



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 1, January 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Formation of the Microclimate of Premises of a Residential House with a Passive Solar Heating System under Climate Conditions of the Republic of Uzbekistan

(PhD)dots.Nusiratjon Norov, asst.Yulduz Khudaynazarova

Tashkent Institute of Architecture and Civil Engineering, Uzbekistan

ANNOTATION: In Uzbekistan, large-scale measures are being taken to introduce energy-saving technologies in the construction industry, aimed at reducing the operational energy consumption of civil and industrial buildings. One of the important issues in the implementation of these tasks is the improvement of building design methods with solar energy supply for the development of houses with specified energy efficiency characteristics, the design of enclosing structures that provide the necessary heat resistance of the building.

KEYWORDS: energy saving, solar heating, solar energy, building energy consumption, comfort, alternative sources, thermal inertia, temperature conditions.

Due to the limited reserves of fossil fuels and environmental pollution by combustion products, much attention is paid in the world to the use of environmentally friendly renewable energy sources, primarily solar energy, for energy supply of buildings. One of the promising areas is the use of solar energy for heating buildings. In developed countries, such as the USA, Germany, Russia, Denmark, Italy, Finland, the Netherlands, Japan and other countries, special attention is now being paid to the creation of new types of energy-efficient buildings with solar heating.

The strategy for the further development of the Republic of Uzbekistan for 2017-2021 set such tasks as: "... increasing the competitiveness of the national economy, ... reducing energy and material costs in the economy, widespread introduction of renewable energy sources and energy-saving technologies in the construction."

One of the important issues in the implementation of these tasks is the improvement of building design methods with solar energy supply for the development of houses with specified energy efficiency characteristics, the design of enclosing structures that provide the necessary heat resistance of the building.

Uzbek solar technicians G. Umarov and R. Avezov in the early 70s of the last century studied the possibility of using solar energy to heat buildings. The study of architectural issues in the design of heliodoms was carried out by V.A. Akopdzhanyan, M.M.Zakhidov, A.A.Saidov and N.N. Norov. An analysis of previous studies, as well as experience in the design and construction of solar houses in Central Asia, shows that the development of more advanced and energy-efficient design solutions with a stable temperature regime in accordance with hygienic standards requires the accumulation of sufficiently complete and reliable information about the processes of formation of the temperature regime in heliodome in local climatic conditions.

In addition, taking into account the existing discrepancies between the data of theoretical and experimental studies, known approximate formulas for estimating the attenuation of temperature fluctuations and thermal inertia, which were obtained on the basis of a simplified linear model of the process of unsteady heat conduction that replaced the nonlinear model of the heat transfer process, need to be clarified [1].

The Law of the Republic of Uzbekistan "On the rational use of energy" provides for the use of renewable energy sources, as an important direction in ensuring the saving of depleted hydrocarbon fuels and replenishing the country's energy resources in order to ensure sustainable development of energy, which is the basic sector of the country's economy.

Forecast estimates for the country of the gross energy potential of renewable sources by region were obtained, possible scenarios for their use were developed, and the expected replacement of mineral fuel was determined. The environmental and social aspects of the use of alternative energy have been worked out. The collected and analyzed materials in this area prove the need to accelerate the use of renewable energy sources, primarily in rural areas, especially in areas not provided with natural gas and electric energy. Scenarios for the use of renewable energy sources have been worked out taking into account international requirements for the development of energy in any country



using national level criteria. At the same time, scenarios of energy development were simulated. According to the traditional development without involving alternative sources, and the most effective scenario with an active policy on the use of renewable energy sources. At the same time, possible positive structural changes in the production structure of the balance of primary fuel and energy resources were identified [2].

According to the results of work at the macroeconomic level, the forecast scenario for the primary fuel and energy resources of the balance and consumption of these resources for the period 2010-2020. and taking into account the situation with pollutant emissions in the regions of the republic, electricity shortages in certain regions, problems with heating rural houses in certain regions, the forecasted socio-demographic situation and the experience of using renewable energy sources, priority directions for involving renewable energy sources in the balance of the republic's regions were identified Uzbekistan.

