Low-energy architecture in the south of Russia

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Abstract. For the certification of the building (establishing the efficiency class), a simplified calculation of the excess heat energy during direct solar heating of the building can be applied. This excess is possible under appropriate climatic conditions of the construction site and the parameters of translucent structures. An example of a building project with low-energy architecture for the climatic conditions of Krasnodar is given. The use of passive solar heating devices reduces energy consumption for building heating by 43% and, accordingly, reduces carbon dioxide emissions into the atmosphere.

Introduction
The Decree of the Government of the Russian Federation of January 25, 2011 No. 18 “On Approval of the Rules for Establishing Energy Efficiency Requirements for Buildings, Structures and Requirements for the Rules for Determining the Energy Efficiency Class of Houses” states that all buildings must have energy consumption labels inform consumers and influence the further development of the industry.

The development of advanced technologies and technical solutions for new types of energy efficient buildings of class A and B with passive solar heating and cooling based on a sun-optimized architecture taking into account the climatic conditions of the southern Russia and using local building materials will allow such design.

The U.S. Department of Energy and the National Renewable Energy Laboratory (NREL) conducted extensive national surveys of passive solar homes, home owners and potential buyers [1]. Some key findings:

- Passive solar homes work generally require an average of about 30% less energy for heating than "conventional" houses, with some houses saving much more.
- Occupants of passive solar homes are pleased with the performance of their homes (over 90% "very satisfied"), but they rank the comfort and pleasant living environment as just as important (in some regions, more important) to their satisfaction, and in their decision to buy the house, as energy considerations.
- Passive solar home owners and lenders perceive the resale value of passive solar houses as high.

According to the Institute of Energy Strategy, the potential of solar energy entering the territory of Russia in just three days exceeds the energy of the entire annual electricity production in the country. The amount of solar radiation varies from 1500 hour per square meter per year in remote northern areas to more than 2000 hour in the south (Figure 1). In many regions using solar energy is beneficial. For
example, in Transbaikalia and Yakutia there are more sunny days and solar radiation than in such southern areas as Krasnodar or the Crimea.

![Russian federation. Insolation map](image)

**Figure 1.** Zoning of the territory of the Russian Federation by the number of hours of sunshine per year. A source: cn.solarsystems.msk.ru

**Analysis of recent achievements and publications**

An excellent ancient example to illustrated thermal mass principle is cliff dwellings in Colorado created by the ancestral Pueblo people. By the end of the 12th century, they began to construct the massive cliff dwellings. The south facing structure and overhang provides summer shade by blocking the sun thereby cooling the space below from the desert heat (Figure 2, left photo). Buildings on the south side are heated by a low winter sun (Figure 2, right photo).

There are two concepts of passive solar heating of buildings [2,3]:

In Direct Gain passive systems solar radiation, transmitted through south-facing glazing is directly absorbed within the building interior space as sensible heat (Figure 3). Since both solar collection and heat storage occur within the living space of the building, large quantities of thermal storage mass are required per unit window (or collector) area in order to keep interior temperature fluctuations to a minimum.

![Figure 2. Mesa Verde Park. Source http://www.visitmesaverde.com/](image)

In an indirect gain passive system solar radiation is intercepted and absorbed external to the heated space (Figure 4). Thence the absorbed thermal energy is either naturally conducted through mass storage to the heated space, or naturally convected by a fluid to heat storage and/or the heated space. Since solar collection is removed entirely and heat storage partly removed, or uncoupled, from the living space in
an indirect gain passive system, the temperature variation, within the living space is minimized while allowing wider temperature variation and proportionately less mass of heat storage materials than in a direct gain system.

**Figure 3. Sunspace**

**Figure 4. Thermal Storage Wall**

An unresolved part of the problem of increasing energy efficiency is the lack of an information model for the process of passive solar heating of buildings, which includes the parameters of the climatic conditions of Russia, the constructive parameters and the position parameters of translucent structures.

Advantages of Passive Solar [1]:

- Energy performance: Lower energy bills all year-round
- Attractive living environment: large windows and views, sunny interiors, open floor plans
- Comfort: quiet (no operating noise), solid construction, warmer in winter, cooler in summer (even during a power failure)
- Value: high owner satisfaction, high resale value
- Low Maintenance: durable, reduced operation and repairs
- Investment: independence from future rises in fuel costs, will continue to save money long after any initial costs have been recovered
- Environmental Concerns: clean, renewable energy to combat growing concerns over global warming, acid rain and ozone depletion

The aim of the work is to assess the increase in energy efficiency of buildings with low-energy solar architecture of the south of Russia.

