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Modern research of using alternative energy resources in Azerbaijan

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ABSTRACT

The article provides a comprehensive analysis of modern trends and prospects for the use of solar batteries in various sectors of the economy and the agricultural sector. The purpose of this article is to analyze the possibility of energy saving for a private residential building in Gobustan using solar energy storage in a greenhouse extension and a heat pump to transfer heat to the heating system. The calculation showed that in the coldest month, December, the potential of solar thermal energy is 15-38% of the required heat demand, depending on the material used in the extension design. In March and April, excess heat is generated, which can be used for hot water supply needs. Thus, for an individual residential building, the use of solar heat accumulated in a greenhouse extension is relevant as an additional source of heat for the heating system. Surface density of solar radiation flux, W/m^2: surface density of direct solar radiation flux: 1,680 (November), 1,530 (December), 1,870 (January), 2,730 (February), 3,270 (March), 3,180 (April); Surface density of diffuse solar radiation flux: 650 (November), 450 (December), 480 (January), 680 (February), 1180 (March), 1,830 (April).

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1. INTRODUCTION

Humanity began to use the energy of the sun a very long time ago. By placing mirrors at certain angles, they heated the water in the thermal baths and also illuminated rooms without windows. The relevance of developing alternative energy sources is becoming a key aspect of ensuring sustainable development. Statistics on global energy consumption worryingly indicate the need to find new sources. Deterioration of the environment, pollution, and depletion of natural resources have forced humanity to think about how to obtain electricity and heat from renewable sources [1], [2]. Energy generated primarily from fossil fuels and nuclear power plants is being replaced by energy generated from sunlight, water flows, wind, tides, biofuels, and geothermal heat, and new ways of generating energy are being developed. In addition to the environmental reason that motivates the transition to alternative energy and the search for new solutions, there are a number of other reasons [3], [4]. It is necessary to replace thermal power plants operating on traditional fuel with plants that use hydrogen as fuel; such installations will not have dangerous emissions. The most widely used and effective alternative energy source in Azerbaijan, or more precisely in Absheron, is solar panels. The task of meeting the needs of the population, industry, and agriculture for electrical and thermal energy, especially in regions remote from centralized power grids, as well as issues of sustainable development and reducing the negative impact of energy on the environment, dictates the need to develop renewable energy. Passing through the atmosphere, solar radiation is weakened, partially penetrates the atmosphere with direct rays, and reaches the earth's surface in the form of direct and diffuse radiation [5], [6]. The efficiency of practical use of solar energy largely depends on how accurately the patterns and specific data on the arrival of solar radiation at the location of the proposed operation of the installations were taken into account during design development. The difficulties in developing solar energy are related to the fact that the areas most suitable for its development are located far from water sources, and the areas adjacent to water sources, where the majority of the population is concentrated, in turn, do not have such favorable conditions for the production of solar energy [7], [8]. The problem of practical application of solar energy contains two main aspects: its conversion into electrical energy and heat [9].

The possibility of accumulating low-potential heat in a specially equipped extension (greenhouse) for conversion by an air-to-water heat pump is analyzed, in order to subsequently use it for heating needs. Two designs were considered as finishing materials for the extension: double-layer polycarbonate with an air gap and energy-saving glass. The use of solar energy to heat the coolant to meet the need for heating is becoming increasingly popular. This is due, among other things, to the rapid reduction of the planet's natural resources and, as a result, the rise in prices for fossil fuels. Today, the use of solar energy for the construction of energy-efficient or passive houses is widespread. There are many examples of not only the construction of new passive houses, but also the reconstruction of old uneconomical buildings using the basic principles of energy efficiency around the world. It is quite common to use air solar collectors and other methods of accumulating solar heat to improve the energy efficiency of indoor spaces. However, it is worth noting that the efficiency of solar heating directly depends on the angle of incidence of the sun's rays. Technologies have been developed that allow following the angle of incidence of the sun's rays throughout the year or day. The idea of using additional extensions to accumulate solar heat and use it later during the dark hours has long been described in scientific papers. Solar energy is one of the sources of renewable energy, but in the Gobustan region during the cold season, the use of solar energy is difficult due to low outside temperatures [10]–[12]. Another mandatory condition when designing a passive house is the use of recuperation. Heat pumps allow you to collect and save the maximum amount of energy received from the sun. Thus, a two-story frame house with an attached greenhouse was considered in a scientific paper. To transfer heat from the extension to the northern wall, a system of pipes with water as a heat carrier is used [13], [14].

