RT&A, Special Issue № 6 (81), Part-2,
Volume 19, December 2024

PRODUCTION ASSESSMENT ON EFFICIENCY OF USING ALTERNATIVE ENERGY SUPPLY OPTIONS

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Abstract

The article considers the theoretical and methodological basis associated with the study of problems in the field of increasing the efficiency of using alternative energy supply options for production. The potential of alternative energy and the possibility of its use in the energy supply of production has been investigated and evaluated. A mechanism for analyzing the use of alternative options in the energy supply of production has been developed. The reserve possibilities associated with the use of alternative energy sources have been studied. A model for evaluating the efficiency of using alternative energy sources is proposed. A mechanism has been developed to increase the efficiency of using alternative energy supply options for production.

Keywords: efficiency, alternative energy supply options, expenses, energy sources, cost, investment

I. Introduction

Nowadays, factors such as rapid development of industry and agriculture along with the increase in the number of people and the rising standard of living of the people, sharp increase in the number of energy-usage in households, increase of the demand for organic and inorganic fuels day by day proves to be challenging, and leaves us crossroads to face the global environmental problems, and to search for the application of new, ecologically clean energy sources, is causing scientists to think more often on the above matter.

Over time, it is inevitable that the countries of the world will face the exhaustion of non-renewable energy sources - oil, gas and coal. In addition to depletion of these sources, it is also observed that they are becoming more expensive. Also, the negative impact of traditional energy exploitation, burning and other factors on the ecological situation of our planet is becoming more and more evident. To prove the usefullnes of the transition, since the use of renewable energies as alternative energy sources is more ecologically efficient, it is necessary to investigate their sources, ways of using them, their effects on nature, and many more issues as they have become very relevant in the current period. Wind, solar, wave and hydrological energy of small rivers are just such sources and their potential possibilities are limitless and inexhaustible. What we mentioned above reflects the relevance of the topic [3].

II. Methods

The economic indicators of using alternative energy sources are somewhat more expensive than the economic indicators of using traditional energy sources. Turkish scientist Muhammet Kayfeci has investigated some of the renewable energy sources in detail. The first area observed in this regard will be solar energy. Solar energy is radiant energy produced by the conversion of hydrogen into helium at high pressure and heat in the core of the sun. The amount of energy generated by the sun in 1 second is more than the amount of energy used by society. The world receives only one billionth of the energy from the sun. The volume of solar rays entering the earth's surface is 0-1100 W/m2. According to the researches of Muhammet Kayfeci, we can concentrate the application of solar energy in 2 groups.

Group I – Conversion of heat obtained from solar energy into electrical energy

Group II – Direct conversion of solar energy into electrical energy

In the system belonging to group I, heat is first obtained from solar energy. In addition to using this heat energy directly, it can also be used in electricity production. In group II, solar rays are directly converted into electrical energy through systems mentioned as Photogalvanic. The most basic system investigated here in connection with our topic is the application of the system mentioned as solar panels or photovoltaic panels. These panels are semiconductor materials that directly convert sunlight falling on their surfaces into electrical energy. These panels are mostly square and round and have a surface area of about 100 cm2 and a thickness of 0.2-0.4 cm. When light falls on the surfaces of the panels, an electric voltage is generated at their ends. In this regard, the source of the electric energy provided by the panel is the solar energy falling on the surface. Many panels are placed parallel to each other to increase the volume of generated energy. The structure in this form is called a photovoltaic model. These models create systems that provide energy from several W to MW. The productivity of panels used for obtaining solar energy varies according to the type of materials used in production.

15%-17.5% in monocrystalline structures

12%-14% in polycrystalline structures

In siliceous structures, a productivity of 5%-8% is created. [5]

Associate Professor Sabahatdin Unalan divided the use of solar energy into 3 parts according to the limits of heat during his research:

- Low heat level (below 150°C) – used for salt production, heating of buildings, drying of crops in the farm.
- Medium heat level (150-600°C) – start small motors and generate electricity with steam generator
- High heat level (600 °C and more) – electricity production, creation of exotic substances, use of solar ovens.

Currently, the technical potential of wind energy in the world is calculated as 53,000 tWts/year. The most important parameter in calculating the amount of energy generated using wind power is wind speed. From this point of view, the amount of wind energy that can be produced is expressed in the following form:

$$P = \frac{1}{2}\rho A V^3 \quad (1)$$

P – amount of energy produced;

A – Rotor swept area;

ϱ – air mass density;

V – air velocity.

