# EVALUATION OF THERMAL ENERGY PRODUCTION BY SOLAR PANELS FOR KARABAKH "GREEN" ENERGY ZONE

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**Abstract**

*The global "green" energy trend is also rapidly developing in Azerbaijan, although the country's economy is still mainly dependent on oil and gas production. Analysis of the prospects for the efficient use of renewable energy sources is a topical issue in terms of the implementation of the decree on the transformation of the Karabakh zone of Azerbaijan into a "green" energy zone. The article examines the prospects of applying solar vacuum tube panels for the climatic parameters of the Gubadli region of Karabakh. The thermal energy production capacity of the solar panels was evaluated by the "Helios-house" program. The results show that the number of Hevelius SCM-12 180-58 panels placed in the area of 50m² in Gubadli region should be 12 with the efficiency 70%, the heat loss coefficient of vacuum tubes is 0.5W/m², the average amount of thermal energy received by solar radiation is 1625 kW/m² and the total thermal energy production is 14938 kWhr/year. The proposed evaluation methodology can be applied to any region of Azerbaijan.*

**Keywords:** Karabakh, "green" energy zone, solar panels, renewable energy sources, thermal energy

## I. Introduction

The depletion of hydrocarbon resources and their negative impact on the environment has raised the need for renewable energy consumption in Azerbaijan, as well as around the world [11]. The country already has a positive experience in this area and uses solar, wind, and other environmentally friendly energy sources. The global "green" energy trend is also rapidly developing in Azerbaijan, although the country's economy is still mainly dependent on oil and gas production [10]. Azerbaijan has great potential in the field of renewable energy use. Azerbaijan sees its future energy supply policy as focusing on the consumption of "'green" energy. Azerbaijan, one of the world's leading countries in the development of oil and natural gas production, has set a goal to increase energy consumption from renewable energy sources to 50% by 2050. "Green" energy potential in megawatts for Azerbaijan is:

-solar energy - 5000, which has the most part of the total potential of renewable energy sources;

-wind energy - 4500, which is in the second place by the amount and using perspectives;

-biomass - 1500;

-geothermal energy- 800;

-energy potential of small rivers- 350.

Currently, special attention is paid to energy supply development projects in the liberated territories. Karabakh region has a huge potential for renewable energy sources. From 2021, the development of "green" energy zone projects in the liberated territories of Karabakh has begun. As the President of Azerbaijan Ilham Aliyev has repeatedly stated: "Karabakh region, as a "green" energy zone, must be exemplary for the whole world. The "green" energy comes from solar, wind, water, etc. with efficient and economically rational technologies". According to preliminary estimations, Karabakh areas have a potential of more than 4,500 megawatts of solar energy and up to 550 megawatts of wind energy [1].Wind energy production will also be developed in Kalbajar and Lachin regions. In the mountainous parts of these regions, the average annual wind speed reaches 7-8 m/sec. Wind plants producing wind energy will be used here. The Karabakh region is also rich by water resources, which is a favorable factor for the development of hydropower. 25% of Azerbaijan's local water resources are formed in Karabakh. It is expedient to build power plants on rivers such as Khakari, Bazarchay, Tartar and their tributaries [8]. Hot water projects are being developed in the near future: 3,000 $m^3$/day in Kalbajar and 400 $m^3$/day in Shusha.

Eight regions with high potential for solar energy have been selected in this Karabakh zone, as Kalbajar, Lachin, Gubadli, Zangilan, Jabrayil and Fizuli, which are considered the most favorable in terms of construction of solar power plants. The article examines the prospects of applying solar vacuum tube panels (SVTP) for the climatic parameters of the Gubadli region of Karabakh. The thermal energy production capacity of the solar panels was evaluated by the "Helios-house" program.

## II. Using solar energy

Solar energy is used to generate both electricity and hot water. The types of using solar energy may be active and passive [9]. Passive solar use is applying some architectural solutions for optimization to gain solar energy: building shape, orientation, geographical location, shading, etc. Active solar use is applying some technologies: panels, turbines, pump stations, pressure regulators, and so forth. Figure 1 shows examples of active solar energy use- SVTP and photovoltaic panels [5].

