Energy management strategy in the construction industry

S Prokhorov

1 Vladimir State University named after Alexander and Nikolay Stoletovs, Gorkiy street, 87, 600000 Vladimir, Russia

E-mail: oc204@bk.ru

Abstract. Saving energy resources is the first priority of the world community. In modern society, construction industry has a huge impact on the economic, social and technological environment of human life. New architectural forms and concepts are emerging, building materials and technologies are improving, environmental friendliness and friendliness of buildings to the surrounding nature increases. Currently, issues related to improvement of the economy's energy efficiency are attracting everyone's attention. Projects of energy-saving and energy-active houses are becoming increasingly popular. Existing construction regulations originate in the 70-90s of the last century, and do not reflect modern reality. Another important aspect of the introduction of modern technology is the environmental pressure during construction and installation works. It raises a question about the need to develop economically and technically sound standards in the design and organization of construction, compliance with which would be monitored not only at the stage of project documentation, but also during the building process. The study addressed the issues of energy consumption reduction at the construction design and maintenance stages, during building and installation works, as well as in sanitary, technical and material support of construction production

1. Introduction

The problem of energy efficiency improvement in our country, is regulated by Federal Law No. 261 “On energy saving and on energy efficiency improvement and amendments of certain legislative acts of the Russian Federation”. Therefore, the quality and high manufacturability of all components of construction, on which the achievement of high energy efficiency depends, are of particular importance.

The life cycle of a building is quite diverse, but it can be divided into several main stages: design, implementation of the project (construction of a building or structure), operation (maintenance) and dismantling (reconstruction). At all these stages, it is necessary to consider the opportunity of minimization of energy costs and the resource saving possibility. And if the approaches to the design and operation of real estate objects are well studied, from the energy saving point of view, then, in modern Russian reality, not enough attention is paid to energy efficiency issues at the stage of project implementation. [1, 2] However, if to analyze the accumulated experience and requirements for passive and energy-active structures, we can build a strategy which will help to improve resource saving and energy efficiency in the performance of installation and construction works. [3,4] Modern construction industry - is a great interconnected system of various departments, the coordinated work of which influences the efficiency of construction in general: starting from the development of method statement, preparation of the building area and the immediate construction works, up to quality control.
and processing of as-built documentation. And there is no need to forget about the logistical and utility support of the construction operations. [5].

2. Methods

BIM-technologies are increasingly used in the design of objects. The result of BIM modeling is a comprehensive computer model that describes both, the object itself, and the process of its construction. [6, 7] Compared with the traditional approach, they have several advantages:

- reduction of time for preparation of project documentation;
- ability to detect 2D design errors;
- reduction of construction costs;
- cost control;
- reduction of time for project implementation.

At the design stage of construction organization plan and the plan for the construction works, a digital model of the construction site allows to avoid undesirable effects of negative and harmful factors, to optimize time, material and human resources. In particular, by analyzing the 3D model of the designed building, it is possible to choose the most rational methods of work, to organize the territory of the construction site and to monitor the processes of technological operations, as well as to carry out the operational management of the financial resources. [8,9]

In addition to the obvious advantages, the use of a complete digital model allows to increase the automation and mechanization of construction works, and therefore to save energy for domestic needs (by reducing the construction period), and also to save energy for the operation of construction equipment (by optimizing the performed work and by reducing unnecessary technological operations), etc. [10]

Currently, the geodesic survey of the site and the geodesic control over the construction process is mainly carried out by hand. The development of computer technology and control systems allows us to speed up this work, without reducing the required accuracy of the measurements. Commercially available unmanned vehicles supplied with high-resolution cameras, lidars and other equipment, can easily explore the construction area and promptly display information on digital maps and three-dimensional models, which is a very effective solution compared to traditional methods. [11] In particular, “Brasfield & Gorrie”, one of the largest private construction companies, uses a 3D model obtained with help of drones to compare actual excavation works on a construction site with planned targets. By using unmanned aerial vehicles, they were able to evaluate the results of earthworks much faster than if traditional methods were used, and at the same time didn’t lose accuracy. [12]

Another aspect of energy saving during the property construction is the use of modern construction equipment and modern methods of the mechanized works production. This task can be divided into two subtasks: the first is the direct reduction of energy consumption by using modern machines and mechanisms, the second is the minimization of technological operations and errors caused by the human factor. Modern models of construction equipment produced by leading manufacturers, are equipped with hybrid propulsion systems, which allow not only to reduce fuel costs, but also to reduce noise and emissions to the environment during their work. [13] One of the most effective energy saving means of the construction machines with hydraulic drive equipment, is recuperative system with an energy storage device. [14].

