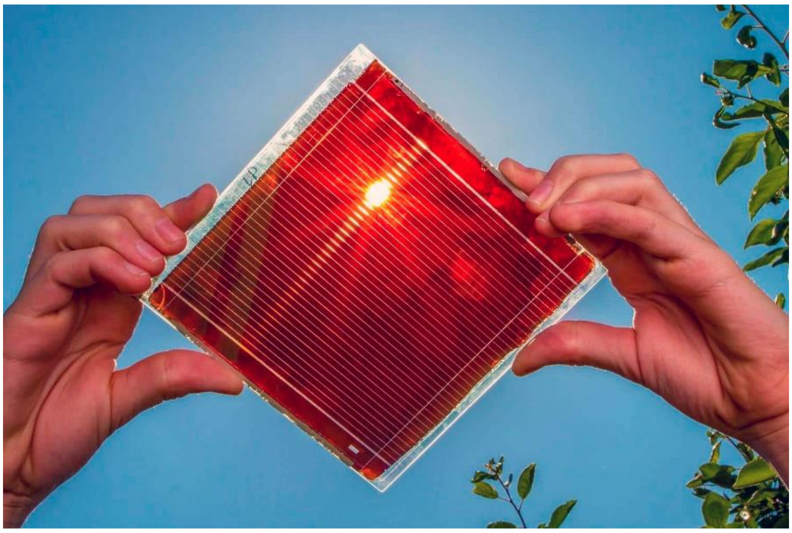


Figure 3.25. Perovskite solar cell

A type of Gresel element is organic polymer materials developed using the solar element. These cells are based on organic photovoltaic conversion concept, which uses organic polymers or molecules to capture light and generate electric current. The advantages of organic solar cells such as the Gresel element include low production costs, flexibility and lightness. They can be manufactured using relatively simple technologies that can reduce costs and expand application capabilities, such as in embedded systems or wearable devices. However, at present, organic solar cells have low efficiency compared to traditional silicon solar cells. This limits their use in most commercial solar applications, although research in this area continues to increase the efficiency and stability of organic solar cells. The Gresel element is a new type of organic solar cell, the performance and efficiency of which can vary significantly depending on the specific implementation, materials and technologies used. Currently, organic solar cells, including Gresel cells, usually have low efficiency compared to traditional silicon solar cells. However, they have other advantages such as flexibility, ease of use and low production costs.

General performance and efficiency characteristics of organic solar elements, including Gresel cells:

**1. Conversion efficiency:** generally, organic solar cells have the efficiency of converting solar energy into electricity from a few percent to tens of percent. Efficiency for a Gresel cell can range from 5-10%.

**2. Strength tolerance:** this is the range of deviation of the true strength of the cell from the declared value. Typically, power tolerance is plus/minus a few percent.

**3. Temperature dependence:** the efficiency of organic solar cells usually decreases with increasing temperature, but this may depend on the specific material and design of the cell.

**4. Service life:** since organic solar cells are a relatively new type of technology, their service life and performance stability require further research and development. Organic solar cells, including Graetzel cells, represent an interesting area of research and development in the field of photovoltaic solar energy conversion. Their potential includes the ability to create flexible and lightweight devices that can be used in a variety of applications, including wearable devices, embedded systems, etc.

**Questions about Chapter 3:**

1. Modern types of solar photovoltaic panels?
2. The structural structure of solar batateas?
3. What does the volt-Ampere indicator of solar panels mean?
4. Poured requirements for the installation of solar panels and connecting-based systems?
5. The main technological processes in the preparation of solar cells?
6. Methods for obtaining electricity from solar energy and their effectiveness?
7. The advantage and disadvantage of monocrystalline, polycrystalline and amorphous solar panels?

# CHAPTER 4. SOLAR POWER PLANT AND ITS MAIN ELEMENTS

## § 4.1. Solar power station

Solar power plants (SPP) are a set of devices that use solar panels to convert solar energy into electricity. Below are the main types, effectiveness and methods of connecting SPP

**1. Types of solar power plants:**

A. photoelectric solar power plants (PSPP): photoelectric solar panels are used to convert solar energy into electricity. This is the most common type of solar power plants.

B. Thermal solar power plants (TSPP): solar collectors are used to heat cooling water, which is then used to start turbines and generate electricity. It is usually used in a wide range of devices.

C. Incarnating (concentric) solar power plants (CSPP): mirrors or lenses are used to concentrate sunlight on a small area where photoelements or heat receivers are installed. This makes it possible to increase the efficiency of converting solar energy into electricity.

**2. Efficiency of solar power plants:** the efficiency of solar power plants depends on various factors such as location, panel angle, climatic conditions and type of technology used. Typically, the coefficient of conversion of solar energy into electricity (efficiency) from 15% to 22% gacha, depending on the type of panel and operating conditions of solar panels.

**3. Methods for connecting solar power plants:**

a. off-grid (autonomous): solar power plants can operate independently of the power grid using batteries to store excess energy for use at night or when there is little sunlight.

b. on-grid (grid-connected): solar power plants can be connected to the power grid, which allows them to transfer excess energy to the grid during the day and extract energy from the grid at night or in the absence of sunlight.

c. hybrid systems: combine solar power plants with other energy sources such as wind turbines or diesel generators to ensure a continuous and stable energy supply. Each of these types of solar power plants has its advantages and disadvantages, and the choice of a particular type depends on the specific requirements, location and budget of the project. Methods of increasing the efficiency of a solar power plant. Improving the efficiency of solar power plants plays an important role in increasing their efficiency and economic feasibility.

Some ways to increase the efficiency of solar power plants:

**1. Choosing the optimal location:** placing a solar power plant in places with high solar activity and minimal shade will help maximize solar energy.

**2. Optimization of panel angle and orientation:** the slope and orientation of solar panels should be optimally selected to maximize solar radiation absorption during the day and throughout the year.

**3. Using solar observation:** the installation of solar observation systems allows the panels to rotate in the direction of the sun during the day, increasing the amount of solar energy generated.

**4. Application of high-performance solar panels:** high conversion factor (efficiency) the use of solar panels helps to increase system power.

**5. Optimization of the installation system:** the correct selection and adjustment of the installation system allows you to maximize the use of the area of the installed panels and minimize the shade.

**6. The use of solar collectors:** the application of effective solar collectors for thermosolar power plants helps to maximize the collection of solar thermal energy.

**7. Use of energy storage:** the installation of energy storage systems such as batteries allows you to save excess energy obtained during periods of high solar activity and use it during periods of low activity or at night.

**8. Monitoring and control:** regularly monitoring the operation of the system and using effective control systems will help optimize the operation of the solar power plant and eliminate possible problems. These techniques and technologies help increase the efficiency of solar power plants, making them competitive and environmentally sustainable energy sources.

In order for solar panels to be a reliable source of electricity, it is necessary to provide additional elements in the system: cables, structure, electronic inverter, battery pack and charge-discharge controller, depending on the type of system (FeS connected to the network, autonomous, reserve). Such a system as a whole is known as a solar photovoltaic system or solar station. There are 3 main types of photoelectric systems: 1. Autonomous SPP applied by default for the power supply of individual houses; 2. Intedrated PVP; 3. Reserve PVP.

**Autonomous photoelectric systems:** autonomous photoelectric systems are used where there is no centralized power supply. A battery battery (AB) is necessary for the power supply during the night of the day and for those times when the sun does not shine well. Autonomous photovoltaic systems are often used for the power supply of individual houses. Small systems can provide basic loading (lighting source, sometimes TV or radio), super-powered systems water pump, radio station, refrigerator, electroequipment, etc. Such a system is made up of the following (figure 4.1).

