



**SYNOPSIS**

Report 92 p., 19 fig., 15 tab., 59 sources, 11 appendixes.

ENERGY EFFICIENCY, ENERGY CONSUMPTION OF BUILDINGS, ENERGY SAVING, ENERGY CAPACITY, INVESTMENT.

Research object: energy efficiency in all sectors of economic activity and ways to improve it.

The purpose of the research is to develop an effective model of "energy efficiency" of buildings that will contribute to economic growth and improve the quality of life of the population.

Research methods: the methodological basis of the report was the fundamental research of domestic and foreign authors in the field of energy efficiency policy; methods of statistical, comparative, econometric analysis.

Main results and novelty. As a result of the project implementation for the period, the following were identified: problems of “energy efficiency” of buildings in housing and industry; considered the international experience of investment incentives for energy efficiency projects in housing and communal services and industry, including the analysis of regulations; the collection and processing of data on the actual energy consumption of buildings and financial indicators of investments in energy efficiency, including an examination of one building; a methodology for rating assessment of energy efficiency projects was developed and new standards were proposed; proposals to activate a green economy based on the PPP principle and the introduction of energy service contracts were developed, including a proposed business plan based on an expertise of the building; scenarios for investment incentives of energy efficiency in buildings and tools for innovative services and business models have been developed, an algorithm for the implementation of energy efficiency tools in buildings for the Republic of Kazakhstan has been proposed.

The main design, technical and economic indicators: an expertise of building was carried out, investment proposals were developed to reduce energy consumption to 62% of the current level.

Degree of implementation - a package of recommendations has been prepared for the implementation of energy efficiency projects for private companies (there are implementation acts) and government authorities of the Republic of Kazakhstan.

Field of application - in the system of housing and communal services, in industry to improve the energy efficiency of buildings and reduce energy consumption.

Efficiency: applied investment instruments are identified.

During 2018-2020, the project participants published 17 articles, including 6 in journals included in the Scopus database and 6 at the conferences included in the Scopus and Web of science databases, published one textbook, one monograph and received three copyright certificates.

**РЕФЕРАТ**

Есеп 92 б., 19 сур., 15 кесте, 59 дереккөз, 11 өтінім.

ЭНЕРГИЯ ТИІМДІЛІК, ҒИМАРАТТЫҢ ЭНЕРГИЯ ТҰТЫНУЫ, ЭНЕРГИЯ СЫЙЫМДЫЛЫҚ, ЭНЕРГИЯНЫҢ ЖҰМСАЛУЫ, ИНВЕСТИЦИЯЛАР.

Зерттеу нысаны: экономикалық қызметтің барлық салаларындағы энергия тиімділігі және оны арттыру жолдары.

Жұмыстың мақсаты - экономикалық өсуге және халықтың өмір сүру сапасын жақсартуға ықпал ететін ғимараттардың «энергия тиімділігі» тиімді моделін жасау.

Зерттеу әдістері: есептің әдіснамалық негізі отандық және шетелдік авторлардың энергия тиімділігі саясаты саласындағы іргелі зерттеулері болды; статистикалық, салыстырмалы, эконометрикалық талдау әдістері.

Алынған нәтижелер мен жаңалық. Жобаны іске асырудың нәтижесінде бүкіл іске асыру кезеңінде қолданылатын қаржы өнімдерінің тізімі үшін ғимараттардағы энергия тиімділігіне салынған инвестициялардың қаржылық көрсеткіштері туралы келесі мәліметтер жиналды және өңделді; жасыл рейтингісінің құрылуының халықаралық тәжірибесі қаралды; энергия тиімділігі жобаларының рейтингтік әдістемесі жасалды; МЖC (Мемлекеттік жеке серіктестік) қағидаты негізінде жасыл экономиканы жандандыру және энергетикалық қызмет көрсету келісімшарттарын, оның ішінде ғимараттың сараптамасына негізделген бизнес-жоспарды енгізу бойынша ұсыныстар әзірленді; ғимараттардың энергия тиімділігін инвестициялық ынталандыру сценарийлері жасалды.

Негізгі жобалық-техникалық-экономикалық көрсеткіштер: ғимараттарға сараптама жүргізілді, энергияны тұтынуды қазіргі деңгейден 62%-ға дейін төмендету үшін инвестициялық ұсыныстар әзірленді.

Іске асыру дәрежесі - жеке компаниялардың (іске асыру актілері бар) және мемлекеттік органдардың қызметінде энергия тиімділігі жобаларын іске асыру бойынша ұсыныстар пакеті дайындалды.

Қолдану саласы - тұрғын үй-коммуналдық шаруашылық жүйесінде, өнеркәсіпте ғимараттардың энергия тиімділігін арттыру және энергия шығынын азайту.

Тиімділік: қолданылатын инвестициялық құралдар анықталды.

2018-2020 жылдар аралығында жоба қатысушылары 17 мақала жариялады, оның ішінде 6-сы Scopus мәліметтер базасына енген журналдарда және 6-сы Scopus және Web of Science дерекқорларына енгізілген конференцияларда, бір оқулық, бір монография шығарды және үш авторлық куәлік алды.

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**SYMBOLS AND ABBREVIATIONS**

The following notations and abbreviations are used in this research report:

AHS - automated heating station;

GDP - gross domestic product;

PPP - public-private partnership;

J. - joule;

EBRD - European Bank for Reconstruction and Development;

EU - European Union;

Energy conversion efficiency - coefficient of efficiency;

IFI - international financial institutions;

IEA - International Energy Agency;

R&D - research and development;

UN - United Nations Organization;

RK - Republic of Kazakhstan;

USA - United States of America;

t.o.e. -called - tons of oil equivalent;

t.f.e. - tons of fuel equivalent;

FEB - fuel and energy balance;

EED - EU Energy Efficiency Directive;

ESCO - energy service company;

UNIDO - United Nations Industrial Development Organization.

**INTRODUCTION**

Today, Kazakhstan has large-scale tasks for the effective implementation of best practices in energy efficiency management in various sectors of the economy. Advanced international experience is not the last in this policy, which allows the use of ready-made solutions according the specifics and conditions of development of the republic's economy.

Today, the energy intensity of industry and housing and communal services in Kazakhstan is 4-5 times higher than in European countries. On average, there are 13.8 kg o.e. per square meter in Kazakhstan (162 kWh per m2), and in Germany and France 3.24-3.76 for apartments (38-43.7 kWh) and 7.2-8.2 for individual houses (83.7-95 kWh). The reason for this, in addition to the climatic conditions, is the deterioration of the housing stock. Approximately 70% of buildings in Kazakhstan were built between the 1950s and 1980s of the XX century and do not meet modern thermal insulation requirements, which causes significant heat loss. Losses of resources in other support systems of the agglomerations are 3-4 times higher than the normative indicators, which affects on the inflated tariffs of housing and communal services.

