Assessment of the Technical Potential of Solar Energy in the Navoi Region

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Abstract. The article discusses the composition of solar radiation and presents the distribution of its intensity across regions of the Republic. The potential of solar power stations in the Republic has been studied and analyzed. Information is provided about the physical-chemical and electrical parameters of silicon, the main material in the composition of solar panels, which are the key elements of solar power stations. The article also outlines the generation of electrical power through solar radiation and the dependence of this power on temperature. The volt-ampere characteristics of the panels in relation to solar radiation frequency are discussed. Furthermore, the article presents experimental studies and their results from regions in Navoi province where solar radiation is most prevalent. The study concludes with recommendations for applying these findings in practice to increase the energy efficiency of small-capacity solar power stations installed in the Republic and ensure uninterrupted electricity supply to consumers.

INTRODUCTION

The intensity of solar radiation in free space at a distance equal to the average distance between the Earth and the Sun is called the solar constant. Its value is 1353 W/m2. When passing through the atmosphere, sunlight is weakened mainly due to the absorption of infrared radiation by water vapor, ultraviolet radiation by ozone, and visible radiation is scattered by gas molecules and atmospheric dust particles and aerosols in the air. Figure 1 shows the percentage of radiation reaching the Earth. Mapping suitable land for solar energy development, taking into account factors like land ownership, environmental constraints, and proximity to grid infrastructure. Evaluating the capacity and limitations of the existing electrical grid in Navoi region to accommodate large-scale solar energy integration. Estimating the theoretical maximum capacity of solar power plants that can be installed based on available land, solar irradiance, and grid capacity. Navoi region benefits from high solar irradiance levels, particularly in the desert areas, contributing to high solar energy potential. Navoi region holds significant technical potential for solar energy development. The high solar irradiance, abundant land availability, and ongoing efforts to expand the electrical grid provide a favorable environment for utilizing solar energy for both grid-scale and distributed applications. A comprehensive assessment of the region's technical potential, including factors like grid capacity, environmental impacts, and economic feasibility, is crucial for creating a sustainable and successful solar energy development plan[1].

It reaches the Ground:

- Ultraviolet radiation (wavelengths up to 0.4 microns) – 9% intensity;
- Visible radiation (wavelengths 0.4 - 0.7 microns) – 45% intensity;
- Infrared (thermal) radiation (wavelengths greater than 0.7 microns) – 46% intensity.

MATERIALS AND METHODS

Understanding the factors that influence sunlight intensity is essential for a wide range of applications, from energy production and climate modelling to agriculture and human health (Fig.1.). Near the Earth's surface, an average solar radiation intensity of 635 W/m^2 can be assumed, on a very clear sunny day this value ranges from 950 W/m^2 to 1220 W/m^2, and the average value is approximately 1000 W/m^2. Sunlight is the primary source of energy for solar panels. Understanding the variation in intensity throughout the day, year, and location is essential for designing efficient solar power systems, calculating energy output, and maximizing electricity generation. Solar thermal power plants utilize sunlight to heat water or other fluids, generating electricity. The intensity of sunlight dictates the efficiency of these systems. Sunlight is the primary driver of Earth's climate. Understanding the variation in solar radiation reaching Earth's surface is essential for modeling global climate patterns, understanding the effects of clouds and greenhouse gases, and predicting future climate change. Sunlight is crucial for photosynthesis, the process by which plants convert light energy into chemical energy. Understanding the variation in sunlight intensity allows farmers to optimize crop production by selecting appropriate planting dates, providing supplemental lighting when needed, and understanding the impact of shade on crop yields. The intensity of sunlight affects evapotranspiration (water loss from plants and soil), which is a critical factor in water management for irrigation and drought monitoring. Sunlight is essential for the production of vitamin D in our skin, which plays a vital role in bone health and immune function. High sunlight intensity can lead to heat stress, which can be dangerous, especially for people working outdoors.