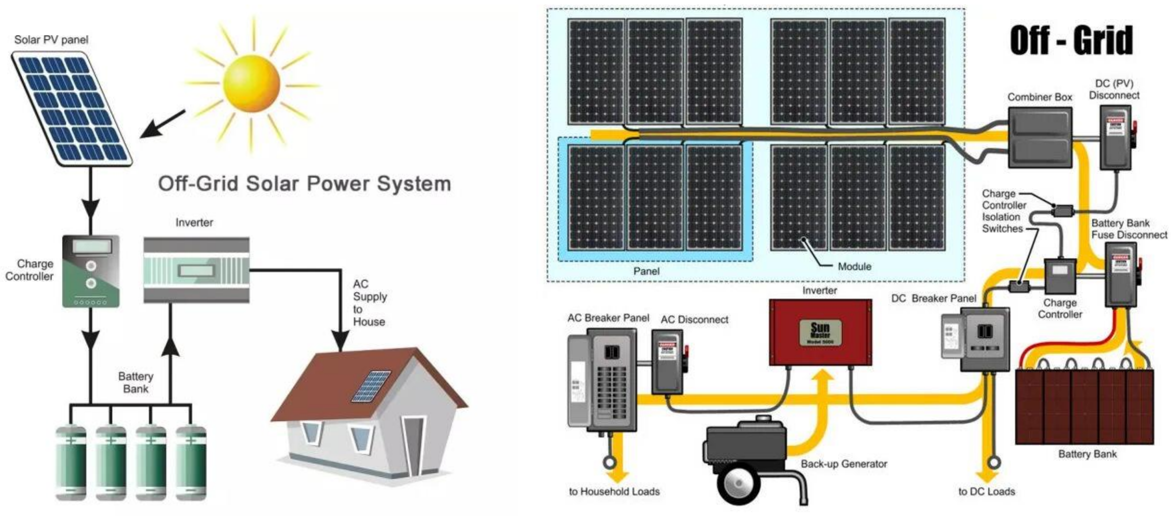



Figure 4.1. A simple off grid Solar PV system

**Grid-connected solar photovoltaic systems:** even if there are centralized power supply sources, there will sometimes be interference with the use of a clean power source, in which solar panels will be connected to the grid. When a sufficient number of solar panels are connected with each other, part of the load can be supplied from solar electricity at home. Network-connected photoelectric systems typically consist of one or more panels and an inverter, cables, a slave system, and an electrical load.(Figure 4.2).

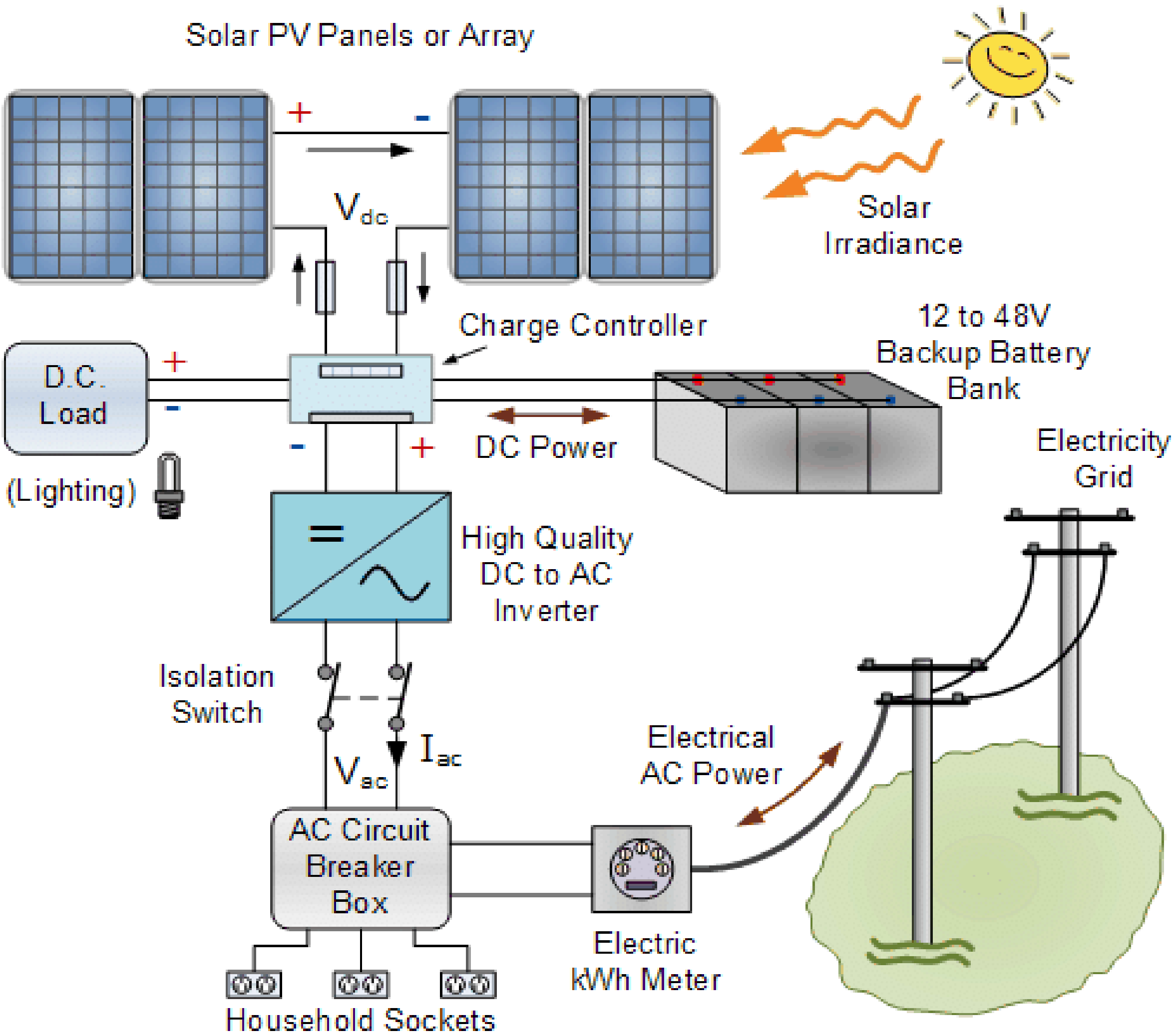
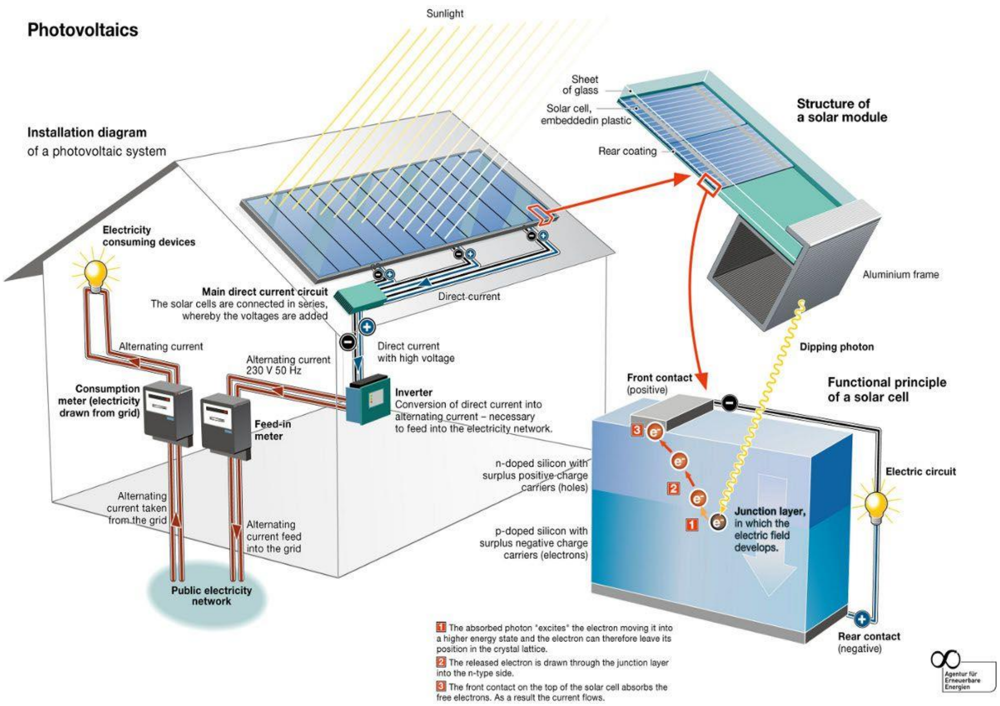