Rick DeGunther, a graduate of Stanford University, considered the following alternative energy source in his research. The aim of these studies is to identify different renewable energy sources and discover the possibilities of their effective use.

Biomass, which is the main source of energy in many parts of the world, is the biological mass formed as a result of plants converting solar energy into chemical energy through photosynthesis. Biomass energy is the type of energy produced as a result of using biomass waste by burning it or going through different procedures. Biomass energy sources include 3 elements, which are part of the daily life of 1/3 of the world's population. They include natural products, animal manure, industrial and household waste. Turning waste into usable energy has very little negative impact on the environment.

Hydroelectric power - water in lakes, seas or rivers evaporates under the influence of the sun, and the resulting water vapor moves and falls on the slopes of mountains in the form of rain and snow, feeding water basins. Here, the production of energy consists of the energy generated during the movement of a large amount of water from a certain height to a lower level, using turbines to bring it into the form of mechanical energy.

There are 3 systems for using wave energy. A Shoreline system is a system fixed on the seashore, easy to maintain and does not require underwater electrical wiring. The OVC system is located under water, and as a result of the wave hitting the system, the water level rises, the air level is compressed, and the turbine rotates and electricity is produced. The pendular system is a cube-shaped system with one side facing the sea. The cover placed on it moves back and forth under the influence of the wave and produces electricity (2). Jenny Hayward and Peter Osman in their article "The potential of wave energy" suggested that wave energy is important and proposed 3 devices for its use. The point absorption device is located in the depths of the water and moves as a result of the pressure generated regardless of the direction of the wave movement and energy is produced. A device called linear absorption has large propellers relative to the height of the wave and rotates depending on the speed of the wave and produces energy. The device called Terminator works only due to the waves in the direction in which it is installed.

Determining the kWh costs resulting from the application of different technologies makes it possible to compare those technologies and determine which one is more efficient (5). The calculation of the cost of energy production is as follows:

$$C_e = [CI + (M \cdot CI \cdot V_u)] \div (P \cdot h \cdot V_u) \quad (2)$$

C_e-cost of energy production (USD/kW);
CI-initial cost of installation;
M-maintenance costs (annual interest on initial cost of installation);
V_u-the number of useful years that can be used;
P-installed power (kW);
h-annual usage hours [6].

Along with the positive aspects of alternative energy types, there are also negative aspects and they are reflected in Table 1.

Table 1: *Advantages and disadvantages of energy types*

Types of energy	Advantages	Disadvantages
Sun	It is an inexhaustible, abundant, cheap, non-dependent resource	The constant absence of sunlight, the lack of sunlight during the winter months and the absence of it at night
The wind	It is found freely in the atmosphere, its price does not increase over time, maintenance and use costs are low	The initial investment cost is very high, there is a mismatch between supply and demand, and it is noisy
Geothermal	Productivity is more than 95%, lack of meteorological dependence, minimum area requirement	Lack of portability, cannot be produced everywhere
Hydroelectricity	No waste during production, high productivity, cheap energy production	The cost of creating a HPP is high, it affects the climate where it exists, and it affects animals and plants.
Biomass	The possibility of storage, the possibility of using everywhere, not causing acid rain	Release of methane gas that can affect the ozone layer, high demand for water.
Wave	It is infinite, has no impact on the environment, the possibility of turning salt water into fresh water	A system must be built for each wave height, it is noisy, and maintenance costs are expensive.

Another criterion is the evaluation of the investment in the field of alternative energy, where there are 3 methods.

Payback period – It is used to calculate how many years the initial investment will be returned

Net Present Value (NPV) - if the present value of the amount of money received in the future is greater than the amount of the initial investment, the project will be implemented.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - \dot{I} \quad (3)$$

CF_t- cash flow at the end of year t

İ- initial investment

r- discount rate/required rate of return on investment

n- duration of the project

Internal rate of return (IRR) is an indicator of the net cost for the project equal to zero. It covers the situation where the costs are equal to the future cash flows.

III. Results

Thus, the following are the conclusions and suggestions we have obtained thanks to our research:

1) The development of the alternative energy market will create conditions for the formation of the need for specialized personnel not only in this field, but also in repair, assembly, logistics and sales - new jobs will be opened.

2) An entrepreneur who applies renewable energy systems will not incur additional costs for obtaining energy from the state and will make a profit as a result.