The Republic of Kazakhstan has the potential for energy saving, which is capable of solving the problem of ensuring the country's economic growth. This potential is comparable to an increase in the production of all primary energy resources and is estimated at a 20-30% decrease in energy demand, or approximately 4.6 million tons of fuel equivalent per year, or about $ 2 billion.

The purpose of the work is to develop an effective model of "energy efficiency" of buildings that will contribute to economic growth and improve the quality of life of the population.

The research results in this stage make it possible to form a methodological, regulatory and information base for the transition to an energy efficient economy based on the best world practices for improving energy efficiency, including:

- development of new investment mechanisms and economic incentives to improve the energy efficiency of the building;

- analysis of methods for assessing green building in the context of sustainable development;

- research and adaptation of international experience in rating assessment of energy efficiency projects according the life cycle of a building;

- modeling investment costs to improve the energy efficiency of a building.

These results are presented in this report. As part of the research, interim project reports were used: for 2019 №0219RK01026 and for 2018 №0218RK00163.

In accordance with the work program and schedule, the project executors have completed all the tasks and objectives.

**1 Improving the energy efficiency of housing in Kazakhstan**

The problem of thermal efficiency of existing residential buildings for Kazakhstan is urgent and acute, since the residential sector is the third largest consumer of heat and electricity after the industrial sector, and is also the largest entity in terms of greenhouse gas emissions [1]. In terms of housing and communal services, most of the operated buildings are multi-storey buildings with centralized heating based on separate boiler houses or CHP plants [2,3].

Housing and communal services of Kazakhstan includes 2207 heat supply sources, 5477 power plants (boilers), 11 386.7 km of heating networks. To generate 1 Gcal of thermal energy in housing and communal services from general house heating boilers, it is necessary to use from 0.140 to 0.199 tce. Also, it is necessary to take into account the specific consumption of cold water supply per unit of generated heat energy, which is consumed in the thermal system, from 0.11 to 1.32 cubic meters/Gcal. Electricity consumption for the production of 1 Gcal of thermal energy is from 36 to 47 kW/h [4].

The duration of the heating season in different regions ranges from 3000 to 5000 hours per year. Of the total consumption of heat energy in the amount of 175.2 mln. Gcal, about 74.8 mln. Gcal is heating and hot water supply for the housing stock.

The fixed assets of utilities are already worn out (their wear exceeds 60%) and are energy-intensive, since equipment and technologies have remained from the middle of the 20th century. As a result, emergency outages of hot water supply occur, and the provision of other utilities may also be limited, as a result, the quality characteristics and reliability of the system as a whole decrease. The amount of heat energy losses arising from these reasons amounted to about 8.1 million Gcal in 2016 with the total transfer of heat energy to consumers at 24.3 million Gcal (a total of 64 million Gcal of thermal energy was transferred to consumers) [4].

The housing stock of the Republic of Kazakhstan is 342.6 million m2 of total area (structure based on wall materials in Figure 1), of which 27% of the housing stock related to multi-apartment residential buildings needs various types of repair (repair of facades, roofs, joints wall panels, etc.), and 1.6 million m2 or 0.5% of the housing stock is in disrepair and requires demolition as not appropriate for further living [5].

Figure 1 - Characteristics of apartment buildings by wall materials, area in million m2

Note - compiled by the authors based on [5]

There is a general tendency of energy consumption growth in the republic. We present the average data on heat consumption in the housing and communal services sector of Kazakhstan (230-270 kW \* h/m2), this indicator exceeds the EU average (100-120 kW \* h/m2) and can be compared with the level of consumption in Russia (210 kW \* h/m2) [5].

On average, there are 13.8 kg o.e. per square meter in Kazakhstan (162 kWh per m2), and in Germany and France 3.24-3.76 for apartments (38-43.7 kWh) and 7.2-8.2 for individual houses (83.7-95 kWh).

The reason for this excess, in addition to the climatic, is the deterioration of the housing stock. Approximately 70% of buildings in Kazakhstan were built between the 1950s and 1980s of the last century and do not meet modern thermal insulation requirements, which causes significant heat loss. The level of losses of energy resources in the infrastructure for supplying cities is 3-4 times higher than the normative ones, which is reflected in high tariffs for utilities. The policy in the field of tariff regulation and social protection of energy consumers does not contribute to an increase in the level of availability of high-quality and reliable services for socially disadvantaged groups of the population, and becomes the main obstacle in attracting private capital to modernize the ineffective infrastructure of communal heat supply systems, this issue is especially acute in front of small towns.

Total comparative housing sector energy consumption in kg o.e. per m2 is shown in Figure 2.

Figure 2 - Total energy consumption of the residential sector by country

Note - compiled by the authors based on [6] and ODYSSEE data

When building new residential buildings in accordance with the Law on Energy Saving and Energy Efficiency, a prerequisite for putting houses into operation is the availability of modern energy-saving materials, as well as the use of automated metering systems for heat energy and heating consumption, including the mandatory installation of individual metering devices. For buildings and structures in operation, when carrying out major repairs or modernization measures, a prerequisite for the use of modern heat-saving materials with installation in the heat supply system of individual metering devices is mandatory. But these measures are little implemented due to insufficient funding for such events.

By introducing energy saving measures in the modernization of old standard buildings, it is possible to achieve energy savings of up to 59%, including:

- 25% - as a result of increased thermal protection of external walls and ceilings of cold basements and attics;

- 10% - as a result of increased thermal protection of window structures;

- 6% - as a result of a decrease in the volume of air infiltration in the apartment;

- 18% - as a result of the installation of an automated control unit for the heating system.

**2 Energy efficiency projects rating**

The investment attractiveness of energy efficiency projects depends on the use of a variety of assessment tools. Based on financial, technical, environmental and social performance and on previous standards: LEED - Guide to Energy and Environmental Design (USA); BREEAM - Environmental Assessment Method (UK); DGNB - certificate of sustainable construction (Germany), Standard STO NOSTROY 2.35.4-2011 - Residential and public buildings. A rating system for assessing the sustainability of the habitat (Russia) and studies of the concept of optimal cost (cost-optimal methodology), which became widely used after the adoption of the Directive 2010/31 / EC on the energy performance of buildings: Araujo et al. (2016), Ascione et al. (2016), Atanasiu et al. (2013), Ballarini et al. (2017), Becchio et al. (2015), Hamdy et al. (2017), Haase et al. (2015), Enseling and Loga (2013), Leutgöb and Rammerstorfer (2013), Ortiz et al. (2016), Pikas et al. (2015), Tadeu et al. (2016), we developed a rating score to assess the attractiveness of energy efficiency projects [7-19].