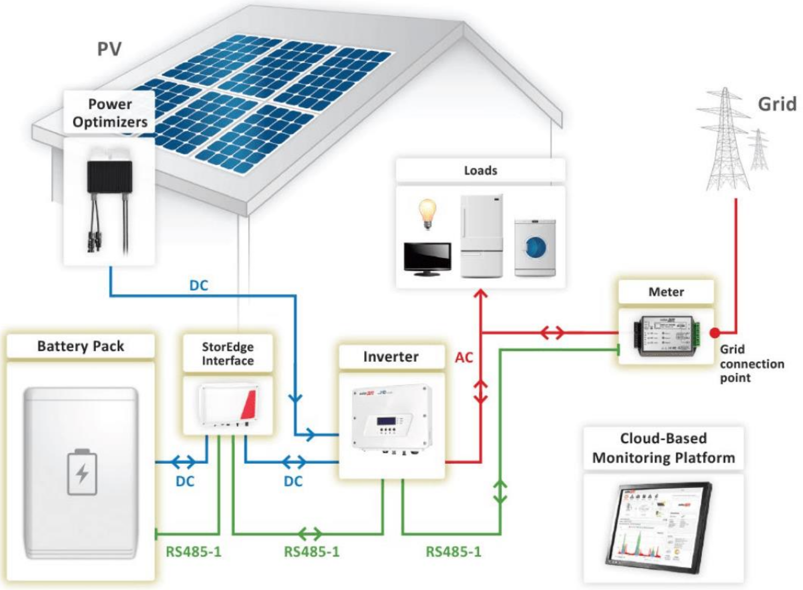

Figure 4.2. Grid-connected solar photovoltaic system

The inverter serves to connect solar panels with the grid. There will also be AS-panels with an inverter mounted on the back. Excess electricity can be transmitted to the power grid. If special enhanced tariffs are used for solar power supply, then 2 electricity meters are installed, one for generation, and the next for consumption.




Now it has electronic meters that calculate the amount of electricity flowing in a double direction. In this case, electricity developed by solar panels is sold to the network at a high tariff, while the House's electricity needs are often charged from the network at the usual price. So not only the year-long output to electricity, but also the consumption within the year (in summer, excess energy is sent to the network, and in winter, during daylight hours, the house is mainly provided through the network.)

**Reserve systems:** in such cases, Reserve solar systems are used if the centralized power supply is connected to the network, but not reliable. Reserve systems are used to supply electricity at seasonal times even when there is no voltage on the network. Small reserve solar systems are used for communication facilities, computers (telephone, radio, fax and hakozo) power supply. Large Solar Reserve systems can also provide energy to refrigerators during times of outages on the network. For the necessary feeding of the load, especially at a time when there are frequent nodes on the network, it is necessary that the photoelectric system has a large capacity. If there is a network, the system will work with it as usual. The system consists of a solar panel, controller, AB, cables, inverter, loading and base structure (fig.4.3).




**Charge-discharge controllers:** in autonomous photoelectric systems, charge-discharge controllers protect the accumulator battery (AB) from deep discharge in case of excessive energy consumption, and in the case of full charge AB, the solar panel protects the AB from recharging status during electrical energy generation. (fig. 4.4.). One of the advantages of using a charge-discharge controller is that AB immediately disconnects the load in the discharge state. Typically, photoelectric systems are supplied with charge-discharge controllers. Therefore, the boot never connects directly to AB, in which AB may fail.

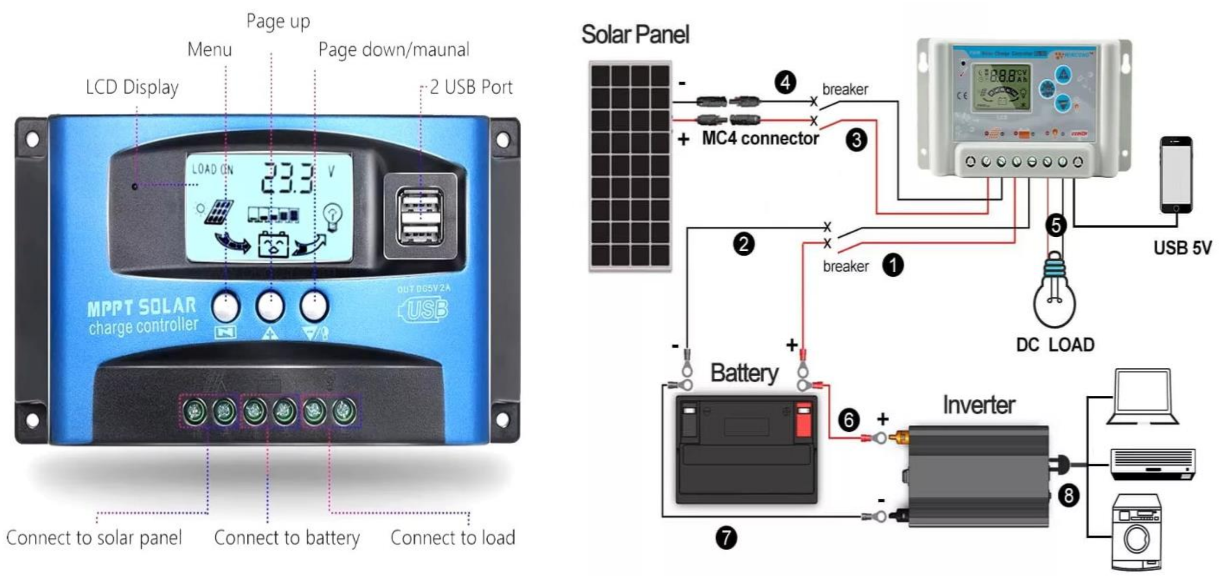



Figure 4.4. Solar charge controller (a) and connection diagram (b)

Controllers with a wide –pulse modular charge current: ordinary controllers disconnect the energy source (solar battery) when the voltage AB reaches 14.4 V (rated voltage AB is 12 V). When the voltage at AB decreases to ≈ 12.5− 13 V, the solar panel is reconnected and the charge is restored at AB. Therefore, the AB maximum discharge rate is 60-70%. The shelf life of AB is reduced if the full charge is not met on a regular basis.

Modern controllers use a process known as broad pulse modular charge current at the charge termination stage. In this case, the charge AB is charged up to 100%. fig. 4.5 shows 4 stages of AB charging using a solar panel.

1) Charging with maximum current. At this stage, AB uses all current coming from the solar panel.

2) Using wide pulse modulation charge current. When the voltage at AB rises to a clear level, the controller begins to provide at the expense of wide pulse modulation charge current with a constant voltage. This prevents gas release and overheating at AB. The current decreases with the AB charge level.

3) Equalization. During periodic charging, the working process is improved until the formation of a gas AB with many liquid electrolytes, the electrolyte is mixed and the plates are cleaned, the voltage is equalized in different jars AB.

4) Base charge. Even if AB is in a state of full charge, the charge voltage decreases when gas is released from the battery or during its heating, and at this point AB remains in a state of charge.