a-  b- 

**Figure 1:** *Solar installations: a- solar vacuum tube panels, b- photovoltaic panels*

Hot water production by using solar technology is the most widely used method. Different types of solar panels are applied for this purpose. The simplest and cheapest way to use solar energy is to heat household water with SVTPs [6], [7], [2]. Unlike solar photovoltaic panels with an efficiency of 15-25%, SVTPs have an efficiency of up to 90%. They can successfully cope with receiving hot water in buildings at any temperature in spring, summer and autumn. In wintertime, additional heating sources are usually required to heat the building [12]. Therefore, solar water heaters are usually designed to operate in the spring-summer-autumn period and are used in addition to the main system in the winter. The solar hot water system consists of a solar panel, pump group, control devices, water storage tank, connecting elements and fittings, and expansion tank (Figure 2). It should be noted that solar heating is combined with traditional heating systems. [13] The evaluation of solar vacuum tube panels used for the production of hot water can be carried out through the program Helios-house.

a- b-

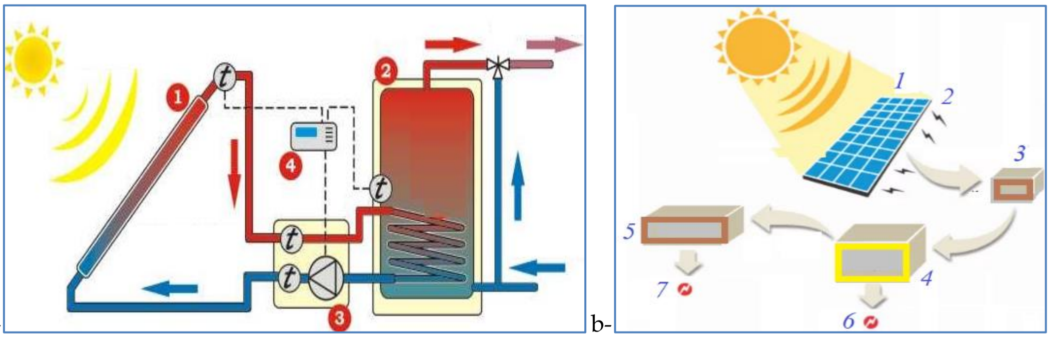


**Figure 2:** *Types of solar installations and their major component parts [14]:*
*a- vacuum tube panels - for hot water production, 1-panel, 2- heat exchanger, 3- pump group, 4- controller;*
*b- photovoltaic panel for production electricity, 1-panel, 2-power supply, 3-controller, 4- rechargeable battery, 5- inverter, 6- direct current, 7- alternating current*

SVTP is equipment for direct conversion of solar energy into thermal energy for hot water supply and space heating. It collects the thermal energy of the Sun carried by visible light and infrared radiation. Unlike photovoltaic panels (photocells) that produce electricity directly, SVTP heats the heat-carried medium directly. Modern domestic SVTPs are able to heat water up to the boiling temperature even at negative ambient air temperatures [15].

A SVTP cannot be 100% efficient, as it has inevitable losses in the conversion of thermal energy, as well as optical losses. The efficiency of the entire solar hot water system depends to a large extent on the efficiency of SVTP. All design features of any solar panels should ensure maximum absorption of solar energy and minimum heat loss [16]. The more solar energy the panel absorbs, the faster it converts this radiation into thermal energy and the less it losses on the way to the heat storage tank, the more efficient the DHW system will work. The efficiency of SVTP in practice can differ significantly from the calculated values (technical characteristics). It is necessary to take into account such parameters as the flow rate of the heat-carried medium and the connection of the collector groups, as well as some other recommendations. In most operation modes, a sufficient flow of heat-carried medium must be ensured through the solar panel, otherwise, if the heat-carried medium stagnates in the panel, it may overheat (in summer) or freeze (in winter). The circulation of the heat-carried medium is ensured by the use of individual pumps (Figure 3) or pump groups (solar pumping station). To ensure optimal operation modes of heat supply systems with solar panels, electronic solar controllers are used. The solar panel and the water heater are connected with a flexible pipe connection.

The temperature of the heat-carried medium in the solar collector can drop below zero (to the temperature outside) or exceed 100 $^{0}$C, such harsh operation conditions impose restrictions on the use of water as a heat-carried medium. Thermal energy storage occurs due to the storage of heat in the volume of water. For this, the systems have reservoirs of considerable capacity. The capacity is determined by the recoverable thermal power of the panels and the required consumption of warm water (Figure 3).

## III. Energy production capacity of the tubular solar panels

The evaluation of energy production of the solar hot water system was made for Gubadli city. The hot water demand of the consumer is taken as the initial estimation indicators and it is carried out through the evaluation program. The evaluation stages are as follows [3], [4]:

1. determination of the amount of solar water heating panels;
2. calculation of the amount of thermal heat due to total amount of solar radiation;
3. evaluation amount obtained hot water from SVTPs.