2. RESEARCH METHOD

In this article, the object of study is a private residential house with the possibility of partially satisfying heating needs with accumulated solar energy collected by a heat pump in an extension-greenhouse (Figure 1). The following tasks were set: i) to determine the thermal performance of the object under study, ii) to calculate the heat input from solar radiation into the greenhouse for each month of the heating period, and iii) to evaluate the efficiency of using the heat of solar radiation. An analysis of the results of calculating the influx of solar radiation into the extension volume is carried out, and a comparison with the estimated heating load is made, as shown in Figure 2. Main part: description of the object:

- Construction site: Gobustan (low-humidity zone).
- Purpose of the place: residential; indoor air temperature, t_{air}=20 °C.
- Place height: 8.2 m, number of floors: 2, total area: 95 m^2.
- Calculated parameters of outdoor air, for heating design: air temperature of the coldest five-day period with 0.92 t^5, outdoor air=-22 °C, duration of the period with average daily temperature ≤8 °C, z_{period}=199 days, average temperature for this period t_{period}=-4.3 °C.
- Greenhouse dimensions 3×6.4 m, roof has a slope of 20°, height at the junction with the house h=3.8 m, as shown in Figure 1.

Polystyrene concrete is adopted as the main material for the walls of the residential building. Thermal engineering calculation of the wall is performed taking into account heterogeneities. The elements of the curtain wall ventilated facade are adopted as thermal engineering heterogeneities: self-tapping screws 70 mm long and 4.2 mm in diameter, a wooden beam with a cross-section of 50×50 mm. There are 4 elements of thermal engineering heterogeneity per 1 m^2 of wall. The required heat transfer resistance R^h=3,092 m^2·°C/W. Averaged over the area, the conventional heat transfer resistance R_0^{cond}=4.74 (m^2·°C)/W, the reduced heat transfer resistance of a blank (without openings) wall with NFS R_0^{pre}=4.42 (m^2·°C)/W, the coefficient of thermal inhomogeneity was 0.93. The heat loss calculation was made for the months of the year with an average monthly temperature under 8 °C. Heat loss is divided into 2 parts: through enclosing structures Q_{org}, and heat consumption for heating, ventilation air Q_{vent}. At the design temperature t_{air}=-22 °C, Q_{org} amounted to 5,460 W. Alternative energy is the most promising way of obtaining, transmitting, and using energy, less widespread than traditional energy, but of great interest due to the lower risk of harming the environment [15]–[17]. Azerbaijan has all types of renewable energy sources; most subjects have resources of several types. It cannot be said that these resources are distributed evenly across the territory, but they exist, and with their help, it is possible to solve the main tasks. Today, alternative energy in Absheron is at an early stage of its development; several alternative energy facilities are located on its territory [18].

Figure 1. Use of Gobustan solar panels in agriculture

Figure 2. Used solar panels in Gobustan (Azerbaijan, Absheron Peninsula)

3. RESULTS AND DISCUSSION

The heat requirement for heating the ventilation air is determined at a rate of 3 m^3/h per m^2 of living space in the house. The required flow rate of supply ventilation air is 241 m^3/h, and the minimum required flow rate of exhaust air is 165 m^3/h (Table 1). Heat loss through enclosing structures and ventilation showed differences between January, December, November, and other months. According to the balance, the flow rate of exhaust air is increased to 216 m^3/h. The mechanical ventilation system adopted as the most reliable and provides stable air exchange [19]. To reduce the heat load on heating the supply air, it is customary to use a plate recuperator in the supply and exhaust unit as one of the most effective solutions for saving energy resources for residential buildings [20]. A supply and exhaust unit with a membrane recuperator has been selected. With minimum recuperation efficiency (according to technical specifications, the recuperator efficiency is 68–84%) at the design temperature, the heat consumption for heating the supply air will decrease from 3,435 to 1,129 W. Maximum air flow is 319 m^3/h. Evaluation of the efficiency of using solar radiation heat parameters, as shown in Table 2.