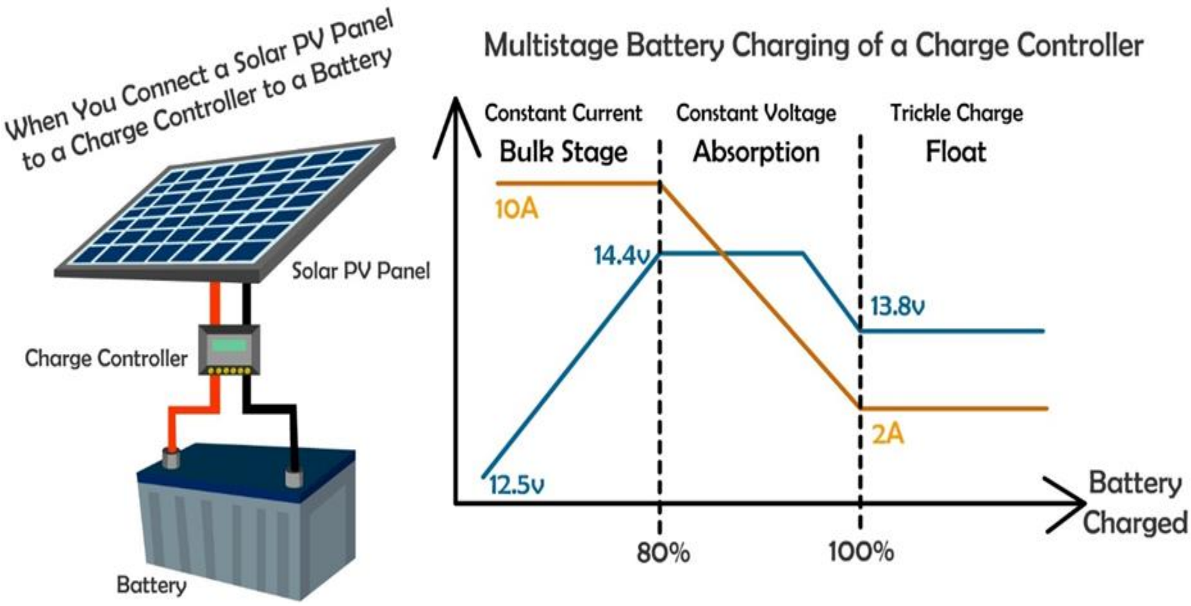



Figure 4.5. Stages in charging the battery from the solar panel

**Controllers designed to monitor the maximum power point:** if it is necessary to increase the amount of energy that solar cells are producing, even without the addition of additional solar panels, a simple controller must be replaced with a controller designed to monitor maximum power (MMM) in a solar battery specifically called the "Maximum Power Point Tracker" (MPPT). The MPPT controller constantly monitors the voltage and current in the solar cell, its values cup off to determine the current voltage pair at the maximum solar cell capacity. The built-in processor monitors the charge stage of AB (saturation, super-saturation, equalization, base) and, on the basis of this, determines what amount of current is given to it. The processor also gives a command to the parameter indicator in the tableau at the same time (data storage, etc).

The maximum power point can also be calculated in different ways. The methods of searching for TMM are also different.

1) the Perturb and Observe method is commonly used. That is, a periodic full scan (1 time in 2 hours) of the Volt-Ampere characteristic of the solar battery is carried out with MMM. Continuing to search until the next scanning process, the controller calculates the power oscillation of the solar cell and pushes it to a new working Point, a new voltage, if the power in it is large. Practically all controllers use this method. Its disadvantage is that it is always necessary to carry out measurement work and at this time the interruption of the energy coming from the panel. Different manufacturers choose the parameters of frequency iterations, full scanning periodicity, and search depth of the optimal amount of energy coming from The Sun to optimally observe the maximum power point of the solar bataerea.

2) The second method is "Scan and Hold". After the first scanning process, the voltage is determined at the Found point level and held until the next full scanning state. Such a method is considered good when shadows and clouds do not appear on the solar panel. Advantages-high speed of work, during the measurement process there are no interruptions at the time of generation.

3) The third method is Percentage of open circuit voltage. The inding voltage and the Working point at ($U_i \cdot k$) are measured. Where k can range from 0 to 1 (k-

0.8). The point is held until the next scanning process. Such a method is best for cases when there is a shadow drop on the panels and there is no cloud. Advantages-high speed of work, there are no interruptions in the generation at the time of measurement.

4) The fourth method is to strictly select the working point. The desired voltage on which the controller supports is determined. He does not perform any measurements and calculations, is constantly working. Disadvantages-the selected voltage can be far from the actual MMM dock. However, it is clear that at what voltage the battery produces maximum power, and it is better to use this method when the solar battery is constantly working outdoors in practice. When the system is started, the voltage with which the controller supports is given, that is, it is calculated according to the exact parameters of the solar battery.

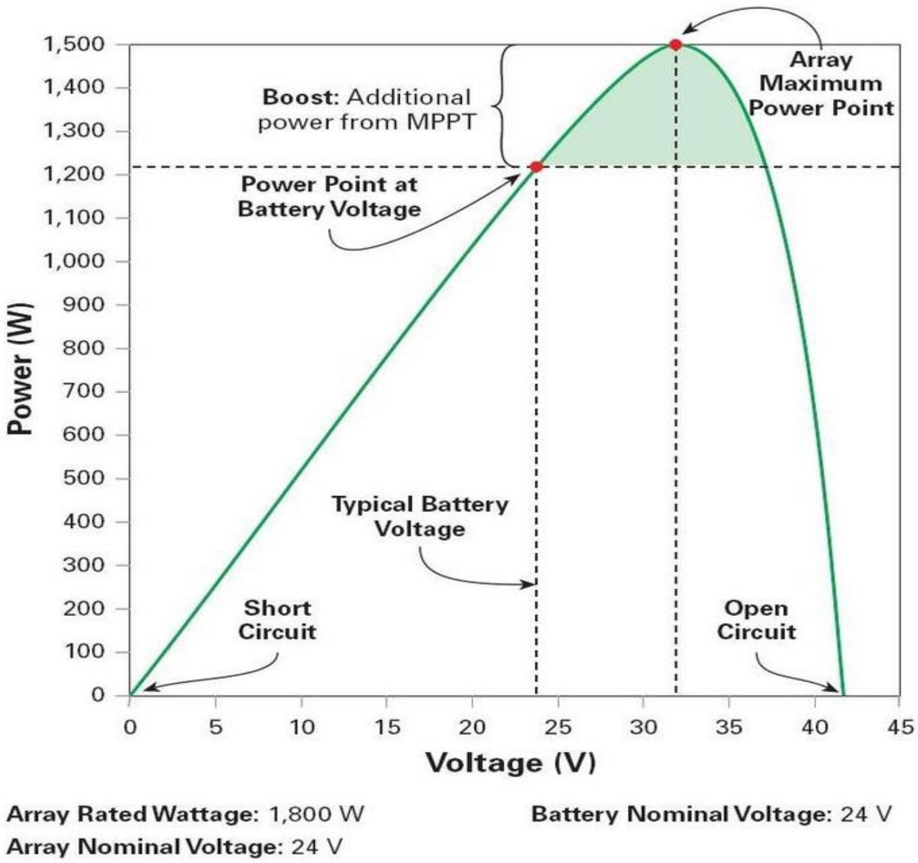



Figure 4.6. MPPT is the amount of energy additionally obtained when using a controller.

The state of MMM depends on the illumination of the panels, temperature, variety of panels used, etc. The controller periodically tries to "change" from the point in the previous stage, in which the power of the solar panel must be raised so that it moves to the work at the new point. Theoretically, some energy is transmitted during the search for MMM, but this energy is additionally much less compared to the energy provided by the MPPT controller. In addition, it is very difficult to determine the energy obtained in this case. In addition, the factors that influence the production process are the temperature and AB charge levels caused (figure 4.6).

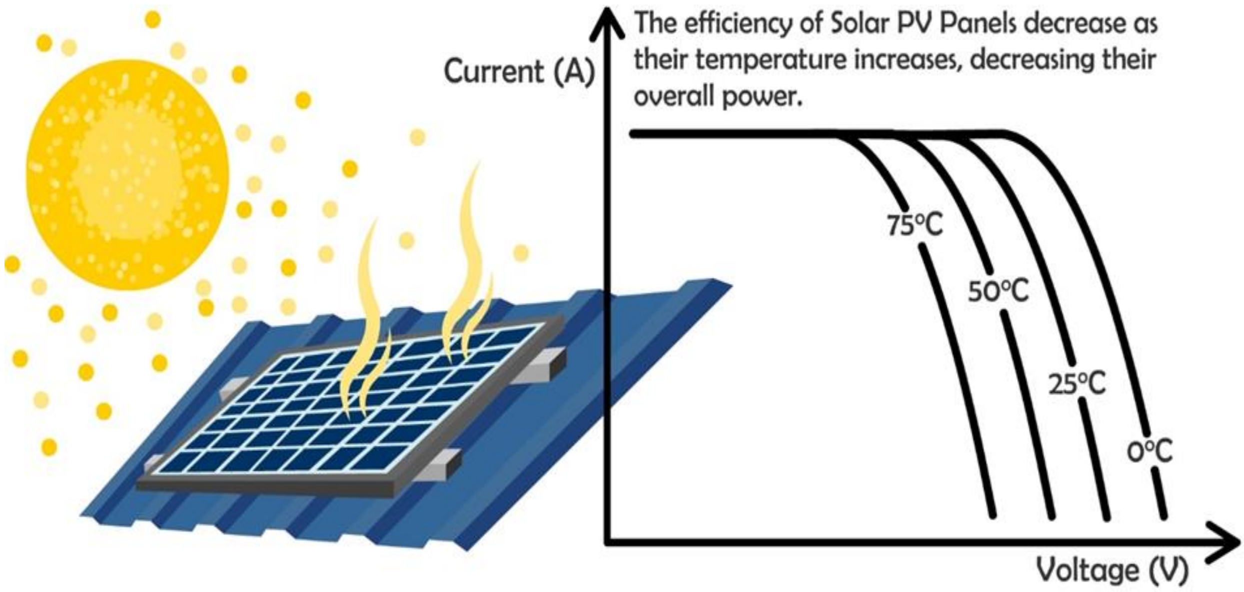



Figure 4.7. Solar panel voltage at MPP depending on panel temperature.