The rating is determined by analyzing quantitative and qualitative factors. Among the energy efficiency indicators themselves, 5 groups are distinguished: by measurement methods, by the type of buildings, by the integrity of buildings, by stages of the life cycle of buildings, by types of measurements. According to the groups, groups of indicators are formed, united by certain criteria (Appendix A) [8].

The rating of energy efficiency projects is an opinion on the overall attractiveness of a given project for investors and its development potential. The rating system evaluates energy efficiency projects in 3 main categories. Each of the criteria is expressed by one or a group of indicators. Table 1 proposes rating criteria for evaluating energy efficiency projects.

To assess the overall potential, we sum up the partial parameters:

1) Collection of information and indicators characterizing each particular parameter necessary to assess the overall potential.

2) Calculation of the integral indicator of the parameter for the section.

3) Calculation of the integral indicator of the general indicator.

4) Assigning an energy efficiency rating to the project.

5) Analysis of the results of assessing the rating of energy efficiency.

The final rating assessment is carried out on the basis of the resulting total value of the indicator.

Table 1 - Rating criteria for evaluating energy efficiency projects

|  |  |  |
| --- | --- | --- |
| Criterion | Parameter | Points (maximum) |
| Energy saving and energy efficiency | | 35 |
| Heat consumption for heating, hot  water supply and ventilation of the building | Saving heat energy is achieved through energy-saving measures in the heating system. | From 2 to 16 depending on the energy efficiency category |
| Electricity consumption | Specific electricity consumption for lighting public places in relation to the normative indicator and the use of energy-efficient lighting | 6 |
| Primary energy consumption for utility systems | Equipment energy efficiency according to EU standards From 1 to 8 depending on the energy efficiency category | From 1 to 8 depending on the energy efficiency category |
| Consumption control | Availability of automatic heating point and individual control and regulation of heat consumption | 5 |
| Sustainable and environmental development | | 30 |
| Use of secondary resources | Use of systems of secondary use of resources (ventilation with heat recovery, etc.) | 6 |
| Use of renewable resources | Use of a heat transfer system for hot water supply | 6 |
| Automation of flow control processes | Application of automatic control systems for lighting, humidity and air exchange | 6 |
| Compliance with the standards of light comfort (building insolation) and humidity | Compliance of insolation with the normative coefficients of natural light and compliance with the distance between buildings in accordance with СП РК 2.04-104-2012 and СП РК 3.01-101-2013 | 6 |
| The quality of the organization of waste collection and disposal | Presence of separate waste points within the quarter | 6 |
| Economic efficiency | | 35 |
| The life cycle cost of a building per m2 of a building at NPV> 0 | Total discounted cost of ownership, operation, repair and disposal of a building over a period of time to the corresponding value for an analogue or reference object | 20 |
| Annual cost  operating costs per m2 of the building | Ratio of the average annual cost of operating a residential building to the costs of an analogue or reference object | 6 |
| Payback period | Comparison of the payback period in relation to an analogue object or a reference | 6 |
| Note - compiled by the authors based on [9-22] | | |

When calculating an energy efficiency rating, it is important to understand that the life cycle cost of a project is most sensitive to changes in the level of costs for energy efficiency measures (see Figure 3).

Higher level of investment

Higher level of energy efficiency

Figure 3 - Relationship between investment costs and energy efficiency

Note - compiled by the authors

Depending on the amount of points scored as a result of determining the value of points, the project (building) is assigned one of seven ratings: A, B, C, D, E, F, G (Table 2).

Table 2 - Rating scale of energy efficiency projects

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Factor,  points | 90-100 | 75-90 | 60-75 | 45-60 | 30-45 | 15-30 | 0-15 |
| Classes  appraisals | A | B | C | D | E | F | G |
| Note - compiled by the authors based on [9-22] | | | | | | | |

The process of interrelation of criteria is shown schematically in Figure 4.

Definition of the rated facility (building: new or existing or project of energy efficiency measures)

Identifying energy efficiency measures

Determination of financial and economic conditions

Definition of technical conditions

Calculation of the achieved technical conditions for energy efficiency

Calculation of the achieved financial and economic conditions (LS, NPV oth.)

Comparison of financial and economic characteristics of technical parameters

Comparison of the achieved technical parameters

Determination of the best option for an energy efficiency project

Assigning a rating to a project

Figure 4 - Scheme for assigning a rating to energy efficiency projects

Note - compiled by the authors

The factor «energy saving and energy efficiency» analyzes the parameters of energy efficiency.

The rating parameters for this section are determined according to Figure 5.

Figure 5 - Criteria for the section Energy saving and energy efficiency

Note - compiled by the authors

According to the consumption of heat energy for heating, it is necessary to determine the specific consumption of heat energy for heating the building during the heating period. According to the specific consumption, the efficiency class of the building is determined according to Table 3 and the number of points is assigned from 16 for the most energy efficient (A ++, A +) to 2 for the building of class G.

Table 3 - Energy efficiency class of buildings

|  |  |  |
| --- | --- | --- |
| Energy efficiency class | Energy consumption, kW∙h/ (m2 ∙ year) | Note |
| А++  А+ | less than 25 | passive house standard |
| А | less than 40-50 | ultra low energy house |
| В | less than 80-90 | low energy house |
| С | less than 120-140 | house that complies with building codes and regulations |
| D | less than 160-190 | old buildings that have not been refurbished |
| E | less than 200-240 |
| F | less than 280 |
| G | 280 and more |
| Note - compiled by the authors based on [23] | | |

The scale is based on the end use of single-house and multi-apartment complexes according to the standards of the EU countries - Austria and the Czech Republic. Energy consumption includes heating, hot water production, mechanical ventilation, lighting and additional energy requirements for the standard use of the building.

Electricity consumption for lighting public areas is determined according to Table 4 and is assigned 6 points for compliance with the standard indicator and the presence of LED lighting, 3 points for an excess of 10-20% and 0 for non-compliance.

Table 4 - Basic level of specific energy consumption for lighting systems of public areas of residential buildings, kWh / (m2 year)

|  |  |
| --- | --- |
| Public areas | Indicator |
| Interroom and elevator halls, staircases and entrance lobbies without natural light | 30,0 |
| Elevator halls, stairwells, entrances with natural light | 20,0 |
| Note - compiled by the authors based on [24] | |

Primary energy consumption for utility systems is determined by the level of energy efficiency of the equipment. The energy efficiency class is labeled in 7 main classes, from A (lowest consumption) to G (most energy-consuming), depending on the number of kW consumed by the equipment. After the products reach energy efficiency class A, additional classes A +, A ++, A +++ are added.

According to the labeling of the building efficiency class, a number of points is assigned from 8 for the most energy efficient (A +++, A ++, A +) to 1 for the G class (or no labeling).

For the presence of an automatic heating point, an individual apartment meter of energy consumption and consumption regulation, 5 points are given, for the presence of only a general automatic heating point, 3 points are given and for the absence of these elements - 0 points.