However, the large-scale use of renewable energy sources is constrained by the lack of development of specialized laws, regulatory documents and legal acts aimed at stimulating the development of the use of renewable energy sources. A study of the current regulatory framework shows that there is no mechanism to stimulate the development of alternative energy, such as the use of soft loans and taxation. There is no direct law or any single act covering the necessary practical aspects of the development and implementation of renewable energy sources. Based on the analysis of foreign legislative practice, the main barriers to development and investment in the field of renewable energy sources are identified. Three scenarios have been developed for the development and improvement of the regulatory framework of the Republic in the field of renewable energy.

One of the main solar engineering requirements for designing buildings with solar heating is the directivity of the solar radiation receiver. Since the productivity of heat depends not only on the technical characteristics of solar systems, but also on the angle of inclination and the orientation of its beam-receiving surface.

The purpose of this research is to determine the optimal tilt angle of the solar receiver and the sector of its acceptable orientation for passive solar heating systems. To determine the limits of a possible deviation from these solar technologies in specific situations of architectural design [3].

The amount of heat generated by the solar receiver can be determined by the formula:

$$Q_v = Q_p \times \eta \times F_g \quad (1)$$

Where, Q_p - total solar radiation incident per unit helio receiver surfaces;

η, F_g –accordingly, the efficiency and area of the solar receiver.

As can be seen from formula (1), the heat generated by the installation is directly proportional to the total solar radiation entering its surface. In turn, the intensity of solar radiation is a function of the orientation and angle of the installation itself, i.e.

$$Q_p = f(\alpha, A) \quad (2)$$

Where, α, A - tilt angle and azimuth of the helio receiver.

It is known that the southern orientation is the optimum azimuth of the helio receiver. In order to determine the optimal angle of inclination of the solar receiver, we calculated the total solar radiation received on various surfaces installed at an angle of 30, 40, 50, 60, and 90 °. The direct radiation intensity is determined according to the method proposed by I.S. Sukhanov. The value of the scattered radiation arriving at the surfaces under consideration is determined by the following formula:

$$D_n = \frac{1+\cos\alpha}{2} D_g \quad (3)$$

The calculation results for the months included in the heating period in Uzbekistan are shown in table 1.

Table 1.

Receipts of total solar radiation for geographic conditions 40° S, (kJ/m² hour)

Month	Sunny time		Sun coordinates		Total radiation incident on various surfaces						
	The first half of the day	Afternoon	Height	Azimuth	Norm	Horizon	Inclined angles, degrees				
30							40	50	60	90	
21/XI							8	4	8,2	55,4	403
	9	3	17,0	44,1	687	243	1886	2074	2212	2271	2074



	10	2	24,0	31,0	795	374	2669	2895	3042	3092	2719
	11	1	28,6	16,1	838	454	3155	3390	3541	3578	3083
	12		30,2	0,0	854	483	3314	3561	3700	3737	3205
	Amount per day				26397	11694	20300	22064	23234	23657	20971

Month	Sunny time		Sun coordinates		Total radiation incident on various surfaces						
21/XII	The first half of the day	Afternoon	Height	Azimuth	Norm	Horizon	Inclined angles, degrees				
							30	40	50	60	90
	8	4	5.5	53.0	271	43	498	574	641	687	716
	9	3	14.0	41.9	662	198	1722	1940	2095	2183	2083
	10	2	20.7	29.4	796	326	2552	2820	3000	3088	2820
	11	1	25.0	15.2	853	408	3050	799	3347	3612	3218
12		26.6	0.0	869	436	3230	3511	3700	3779	3356	
	Amount per day				25278	9997	18876	11960	22069	22755	21029

Month	Sunny time		Sun coordinates		Total radiation incident on various surfaces						
21/I	The first half of the day	Afternoon	Height	Azimuth	Norm	Horizon	Inclined angles, degrees				
							30	40	50	60	90
	8	4	8.1	55.3	1802	356	821	939	1031	1081	1068
	9	3	16.8	44.0	3029	1052	1969	2170	2313	2372	2170
	10	2	23.8	30.9	3478	1609	2765	3008	3163	3222	2828
	11	1	28.4	16.0	3666	1957	3260	3520	3683	3721	3210
12		30.0	0.0	3733	2087	3427	3691	3846	3884	3335	
	Amount per day				27683	12034	21071	22965	24227	24675	21889