At the maximum power point, the voltage of the solar panel changes at different temperature magnitudes of the panel (figure 4.7). The hotter the solar panel, the lower the voltage, the lower the production efficiency of the solar cell. At some point, the magnitude of the maximum power point (MPP) can be even smaller than the voltage at AB, in which cases there is no gain compared to a simple controller. This happens at times when partial shade falls on the solar cell. The current price of MPPT controllers makes it possible to apply them on solar panels or panels with non-standard voltage, starting from a power of 200 W.

## § 4.2. Inverters for photovoltaic systems

A **power inverter**, **inverter**, or **invertor** is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC). The resulting AC frequency obtained depends on the particular device employed. Inverters do the opposite of rectifiers which were originally large electromechanical devices converting AC to DC.

The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

A power inverter can be entirely electronic or maybe a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process.

Power inverters are primarily used in electrical power applications where high currents and voltages are present; circuits that perform the same function for electronic signals, which usually have very low currents and voltages, are called oscillators. Circuits that perform the opposite function, converting AC to DC, are called rectifiers.

Figure 4.8. Modern inverters

In grid-connected systems, inverters (grid inverters) receive energy from solar panels and convert them to alternating current, then transfer it to the grid as well. Most solar panels produce permanent current. There are also panels applied with integrated inverters called microinvertor AC panels (figure 4.9).

Figure 4.9. Microinvertor mounted on the back of the solar panel

Their advantages are that easy adjustment, easy addition of such panels to the photoelectric system is the possibility of expanding the scale with wool. Such inverters are only used in grid-connected systems. In autonomous systems, it will be necessary to change the current in AB or solar panels to provide standard household devices with a variable voltage of 220 V. Also, in reserve systems, this problem is to change the constant current in AB and provide the usual equipment.

There are many inverters that differ in power and types. Some of them-have high efficiency. If the inverter is unloaded in most cases, it is necessary to give a small amount of power consumed in standby mode. If it provides loading in most cases, then it will be necessary to choose an inverter with a maximum C.E.

Қуёш панели домий ток ишлаб чиқаради, АБ эса доимий ток кўринишида энергияни сақлайди, лекин кўпчилик жиҳозлар 220 В ёки 380 В ўзгарувчан ток кучланишини талаб қилади. Инвертор домий токдаги кичик кучланишлар 12, 24, 32, 36, 48, 96, 120 В ни юқори кучланиш 220 В га ўзгартириб беради. Ўзгартириш вақтида энергиянинг бир қисми йўқолади, яъни 5% дан – 20 % гача, бу эса унинг иш режими вақтида сифатининг даражасига боғлиқ бўлади.

Off-Grid инвертор - Мустақил ишлай оладиган ва ўзининг юкламасини ўзгармас ток билан таъминлай олади (4.10-расм).

The solar panel produces a DC, while AB stores energy in the form of a DC, but most equipment requires an AC voltage of 220 V or 380 V. Small voltages on the inverter DC 12, 24, 32, 36, 48, 96, 120 V is changed to a higher voltage of 220 V (AC). At the time of change, part of the energy is lost, that is, from 5% to 20%, which will depend on the level of its quality at the time of its operation. An Off-Grid inverter is an inverter that can operate independently and provide its load with a fixed current (figure 4.10).

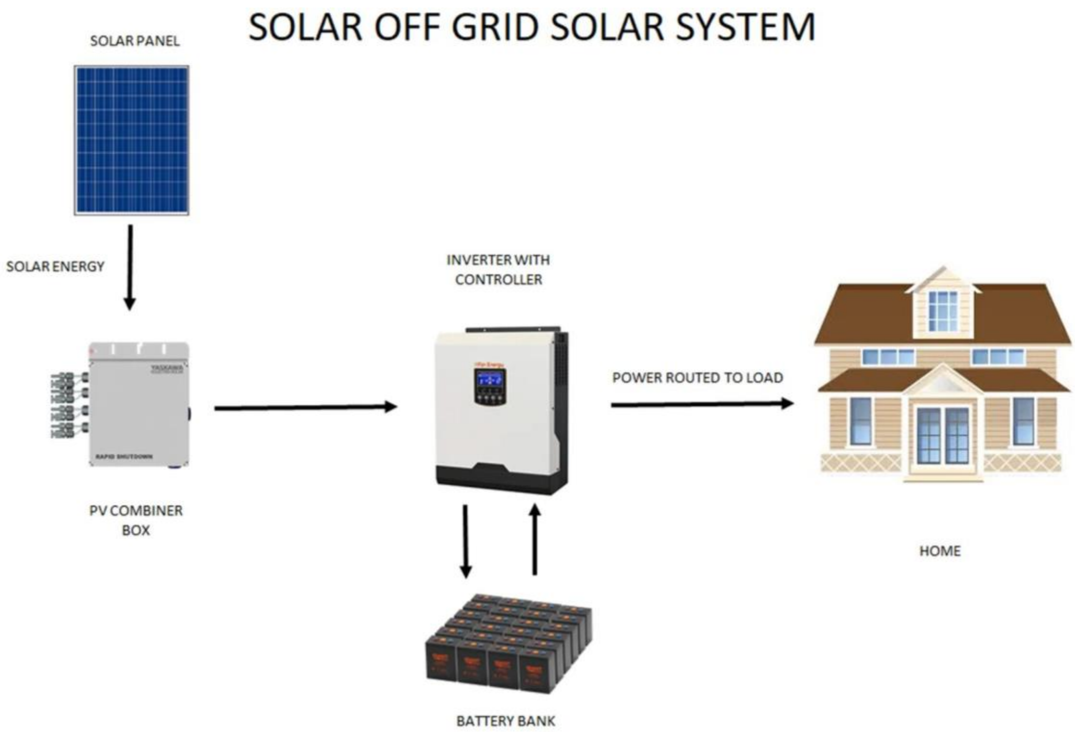



Figure 4.10. Off grid soalr system (autonomus)

Inverters are at different capacities, the type of which is selected depending on the state of application. In small autonomous systems, low-power inverters (100-1000 W) are used to provide television, radio, light bulbs and other equipment. In these inverters, the input voltage is 12 V or the output voltage of 24 V is 220 V. In large power inverters, the input voltage can be 24 V, 48 V or 96 V or higher. Cheap iinvertors change energy during generation in a phased or rectangular form, or in a quasisinusoidal or modified sinusoid with a common name as a signal. This form of voltage does not always correspond to all equipment. Pure sinusoidal inverters can provide the desired load without any problems, such as quality current as in the network. The on-grid inverter-cannot operate independently, but can operate synchronously with the main power grid (figure 4.11.).

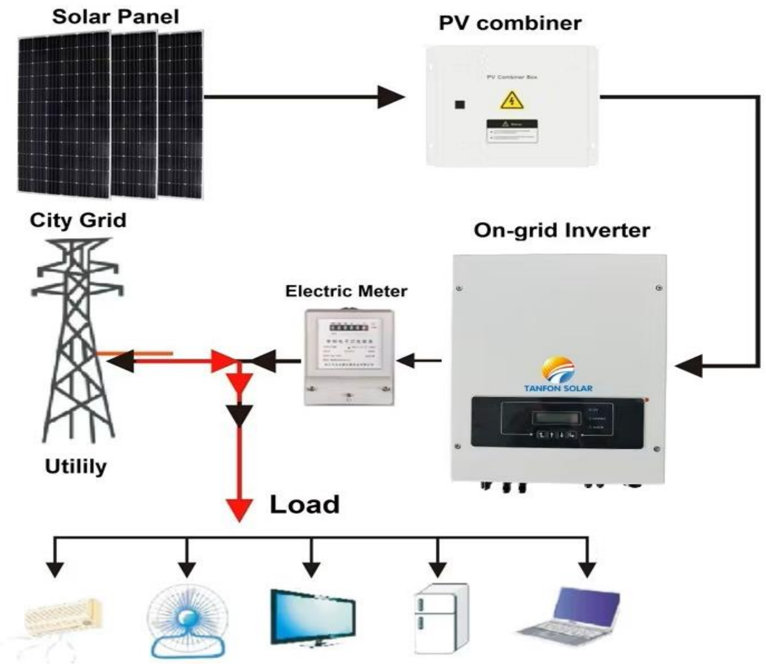



Figure 4.11. Network parallel operation system (on-grid)

**Function of modern inverters.** The inverter display describes voltage, current, frequency and power.

Ability to automatically add generator. The inverter has an additional relay to stop or auto-add the reserve generator depending on the AB voltage. This function is attached to the inverter in most cases in the form of a separate block. Modern inverters can be charged from the network at a specific time AB, It is advisable to do the addition of the generator during the day (due to noise). A hybrid inverter is an Off-Grid inverter (figure 4.12) with fixed current contolls. The Smart On-Grid inverter is able to operate synchronously with the Central Power Grid and has its own fixed and variable current control capability.