**Low-energy architecture**

For areas with a large number of sunny days per year, more than 1,700 (Figure 1), the energy efficiency of buildings can be significantly improved through the use of low-energy architecture. During the heating period, this is carried out by means of passive solar heating, which is provided by passive solar heating devices: south-facing windows, sunspace, and thermal storage wall. Figure 5 shows the southern facade of a three-story energy-efficient building with ground and mansard floors, designed according to the principles of low-energy architecture. Figure 6 shows the interior of the living room in winter. A low winter sun insulates solar space and living space to its full depth, thereby providing efficient passive solar heating.

In the summer, protection against overheating is provided by solar protection devices or sunspace, as shown in Figure 7. With a high summer sun, insolation of sunspace is insignificant. This can be judged by a narrow solar strip in the interior of solar space.

**Heat balance**

For the certification of the building (establishing the efficiency class), a simplified calculation of the excess heat energy during direct solar heating of the building can be applied. Excessive thermal energy passing through the windows of the south orientation:

\[ \Delta Q_w = Q_{ins} - Q_{loss} \]  

(1)
where $Q_{\text{ins}}$ - average hourly isolation for the heating period,

$Q_{\text{loss}}$ - average hourly heat losses during the heating period.

\[ Q_{\text{ins}} = I_s \times \tau_1 \times \tau_2 = 78W/m^2 \times 0.75 \times 0.76 = 44.5W/m^2 \quad (2) \]

where $I_s$ - total hourly solar radiation to the south facade for the heating period, which can be selected on the solar radiation isoline map [4]; $\tau_1$ - opaque shading factor; $\tau_2$ - solar transmittance.

The values of the average hourly total solar radiation for the heating period are selected from the map (Figure 8), which is designed as an information model that includes the following information:

- average hourly solar radiation;
- duration of the heating period for which solar radiation is determined;
- total solar radiation, which is related to one square meter of the vertical facade of the southern orientation.

Average hourly heat losses during the heating period in Krasnodar:

\[ Q_{\text{loss}} = K \times (t_{\text{in}} - t_{\text{out}}) = 1.8 \times (20 - 2.5) = 31.5W/m^2 \quad (3) \]

where $K = 1/R = 1.8W/m^2\, ^\circ C$ - thermal conductivity of the glass;

$R = 0.55$ - coefficient of resistance to heat transfer of translucent structure;

$t_{\text{in}}$ - indoor temperature [5];

$t_{\text{out}}$ - average daily outdoor temperature during the heating period [5].

Excessive thermal energy passing through the windows of the south orientation:

\[ \Delta Q_w = Q_{\text{ins}} - Q_{\text{loss}} = 44.5W/m^2 - 31.5W/m^2 = 13W/m^2 \quad (4) \]
This means that the building receives an additional 13W of solar heat every hour through the square meter of the southern orientation translucent structure during the heating period.

Reducing the environmental burden on nature is carried out by reducing the burning of fossil fuels using passive solar heating. The heat balance diagram (Figure 9) shows that in a designed building in the climatic conditions of the Krasnodar Territory, the burning of fossil fuels can be reduced by 43%.

As a result of research [6], during the combustion of gaseous fuel $V_{\text{fossil}}$, equal to 1.05 m³/m³, each saved kWh of thermal energy reduces CO₂ emissions by 2.87 kg. This will lead to a proportional reduction of CO₂ emissions, which will contribute to improving environmental safety and sustainable development of the southern regions of Russia.

![Figure 8. The total solar radiation on the vertical south facade with really cloudy, W/m²](image)

![Figure 9. Heat balance of the building during the heating period](image)

**Summary**

1. In areas of the Russian Federation with more than 1,700 sunny days per year, the energy efficiency of buildings can be significantly improved by designing buildings on the principles of low-energy architecture. At the same time, the energy saved for heating the building is not less than 30%. In the example given in the article, the savings of fossil fuels amounted to 43% for a building in Krasnodar.

2. Significant energy savings consumed by the building for air conditioning during overheating can be achieved through effective sun shading. This is the prospect of further development in this area.

**References**

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