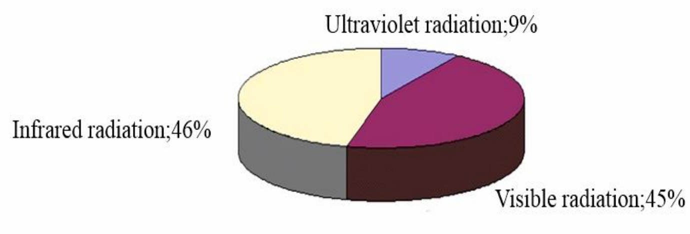

FIGURE 1. The percentage of radiation reaching the Earth

Understanding the variation in sunlight intensity helps in developing strategies to mitigate heat stress, such as providing shade and recommending appropriate clothing. Architects and designers consider sunlight intensity to optimize natural lighting, reduce energy consumption for heating and cooling, and create comfortable living spaces. Sunlight intensity influences the degradation of materials, such as plastics and paints. This information is essential for selecting appropriate materials for outdoor applications. Sunlight intensity is a crucial factor in many aspects of our world, influencing everything from the energy we produce to the health of our crops and ourselves[2].

- Conduct detailed feasibility studies for specific solar energy projects, considering local site conditions and environmental considerations;
- Invest in grid infrastructure upgrades to accommodate the integration of large-scale solar power plants;
- Implement policies and incentives to encourage both large-scale and distributed solar energy development;
- Foster public awareness and education regarding the benefits of solar energy utilization.

Contrary to popular belief, there are a lot of places in Uzbekistan where it is profitable to convert solar energy into electricity using solar panels. Figure 2 shows the potential of photovoltaic energy production in Uzbekistan, and Fig.3. shows direct solar radiation to the surface of Uzbekistan (Fig.2.).

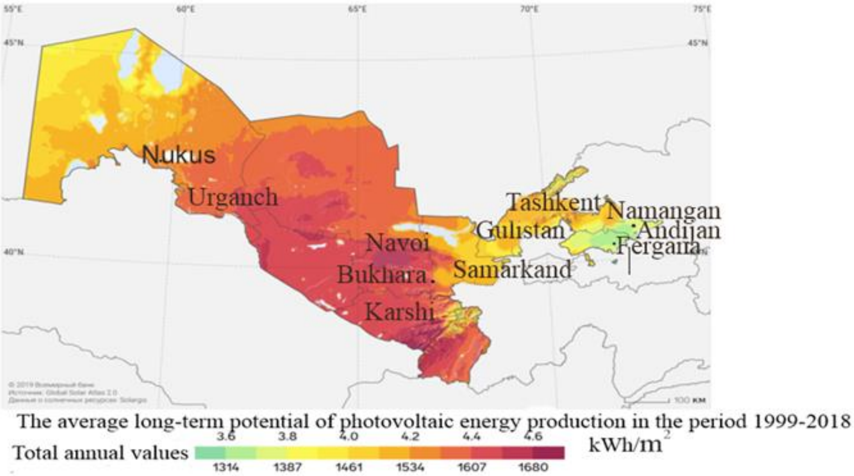

FIGURE 2. Potential of photovoltaic energy production in Uzbekistan

Solar radiation to the Earth's surface depends on many factors:

latitude and longitude of the area;
geographical and climatic features;
the state of the atmosphere;
the height of the Sun above the horizon;
placement of the solar radiation receiver on the Ground;
placement of the solar radiation receiver in relation to the Sun, etc.

The total solar radiation reaching the Earth's surface usually consists of three components:

Direct solar radiation coming from the Sun to the receiving area in the form of parallel rays;
Diffusive, or scattered by molecules of atmospheric gases and aerosols, solar radiation;
The fraction of solar radiation reflected by the earth's surface.