For electric propulsions, energy recovery systems are becoming more and more relevant. The regenerative braking system allows to stop the car without using conventional brakes, thereby increasing their service life, and in the meanwhile turning the kinetic braking energy into electric current. [15]

VirtualSite Solutions” software provides real-time monitoring of technical conditions, as well as performance of the equipment, and can quickly identify the underutilized machines. [16] The integration of these products with 2D and 3D positioning systems allows to more carefully monitor the effectiveness of the use of machines and produce their maintenance. The use of modern diagnostic remote control systems, aimed to maintain equipment in good condition, reduces the risk of sudden
failure and reduces energy consumption during the operation of machines with defective equipment [17].

The next important aspect which can increase energy saving during the production of construction and installation works, is the household supply.

Building companies already aspire to maximize the use of the thermal energy released inside the residential and public buildings, and maximally protect them from heat loss through external surfaces and ventilation. Unfortunately, this method is marginally used in construction camps and auxiliary facilities. The basic principles of designing an energy efficient facility - are the maximum use of the thermal energy released inside the object, maximum protection against heat loss through external surfaces and ventilation, and the use of alternative energy sources. [18]

These buildings tend to use heating technology, ventilation, lighting, water supply, sewerage which require minimal energy consumption. For this purpose renewable energy sources are used (solar, wind, etc.). Along with this, attention is drawn to reduction of heat loss, reduction of air leakage and its infiltration through gaps and joints, as well as to the increase of the resistance of heat transfer to the outside, in the winter season. [19] In summer, natural ventilation is provided by airing, and for cooling there used radiators or evaporation method. Furthermore, the flow of solar energy reduces by shielding. The above-mentioned measures in the complex with local climatic conditions, make it possible to provide good heat transfer regulation in domestic premises, and to reduce energy costs.

In general, all activities can be divided into:

- Space-planning solutions, which facilitate energy savings;
- The use of energy-efficient thermal insulation of exterior walls, in order to reduce the transfer of heat to the outside of the building;
- The use of energy-saving windows, vents, blinds;
- Increasing the entry of daylight into the room, in order to reduce artificial lighting costs;
- Heat recovery and recovery of warm air which removes from the building.
- The use of energy-saving lighting.

In particular, the transition from stand-alone construction trailers to modular and interlocked premises reduces the area of the cooled surface, and thus improves the thermal performance of buildings. In integrated buildings it is possible to use a heated vestibule, which can significantly reduce the cost for the maintenance of internal temperature.

The use of self-powered heat supply sources with a quantitative and qualitative method of heat output regulation, as well as automated heating units with weather-dependent regulation, can significantly reduce heating costs.

Electric heaters must be replaced with air heating systems, which allows to quickly warm up the room and to maintain the required temperature. It is advisable to combine heating systems with ventilation and air conditioning systems, so this will allow to use recuperation systems and reduce energy consumption for heating and dehumidification.

It is also necessary to foresee the possibility of moving away from traditional types of boilers towards alternative sources of heating (for example, solar panels and collectors), heating with air (which implies electric heating of the air supplied by means of a controlled ventilation system).

As practice has shown, for the summer daylight hours in the Moscow region, one flat-plate collector is able to heat 250-300 liters of water up to 90°C for 7 hours. At the construction site, where the roof area is small, solar collectors can be used as primary water heaters. [20]

To illuminate the construction site, it is advisable to use solar panels with batteries. In particular, the Twilight system tracks the movement of workers and cars, and automatically adjusts the level of lighting. This will cause the initial costs, but will pay off during constant use. In addition, the use of lamps based on LEDs can significantly reduce energy consumption and regulate the luminous flux.