If the automatic regulation of the heating temperature is limited by a CHS (central heating station), then the system corresponds to an ineffective class D, since the heat carrier of the same temperature is supplied to different rooms of the building with different heating requirements. In order to comply with at least standard class C, it is necessary to provide room-by-room temperature control at least one of the listed methods: radiator valves, thermostats, room controllers, etc. For class B, it is necessary to organize room-by-room temperature control with communication between the controllers and the central station. And finally, in order to comply with class A, it is necessary to provide room temperature control with communication between the controllers and the central station plus control of the presence of a person in the room [25].

The factor «sustainable and ecological development» analyzes the parameters of environmental friendliness of housing. The parameters for the section on sustainable and environmental development are shown in Figure 6.

Figure 6 - Criteria for Sustainable and Environmental Development

Note - compiled by the authors

For the first parameter - the use of secondary resources - a maximum of 6 points are given for the use of systems for the secondary use of resources (ventilation with heat recovery and/or heating from sewage, etc.). For the second parameter, a maximum of 6 points are given for the use of one or more systems for the use of renewable resources, such as heat pumps or solar panels. [26]

Humidity and temperature should correspond to the parameters in tables 5 and 6.

Table 5 - Optimal temperature and permissible relative humidity inside the building for the cold season

|  |  |  |
| --- | --- | --- |
| Building type | Air temperature inside the building t, ° С | Relative humidity inside the building,%, no more |
| Residential | 20 -22 | 55 |
| Note - compiled by the authors based on [27-28] | | |

Table 6 - Permissible temperature and relative humidity of air inside the building for the warm season

|  |  |  |
| --- | --- | --- |
| Building type | Air temperature inside the building t, ° С | Relative humidity inside the building,%, no more |
| Residential | 24 -28 | 60 |
| Note - compiled by the authors based on [27-28] | | |

For compliance with all parameters, 6 points are given, otherwise 0.

According to the fourth parameter, compliance with the standards of light comfort and humidity, the lighting system of the facility must meet the requirements in accordance with SR RK 2.04-104-2012 Natural and artificial lighting and to insolation and sun protection of premises, in accordance with national sanitary and hygienic standards (Order of the Minister of Health of the Republic of Kazakhstan dated 26 October 2018 No. RK DSM-29). When calculating natural lighting, the calculated value of the weighted average reflection coefficient of the internal surfaces of the premises should be taken in residential and public premises equal to 0.5 [27-28].

According to the fifth parameter, if there is a separate waste collection system within the quarter, 6 points are given, otherwise 0.

For the economic and financial assessment of energy efficiency projects in buildings, Figure 7 presents the criteria for the section «economic efficiency».

Figure 7 - Criteria for the section Economic efficiency

Note - compiled by the authors

The building life cycle cost is the total discounted cost of owning, operating, repairing and disposing of a building or complex of buildings over a period of time [7].

Calculation of the total cost of the building's life cycle [29]:

BLCC = 𝛴(Cost of land and engineering)/ (1+r)n + 𝛴(Design and construction costs)/ (1+r)n+ 𝛴(Operation and repair costs)/ (1+r)n+𝛴(Demolition costs - income from material sales)/ (1+r)n,

where r is the discount rate and n is the planned life of the building.

Among the factors that contribute to the achievement of improved performance are:

- lower discount rate,

- increase in energy prices,

- reduction of investment costs (or finding the optimal solution).

The second parameter compares the annual operating costs of a building with an analogue or reference building. Annual operating costs per m2 is the average cost of ownership and operating costs per square meter and includes costs for energy, water and other utilities, building maintenance and repairs.

The third parameter shows in what terms the energy efficiency project pays off, considering the savings in operating, maintenance and low resource consumption of the building.

The rating model is based on the developed matrices for choosing alternative options for energy-saving technologies for different types of residential and public buildings, considering the best practices technologies.

The calculation parameters are shown in Table 7.

Table 7 - Calculations for the economic efficiency of the building

|  |  |  |
| --- | --- | --- |
| Economic efficiency | | Points |
| Building life cycle cost per m2 building at NPV>0 | The total discounted cost of ownership, operation, repair and disposal of a building or a complex of buildings over a period of time for a residential building to the corresponding value for an analogue or reference object | 20 at a lower cost, 10 at a comparable amount, and 0 at a higher cost |
| Annual operating costs per m2 building | The ratio of the average annual cost of operating costs for a residential building (energy, water, maintenance, repairs) to the costs of an analogue or standard object | 6 for less cost, 3 for equality or 0 for exceeding |
| Payback period | Comparison of the payback period in relation to an analogue object or a reference | 6 for a shorter payback period, 3 for equality and 0 for exceeding |
| Note - compiled by the authors based on [9-22] | | |

The choice of the best option in terms of the life cycle cost indicator provides for a multivariate analysis of a large number of possible technologies, types of equipment, engineering networks and systems. When determining, it is important to apply the so-called «Trias Energetica» principle, which is based on the following three-step approach:

1) Reduce energy demand by avoiding waste and implementing energy saving measures;

2) Use sustainable energy sources such as wind, sun, water and land;

3) Use the energy of fossil fuels as efficiently as possible and only if there are no sustainable energy sources [9-19].

**3 Investment opportunities of energy efficiency projects**

Increasing investment in energy efficiency requires the country to take an integrated approach to overcoming existing barriers. As a rule, only the simultaneous adoption of measures at the regulatory, economic, financial and socio-political levels ensures the successful creation and subsequent improvement of conditions for the activities of national and international investors to improve energy efficiency in a particular country.

Let's move on to considering the main traditional financial instruments for measures to reduce energy consumption. First of all, price setting is the main stimulating factor in attracting financial investments in energy saving, since prices and tariffs for energy resources have a decisive influence on the use of these resources for heating premises and heating water. Moreover, they directly affect the choice of energy resources, have an impact on specific gravity of the electricity used for those needs for which it is possible to use alternative fuels for space heating and water heating. In all CIS countries, tariffs for energy resources are still below their cost of production, which negatively affects incentives to improve energy efficiency.

The next important item of interest on energy efficiency is the policy for public utility companies. A common measure here is cost-based tariff setting and reforms to increase subsidies for energy prices. Changing the subsidy policy in the energy sector in order to stimulate the use of the most rational investments significantly reduces the burden on the country's budget and allows the released funds to be invested in more energy efficient alternatives, such as government energy efficiency programs, in all sectors of the economy.