Table 1. Heat loss through enclosing structures and ventilation

Parameters	Months					
	November	December	January	February	March	April
Average monthly temperature, °C	-0.9	-9.5	12.8	-9.0	-2.0	4,9
$Q_{tes.}$ (W)	625.80	1,263.61	1,493.52	1,233.94	722.41	185.06
$Q_{vent.}$	1,708.3	2,411.2	2,664.5	2,378.4	1,806	1,242.4
$Q_{vent.recup.}$	461.1	732.9	830.8	720.4	499,0	281.0
Recovery efficiency, W	1,247.1	1,678.2	1,833.6	1,658.3	1,307.4	961.4

Note: $Q_{vent.}$: vent with recovery; $Q_{vent.recup.}$: vent without recovery; and $Q_{org.}$ (W): through enclosing structures

Table 2. Evaluation of the efficiency of using solar radiation heat

Parameters	Months					
	November	December	January	February	March	April
Average monthly temperature, °C	-0.9	-9.5	12.6	-9.1	-2.1	4.8
Specific heat loss without recuperation, W	2,334	3,675	4,158	3,612	2,529	1,427
Specific heat loss with recuperation, W	1,087	1,996	2,324	1,954	1,221	466
Heat loss without recuperation per day, W·day	56,016	88,193	99,792	86,696	60,688	34,257
Heat loss with recuperation per day, W·day	26,085	47,915	55,784	46,900	29,314	11,184
For polycarbonate						
Total heat input to the greenhouse, W·day	23,332	8,909	8,048	31,473	58,545	87,001
Providing heating without using recuperation (%)	42	11	9	37	96	254
Providing heating using recuperation (%)	89	19	14	67	200	778
For an energy-saving glass unit						
Total heat input to the greenhouse, W·day	29,433	18,614	20,903	40,635	64,931	87,037
Providing heating without using recuperation (%)	53	22	21	48	108	254
Providing heating using recuperation (%)	113	39	37	87	222	778

The extension is a rectangular room in plan, having one common wall with the house. The other three walls and the roof are made of translucent structures. The dimensions of the extension in plan are 6.4×3 m. Height: from 2.7 to 3.8 m. The angle of the roof of the extension is 20°. Two design options were considered: a greenhouse made of polycarbonate; a greenhouse made of energy-saving glass [21], [22]. Figure 3 shows a graph of the total radiation flux per 1 m^2 of a greenhouse by hours of the day in January and March onto the wall and roof at an angle of 20° in the southwest direction, as shown in Figure 3, Q_{vent} is ventilation with recovery, $Q_{vent.recup}$. is ventilation without recovery, and Q_{org}. (W) is ventilation that passes through the enclosure structure.

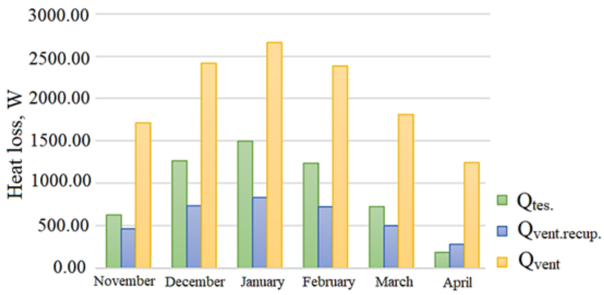


Figure 3. Heat loss through enclosing structures and ventilation with and without the use of recuperation

The task of calculating the heat flow into a greenhouse depends on many factors: the accumulative capacity of enclosing structures and surfaces, the temperature regime of the heat pump, heat input from solar radiation during daylight hours, heat input through the wall of the house from heated rooms, heat loss through translucent enclosures, and the distribution of air flows inside the greenhouse [23], [24]. To simplify the task at this stage of the research, for the winter months (December, January, and February) the temperature inside the greenhouse is taken as 0 °C, for November, March, April +5 °C, and the heat flow through 1 m^2 of translucent enclosing structures is calculated in a simplified way, as the daily sum of heat input for each hour of the day, W/m^2. Figure 4 shows the results of calculating the heat flow through 1 m^2 of the greenhouse roof.