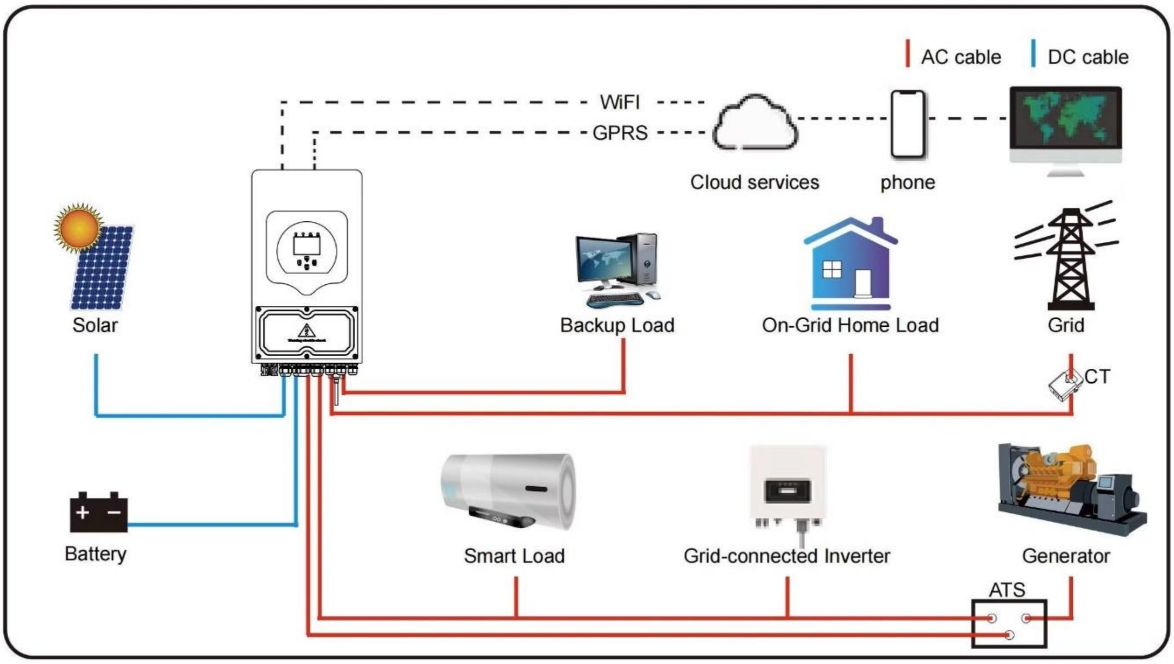
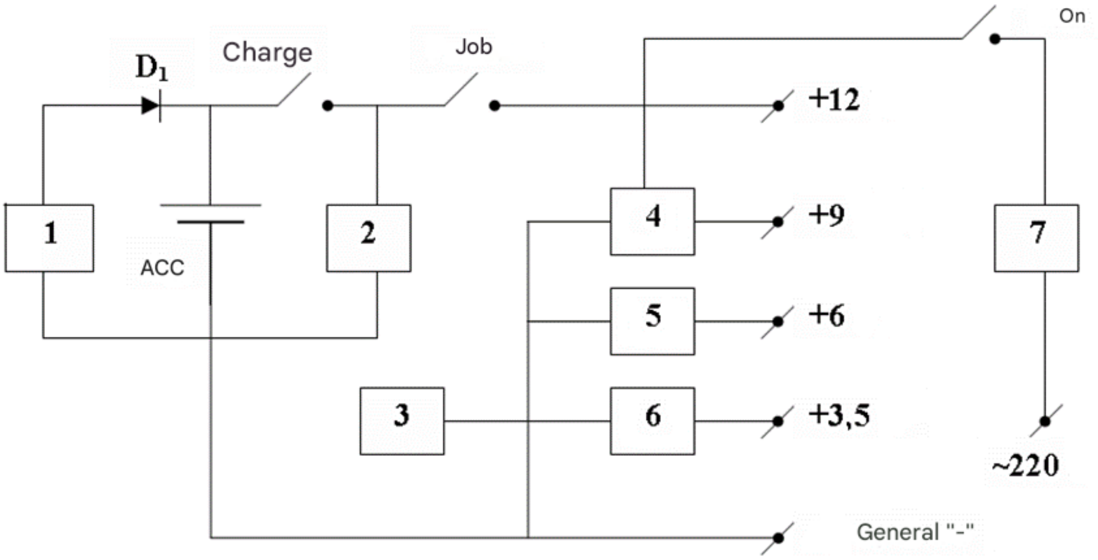



Figure 4.12. Hybrid solar system

Be able to work in parallel with the network. Network inverters convert energy directly from the solar battery to the network without AB. This will only reduce the cost of the system, which means it will make electricity cheaper. Built-in charging device. Such inverters can charge AB using a generator or grid. At some point, they can also transfer energy directly to consumers.

**Parallel connection.** Some inverters can also be connected in parallel to increase power. Currently, solar photoelectric cannot compete with traditional methods of obtaining energy on the economic indicators of modifiers. Therefore, their field of practical application is the introduction of electrical energy from the centralized lines of electrospray while fuel injection for complex autonomous diesel-generators is a small autonomous equipment that is located in areas that are not suitable for the economic side. Specific examples of the use of solar energy are: shepherds ' houses in pastures, energy supply of electric jixozes in nomadic beekeeping, energy supply in difficult-to-reach places (mountain and desert) of the apparatus of hydrometerorological and radiogeodesic stations, for storage and transportation of various medical substances in rural areas and field hospitals, and power supply of navigational signs in water and one of the most promising goals of solar energy is the dressing of portable or mobile photovoltaic equipment with a silicon-based solar element, which changes the energy of the correct and organizing solar scattering radiation with a C.E. of 15% and a power of 2 to 100 W.




4.13. Structural scheme of autonomous solar power supply:
1-solar battery; 2 – battery charging and discharge control equipment; 3 – current overloading protection equipment; 4,5,6 – voltage stabilizers; 7-inverter.

Figure 4.13 shows a description of the solar battery load Volt-Ampere, which is measured at $E_{descent}$=810 W/m$^2$, t=10 $^0$C under the conditions of the city of Tashkent, and the dependence of qb power on the voltage at the load (2). From the Volt-Ampere description it appears that at the optimal loading point (V=14.5 V and I=1.3 A) the solar battery capacity is 9 W. SB tests show that the average daily accumulative energy in the battery battery (AB) is 12-13 A·h for November and approximately 10 A for December 28 A·h. When the sun turns its battery and the sun orients it.charging a battery of 24БССА 38PC with a volume of s is carried out. The "charge-discharge" control equipment for automatic charging of the battery is turned on, which monitors the charge current and voltage magnitude, thereby preventing the recharging procedure, which is harmful to the battery, and also reports the battery's charge level using a tabletop on the light emitting diode to the front panel.

The areas of use of the developed autonomous solar portable power supply source are diverse, in particular: - Power supply of electric razors, lighting flashlights, portable radio receivers, tape recorders, televisions, audiopleyers, coffee makers, mixers and other household appliances; - Field radio stations and radio telephones of the "Altai" type, electric pumps of the" dwarf " type, internal and external lighting of field stations, power supply source in grazing and driving livestock; - Power supply source in combination with thermapar refrigerators with a useful volume of up to 12 l for storing and transporting vaccines, serums and other medicines in medicine and veterinary medicine; - Electrical supply source of radio communication equipment apparatus in hydrometerochismate and hyologocidiruv; - Charging batteries in field conditions repair car cameras using an electrovolcanizer (for example, for an autoturist).