3) In order to increase the efficiency of using solar energy in the production process, the use of PV panels, the panels should be placed at an inclination angle of 25°, and in order to minimize the amortization period, which has the ability to pay 80% of the consumer demand, including the number of sunny and windy hours in our country. However, I suggest the establishment of systems in this field, the implementation of transfers by the state to entrepreneurs, and the creation of photovoltaic systems with monocrystalline structure from wave and hydroelectric power in regions with abundant water bodies, as well in the places where industrial enterprises are located.

IV. Discussion

I. Study of backup possibilities related to the use of alternative energy sources.

Below is the trend of the cost of production of 1 kWh of energy between (2014 –2022).

According to the forecasts of the International Renewable Energy Agency, it is estimated that by 2025, the costs incurred for the production of 1 kWh of energy will decrease by 30-50%. Also, it is thought that the investment volume for 1 kW will decrease from the level of 5000-6000 US Dollars to the level of 3500-4000 US Dollars.

Naturally, the decrease in investment and production costs will lead to the establishment of new systems in this field and the opening of new jobs. In particular, the development of the alternative energy market will create conditions for the formation of the need for specialized personnel not only in this field, but also in repair, assembly, logistics and sales. The International Renewable Energy Agency reports that 10 million people are currently working in this field. In the last 4 years, the number of workers working in the fields of solar and other energy production has doubled, and it is planned that 24 million people will be employed by 2030. The distribution of employees by fields is as follows [2]

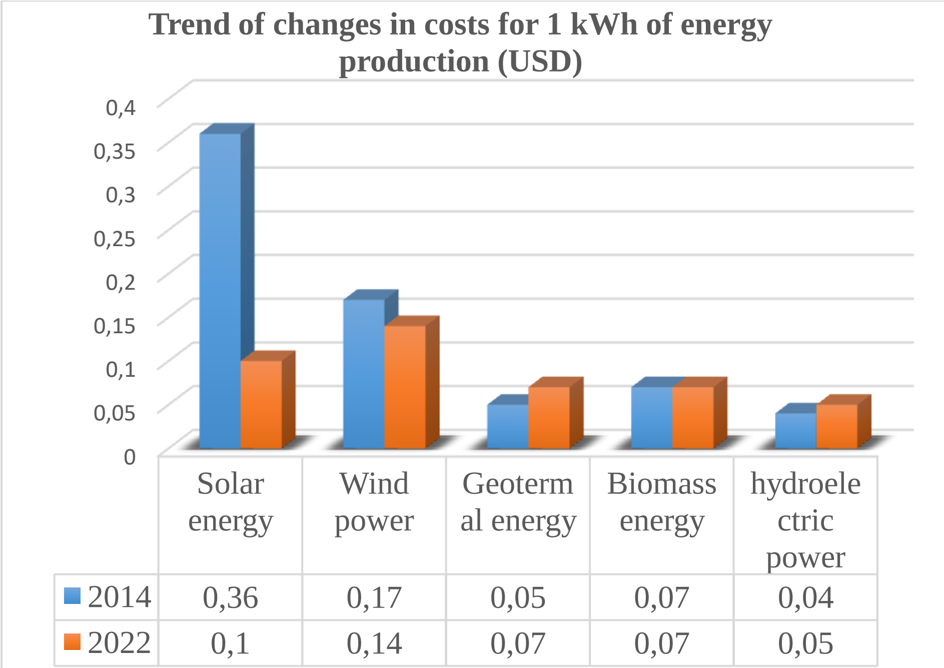

Figure 1: *The trend of change in the costs incurred for the production of 1 kWh of energy provided by the IRENA organization.*