The next most common financial instruments are government grants or government support programs designed to help private investors finance large projects or events that cannot receive sufficient funding from their own resources. One of the instruments of this direction is a program of direct support from the state, in which the share of subsidies from the budget should not reach the established maximum level of the total amount of developed energy efficiency measures. An example of a direct support program is one used in France, where an individual property owner has the right to apply to public authorities for a municipal grant for the renovation and energy efficiency of his permanent home (Energy Charter Secretariat, 2004). [30]

Also, a widely used alternative to forms of financial support are government interest-free loans and grants, due to which there is an opportunity to pay interest on a loan. One of the most important areas in terms of financial aspects is tax incentives. In this regard, it is necessary to highlight six main fiscal aspects that are especially important for the issue under consideration:

1. specialized taxes for energy saving projects;

2. application of tax incentives to energy efficiency projects;

3. reduction of capital gains tax after the implementation of energy saving measures;

4. reduction in property tax;

5. reduction of value added tax;

6. allowance for accelerated depreciation or arbitrary depreciation of fixed assets.

One of the promising areas is the development of voluntary agreements between the public and the private sector (PPP). The purpose of signing such programs is to achieve agreed targets in the field of energy conservation that are beneficial for both parties, and for the state - to reduce the volume of emissions of harmful substances into the environment, environmental safety, development and implementation of new energy efficient technologies. An incentive for private investors can be the receipt of tax incentives in exchange for work on the introduction of energy efficient technologies, technical support from the state, and the inclusion of such companies in energy reviews or subsidies in any other form. [30]

Currently, the “white certificates” tool is widely practiced. This is a document confirming the achievement of a certain reduction in energy consumption. The basic principle of white certificates is to set energy efficiency targets and impose obligations on energy companies to achieve these indicators [31-32]. The government intervenes in the market pricing of these certificates in order to stop price reductions and stimulate investments in various types of projects, for example, with a higher social value, or to limit consumer spending.

Another instrument, such as an energy service contract, must guarantee the expected savings in primary energy resources as a result of the implemented measures, which in the PPP model is reflected as an appropriate financial flow that guarantees a return on investment.

Most of the agreements between customers and ESCO are backed by energy efficiency contracts, which determine recurring payments and oblige ESCO to install equipment and guarantee energy savings. ESCO (Energy Service Companies) are generally considered to be an important instrument for increasing investment in energy efficiency [33].

According to Article 18-1 of the Law of the Republic of Kazakhstan “On Energy Saving and Improving Energy Efficiency of the Republic of Kazakhstan” dated January 13, 2012 “in order to save energy and improve the energy efficiency of resources used by individuals and legal entities, including state institutions and subjects of the quasi-public sector, energy service contracts may be concluded with energy service companies”. [34]

By order of the Minister for Investment and Development of the Republic of Kazakhstan dated March 31, 2015 No. 402, standard forms of energy service contracts for individuals and legal entities, including for subjects of the quasi-public sector, were approved.

Figure 8 shows a model of interaction between participants in an energy service contract.

energy saving measures

The financial obligations of the customer during the entire period of the contract are to make payments from the savings that make up the economic effect

ESCO  
Payment by own or  
credit funds,  
realization  
energy efficient  
programs on  
decrease in consumption  
energy resources at the facility  
customer.

• Energy audit  
• Development of an action plan  
• Determining the amount of resource savings  
• Renovation, supply, installation and commissioning of equipment  
• Maintenance of equipment  
• Analysis of results

payment under the contract

Figure 8 - Model of interaction of participants in the energy service contract

Note - compiled by the authors

The main advantages of energy service contracts are the following:

- lack of financial investments and loan obligations by the customer;

- determination of savings indicators based on energy audit data and required equipment;

- availability of an effective mechanism for the return of investor funds due to the savings obtained as a result of energy efficient technologies implementation.

However, despite the obvious advantages of this tool, as well as the adoption of a number of fundamental regulatory legal acts, the growth of the energy service sector in Kazakhstan has not been properly developed.

The reasons for the underdevelopment of energy service contracts in the Republic of Kazakhstan are:

- faults in the regulatory framework that do not allow investors to effectively invest in energy service contracts;

- unfavorable conditions for ESCO for the payment of VAT and CIT, since the companies receive payments for the project within four to five years, at the same time, banks do not provide borrowed funds to pay taxes, and taxes are paid from their own funds;

- weak information support of mechanisms for financing energy saving projects.

An energy service contract is a complex mechanism of interaction between the parties, which consists of the following stages by the customer (Figure 9).

Figure 9 - Stages of the implementation of the energy service contract by the customer

Note - compiled by the author

Figure 10 shows the stages of the implementation of the energy service contract by ESCOs.

Figure 10 - Stages of the implementation of the energy service contract by the ESCO

Note - compiled by the author

Figure 11 shows the stages of the implementation of an energy service contract by a financial organization.

Figure 11 - Stages of the implementation of the energy service contract by the financial organization

Note - compiled by the author

The above financial methods or instruments (tariff setting and government programs) can be attributed to the group of traditional ones that have proven their validity. Let us consider innovative methods of using financial instruments using the attraction of funds from pension reserves, the stock and credit market, insurance mechanisms and a new mechanism for attracting crowd-funding investments in order to attract financing at the lowest possible cost.

In order to mobilize financial resources at a lower cost, which would be most consistent with the best risk / reward ratio in energy efficiency programs, finance professionals actively use the possibilities of attracting funds from pension reserves, insurance mechanisms and the use of crowd-funding in their work.

New instruments appear on the stock market, such as the developed initiative to issue on the stock market, the so-called climate bonds, which is a non-profit international enterprise with the purpose to attract financial resources from the stock market. Climate bonds are typically issued to attract funding for programs to develop low-carbon economies such as high-speed railways, as well as to attract investment in energy conservation, including the design and manufacture of energy-efficient household appliances and the production of electric vehicles [35, 36].

“Green bonds” of the stock market are “new debt instruments, upon the sale of which the issuer-borrower acquires capital from investors to use for its internal corporate needs. The issuer-borrower, in the future, pays certain amounts to the investor when the bond is redeemed, taking into account the amount of interest for the entire term of its circulation”. A special difference of green bonds is that the proceeds from the sale of bonds are used only for projects related to renewable energy, energy efficiency, environmentally friendly transport or low-carbon infrastructure. [37, 38]. Green bonds serve as a vehicle for investing in sustainable energy. By financing such bonds, investors represented by the state can ensure a policy of achieving sustainable development goals, and companies can demonstrate their social responsibility to society (Figure 12) [39, 40].

Figure 12 - Issues of green bonds by purpose for 2014-2018

Note - compiled by the authors based on [40]

These bonds are based on a common debt instrument that is understandable for investors, which is characterized as a relatively safe investment in comparison with other equity instruments. According to the standards (Climate Bonds Standard 3.0, December 2019), updated annually by the green bond working group coordinated by the International Capital Markets Association, these include [39, 41-48]:

1 climate change mitigation and adaptation,

2 natural resource conservation,

3 biodiversity conservation,

4 prevention and control of pollution.