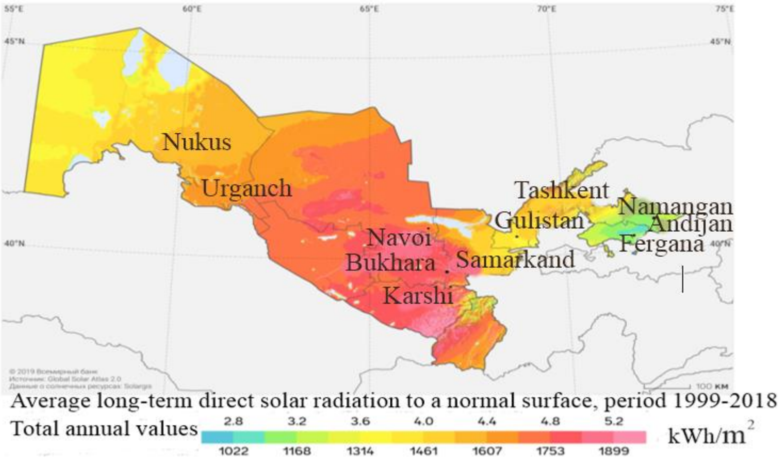

FIGURE 3. Direct solar radiation on the surface of Uzbekistan

The first component of solar radiation may be completely or partially absent during both short (minutes, hours) and long (days, weeks) time intervals at a specific point on Earth. A solar power plant on Earth has zero guaranteed power when using only solar radiation without combining with other energy sources. The use of solar panels is especially advantageous where there are no centralized electrical networks. Moreover, even where there are networks, the use of solar panels working in parallel with the network can significantly reduce energy costs. Solar radiation, a critical component for solar power generation, can be intermittently absent for short (minutes, hours) or long (days, weeks) periods at specific locations on Earth. Relying solely on solar energy for a power plant means facing zero guaranteed power during these intervals. However, solar panels are particularly beneficial in areas lacking centralized electrical networks, providing an independent energy source. In locations with existing power grids, integrating solar panels can lead to significant reductions in energy costs. By working in parallel with the grid, solar systems can enhance energy resilience and sustainability, making them a valuable investment for both remote regions and urban settings.

These are just approximate values. The actual solar radiation intensity at a specific location and time will vary based on the factors mentioned above[3].

Specialized tools and software are available to obtain more precise solar radiation data for specific locations.

The main material for solar panels is crystalline silicon, which is obtained from natural quartz minerals. Solar radiation in the spectral region is $h\nu \geq \Delta E$ almost completely absorbed in c-Si or mc-Si:H at a single pass through a layer several hundred microns thick. Calculations show that 95% of the radiation is absorbed by the c-Si layer. The production of crystalline silicon is shown below by reactions:

$$SiO2 + 2C \rightarrow Si + CO2\uparrow \quad (1)$$

For amorphous silicon:

$$SiO2 + Mg \rightarrow 2MgO + Si \quad (2)$$

In industry:

$$SiO2 + 2C \rightarrow Si + 2CO\uparrow \quad (3)$$

$$SiCl4 + Zn(H2) \rightarrow 2ZnCl2 + Si \quad (4)$$

$$SiCl4 + H2 \rightarrow 4HCl + Si \quad (5)$$

Some physic-chemical and electrical properties of silicon are presented in Table 1.

TABLE 1. Physico-chemical and electrical properties of silicon

№	Silicon Parameters	Meaning
	Physico-chemical	
1	Amorphous brown	Si
2	Crystal Dark Grey	c-Si
3	Density	2.33 g/sm^3
4	Melting point	1414.85°C(1688 K)
5	Boiling point	Tkip.-2349,85°C
6	Crystal lattice	cubic, diamond
7	Thermal Conductivity (300 K)	149 W/(M.K)
8	Ionization energy of the primary electron	786.0 kj/mol, 8.15 eV
	Electric	
1	Dielectric constant	12

2	Electron mobility	1200-1450 $sm^2/(V \cdot s)$
3	Mobility of holes	500 $sm^2/(V \cdot s)$
4	The width of the forbidden zone at 0 K	1.21 ev
5	The free path length of electrons is of the order	1 mm
6	The free run length of the holes	0.2-0,6 mm
7	Intrinsic concentration of charge carriers (300K)	$5.81 \cdot 10^{15}$

RESULTS AND DISCUSSION

I In the crystal structure, silicon atoms have valence electrons, which form a covalent bond between the atoms. The crystal structure and chemical bonding of silicon atoms is shown in (Fig.4.).