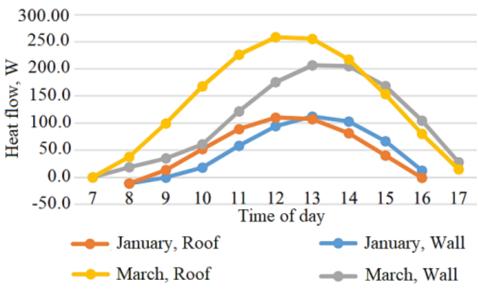


Figure 4. The total radiation flux per 1 m^2 of a greenhouse by hours of the day in January and March onto the wall and roof at an angle of 20° in the southwest direction

The results of the calculation for assessing the efficiency of using solar radiation heat entering the greenhouse extension for enclosing structures made of polycarbonate and energy-saving glass units are presented in Table 3. The prospects of using solar batteries and autonomous power plants based on them are beyond doubt. As modern development trends in this area show, the widespread introduction of solar energy into life is not related to the level of development of this problem, but primarily to economic feasibility for each class of consumers. Based on climatic conditions, population density, and the distance of consumers from sources of general power supply, the use of autonomous photovoltaic stations is most relevant [24], [25]. There is great potential for increasing electricity production from renewable energy sources both in Azerbaijan and in the world, and targeted use of this potential can play an important role in the sustainable supply of electricity to countries. Surface density of solar radiation flux, W/m^2: Surface density of direct solar radiation flux 1,680 (November), 1,530 (December), 1,870 (January), 2,730 (February), 3,270 (March), 3,180 (April); Surface density of diffuse solar radiation flux 650 (November), 450 (December), 480 (January), 680 (February), 1,180 (March), 1,830 (April).

Table 3. Effect of different light conditions on the output of photovoltaic modules (in % of total power)

Condition	% of "full" sun
Bright sun-panels are located perpendicular to the sun's rays	100
Light cloudiness	60-80
Cloudy weather	20-30
Behind the window glass, one layer, glass and module are perpendicular to the sun's rays	91
Behind the window glass, 2 layers, glass and module are perpendicular to the sun's rays	84
Behind the window glass, one layer, glass and module at an angle of 45° to the sun's rays	64
Artificial light in the office, on the surface of the desk	0.4
Artificial light inside a bright room	1.3
Artificial light inside a living space	0.2

Figure 5 shows a graph of the total radiation flux per 1 m^2 of a greenhouse by hours of the day in January and March onto the wall and roof at an angle of 20° in the southwest direction. The task of calculating the heat flow into a greenhouse depends on many factors: the accumulative capacity of enclosing structures and surfaces, the temperature mode of the heat pump, heat input from solar radiation during daylight hours, heat input through the wall of the house from heated rooms, heat loss through translucent enclosures, and the distribution of air flows inside the greenhouse. To simplify the task at this stage of the research, for the winter months (December, January, and February) the temperature inside the greenhouse is taken to be 0 °C, for November, March, April +5 °C, and the heat flow through 1 m^2 of translucent enclosing structures is calculated in a simplified way, as the daily sum of heat input for each hour of the day, W/m^2.

A solar battery produces much less energy in cloudy weather than a solar one. The solar voltage generated by a solar element depends on how the light flux falls on it; the voltage, with increasing illumination, increases only to a certain level and does not increase further. For a silicon element, this voltage is 0.6 V, and to increase the voltage of a solar panel, the elements are connected in series. The voltage reserve ensures that the battery is charged when the light flux drops in cloudy weather or when the sun sets behind the clouds and due to the presence of internal resistance in the solar element, which reduces the output voltage when the load is connected, and also to ensure that the battery is charged to the required 14.4 V. Figure 6 shows the graphs of average hourly solar power generation on a clear sunny day (Figure 6(a)), cloudy day (Figure 6(b)), variable cloudiness (Figure 6(c)), and snow cover (Figure 6(d)). One of the negative properties of the solar battery is the fact that the maximum power is taken from the solar battery when the resistance of the external load satisfies the condition. Since, with a constant external load, this condition is continuously violated depending on the illumination and temperature, it is necessary to take this circumstance into account when developing solar power plants.