## § 4.3. The use of solar energy in modern construction and architecture

Solar energy is becoming an increasingly popular and important element of modern architecture and construction. Its use helps to increase the energy efficiency of buildings, reduce dependence on traditional energy sources and reduce greenhouse gas emissions. Some methods of integrating solar energy into modern architecture and construction:

**1. Roof solar panels:** installing solar panels on building roofs allows you to convert solar energy into electricity, which can be used to power the building or supply energy to the network. Modern designs of solar panel roofs usually harmonize with the overall style of the building, which makes them invisible or even complement their appearance.

**2. Solar facades:** solar panels can be integrated directly into the facades of buildings, allowing the use of vertical surfaces to generate electricity. This opens up new opportunities for aesthetic and functional use of solar energy in architecture.

**3. Solar windows:** solar windows are an innovational solution that uses transparent solar panels mounted on double-glazed windows to convert sunlight into electricity. This allows buildings to use solar energy even on windows that do not occupy a large area.

**4. Solar pergolas and umbrellas:** solar pergolas and umbrellas provide shade and protection from solar radiation and generate electricity through solar panels installed on them. This is a useful solution to facilitate thermal balance in buildings and create a comfortable environment in open spaces.

**5. Solar pipes and light wells:** solar pipes and light wells use solar collectors and optical systems to direct sunlight into the building, allowing the rooms to be illuminated with natural light during the day and reducing the consumption of electricity for artificial lighting. The use of solar energy in modern architecture and construction not only helps to improve the energy efficiency and environmental sustainability of buildings, but also contributes to their innovation and aesthetic design.

**Architectural solutions.** Solar energy integration is essential for the construction of energy-efficient buildings, where the use of solar energy significantly reduces environmental impact, optimizes energy consumption, and reduces costs. The inclusion of solar technology in building projects not only benefits the environment, but also emphasizes the ability of sustainable architecture to solve future problems. Increased attention to sustainable development and renewable energy has led to an increase in demand for the integration of solar energy into modern buildings. With increasing awareness of climate change and environmental problems, there is a transition to sustainable construction practices. The government is pursuing a policy of promoting the introduction of renewable energy, providing opportunities for the integration of solar energy into the construction industry. As a result of this, the ground is laid for the emergence of the following trends in the modern energy market:

**- Growing advantage of green building certificate:** LEED and BREEAM certificates are gaining popularity, emphasizing energy efficiency and environmental sustainability. This trend increases the demand for solar-powered buildings.

- **Advances in solar technology:** innovations such as BIPV and solar roof tiles help architects and developers to continuously integrate solar energy into construction projects, allowing solar solutions to be implemented more efficiently.

- **The demand for energy-saving buildings is increasing:** increased awareness of the importance of energy efficiency and reduction of carbon dioxide emissions will stimulate the market to sustainable construction practices and help introduce solar technology.

It is known that in the design of ordinary heating systems, the power of the system is determined from the condition of providing heat during the coldest period of the year. At the same time, the system works mainly with a certain load, compensating for real heat losses. In turn, such a load that falls on the heating system can be reduced in the design of the system at the expense of solar radiation energy that falls during the day. Designing a building in such a way that it receives the maximum amount of solar radiation heat can not only significantly reduce energy consumption for conventional heating, but in some cases lead to the absence of such a type of expenditure.

According to the European classification system for buildings and structures, energy efficient buildings are divided into the following types:

- Energy-efficient home-average energy consumption for heating houses no less than 60-70 kWh/($m^2$·year);

- Passive house-houses where the average energy consumption for heating does not exceed 15 kWh/($m^2$·year) per year;

– A building with zero energy consumption is a building with the same architectural standard as a passive house, but designed for energy consumption generated by its own power, with an average energy consumption of 0 kWh/($m^2$.year) for heating.

An active ("energy plus" type) house is a building that produces more energy than is consumed, due to the use of special engineering systems.

**Passive house-**a house with relatively little negative impact on the environment, a high level of energy-efficient and with all the amenities to live in.

The main criterion of a passive house consists in creating a building with an integrated solid shell with a high level of thermal protection layer and thermal conductivity <0.15 W/($m^2$·K).

The following criteria are taken into account when designing and building passive houses:

- "thermal bridges (heat circulation)"

- prevent heat loss areas from remaining;

- compactness of construction;

- passive use of solar energy due to the fact that the building faces south and the shadow does not fall;

– thermal conductivity coefficient <0.8 W/($m^2$·K) and energy conductivity-special high-quality window and window frames with about 50 percent;

- duration of air exchange: n50 = 0.33 x-1;

- recuperation of heat from recycled air, in which the percentage of heat retention is > 75%;

- highly efficient energy efficient devices for domestic use;

- heating water in solar collectors or heat pump yards;

- passive air heating, for example, through a ground-air heat pump.

Looking at the world experience of passive houses, the first eco-house was built in Manchester, New Hampshire, in 1972, much earlier than the construction of the first Passive House and the occurrence of an energy crisis in the US (fig. 4.14).

The house was designed in The Shape of a cube, The Shape of which made it possible to minimize heat loss due to its architectural compactness. The glass layer made up only 10% of the wall surface, and solar collectors were installed on the roof of the House. The outer walls are made up of a two-story structure, and sunscreens are installed on the windows. The architectural solution of the building also made it possible to make the most of the optimal location of the interior rooms, natural lighting. Recuperation ventilation was also considered, as well as the use of special tanks(tanks)to store chilled and heated water.

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Figure 4.14. The first eco-house built in the USA.

The second energy efficient home was in Otaniemi, Finland (1973-1979).) is an "EKONO-house" building built. When designing the "EKONO-house" building, the following main innovative energy solutions are achieved:

- effective use of the internal volume of the building to reduce the area of closed structures and reduce heat loss through them;

- forming an efficient thermal protection layer of barrier structures to reduce heat loss;

- the use of barrier structures with high heat capacity in order to increase the thermal (thermal) resistance of the building and concentrate heat;

- accumulation of solar radiation heat on the basis of the structure in order to reduce the load corresponding to the account of the heating system;

- the use of windows with air ventilation to reduce heat flow inside during the summer season of the year and heat loss outside during the winter season of the year;

- minimize air leakage (building Hermeticism) and external air flow consumption in the ventilation system in order to reduce energy consumption when heating the building;

- efficient lighting in order to reduce electricity consumption; an automatic control system of climatic and lighting equipment was used for the purpose of alternative energy consumption and accounting for energy consumption.

The"EKONO-house" had an annual specific heat consumption of 124 kWh/m2 in the First Ward, which was 50% lower than the figure in office buildings in Finland. Comparable heat consumption figures for similar buildings in the United States had an even higher value. The annual comparable electricity consumption figure for heating the first compartment was 79 kWh/m$^2$ per year, which was lower compared to the figures in Finland and the United States. The specific heat consumption for heating the second compartment of the" EKONO-house " building is 70 kW/m$^2$ per year, the specific electricity consumption for heating is 57 kW/m$^2$ per year, which is equal to 1/3 of the energy consumption of conventional houses of this type.

Figure 4.15. Overview of a passive house built in Germany in 1991

The first Passive House was built in 1991 in Darmstadt, Germany. (Figure 4.15). This project confirmed the excellent operation of all important systems in it in the operation of such types of houses. So far, with the average energy consumption for heating remaining unchanged (less than 10 kWh/(m$^2$·years)), the percentage of savings compared to a traditional house is more than 90 percent, the relative high quality of air in the house and favorable temperature conditions were noted. The

Passive House Institute has been established with the aim of extensively conducting and continuing research on the development and improvement of indicators of passive type houses. As of may 2011, more than 32,000 Certified Passive Houses have been built, and as of 2020, a passive construction standard (annual average energy consumption figure for heating is 15 kWh/m$^2$) has been mandated in the European Union.

## § 4.5. Energy efficient and efficient technologies

Energy-efficient and energy-efficient, solar-based technologies play an important role in reducing energy consumption and reducing the harmful effects on the environment:

**1. Solar collectors for water heating:** solar collectors for water heating are an efficient technology that uses solar energy to directly heat water. It can be a system installed on the roof of a building or independent solar collectors.