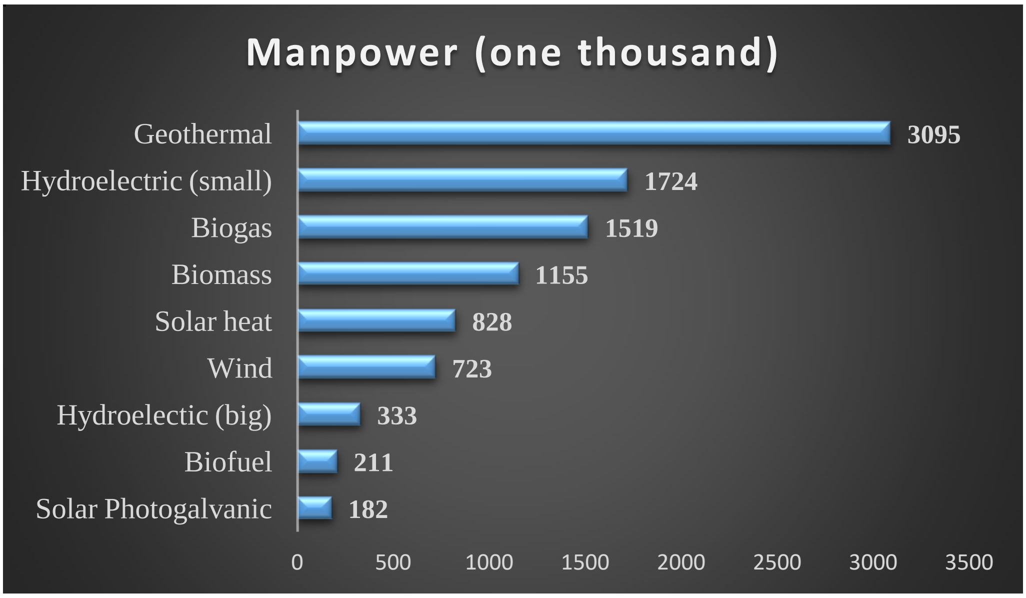

Figure 2: *Number of employees working in the field of alternative energy*

II. The efficiency of using alternative energy sources evaluation model

As a result of our research, we have identified a number of positive and negative aspects of renewable energy sources. Currently, the most widely used solar energy systems around the world have a certain economic benefit, both economically and environmentally. First of all, let's note that photovoltaic panels used for obtaining solar energy are monocrystalline, polycrystalline and thin-layer silicon crystals. [4] To determine the efficiency that those panels give us, the calculation of the hourly ray coming to the horizontal surface is initially calculated by the formula (4):

$$\dot{I}_{TE,s} = \dot{I}_{be,s} + \dot{I}_{de,s} + \dot{I}_{re,s} \tag{4}$$

In this calculation, the hourly solar radiation arriving at the horizontal surface $İ_{TE,s}$ (kVth/m²)), direct (or direct) rays falling on the surface $İ_{be,s}$ (kVth/m²), scattered rays $İ_{de,s}$ (kVth/m²) and $İ_{re,s}$ (kVth/m²) are defined as the sum of reflected rays. In Liu and Jordan's model, the calculation of direct (or direct) solar radiation falling on the surface is determined by the formula (5):

$$İ_{be,s} = İ_{b,s} R_b \tag{5}$$

Here $İ_{b,s}$ (kVth/m²)is the hourly amount of direct rays falling on the horizontal surface, and , R_b is the energy conversion factor of that ray.

Calculations on electricity production based on the sun's rays falling on the earth's surface have been carried out. As a result of these calculations, the total collector area $A_k(m^2)$, hourly electricity production $E_s(kWts)$ (6), daily electricity production $E_{gün,n}(kWts)$ (7), monthly electricity production $E_{ay,i}(kWts)$ (8) and annual electricity production $E_i(kVts)$ are given in equations (9)

$$E_s = İ_{TE,s} * A_k * \eta^* \tag{6}$$

$$E_{g,n} = \sum_{s=5:00}^{19:00} E_s \tag{7}$$

$$E_{a,i} = \sum_{n=1}^{y} E_{gün,n} \tag{8}$$

$$E_i = \sum_{i=1}^{12} E_{ay,i} \tag{9}$$

Here, the s-index indicates the time at which the calculations are made, the n-index indicates the number of days in a year, the i-index indicates the month in which the calculations are made, and the y-index indicates the number of days in a month η* the electricity production of the panel due to the heat from the sun [8]

In our article above, we mentioned that the use of solar energy systems has both economic and environmental benefits. First, let's consider its environmental efficiency and do the math. As we know, a certain amount of CO2 emissions are released into the environment during the production of heat or electricity using traditional fuels.

Solar photovoltaic systems are used to reduce this and for a healthier environment. As a result of the application of those systems, the amount of CO2 emission avoided in general was calculated in the equation $T_{avoided-CO_2}$ (kg CO_2) (10), the produced emission factor $n_{CO_2}(\frac{kgCO_2}{kwts})$. The produced emission factor is given below (Table 2), and the product of the annual energy production volume and the production rate of the corresponding fossil fuel indicates how much CO_2 emissions are prevented.