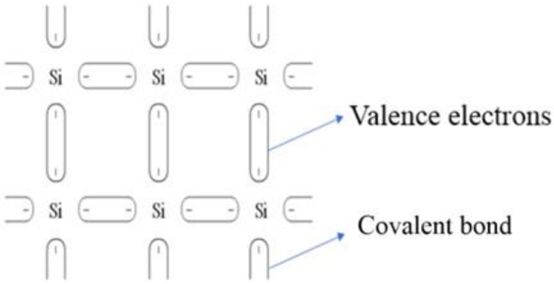

FIGURE 4. The crystal structure of silicon

Photovoltaic energy generation is caused by the spatial separation of positive and negative charge carriers when electromagnetic radiation is absorbed in a semiconductor shows the design of the solar cell (Fig.5.).

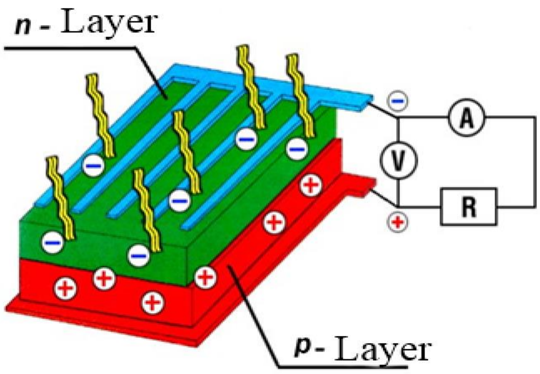

FIGURE 5. Solar cell design

A solar cell consists of two interconnected silicon wafers. The light falling on the upper plate knocks electrons out of it, sending them to the lower plate. This is how the EMF of the element is created. The series-connected elements are a direct current source. When light quanta are exposed to the volume of a semiconductor, additional no equilibrium current carriers (photoelectrons and photo holes) are formed in it. As a result, the electrical resistance of the semiconductor decreases [4].

The electron-hole junction (p-n junction), as already noted, is a region of a monocrystalline semiconductor in which the conductivity changes from electronic to hole. Such a transition is formed in a semiconductor crystal, one part of which is doped with an acceptor impurity (p-region), and the other with a donor (n-region). In the region of the p-n junction, there is a double electric layer of stationary bulk charges, namely, ions of the acceptor and donor impurity. This double layer creates a contact (diffusion) electric field and a potential barrier for the main carriers, $q\Delta\varphi k$ ($\Delta\varphi k$-contact potential difference). Let the energy of the light quanta be greater than or equal to the width of the band gap ΔE($h\nu \geq \Delta E$), then pairs of no equilibrium current carriers, photoelectrons and photo irks, are formed in the region of the p-n junction. Under the action of a contact electric field, the formed no equilibrium carriers are separated: photoelectrons pass into the n-region, and photo irks into the p-region (Fig.6).

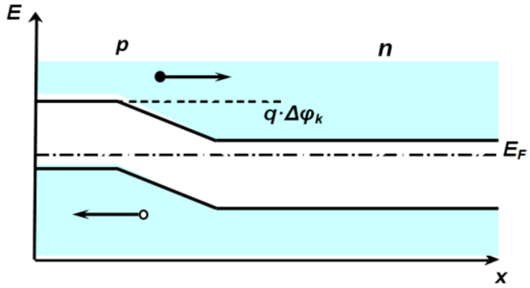

FIGURE 6. Potential barrier for the main carriers in the region of the p-n junction