Month	Sunny time		Sun coordinates		Total radiation incident on various surfaces						
21/II	The first half of the day	Afternoon	Height	Azimuth	Norm	Horizon	Inclined angles, degrees				
							30	40	50	60	90
	7	5	4.8	72.7	884	126	247	268	293	306	284
	8	4	15.4	62.2	2870	934	1462	1563	1617	1626	1370
	9	3	25.0	50.2	3511	1693	2501	2627	2681	2665	2141
	10	2	32.8	35.9	3779	2284	3281	3435	3473	3423	2694
11	1	38.1	18.9	3909	2644	3758	3922	3976	3893	3235	
12		40.	0.0	3947	2455	3922	4089	4140	4064	3138	
	Amount per day				33855	17816	26422	27721	28224	27888	22169



Month	Sunny time		Sun coordinates		Total radiation incident on various surfaces						
	The first half of the day	Afternoon	Height	Azimuth	Norm	Horizon	Inclined angles, degrees				
							30	40	50	60	90
21/III	7	5	11.4	80.2	2309	620	742	742	725	687	473
	8	4	22.5	69.6	3373	1538	1890	1902	1860	1764	1194
	9	3	32.8	57.3	3805	2334	2899	2925	2874	2728	1856
	10	2	41.6	41.9	4006	2941	3683	3725	3658	3214	2375
	11	1	47.7	22.6	4127	3348	4190	4236	4152	3964	2711
	12		50.0	0.0	4152	3482	4358	4412	4332	4127	2820
	Amount per day					39390	25044	31165	31471	30872	28840

Based on a comparative analysis of the solar radiation arriving at the surface, installed at different angles of inclination, it was revealed that in winter the optimum angle of inclination is that angle that allows you to capture the sun's rays at noon, in other words, in the middle of the day, the sun's rays fall perpendicular to the installation[5]. This can be expressed by the following formula:

The most unfavorable month for solar heating is January, since during this period the efficiency of the solar collector is the lowest at the maximum values of the heat load of the heated building. Therefore, the angle of inclination of the solar receivers must be selected based on the maximum collection of sunlight in January. If we take into account that the average solar declination in January = - 20°, then formula (5) will take the following form:

$$\alpha_{onm} = \varphi + 20^\circ \quad (6)$$

Thus, the optimal tilt angle of a solar receiver designed for heating buildings is the latitude of the area where the construction of a solar house is supposed to be, plus 20°.

Calculation of the thermal stability of a "normal" building using the example of a typical project of a one-story 3-room rural residential building of a higher comfort class, series 184-32s -10.

Table 2 shows the thermal characteristics of a traditional rural residential house of the 184-32s -10 series for cases of single and 0,5 times air exchange.

At the same time, a single air change is the norm for living quarters, and 0.5 times air change is accepted as a norm in a number of European countries. In the present calculations, reduced air exchange will be considered as a way to reduce the building's heat consumption. As you can see, the calculated thermal characteristic of the compared object has a value of = 527.8 with a single air exchange and = 491.8 with 0.5 times air exchange.

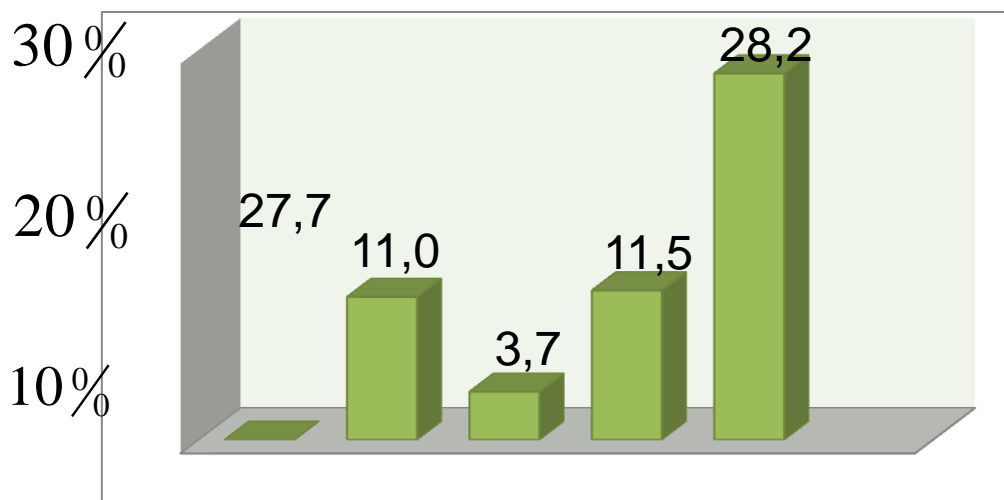


Fig-1. The structure of heat losses through the enclosing structures rural residential building series 184-32s -10.