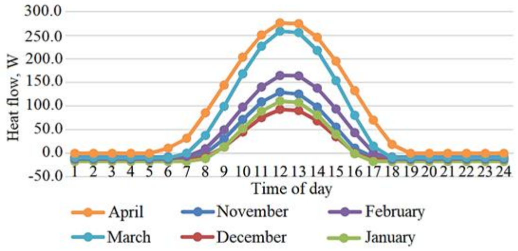
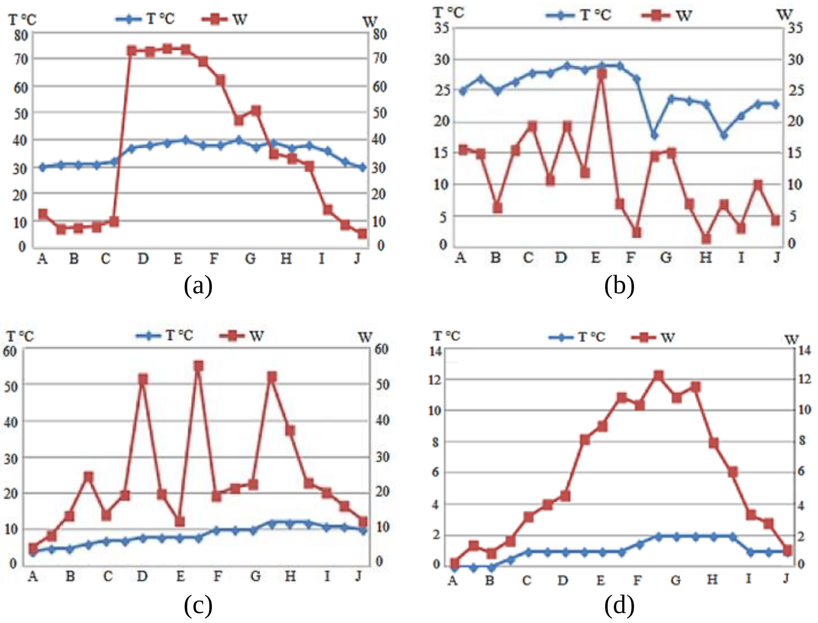


Figure 5. Warm flow through 1 m^2 of greenhouse roof from November to April by the hour during the day on an inclined surface in the south-west direction



Note: Daytime in hours: A-8.00; B-9.00; C-10.00; D-11.00; E-12.0; F-13.00; G-14.00; H-15.00; I-16.00; J-17.00

Figure 6. Average hourly electricity production of a solar panel, depending on time, weather conditions, and seasons of the year of (a) a clear sunny day, (b) a cloudy day, (c) variable cloudiness, and (d) snow cover

4. CONCLUSION

The possibility of using the heat of solar radiation entering the greenhouse extension for a private residential building during the cold season was analyzed. For March and April, heat input from solar radiation fully satisfies the heating needs, and the available surplus can be used to heat water for the hot water supply. When using energy-saving double-glazed windows and heat recovery, heat input into the greenhouse also satisfies the heating needs in November. Using exhaust air heat recovery significantly reduces the heating load. From November to February, the heat requirement can only be partially satisfied by solar energy and the main heat source is required a boiler. Using energy-saving glass units to accumulate solar energy is more efficient; however, the cost of one square meter of energy-saving glass units is, on average, about 102 Manat (Azerbaijan money), and two layers of transparent cellular polycarbonate 16 mm thick will cost about 33.29 Manat per square meter, which will significantly affect the economic indicators. The study of alternative energy sources shows that their use in the future is inevitable, the environmental hazard of each of them is individual, and it is necessary to conduct scientific research on the impact of non-traditional energy sources on the environment.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

This study received permission from the Azerbaijan Republic Government. All informed consents are based on the recommendations of the Ministry of Science and Education of the Azerbaijan on soil research.

ETHICAL APPROVAL

This study complies with the research ethics code, ensures that all procedures are carried out in accordance with established ethical standards, and has received approval from the relevant ethics committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [THA], upon reasonable request.

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