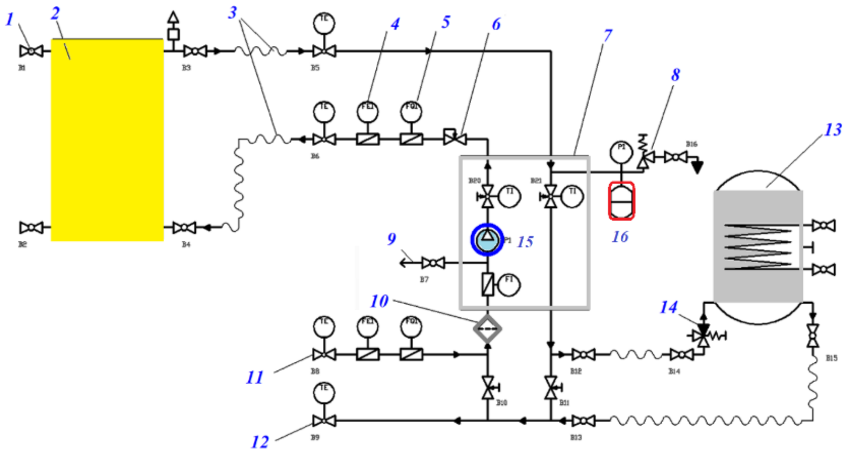


**Figure 3:** *Equipment of the systems with solar vacuum tube collectors:*
*1- manifold connection, ball shut-off valve, 2- flat solar collector, 3- flexible piping, 4- flow meter with pulse output, 5- water meter, 6- pressure regulator, 7- pump group, 8- safety group with hydraulic accumulator, 9- filling connection with shut-off cock, 10- mesh filter, 11 heating radiator connection, return flow, 12- heating radiator connection, supply flow, 13- boiler-water heater, 14- combined safety valve, 15- circulating pump, 16-expansion tank*

Preliminary information for evaluation- technical parameters of the applied Hevelius SCM-12 180-58 Polish panels (Table 1), which were studied:

- number of vacuum tubes in one panel- 12,
- diameter of vacuum tubes - 0.058 m,
- length of vacuum tubes - 1.8 m,
- effective area of one panel-1.9 m$^2$,
- number of vacuum tubes per 1 m$^2$ - 6,
- efficiency of the solar panel - 70%,
- heat loss coefficient of vacuum tubes - 0.5W/m$^2$,
- total area of the planned place for installation of equipment - 50m$^2$.

**Table 1:** *Technical specifications of Hevelius SCM-12 58/1800 solar panel*

| Indicators | Unit of measurement | Quantity |
|---|---|---|
| Type | - | Vacuum tube |
| Geometric dimensions AxBxCxD | mm | 1050x1990x1740x925 |
| Weight | kg | 40.7 |
| The number of tubes in a collector | pieces | 12 |
| The length of a tube | mm | 1800 |
| Outer diameter of the tube | mm | 58 |
| Internal diameter of the tube | mm | 47 |
| The total area of one panel | m$^2$ | 1.9 |
| The absorption coefficient of the panel | - | 0.92 |
| The production capacity of the panel | W | 744 |
| The diameter of the internal heat tube | mm | 8 |
| The stagnation temperature of the liquid | $^0$C | 225.4 |
| Volume of heat- carried medium per liter | litr | 1.2 |
| Maximum working pressure bar | bar | 12 |

Project parameters obtained on the basis of preliminary indicators:
- number of actually installed panels - 12,
- inlet temperature of cold water - 10 °C,
- outlet temperature of hot water - 50 °C.

## VI. Results

Results of the evaluation on hot water demand (Table 2,3,4):
- average annual amount of solar radiation - 1625 kW/m$^2$
- average amount of solar radiation by months, kWhr/m$^2$, was shown in Table 1,
- effective area of the planned place for installation of equipment - 22 m$^2$,
- average production of hot water per day - 2000 liter/day,
- average volume of hot water production throughout the year - 730 m$^3$/year,
- total thermal energy production - 14938 kWhr/year.