The photoelectrons transferred to the n-region create an excess concentration of electrons in it relative to the equilibrium, i.e. they charge the n-region negatively. Photo holes charge the p-regions of the semiconductor positively. The process of accumulation of no equilibrium carriers (electrons in n-holes in the p-region) They are accompanied by a decrease in the height of the potential barrier at the boundary of the p- and n-regions and an increase in the diffusion of the main carriers through the junction. A dynamic equilibrium is coming. In this case, a certain potential difference EF is established between the p- and n-regions of the semiconductor. The potential difference EF that has arisen between the p- and n-regions of a semiconductor as a result of exposure to radiation at the p-n junction is called photo-EMF. It can reach a value of ~1 V, but does not exceed a value numerically equal to ΔE/q (ΔE is the band gap of the initial semiconductor material, q is the electron charge).
The typical temperature coefficient for crystal panels is -0.45%/K (that is, when the panel temperature increases by each degree, its output decreases by 0.45%) [5]. Photovoltaic phenomena disappear, but due to the heating of the body, phenomena similar to photovoltaic phenomena may occur in it: bolometric effect (change in electrical conductivity), pyro electric effect, thermo electronic emission, thermal and other thermoelectric phenomena (Fig.7).

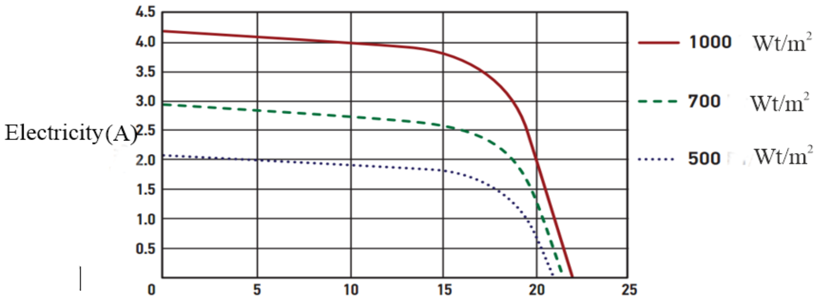

FIGURE 7. Volt-ampere characteristic of the solar panel depending on the illumination

The power of the solar panel varies depending on the illumination in almost direct proportion. At a certain value of illumination, the panel may stop generating. For example, for crystalline panels it is about 150-200 W/m^2, and for amorphous panels it is about 100 W/m^2. Also, the power of a solar panel depends on its temperature and usually decreases when it increases (Fig. 8).

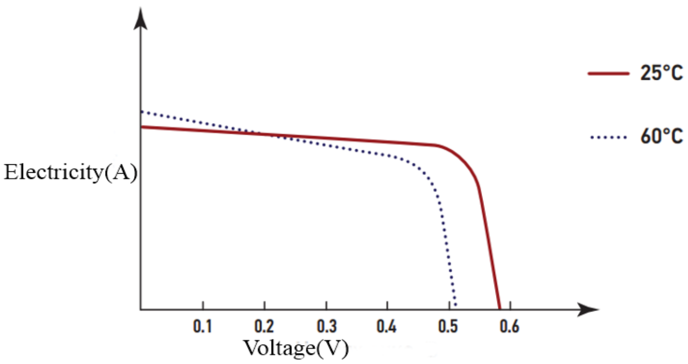

FIGURE 8. Volt-ampere characteristic of the solar panel depending on the panel temperature

The solar panel generates not only electricity, but also heat under the influence of light. In a conventional solar panel, at the point of maximum power, only 10-15% of the solar energy incident on it is converted into electricity, the rest is converted into heat. The factors affecting the heating of the solar panel are:[6]

1.Reflection from the front surface.

The light reflected from the front surface of the solar panel is not involved in the production of electricity. Such light is considered a source of losses that need to be minimized. It also does not heat the panel. Therefore, the maximum heating of the panel is calculated as the power of incident solar radiation multiplied by the reflection coefficient. For a conventional solar panel with a glass front surface, the reflection coefficient is about 4%.