According to the International Development Finance Club (IDFC) policy, activities eligible for climate change mitigation funding include [39, 41-48]:

1 Renewable energy,

2 Low carbon and efficient power generation,

3 Energy efficiency,

4 Agriculture, forestry and use of land,

5 Non-energy greenhouse gas reductions,

6 Waste products and waste water,

7 Transportation,

8 Low-carbon technologies,

9 Mixed issues such as policy support and funding instruments.

The process for issuing a green bond is similar to that of a regular bond, with the addition of an emphasis on governance, transparency and visibility. The process of issuing green bonds with emphasis on this type of process is schematically depicted in Figure 13.

Figure 13 - Green Bond Issue Process

Note - compiled by the authors based on [47]

Based on international experience, it can be summarized that the development of the domestic market of green bonds can help the development of both the financial system and projects in the field of ecology and energy efficiency in Kazakhstan, as it can [44-47]:

- raise awareness of green investments and develop a common understanding of what green investments are;

- create a tool to facilitate interaction between investors and issuers: green bonds expand the investor base and become attractive to investors in the fixed income sector, as, along with financial parameters, they are interested in company's sustainable development plans;

- support government policy of sustainable financing: green bonds provide a tool to reorient capital flows from brown to green through existing market infrastructure;

- contribute to the development of new infrastructure, since long financing terms allow stimulating the reorientation of the technological base;

- implement best practices for disclosing sustainable investments and exposure to climate risks;

- reduce the risk of investment instruments, as the share of green bonds with high investment ratings is higher than the market average;

Green Bonds are an effective tool for financial centers looking to strengthen their competitiveness with respect to sustainable finance goals. Green bonds are a good vehicle for introducing some of the foundations of sustainable finance into a financial center ecosystem. Various parts of the financial center ecosystem can play an active role in the development of green bond markets. Figure 14 shows a diagram of this interaction.

Figure 14 - Scheme of interaction of participants in the green bond market

Note - compiled by the authors based on [48]

Green bonds are well suited to a variety of investors, ranging from individual investors and financial companies to governments and institutional investors (pension funds, insurance companies, and sovereign wealth funds). The latter group is particularly important in the discussion of energy transitions, as institutional investors hold more than $ 100 trillion in assets.

The green bond market is under development in the world and infant in Kazakhstan. This innovative financial instrument has a future, since the projects financed through it expand the list of future investors, emphasizing the company's commitment to sustainable development and preservation of the natural environment. Some of the issues facing the development and distribution of green bonds require in-depth analysis and regulation. The ICMA (International Capital Markets Association) standards can be taken as a basis and verifiers, required for the issue can be determined.

It is promising to use crowd-funding in financing energy efficiency projects, which involves the collection of small personal amounts from individuals (as opposed to large investments made by a small number of investors) and is usually carried out via the Internet, often using social networks. Crowd-funding is considered as a relatively new and safe alternative source of investment by the European Commission.

The banking sector should also participate in financing energy saving and energy efficiency projects. For these purposes, in foreign practice, there are examples of individual specialized banks that capitalize only those companies that make a constructive contribution to solving social, environmental and cultural problems. The Czechoslovak Trade Bank (CSOB), which manages the PHARE Energy Saving Fund (ESF), the Hungarian Credit Bank, which manages the Energy Efficiency Lending Fund (EECF) are among the banks that manage public funds allocated for energy efficiency. This fund was established as part of the energy conservation program run by the German Coal Aid Fund and the Polish Environment Protection Bank, which manages the EcoFund. [49-50].

As a result, therefore, the following can be proposed among the main financial instruments for attracting extra-budgetary financing: an emissions trading scheme; schemes of energy efficiency obligations of energy supply companies – “white certificates”; tariff premiums; environmental taxes, including energy taxes; credit policy; energy service contracts; energy efficiency standards for typical generating equipment; energy saving funds; budgetary subsidies; tax incentives; tax credits; loan guarantees; R&D support in the development of energy efficient technologies.

**4 Implementation of energy efficiency standards through innovative financial instruments**

**4.1 Technical and economic indicators of energy efficiency projects**

Let us consider the calculation of the investment attractiveness of a project to improve the building efficiency based on EPC contracts through energy savings. For the building chosen for inspection in the project, it is known that it was built in the 70s. The heated area of the building is 2076.7 m2. The readings of the heat meter installed in the heat supply station of the building for the period from 02/01/2016 to 03/15/2019 have been analyzed.

For the selected building, the rate of specific heat consumption for heating and ventilation is =0,359W/m3 0С (for a 5-storey building), then during the heating period the heat consumption will be q =0,359\*0,024\* HSDD kWh/m3 a year, HSDD for Almaty 164\*(20-0,4)=3214,40С a day.

Then qv = 27,70 kWh/m3 a year or qs = 27.70\*h kWh/m2 a year = 83,1kWh/m2 a year (h is the height of the building, set to 3,0 m).

Considering that the heated area of the building is 2076,7 m2, it is possible to calculate the total annual heat consumption in the heating and ventilation system Qот = 2076,7 m2 \*83,1 kWh/m2 a year = 172,57 mWh/year or about 148,3Gcal.

If we take into account that the energy efficiency class of such buildings is D, then the deviation from the standardized heat consumption can exceed 50%, i.e. reach 222.45 Gcal per year. In Appendix B, Table B.1 compares the heat consumption of the building for three heating periods and provides an assessment of the energy efficiency class. Thus, it can be stated that the energy efficiency class of the building is E.

Figures 15-17 show diagrams of daily heat consumption of the building for three heating periods.

Figure 15 - Actual daily consumption of heat energy by the building in 2016/17 for heating and hot water supply (Gcal, days) (from 15.04.16 to 15.04.17)

Note - compiled by the authors

Figure 16 - Actual daily consumption of heat energy by the building in 2016/17 for heating and hot water supply (Gcal, days) (from 15.04.17 to 15.04.18)

Note - compiled by the authors

Figure 17 - Actual daily consumption of heat energy by the building in 2016/17 for heating and hot water supply (Gcal, days) (from 15.04.18 to 15.04.19).

Note - compiled by the authors

From Table B.1 and Figures 15-17, it can be seen that the heat consumption for hot water supply in the building does not exceed 13% of the heat consumption for heating and practically has not changed over three heating periods. There was a decrease in heat consumption for heating in 2018/19 compared to the two previous heating periods.

The maximum heat flow for the heating system of a building of energy efficiency class D with a maximum deviation of 50% can be taken as Qmax=148,35 Gcal/year. To calculate the average thermal power for heating, depending on the environmental temperature, we will use the data given in code of practice of RK 2.04-01-2017 Building climatology (Table 8) [51].