The value of the heat accumulated or given off by building structures when their surface temperature changes by 1.00 is determined by the ratio of internal heat-intensive structures. In “ordinary” houses, such as the analyzed typical one-story rural housing, series 184-32s -10, external enclosing structures cannot serve as heat accumulators within the normalized temperature regime of residential premises. On a chip, in winter, the temperature on the inner surface of these structures is much lower or within the minimum allowable air temperature inside the dwelling.

Taking into account the above, the value is calculated only for the internal massive structures of the building. Numerically, this value is equal to 3252 Wh/s. In order to obtain comparable results, heat accumulation by furniture is not taken into account in the calculations. Therefore, the value of the exponential function exponent is:

$$\frac{q}{W} = \frac{527,8}{3252} = 0,162 \text{ with a single air exchange;}$$

$$\text{и } \frac{q}{W} = \frac{491,8}{3252} = 0,151 \text{ at 0.5 times air exchange.}$$

The calculation formulas for the current temperature are as follows:

$$t = t_0 e^{-0,162\tau} + T(1 - e^{-0,162\tau});$$

$$t = t_0 e^{-0,151\tau} + T(1 - e^{-0,151\tau}).$$

Below we calculate the current change in temperature in the room from the moment the heating was turned off. The calculation is performed for the conditions

Tashkent city for January is the most unfavorable month of the heating period, with an average temperature. The final calculation formulas are as follows:

$$t = t_0 e^{-0,162\tau} + \left(\frac{Q}{527,8} - 1\right) (1 - e^{-0,162\tau})$$

with 1 air change and

$$t = t_0 e^{-0,151\tau} + \left(\frac{Q}{491,8} - 1\right) (1 - e^{-0,151\tau}) \text{ at 0.5 times air exchange.}$$

I. CALCULATION OF THERMAL STABILITY OF AN ENERGY-EFFICIENT BUILDING WITH SOLAR HEATING BUILT IN THE VILLAGE OF BURCHMULLA OF THE REPUBLIC OF UZBEKISTAN

1.1. Building dimensions: building area - 267.8 m²; construction volume of one room is 91m³; living rooms area - 27.6 m²; The energy calculation is performed for a room on the ground floor.

1.2. Heat transfer resistance of external walls 1.5 bricks plastered on both sides with effective external insulation 5 cm (Expanded polystyrene).

$$R_0 = \frac{1}{\alpha_n} + R_1 + R_2 + R_3 \dots R_n + \frac{1}{\alpha_e} = \frac{1}{23} + \frac{0,05}{0,04} + \frac{0,02}{0,76} + \frac{0,38}{0,52} + \frac{0,02}{0,76} + \frac{1}{8,7} = \frac{2,19M^2C}{Bm}$$

1.3. Walls 1.5 bricks without insulation, plastered on both sides

$$R_0 = \frac{1}{\alpha_n} + R_1 + R_2 + R_3 + \frac{1}{\alpha_e} = \frac{1}{23} + \frac{0,02}{0,76} + \frac{0,38}{0,52} + \frac{0,02}{0,76} + \frac{1}{8,7} = \frac{0,95M^2C}{Bm}$$

Double glazed PVC windows and stained glass

$$R_0 = 0.31 Bm^0 C/M^2.$$

Table 3

Thermal characteristics of an energy-efficient residential building with solar heating built in Birchmulla Republic of Uzbekistan

No	Heat looss throgh structures	Area m ²	Heat transfer resistance m ² °C/Bт	Heat loss Bтч/°C
1	Wall		3,75	8,5
2	Winter garden		-	<u>Option 1.</u> 23,7
			-	<u>Option 2.</u> 15,7
			-	<u>Option 3.</u> 8,1
3	Doors		-	-
3	Paul ^{*j}		-	-