**Table 2:** *Average amount of solar radiation by months kWhr/m$^2$*

| Month | The average amount of solar radiation | Month | The average amount of solar radiation |
|---|---|---|---|
| January | 3.32 | July | 5.7 |
| February | 3.8 | August | 5.48 |
| March | 4.15 | September | 5.18 |
| April | 4.49 | October | 4.38 |
| May | 4.96 | November | 3.51 |
| June | 5.6 | December | 2.81 |
| Average monthly indicator - 4.45 | | | |

**Table 3:** *Expected hot water production by solar panels for months, liters*

| Month | Hot water amount | Month | Hot water amount |
|---|---|---|---|
| January | 654 | July | 1127 |
| February | 751 | August | 1082 |
| March | 820 | September | 1023 |
| April | 886 | October | 865 |
| May | 980 | November | 693 |
| June | 1107 | December | 553 |
| Average monthly indicator - 878 liters | | | |

**Table 4:** *Energy production of solar panels by month kWhr/day*

| Month | The average amount of solar radiation | Month | The average amount of solar radiation |
|---|---|---|---|
| January | 32.64 | July | 50.55 |
| February | 37.12 | August | 47.46 |
| March | 39.86 | September | 43.23 |
| April | 43.47 | October | 37.88 |
| May | 46.99 | November | 30.89 |
| June | 51.50 | December | 29.30 |
| Average monthly indicator - 40.93 | | | |

Thus, evaluation shows that it is possible to meet the hot water needs of buildings through SVTPs. Figure 4 shows the schedule of thermal energy production by months.

Currently, the authors have developed several projects for the efficient use of renewable energy sources in terms of implementing the transformation of Karabakh zone into a "green" energy zone. The paper is devoted to studying the application of solar vacuum tube panels for climatic parameters of the Gubadli region of the Karabakh "green" energy zone and the assessment of production capacity through an evaluation program Helios-house. The evaluation methodology for obtaining hot water by applying solar vacuum tube panels using "Helios-house" program consists of three main stages:

- the optimal number of solar panels that can be installed in the given area is determined;
- the average amount of solar radiation per month is evaluated;
- depending on the orientation and angle of the panels the amount of thermal energy is estimated.

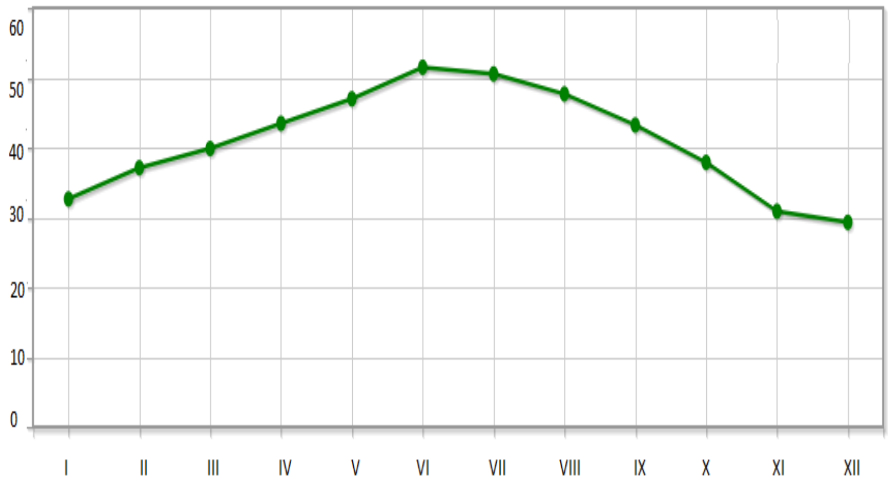


**Figure 4:** *Production of thermal energy by months, kWhr/day*

## V. Conclusion

Solar energy use becomes more and more globally. Like other countries, Azerbaijan is trying to meet its thermal energy and electricity needs by applying renewable energy sources. It is predicted that by 2050, about 50% of the total amount of energy will be produced by "green" energy technologies. At present time Azerbaijan meets only 8% of energy consumption needs with renewable energy.

The obtained results of the study allow making the next conclusions on an initial assessment of meeting the hot water needs of buildings through solar vacuum tube panels. According to the sample evaluation, the amount of Hevelius SCM-12 180-58 (Poland) panels placed in an area of 50 m2 in the Gubadli region is 12, efficiency is 70%, the heat loss coefficient of vacuum pipes is 0.5W / m2, the average production of hot water per day - 2000 liter/day, the average volume of hot water production throughout the year - 730 m3/year, the average amount of thermal energy obtained by solar radiation is 1625 kW/m2 and the total heat production is 14938 kWhr/year.

The proposed evaluation methodology can be applied to any region of Azerbaijan.

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