2. Working point and the efficiency of the panel.

The operating point and efficiency of the panel determine how much of the light absorbed by the panel will be converted into electricity. If a solar cell operates in short-circuit or idle mode, it does not produce electricity, and therefore all the absorbed energy is converted into heat.

3.Light absorption in the panel.

The light that is absorbed in the panel by a non-solar cell will also participate in its heating. The amount of absorbed and reflected light is determined by the color and material of the back layer of the panel.

4.Absorption of infrared light.

Light with energy less than the energy of the forbidden zone of the solar cell does not affect the electrical power, but if it is absorbed in the solar cell or in the panel, it will contribute to their heating. Infrared light is well absorbed by aluminum on the back surface of the solar cell. In elements that do not have aluminum on the back surface, infrared light is not absorbed and can pass through the panel.

5.The level of filling the panel with solar cells.

Solar cells are created specifically to effectively absorb solar radiation. They will produce a significant amount of heat, usually more than the rest of the panel. Therefore, a higher level of filling of the panel with solar cells increases the amount of heat produced per unit surface.

Sunlight travels from the Sun to the Earth. When it reaches the atmosphere, some of the light is refracted, some reaches the Earth, and the other part is absorbed by the atmosphere. Refracted light is what is commonly called diffuse radiation or scattered light. The part of sunlight that reaches the Earth's surface without scattering or absorption is direct radiation. It is the most intense.

Solar panels produce electricity even in the absence of direct sunlight. Therefore, even in cloudy weather, the photovoltaic system will produce electricity. However, the best conditions for generating electricity will be in bright sunlight and when the panels are oriented perpendicular to sunlight[7].

Experimental studies were conducted in the regions of Navoi region to determine the effect of sunlight on the solar panel. A lux meter of the TKA-Lux brand was used to determine the illumination of the regions. Measurements of the illumination and output voltage of the photocell were made in various regions of the Navoi region. The results of the study are presented in Table 2[8].

TABLE 2. Solar radiation affecting the solar panel in the regions of Navoi region

№	**Regions**	Time	Ambient temperature (0C)	Illumination of the experimental zone (lux)	Output voltage (V)
1.	Uchkuduk	13^{00}	33.5	$124.2 \cdot 10^3$	19.3
2.	Zarafshan	13^{00}	35.3	$116.3 \cdot 10^3$	18.7
3.	Zafarabad	13^{00}	36.1	$117.7 \cdot 10^3$	18.4
4.	Konimeh	13^{00}	32.4	$116.5 \cdot 10^3$	18.3
5.	Nurota	13^{00}	29.7	$116.2 \cdot 10^3$	18.0
6.	Karmana	13^{00}	30.6	$115.8 \cdot 10^3$	17.6

As we know, solar panels are charged by the radioactive radiation of the sun and convert the accumulated charge into electricity. Shows that the illumination is higher in the Uchkuduk region. Therefore, the output voltage from the solar panel shows a higher indicator compared to other regions. In addition, the effect of the radiation frequency on a semiconductor photocell with a p-n junction was studied in laboratory conditions. For this purpose, a single-crystal silicon solar cell with a p-n junction supplied by the German company PHYWE excellence in science was selected. The study was performed under the influence of electromagnetic radiation with a wavelength interval of 750 nm, and radiation with a wavelength of 380 nm per semiconductor volume [9].

The spectrum and spectral range of electromagnetic radiation can be created by passing a narrow light beam through a prism (Fig.9.).