During the production of photovoltaic panels, the average emission factor is 3,301$(\frac{kgCO_2}{kwts})$ and is negligible and is marked as n_{PV-CO_2}.

The emission factor $T_{PV-CO_2}(kgCO_2)$ (11), the amount of avoided CO_2 T_{CO_2} $(kgCO_2)$ during the construction of those systems is (12) is shown in the equation, and the power of the overall built photovoltaic system is expressed as $P_g(kWt)$.

Table 2: *Produced emission factor*

Fuel type	Emission factor $(\frac{kgCO_2}{kwts})$
Natural gas	0.201
Oil	0.266
Brown coal	0.327-0.414
Stone coal	0.322-0.358

$$T_{avoided-CO_2} = E_{il} * n_{CO_2} \tag{10}$$

$$T_{PV-CO_2} = n_{PV-CO_2} * P_g \tag{11}$$

$$T_{CO_2} = T_{avoided-CO_2} - T_{PV-CO_2} \tag{12}$$

The next efficiency we will consider is economic. The first area to be calculated is depreciation. Depreciation is denoted by t (year), in equation (13) the initial construction cost G (dollars), the total PV cost G_{PV}, the land cost G_{land} for the creation of solar energy systems is calculated in proportion to the total profit level.

$$t = \frac{G + \text{Gland} + G_{PV}}{K_{top}} \tag{13}$$

The monthly, total, LEIQ, and total local product profit to be obtained during the construction of photovoltaic systems are expressed by formulas (14), (15), (16), (17), respectively. Before moving on to the calculations, it should be noted that wholesale electricity prices $F_{k-1,i}$ is a variable parameter, so different results are always obtained. When calculating the profit to be obtained, the increase in electricity prices is assumed to be approximately 10%. In this regard, the "m" coefficient, which takes into account the increase, was mentioned in the calculation 3.11 regarding the electricity price.

$$F_{k,i} = F_{k-1,i} * (1 + m) \tag{14}$$

$$F_{i-ort} = \frac{\sum_{k=1}^{z} F_{k,i}}{z} \tag{15}$$

$$K_{ay,i} = E_{ay,i} * F_{i-ort} \tag{16}$$

$$K_i = \sum_{i=1}^{12} K_{ay,i} \tag{17}$$

In the formula (14), the electricity sales price for any month is calculated with $F_{k-1,i}$. In the above formulas, the k-index is the number of years, the z-index is for determining the estimated depreciation period as a year, and the i-index is the number of months. As a result of the calculation by formula (15), the annual average electricity price is determined according to the estimated amortization period for each month. [7]

According to the law of unlicensed electricity production, the amount paid by the state for each kilowatt of energy produced with alternative energy and sold to the grid $F_{LE\dot{I}Q}$significantly positively affects the amortization period in economic and technical matters. If the total LEIQ profit is K_{t-leiq}, the electricity consumption according to the consumption demand is shown as $E_c(kVts)$, the total profit from the LEIQ is calculated as follows:

$$K_{t-leiq} = F_{leiq} * (E_i - E_c) \tag{18}$$

PV panels, which provide the production of electricity from solar power plants to the grid, provide state subsidies for each kW if they are produced locally. If we express that paid aid as F_{local}, then the total local profit obtained will be as follows.

$$K_{t-leiq} = F_{local} * (E_i - E_c) \tag{19}$$

As a result of this final calculation, the total efficiency or gain obtained from the use of GES is equal to the sum of the gain obtained from the use of LEIQ, the use of domestically produced PV, and the prevention of the emission factor that jumps into the environment.

$$K_t = K_{t-leiq} + K_{t-leiq} + K_i + K_{CO_2} \tag{20}$$

$t = (G + +G_{PV})/[(F_{local} * \left(\sum_{i=1}^{12} \sum_{n=1}^{y} \sum_{s=5:00}^{19:00} \mathrm{I}_{TE,s} * A_k * \eta^*\right)) + (F_{leiq} * \sum_{i=1}^{12} \sum_{n=1}^{y} \sum_{s=5:00}^{19:00} \mathrm{I}_{TE,s} * A_k *$
η))+i=112(i=112n=1ys=5:0019:00ITE,s*Ak*η**k=1zFk−1,i*1+mz+i=112n=1ys=5:0019:00IT E,s*Ak*η**nCO2−nPV−CO2*Pg*FCO2]* (21)

$$\eta^* = \mathrm{I}_{TE,s}/(\frac{12*3600}{\pi} G_{sc}(1 + 0.033 \cos\frac{360n}{365})*[\cos\varphi \cos\delta\,(\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2-\omega_1)}{180}\sin\varphi \sin\delta]) * (\eta_r - \mu(\left(T_a + (PN\c{C}\dot{I} - 25^\circ C)\frac{I_{TE,s}}{1000}\right) - T_r)) \tag{22}$$