The studies were carried out basing on the calculation procedure of construction organization plan - Guidance Documents in Construction 12-46.2008 "Methodical recommendations for the development and design of construction organization project, the project of demolition (dismantling), and the method statement"
The effectiveness of the decisions taken was evaluated using the ratio of the average price per unit, determined by the standard method \( (P_{av}) \), to the average price per unit in case of using perspective technologies and perspective methods of work organization \( (P_{out}) \) formula (1):

\[
\text{Effectiveness} = \frac{P_{av}}{P_{out}}
\]

The effectiveness of the decisions was evaluated by determining for each option the amount of construction and operating costs, using the dependence (1):

\[
C_{red} = \sum_{t=0}^{t=t_{c}} K_t (1+E_n)^t + \sum_{t=1}^{t=t_{c}} P_t (1+E_n)^t
\]

where \( K_t \) and \( P_t \) are investments and operating costs in the corresponding year \( t \); \( 1/(1 + E_n)^t \) is the cost distance factor that takes into account the decrease in the significance of costs incurred in \( t \) years; \( t_{c} \) is the year that limits the period of summation of costs for the options under consideration:

The use of automation systems helps to improve the use of working time, reduces its loss, and ultimately increases the growth of labor productivity. The growth of labor productivity, while reducing internal labor regime time loss, can be determined by the formula:

\[
W = \left( \frac{100-q_n}{100-q_{n1}} - 1 \right) \times 100
\]

where \( W \) - is the growth of labor productivity,\%; \( q_{n1} \) and \( q_{n2} \) - is the loss of working time before and after the implementation of measures,\%.

3. Results

"Multifunctional sports complex with a swimming pool, universally applicable hall and SPA" in Reutov, Moscow region, was selected for the study. The built-up area is 7500.00 m\(^2\), the building volume is 78421.12 m\(^3\), the total area of the building is 13094.40 m\(^2\).

Table 1. The results of the calculation

| Indicator                                      | Standard (Guidance Document in Construction 12-46.2008) | Calculation (considering energy efficiency measures) |
|-----------------------------------------------|--------------------------------------------------------|-----------------------------------------------------|
| Number of workers per year, people            | 102                                                    | 88                                                  |
| The need for utility rooms, m\(^2\)           | 354.68                                                 | 239.36                                              |
| The need for construction machinery, units    | 45                                                     | 30                                                  |
| The operation cost of construction equipment, million rubles | 45.568                                               | 40.101                                              |
| The need for energy resources:                |                                                        |                                                     |
| - electric energy, kVA                        | 897.9                                                  | 688.8                                               |
| - water m\(^3\)/day                           | 51.9                                                   | 38.8                                                |
| - fuel, tons                                  | 89.3                                                   | 75.5                                                |
| - heating, MW                                 | 12.24                                                  | 10.11                                               |
| Estimated cost of construction, million rubles| 340.568                                                | 368.651                                             |
| Duration of construction, months              | 30                                                     | 24                                                  |
| The effect of duration reduction, million rubles| -                                                     | 21.337                                              |
| Profit for early commissioning, million rubles | -                                                     | 13.563                                               |

The project demand for personnel was determined on the basis of performance rate per worker per year, the cost of annual volumes of work and the percentage of the number of employees by their categories.
The need for basic construction machines, mechanisms and vehicles was determined on the basis of the physical volumes of work and the operational performance of machines and vehicles, taking into account the accepted organizational and technological construction schemes.

The need for energy resources is determined by direct counting.

The building period is determined by the calculation based on the construction norms and regulations 1.04.03-85 * Norms of the duration of construction and backlog in the construction of buildings, structures, and industrial facilities.

Over and above the calculated indicators of the construction organization project, it is necessary to take into account the time for the development of technological documentation using modern design systems.

The use of AUTODESK® software products based on BIM 360 modules has greatly simplified the as-built and design documentation, despite the fact, that at first there were certain difficulties in the cooperative interaction between the customer, the contractor and the general designer. But in view of the fact, that the general designer had prior experience of working with BIM modules in the field of architectural and structural design, it was not a big deal to introduce the control and construction management module. The financial costs on the software products are planned to be recouped by the reduction of time for design and construction, and by the use of more technological solutions during the organization of the construction production. The ability to directly monitor the execution of design and construction and installation work in real time via mobile applications, became an extra incentive of the implementation.

4. Discussion

Studies have revealed both positive and negative points of the proposed solutions:

- The use of modern software products that are based on the creation of a unified database, and providing the possibility of joint management, allows to significantly reduce the time for the design work and the coordination of building technological concepts, especially in case of a possible change in the delivery schedule of building materials, or in case of additional restrictions which were not detected at the design stage (in this project, during construction and installation works, it have been discovered that some service lines were not mentioned in the as-built drawing, so it was required to make changes in the earthworks project and the project of communications disassembling);
- The use of modern systems aimed at automation of production works, and in particular production of earthworks, allows to reduce the number of process operations, and as a consequence to increase the productivity, to reduce operating time of the machine, and thus to increase its lifetime before the service and maintenance;
- The implementation of modern methods of work execution, as well as their proper planning, reduces the need for human and material resources, which ultimately affects the energy savings;
- The use of blocked welfare facilities reduces construction needs for electricity, heat energy and air conditioning;
- The use of modern technologies allows not only to reduce the need for material, technical, human and energy resources, but also to reduce the cost of construction, and to increase the competitiveness of the construction organization.