4	The ceiling ^{**)}		2,73	8,1
5	Total transmission losses			<u>Option 1.</u> 40,3/1,46 *
				<u>Option 2.</u> 32,3/1,17
				<u>Option 3.</u> 24,7/0,89
5	The flow of heat to vent. 88,3м ³ в час		1x88,3x0,24	21,2
			0,5x88,3x0,24	10,6
6	Thermal characteristics-q	1 multiple air exchange		<u>Option 2.</u> 53,5/1,95
				<u>Option 3.</u> 45,9/1,66
		0,5 multiple air exchange		<u>Option 2.</u> 42,9/1,55
				<u>Option 3.</u> 35,3/1,28

(*) - energy consumption per 1 m2 of the heated area of the room at a temperature difference of 1 ° C.

Total heat storage surface of building structures:

$$F_0 = F_{\text{wall}} + F_{\text{paul}} = 18 \times 3,2 + 27,6 = 85,5 \text{ m}^2$$

1.4. Heat loss from the dwelling ($t_v = 20\text{°C}$) through the winter garden is considered as heat loss by a fence protected from the outside air by an unheated room. 3 possible cases of heat loss through the winter garden are considered.

Option 1. Without the use of curtains in the arched opening and blinds of the winter garden.

$$Q = 1/0,31 * 10(t_v - t_{\text{н}}) + 1/0,95 * 6(t_v - t_{\text{н}}) = 3,23 * 10(20 - (+4,65)) = 495,8 + 96,6 = 592,7 \text{ Вт}$$

where $t_{\text{н}}$, the average air temperature in the winter garden,

$$t_{\text{н}} = [t_{\text{в}} \Sigma(F_1/R_1) + t_{\text{н}}(F_2/R_2)] /$$

$$[\Sigma(F_1/R_1) + (F_2/R_2)] = [20 (10/0,31) + (-)5(6/0,95)] / [(10/0,31 + 6/0,95) + (19/0,31)] =$$

$$= (771 - 306) / (38,6 + 61,2) = 465 / 99,9 = + 4,65\text{°C}$$

Option 2. The use of a heat-insulated curtain on the glazing of the winter garden.

$$Q = 1/0,31 * 10(t_v - t_{\text{н}}) + 1/0,95 * 6(t_v - t_{\text{н}}) = 393,3 \text{ Вт}$$

где, $t_{\text{н}} = [t_{\text{в}} \Sigma(F_1/R_1) + t_{\text{н}}(F_2/R_2 + R_{\text{sh}})] / [\Sigma(F_1/R_1) + (F_2/R_2 + R_{\text{sh}})] = +9,8\text{°C}$

Option 3. The use of a heat-insulated curtain on an arched opening and closed blinds of the winter garden glazing.

$$Q = 1/(0,31 + 2 * 0,14 + 0,01/0,08) * 10(t_v - t_{\text{н}}) + 1/0,95 * 6(t_v - t_{\text{н}}) =$$

$$= 1/0,72 * 10(t_v - t_{\text{н}}) + 1/0,95 * 6(t_v - t_{\text{н}}) = 13,9(20 - 9,9) + 6,3(20 - 9,9) = 204,0 \text{ Вт}$$

где, $t_{\text{н}} = [t_{\text{в}} \Sigma(F_1/R_1 + R_{\text{sh}}) + t_{\text{н}}(F_2/R_2 + R_i)] / [\Sigma(F_1/R_1 + R_{\text{sh}}) + (F_2/R_2 + R_i)] = +9,9\text{°C}$

Below, in the form of a diagram, a comparison of specific heat losses per 1 m2 of heated area of buildings is given.

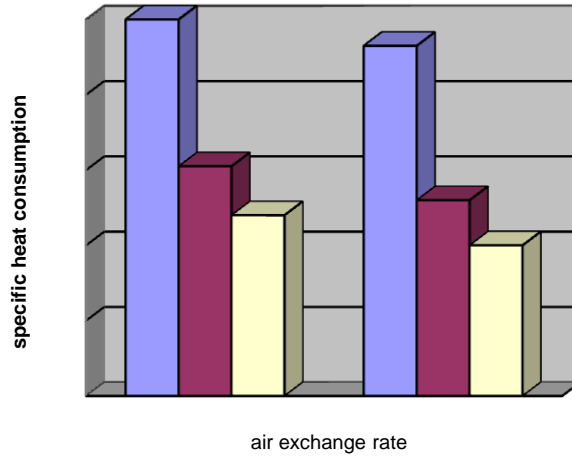


Fig-2. Comparative indicators of specific heat losses.