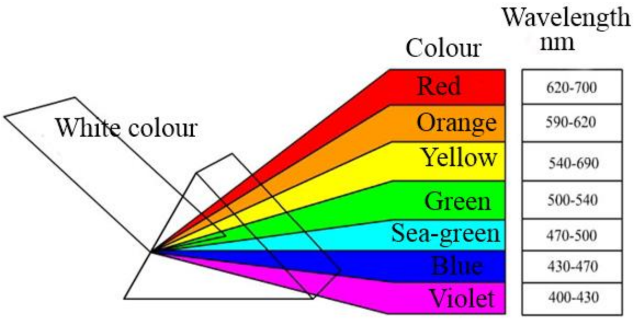

FIGURE 9. Electromagnetic radiation spectrum

TABLE 3. The results of the dependence of the photo EMF on the frequency of electromagnetic radiation

№	Colour	Wavelength range, nm	Frequency range, THz	Photon energy range, eV	photo-E.D. S.V.
1	Violet	400—430	790—680	2.82—3.26	0.39
2	Blue	430—470	680—620	2.56—2.82	0.40
3	Blue	470—500	620—600	2.48—2.56	0.41
4	Green	500—540	600—530	2.19—2.48	0.42
5	Yellow	540—590	530—510	2.10—2.19	0.44
6	Orange	590—620	510—480	1.98—2.10	0.45
7	Red	620—700	480—405	1.68—1.98	0.46

Based on the results of the study, a graph was constructed of the dependence of the PHOTOEMF on the frequency (wavelength) of radiation incident on the semiconductor. It can be seen from the graph that, with a decrease in the frequency of the radiation of the wave incident on the region of the p-n junction of a monocrystalline semiconductor, the value of the photo EMF increases (Fig.10.) [10].

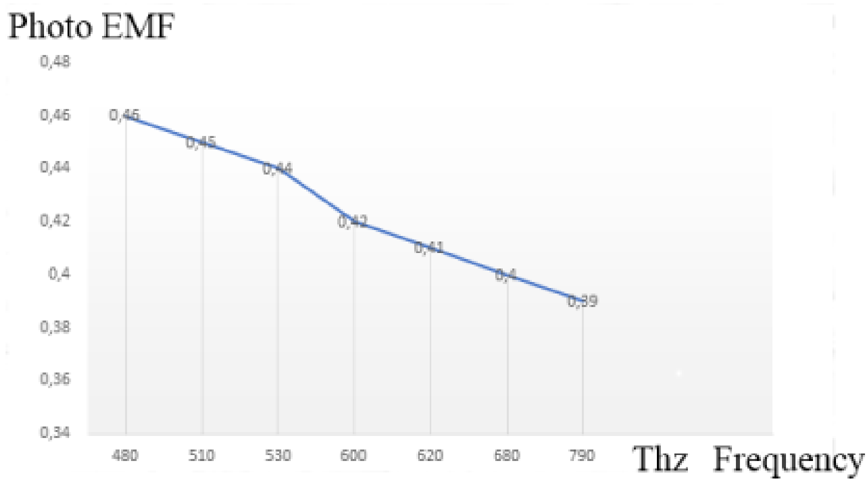

FIGURE 10. Dependence of the photo EMF on the frequency of electromagnetic radiation

CONCLUSION

Recently, there has been an increasing interest in the use of solar energy in Uzbekistan. Its use has become one of the most promising areas of energy. Environmental friendliness, renewable resources, and the absence of costs for major repairs of photo panels for at least the first 20 years of operation - all these are the strengths of solar energy. In actual structures with heterojunctions, the efficiency currently reaches more than 30%, and in homogeneous semiconductors such as monocrystalline silicon - up to 20-25%. The potential possibilities of energy based on the use of direct solar radiation are extremely large. Using only 0.0125% of the Sun's energy could provide all of today's global energy needs. All the data given above once again proves the prospects of scientific research in the field of solar energy and the development of new devices for converting solar energy into other types of energy. Solar energy is a clean and sustainable energy source. Unlike fossil fuels, it doesn't produce greenhouse gases or air pollution, contributing to a healthier environment. The sun provides an abundant and inexhaustible energy source. Solar panels can harness this energy for generations without depleting any resources. Investing in research and development to further improve the efficiency and cost-effectiveness of solar technologies. The future of solar energy in Uzbekistan looks very bright! With continued commitment and strategic planning, the country can harness this powerful resource to achieve a more sustainable and prosperous future.

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