**2. Photovoltaic panels:** photovoltaic panels convert sunlight into electricity. They can be installed on the roofs of buildings or on the ground and used to provide electricity to houses, businesses and even entire areas.

**3. Solar facades:** solar facades are used to integrate solar panels directly into the walls of a building. This allows the use of vertical surfaces to generate electricity and reduces dependence on conventional energy sources.

**4. Solar flares and light wells:** solar flares and light wells use solar panels to charge built-in batteries during the day and illuminate in the evening and at night. They effectively use solar energy to provide lighting in streets, parks, parking lots and other public places.

**5. Solar capacitors and heat pumps:** solar capacitors and heat pumps use solar thermal energy to heat and cool rooms. They can be an effective way to reduce energy consumption and heating and conditioning costs.

**6. Energy storage systems:** energy storage systems such as batteries or heat storage systems are used to ensure the continuity of the energy supply of solar devices. They allow you to store excess solar energy for use in times of low sunlight.

These solar-based technologies help reduce traditional energy consumption, reduce greenhouse gas emissions, and make buildings and infrastructure energy efficient and sustainable.

Energy-efficient and energy-efficient solar-based technologies for construction. Energy-efficient and energy-efficient solar-based technologies for construction include a number of innovation approaches and materials that help reduce energy consumption in buildings and make them environmentally resistant. Let's dwell on some of them in Aries:

**1. Passive solar heating and cooling:** it is a design concept that uses the architectural features of buildings to maximize the use of solar energy for heating in winter and natural cooling in summer. It includes the correct location of the windows, the use of heat storage materials and good insulation.

**2. Architecture solar cells:** integrating solar panels and collectors directly into the architectural elements of buildings, such as roofs, facades, sheds and pergolas. It allows you to combine energy saving functions with the aesthetics and functionality of buildings.

**3. Solar and natural lighting systems:** the use of solar pipes and light wells to maximize the use of natural light inside buildings allows you to reduce the consumption of electricity for artificial lighting.

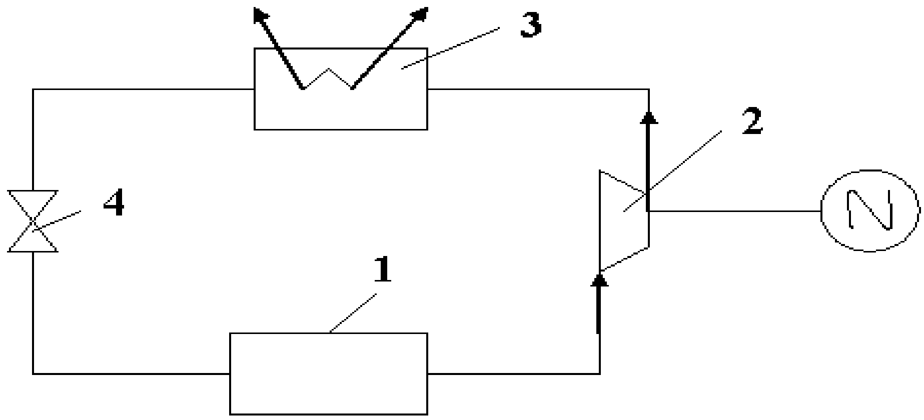
**4. Thermal insulation materials:** application of high-performance thermal insulation materials to minimize heat loss through walls, floors and roofs of buildings. This will help maintain heat inside the building in winter and reduce stress on the heating system.

**5. Solar panels and storage devices:** the use of solar panels and storage media to store electricity from solar panels and the use of this energy to power lighting, heating, condisioners and other energy-consuming systems.

**6. Solar heat pumps and condisioners:** the use of solar heat pumps and condisioners to heat and cool buildings using solar thermal energy allows you to reduce energy consumption and greenhouse gas emissions. These solar-based technologies help create energy-efficient and sustainable buildings that consume less energy and have less negative environmental traces. They help reduce energy costs and reduce dependence on traditional energy sources.

## § 4.6. Modern and promising solutions in the field of solar energy

**Heat pumps.** A heat pump is the opposite of a freezer. It also has some cooling elements. It works only in a different temperature regime and is designed to heat buildings at the expense of the environment (air, water, solar energy of the soil) and use. The heat pump is used to heat buildings in winter and cool them in summer. Pressure and absorption heat pumps will be installed. Like the cooling device, the high-pressure steam heat pump (fig. 4.16) consists of an evaporator 1, a compressor 2, an air conditioner 3 and a throttle valve 4. The working part of the heat pump is carried out in the operating temperature range with savings on the evaporator and condenser.




4.16. Evaporator heat, similar to a refrigerator device.

The balance of the energy of the steam-pressure heat pump:

$$q_к = q_n + l_к \qquad (4.1)$$

it is recorded in the form of an equation, in which $q_к$ –the amount of heat brought out of the capacitor, $q_n$- the amount of heat brought in by the evaporator; $l_к$ - the work of clamping the chedigent in the comperessor.

The efficiency of the device using a heat pump for building heating is characterized by the coefficient of heat (heating) :

$$\varphi = q_K / \lambda_K \qquad \varphi_K = \frac{T_K}{T_K - T_n} \tag{4.2}$$

Heat pump and refrigerant devices that operate on the reverse cycle in temperature diaposon in the vaporizer $T_p$ and condenser $T_k$ have the highest efficiency. In this:

While the freezer coefficient is

$$\varepsilon = \frac{T_n}{T_K - T_n} \tag{4.3}$$

where Tk and Tp are the temperatures in the capacitor and heat transmitter.

As a source of heat brought to the working body of the evaporator in the steam pressure heat pump-from its waters, river, sea, lake, mining soil, external air waters, solar radiation can be used.

The process of bringing and taking heat is carried out from a rotating heat transmitter of water or air.

Depending on the source of heat and the heat-carrying information, the "water", "soil-water", "air-water", "water-air", "soil-air" and "Air-Air" types of heat pumps differ. For a heat pump worker in heating and cooling procedures, a special drossel rail and a four-code valve will be necessary, which will provide a change in the direction of movement of the chladagent to the opposite side.

In the order of heating, the evaporator evaporates into a condenser in the order of heat exchanger cooling and vice versa.

**Modern photoenergetics.** Modern photoenergetics offers a variety of schemes and technologies for converting solar energy into electricity. Below are their principle of operation, achievements and disadvantages.

**Photoelectric solar panel (PSP):** -Principle of operation: PSP converts sunlight directly into electricity using semiconductor materials such as silicon.

- Advantages: easy installation, durability, reliability, low maintenance, lack of moving parts.

- Disadvantages: limited conversion efficiency (usually less than 20-25%), dependence on weather conditions, high production costs.

**Photoelectrochemical solar elements (PESE):** - Principle of operation: PESE uses chemical reactions to convert solar energy into electricity.

- Advantages: potentially high efficiency compared to PESE, the possibility of using non-standard materials.

- Disadvantages: design complexity, work instability, high research and development costs.

**Thermal solar systems:** - Principle of operation: thermal, that is, thermal solar systems use solar energy to heat the heat carrier, and the source obtained in the later stages is used in hot water supply or heating systems.

- Advantages: efficient use of solar energy for heat, low maintenance.

- Disadvantages: requires large collector areas to generate large amounts of heat, limited use in the northern regions due to the low intensity of solar radiation.

**Concentrated solar systems (CSS):** - Principle of operation: CSS uses mirrors or lenses to concentrate sunlight on a small focal area where photovoltaic cells or thermal receivers are installed.

- Advantages: high efficiency, especially in thermal CSS; less collector area compared to other types of solar systems.

- Disadvantages: the complexity of the design, high hardware and installation costs, the need for fine tuning and adjustment. A comparative analysis of these schemes and technologies makes it possible to determine their advantages and disadvantages based on specific application conditions, such as climatic conditions, availability of resources and project budget.

## Questions about Chapter 4:

1. Solar power plant and its types?
2. Types according to the connection of the solar power plant?
3. Ways to increase the efficiency of a solar power plant?
4. The main elements of solar power plant and the principle of their operation?
5. Options for the use of solar energy in modern construction and architecture?

6. Energy efficient and efficient technologies based on solar energy?

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