## Table 8 - Average monthly and annual outdoor temperature, oC

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| City | Average monthly and annual air temperature | | | | | | | | | | | | |
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Annual |
| Almaty | -5,3 | -3,6 | 2,9 | 11,5 | 16,5 | 21,5 | 23,8 | 22,7 | 17,5 | 9,9 | 2,6 | -2,9 | 9,8 |
| Note - compiled by the authors based on [51] | | | | | | | | | | | | | |

In accordance with code of practice of RK 2.04-106-2012 Design of thermal protection of buildings in Table 4 text=210С (Table 9).

Table 9 - Optimum temperature and permissible relative humidity inside the building for the cold season

|  |  |  |
| --- | --- | --- |
| Typo of buildings | Air temperature inside the building *tint* ,  *°С* | Relative humidity inside the building φ*int* %, no more |
| Residental | 20 - 22 | 55 |
| Note - compiled by the authors based on [51] | | |

In accordance with code of practice of RK 2.04-01-2017 Construction climatology we accept tр= - 20,10С. In accordance with code of practice of RK 2.04-01-2017 Construction climatology, the duration of the heating period (OP) is 164 days, the average temperature of the heating period with a temperature not exceeding 80С and tср=+0,40С (Table 10) [51].

Table 10 - Climatic parameters of the cold season

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| City | Average duration (days) and air temperature (oC) of periods with an average daily air temperature oC, no more | | | | | | Start and end date of the heating period (period with air temperature no higher than 8 oC) | |
| 0 | | 8 | | 10 | |
| duration | t | duration | t | duration | t | begin. | end. |
| Алматы | 105 | -2,9 | 164 | 0,4 | 179 | 0,8 | 22.10 | 03.04 |
| Note - compiled by the authors based on [51] | | | | | | | | |

Figure 18 shows a dependency diagram of the standard heat consumption in relation to the outside air temperature, built according to code of practice of RK 2.04-01-2017 Construction climatology.

Figure 18 - Heat consumption of a building when the outside temperature changes according to SR RK 2.04-01-2017 Construction climatology

Note - compiled by the authors based on [51]

To carry out estimated calculations, it is necessary to obtain daily changes in the outdoor air temperature in Almaty by months of the heating periods 2016-19 (according to the data on the website <http://meteo9.ru/>). From the comparison of the curves of changes in meteorological parameters, it is clear that for the calculation and regulation of the heat consumption of a building, it is necessary to install an automated heating point.

Table 11 shows the results of calculating standard and actual heat consumption of the building by months of the heating period, depending on the average external temperature of the heating period.

Table 11 - Standard and actual heat consumption for heating the building by months of the heating period

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Months | Average outdoor air temperature by SR | Q от, Gcal according to SNiP class en. ef D | Average temperature of the outside air during the heating period 2016/17 act  MetеoGuru | Q от act, Gcal , 2016/17 | Average temperature of the outside air during the heating period 2017/18 act  MetеoGuru | Q от act, Gcal, 2017/18 | Average temperature of the outside air during the heating period 2018/19 act  MetеoGuru | Q от act, Gcal , 2018/19 |
| 10 | 9,9 | 18,7 | 6,6 | 31,97 | 10,5 | 22,98 | 10,6 | 27,83 |
| 11 | 2,6 | 64,4 | 0 | 68,43 | 4,8 | 52,61 | -0,2 | 61,18 |
| 12 | -2,9 | 84,7 | 0,5 | 69,68 | -2,8 | 76,2 | -2,9 | 70,03 |
| 1 | -5,3 | 93,6 | -3 | 79,37 | -10,5 | 89,06 | -2 | 64,83 |
| 2 | -3,6 | 87,3 | -1,9 | 73,4 | -2,5 | 67,69 | -1,7 | 60,06 |
| 3 | 2,9 | 63,3 | 3 | 64,62 | 8,3 | 53,34 | 7,9 | 42,21 |
| 4 | 11,5 | 15,7 | 10,7 | 21,59 | 12,3 | 19,65 | 12,5 | 3,97 |
| Note - compiled by the authors based on [51-54] | | | | | | | | |

There is a noticeable excess of heat consumption during transition periods (overheating) and a lack of heat energy (underheating) in the coldest months of the heating period.

Figure 19 - Comparison of standard and actual heat consumption of the building by months of heating periods

Note - compiled by the authors based on [51-54]

Table 12 shows summary data, comparing heat consumption for heating a building by months and for the heating period 2018/19. Taking into account the actual average temperatures for each month, which differ from those given in code of practice, the building's heat consumption is 17% less than the normative. The calculated heat consumption based on the external temperature is 62% higher than the actual one. At the norm for such a building, as the class E is set above, the heat consumption is about 222 Gcal, which is close to the calculated 204 Gcal.

In accordance with sanitary regulations of RK 4.02-01-2011 Heating, ventilation and air conditioning “Energy efficiency of buildings should be ensured through rational architectural solutions, an economically justified increase in the level of thermal protection of buildings and the use of energy efficient window structures, elimination of cold bridges, the use of an efficient heating system, the use of optimal heat supply and air exchange control systems, and the use of non-traditional renewable energy sources and heat from secondary energy resources in heat supply and hot water supply systems, etc.”

From the above data, it follows that to ensure effective heat supply to the building, a system of automatic recording of the external air temperature during the heating season is required and it is necessary to adjust the regulation of heat energy supply on heating (Table 12).

Table 12 - Comparison of heat consumption for heating the building for the heating period 2018/19

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Month of heating period 2018/19 | Actual heat consumption by metering device, Gcal | tср on SR | tср on Meto Guru | Average standardized heat consumption per month at tср on MetoGuru, Гкал | Deviation of the actual heat consumption from the average standardized, % | Estimated heat consumption by outdoor temperature, Gcal | Deviation of the actual heat consumption from the calculate, % |
| 10 | 27,83 | 9,9 | 10,6 | 17,4 | 57 | 5,87 | 366 |
| 11 | 61,18 | 2,6 | -0,2 | 75 | -18 | 38,76 | 58 |
| 12 | 70,03 | -2,9 | -2,9 | 85 | -18 | 49,46 | 42 |
| 1 | 64,83 | -5,3 | -2 | 81 | -20 | 46,3 | 40 |
| 2 | 60,06 | -3,6 | -1,7 | 80 | -25 | 44,89 | 34 |
| 3 | 42,21 | 2,9 | 7,9 | 45 | -6 | 15,36 | 175 |
| 4 | 3,97 | 11,5 | 12,5 | 14 | -72 | 3,24 | 23 |
| Heating period | 330,11 |  |  | 397,4 | -17 | 203,88 | 62 |
| Note - compiled by the authors based on [51-54] | | | | | | | |

To calculate the economic efficiency of the proposed measures, a business plan for energy efficiency measures of the building has been calculated with various options, such as the installation of an automated heating unit, insulation of the building to reduce energy consumption to class B.