G_{sc} – constant sunlight
PNÇİ – Normal operating temperature of the panel($^\circ C$)
η_r – performance indicators of the PV system during the test (%)
T_r – The temperature at which the PV system is tested

$\mu -$ Thermal coefficient of PV system

As a result of the calculations, it was determined that if the average monthly solar energy falling on 1 m^2 of surface is 120-130 kW, then the photovoltaic system used in the GES with a total power of 100 kW is placed at an angle of inclination of 30° and the productivity is 14-15%, and it produces approximately 70,000 kW annually. produces electricity (22). In this case, the amortization period of that PV system is determined to be 10 years (21). The entrepreneur who built this system would have made a profit of approximately 17,000 dollars because he did not buy 70,000 kW of electricity from the state grid. Also, with the construction of this system, 13,873 kg of CO_2 emission factor is prevented from being thrown into the environment. [1]

There are two computer simulations used in this area. One is called RetScreen and the other is called Enhanced simulation. Both simulations were used for systems with a power of 100 mW in areas with 1200-1800 kW of solar energy per 1 m^2 of horizontal surface annually, and the results are listed in Table 3.

The reasons for the differences resulting from the use of both simulations are that the developed simulation, unlike RetScreen, takes into account the increase in the price of electricity production, the amount of CO_2 produced by PV production, the land costs related to the construction of PV systems, and other parameters. The use of this simulation is considered to be more effective because the developed simulation provides conditions for obtaining more extensive, detailed and reliable results.

Table 3: *The results of the simulations used*

Parameter	RetScreen	Advanced simulation	Offset (%)
$E_i(kWts)$	142.000	144.572	-1.8
$T_{CO_2}(ton)$	28.5	29	-1.8
$t(i)$	7.2	7.0	2.7

As we mentioned above, there are monocrystalline, polycrystalline and thin-layer silicon crystal types of photovoltaic systems. Their efficiency differs from each other. Let's consider which one is more efficient:

1) When we use thin-film silicon crystal PV panels, to build a system with 1000 panels with a power of 100 kW, it will cost approximately $85,000, additional installation costs of $97,000, and land costs of $68,950, for a total cost of $250,950. happens. Since the prices of thin-film silicon crystal PV panels are more expensive than polycrystalline panels, it causes us to invest an additional $19,000. At this time, we can produce 45,000 kilowatts of electricity annually. A total profit of $18,000 is obtained during the application of a thin-film silicon crystal PV system, the amortization period is 14 years, and the amount of CO2 emissions avoided is 8,000-9,000 kg.

2) When monocrystalline PV panels are used, the total cost under the same requirements is $245,000. However, due to the high productivity of this type of PV panels, the volume of electricity production has changed and increased compared to polycrystalline panels. As a result of the application of such a system, more than 72,000 kilowatts of electricity is produced annually and $22,000 in profit is obtained. The amortization period is reduced to 11 years, and a total of 14,000 kg of CO2 emissions are prevented.

3) As a result of research on polycrystalline PV panels, it was determined that the amortization period is 9-10 years and it has the ability to satisfy more than 80% of the proposed demand.

Table 5: *Amortization periods that occur as a result of changes in inclination angles in the conditions of meeting consumer demand*

$E_i(kWts)$	Lack of government support for CO_2 mitigation and the use of locally produced PV panels						Availability of government support for CO_2 mitigation and use of locally produced PV panels					
Angles of inclination	20	25	30	35	40	45	20	25	30	35	40	45
186.000	8.60	8.58	8.65	8.78	8.98	9.25	8.53	8.51	8.58	8.71	8.90	9.18
203.000	8.54	8.52	8.60	8.72	8.90	9.16	8.44	8.42	8.49	8.61	8.79	9.05
222.000	8.11	8.09	8.16	8.27	8.44	8.68	8.01	7.99	8.06	8.17	8.34	8.57

Also, the creation of such a hydroelectric power plant is important in terms of environmental protection. Thus, by selling the energy obtained from here to another enterprise or company, the CO_2 emission factor thrown into the environment using fossil fuels of that area is prevented.

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