In an ordinary one-story house, reducing the air exchange rate from 1 to 0.5 times air exchange reduces heat loss by 7%. In solar houses, a decrease in the air exchange rate significantly reduces heat loss. The maximum difference between the specific heat consumption is 2.5 times.

Along the chip, the walls outside are effectively insulated. The temperature of their inner surface is close to the air temperature in the room and they are taken into account when calculating the value

$$W' = 85.5 \cdot 0,15 \cdot 0.2 \cdot 1700 = 4360 \text{ Bm} \text{ } ^\circ\text{C} / \text{Jac}$$

Therefore, the value of the exponent of the exponential function is

$$\frac{q}{W} = \frac{45.9}{4360} = 0.0105 \text{ with a single air exchange}$$

$$\frac{q}{W} = \frac{35.3}{4360} = 0.0081 \text{ at 0.5 times air exchange.}$$

The calculation formulas for the current temperature are as follows:

$$t = t_0 e^{-0.0105\tau} + T(1 - e^{-0.0105\tau}), t = t_0 e^{-0.0081\tau} + T(1 - e^{-0.0081\tau}).$$

As you can see, the exponential function index of an energy-efficient house with solar heating is 7 times lower than that of ordinary rural housing with a single air change and 8.4 times lower with 0.5 times of air change.

Below we calculate the thermal stability of the room through the current temperature change in the room since the heating was turned off. The calculation is carried out for the conditions of Tashkent for January - the most unfavorable month of the heating period with an average outside temperature. The final calculation formulas take the form:

$$t = t_0 e^{-0.0105\tau} + \left(m \frac{q}{45.9} - 1\right) (1 - e^{-0.0105\tau}) \text{ with 1 air change and}$$

$$t = t_0 e^{-0.0081\tau} + \left(m \frac{q}{35.3} - 1\right) (1 - e^{-0.0081\tau}) \text{ at 0.5 times air exchange}$$

where, m is a coefficient that determines the ratio between direct heating by solar energy of the room and accumulated heat.

We calculate the thermal stability of an ordinary house by the example of a typical project of a rural house of the 184-32c-10 series and a solar house by modeling the course of changes in the internal air temperature. In order to exclude other effects on thermal processes, the value of the incoming solar radiation is taken as = 0 in the calculations. That is, the calculation is performed for cloudy weather. The measurement period is taken as 72 hours -3 days. This period was chosen taking into account the fact that the alternation of clear, semi-clear and cloudy weather types from climate analysis most likely occurs every 2 -3 days. The calculated formulas obtained allow varying other possible combinations of weather conditions for other months of the heating period.



II. CONCLUSION

As you can see, in an ordinary house with traditional designs of fencing, as an example of a typical one-story rural housing, series 184-32s -10, the temperature drops quite quickly after the heating is turned off. The first 4 hours, the temperature from 20 ° S drops to 12 ° S. The rate of decline is 2 degrees per hour. In less than a day, in 20 hours it crosses the 0 ° S border. After 29 hours, the air temperature in the room almost drops to an ambient temperature of -1.0 ° S. The daily temperature drop is 20.5 ° S, with an average drop rate of $20.5 / 24 = 0.85$ degrees per hour.

In a sunny house, thanks to the use of effective external thermal insulation, the exponential function index $\frac{q}{W}$ is 15 times less than a regular building with 1 time air exchange and 18.6 times less with 0.5 times air exchange. Due to the increase in heat resistance, the temperature drop is much slower. Despite the fact that temperature changes in a solar house are described by an exponential dependence, due to the minimum value of the indicator $\frac{q}{W}$, a linear dependence is practically obtained.

As can be seen from the graph, in a sunny house, without additional heating, during the day the temperature drops by 4 ° S with a single air exchange and 3°S -0.5 times air exchange. The rate of temperature drop is $4/24 = 0.17$ degrees. per hour and $3/24 = 0.13$ deg. per hour, respectively. In a sunny house, the average daily rate of temperature drop is 5 and 6.5 times slower, respectively, compared to a conventional building. Smoothing temperature fluctuations is considered a mandatory property of a solar house.

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