The negative points include:

- BIM-design requires more time and a higher skill level of the staff, as well as additional software costs. However, the initial time spent on building of a full-fledged 3D model is compensated by the reduced duration of coordination, approval and correction of project documentation between the contractor, the customer and other stakeholders, and for large developers, it is easier to manage projects through mobile applications and the Internet;
- The transition to modern systems of automated production in the field of construction and installation works management, allows to improve the quality of work performed, and to
implement integrated control of construction work on the site. However, in this case, the
machine parks of construction organizations must be fitted with modern equipment, and staff
must be retrained, to be able to work with it, which will lead to the rise of construction costs;
this is especially important for regional organizations;

- Automation leads to the reduction of employees engaged in the production of works, and can
cause social tensions. On the other hand, it stimulates people to master promising technologies
and methods of work, and also frees up personnel and resources for the implementation of a
larger number of projects.

References

[1] Tsygankov V 2015. Real estate: Economics, management. 2. 45-48
[2] Emelyanova Ya. 2018. Theory. Practice. Innovations. 11 (35). 150-154
[3] Larionov A. 2018. Construction economics. 1 (49). 18-26
[4] Vasilenko N 2018 The System Principle of Compactness as a Defining One in the Formation of
Functional and Planning Structure and in the Forming of Power-Saving, Power-Active,
Environmentally-Friendly and Hi-Tech Buildings. IOP Conference Series: Materials Science
and Engineering(2018) 032086
[5] Luchkina V 2018. System technology. 3 (28). 5-13
[6] Park J, Cai H 2017. Automation in Construction. 77. 15-23.
[7] Iyina O 2017. Real estate: Economics, management. 2. 72-75
[8] Vitasek S, Matejka P. 2017. Utilization of BIM for automation of quantity takeoffs and cost
estimation in transport infrastructure construction projects in the Czech Republic. IOP
Conference Series: Materials Science and Engineering. (2017) Vol. 236.
[9] Garyaev N 2018. Analysis of risks arising in the implementation of BIM - technologies in
construction organizations. // MATEC Web of Conferences. (2018) Vol. 251.
[10] Shadyzhev Z, Malsagov M, Evloev Sh, Palunkoev M., Merzhoev I, Mangushev N 2018.
Economics and entrepreneurship. 8 (97). 608-612
[11] Pogorelov V 2016. Engineering Herald of the Don. 1 (40) 58
[12] Korenev V, Orlova N, Ulybin A, Fedotov S 2018. Construction of unique buildings and
structures. 2 (65) 40-58
[13] Kristal M, Kisel T 2018. Economic efficiency of innovations in construction: The use of the
pilotless equipment. MATEC Web of Conferences (2018) Vol.256.
[14] Savinkin V, Kuznetsova V, Yakovlev V 2016. Bulletin of the Siberian state automobile and
road Academy. 2 (48) 18-25
[15] Mukhametshina R, Petrov A 2017. Topical issues and bases of international cooperation in the
field of high technologies. 2 111-113
[16] Shcherbakov V, Buntsev I, Shcherbakov I, Astrakhantsev V 2018. Interekspo Geo-Sibir. 1 57-
63.
[17] Vershinin S 2018. Various aspects of the use of automated control systems in the production of
construction works and as part of a complex of precision agriculture (Orel) pp. 78-89
[18] Albuquerque P, Ohi D, Pereira N, Prata B, Barroso G 2018. Journal of Control, Automation and
Electrical Systems. 29(6) 718-730
[19] Samarín O 2018. Reliability and safety of energy. Vol. 11. No.2. 149-153
[20] Weeratunge H, Hoog J, Dunstall S, Narsilio G, Halgamuge S 2018. Life Cycle Cost
Optimization of a Solar Assisted Ground Source Heat Pump System. IEEE Power and
Energy Society General Meeting (2018) PESGM.2018.8586063