**4.2 Methods for calculating the investment attractiveness of projects by the annuity method**

Based on previous calculations, the need for thermal modernization of residential buildings built before 2000 has been shown. Let's make calculations of investments to improve the energy efficiency of buildings, since the main issue, when deciding to allocate funds for modernization or renovation, is the question of obtaining an economic effect from the implementation of these measures and the economic efficiency of investments. The calculations have been based on the methods of L.N. Danilevsky, O.V. Maksimchuk, O.S. Golubova, A.S. Gorshkov and an analytical center under the Government of the Russian Federation [55-59].

On the basis of the normative and technical characteristics of the building, energy certificates have been developed for a residential five-storeyed brick building without and with insulation. According to Table B.2 of Appendix B, the heat consumption for the heating season before insulation was 318,621.9 kWh/year, and the total heat loss of the building for the heating period was 391,841.1 kWh/year. After energy saving measures, these indicators have been 121309 and 184783 kWh/year, respectively.

Thus, as a result of measures for the insulation of external structures, the consumption of thermal energy during the heating period has decreased by 197312.9 kWh/year, i.e. there has been a 60% decrease. The total heat loss of the building has decreased by 207058.1 kWh/year, i.e. a decrease of 47%. This indicates the effectiveness of this energy-saving measure (Appendixes C and D).

The total amount of expenses required for the thermal modernization of a five-storeyed residential building without purchasing a building-level heat meter is 16,042,506 tenge; with a building-level heat meter it is 16,602,506 tenge.

The methodology for calculating the payback period consists of the following stages:

- decision-making from own or borrowed funds is financed by a residential building renovation project.

- if a decision is made to use borrowed funds, it is necessary to determine the terms of the loan (term, interest rate, number of payments, etc.)

- payback period calculation for different conditions..

We will calculate heat loss to calculate operating costs before and after insulation, as well as with the installation of a building-level heat meter and without. To calculate heat loss through external building envelopes, it is convenient to use the value inverse to the reduced heat transfer resistance, which in international standards is called the heat transfer coefficient of building envelopes and is denoted by the letter U. The value of the heat transfer coefficient is calculated according to formula 1.

(1)

where – heat transfer coefficient of building envelope;

0 - heat transfer resistance of external walls.

The value of U shows how many W of heat energy passes through an outer wall with an area of 1 m2 at 1ºС difference between internal and external temperatures from different sides of the enclosing structure. This coefficient for a given climatic region can be accepted as 1 W/(m2ºС). 0 averages 1,0 m2 ·ºС/W.

The amount of total loss of heat energy passing through 1 m2 of the outer wall is calculated by formula 2:

Gcal (2)

We will calculate the operating costs, taking into account the loss of thermal energy through 1 m2 of the outer wall for one heating season before insulation without installing a building-level heat meter according to formula 3:

(3)

where Ст1 – tariff with VAT for the population living in houses that do not have a common building metering device for heat energy.

According to LLP Almaty Heat Networks, the differentiated tariff for heat supply services without a heat meter is 6,563.75 tenge/Gcal, with a heat meter it is 4,812.19 tenge/Gcal. Table 13 shows the dynamics of growth of tariffs for heat energy in Almaty for the period of 2016-2020.

Table 13 - Growth in the tariff for heat energy for the period 2016-2020

|  |  |  |
| --- | --- | --- |
| Year | Tariff, tenge / Gcal (incl.VAT) | Increase in the cost of heat energy in relation to the previous year, % |
| 2020 | 8841,55 | +24% |
| 2019 | 7130,22 | +18% |
| 2018 | 6042,56 | +15% |
| 2017 | 5585,28 | +12% |
| 2016 | 4975,34 |  |
| Note - compiled by the author based on data from www.alts.kz | | |

We will calculate operating costs, taking into account the loss of heat energy through 1 m2 of the outer wall for one heating season after renovation without installing a building-level heat meter. To do this, we calculate the following parameters according to formulas 4-6:

/(м2·ºС) (4)

(5)

(6)

Operating costs, taking into account the loss of heat energy through 1 m2 of the outer wall for one heating season after renovation with installation of a building-level heat meter according to formula 7:

(7)

Table 14 presents the initial data for calculating the payback period of the investment.

Table 14 – Initial data for calculating the payback period

|  |  |  |  |
| --- | --- | --- | --- |
| N | Characteristics | Designation | Value |
| 1 | Capital costs for the construction of 1 m2 of an external wall without installing a building-level house meter, in tenge | (C1)К1 | 8 431 |
| 2 | Capital costs for the construction of 1 m2 of an external wall with the installation of a building-level heat meter, in tenge | (C1)К2 | 8 725 |
| 3 | Operating costs, taking into account the loss of heat energy through 1 m2 of the outer wall for one heating season before renovation without installing a building-level heat meter, in tenge | (O1)Э1 | 490,9 |
| 4 | Operating costs, taking into account the loss of heat energy through 1 m2 of the outer wall for one heating season after renovation without installing a building-level heat meter, in tenge | (O2)Э2 | 105,02 |
| 5 | Operating costs, taking into account the loss of heat energy through 1 m2 of the outer wall for one heating season after renovation with the installation of a building-level heat meter | Э2(ПУТЭ) (O2heat meter) | 76,9 |
| 6 | The difference in heat energy losses through 1 m2 of the outer wall before carrying out measures to insulate the facades of an existing building (O/Э1) and after warming (O/Э2) without a heat meter, in tenge | ΔЭ(O) | 385,95 |
| 7 | The difference in heat energy losses through 1 m2 of the outer wall before carrying out measures to insulate the facades of an existing building (O/E1) and after insulation (O/E2) with a heat meter, in tenge | ΔЭпутэ(Oheatmeter) | 414 |
| Note - compiled by the authors based on [58] | | | |

The simple payback period of the considered energy-saving measure can be calculated using the formula 8:

(8)

where ΔК – capital costs for the construction of 1 m2 of an external wall - the difference in capital costs reduced to 1 m2 of an external wall, tenge/m2,

ΔЭ – annual savings in money achieved as a result of works on renovation of the facades of an existing building, tenge/m2.

The rate of investment return from facade insulation depends on the cost of thermal energy for heating and the dynamics of its change over time, that is, on the growth of tariffs for thermal energy. Due to the annual increase in heat tariffs, the annual savings in money will increase.

We use formula 9 for calculating the payback period when using our own funds without installing a heat meter, taking into account only the growth of tariffs and the refinancing rate:

(9)

where r - average annual increase in the cost of heat tariffs;

i – interest rate.

This formula reflects such indicators as: the dynamics of the growth of tariffs for heat energy (expressed by a parameter r) and the interest rate (i), which is used to estimate the discounting of future cash flows accumulated as a result of the implementation of a given energy saving measure. In the offered model, it is proposed to make a calculation taking into account the refinancing rate, which is 9.5% according to the National Bank of the Republic of Kazakhstan for 2020.

In the case of a heat meter installation, the payback period according to formula 10 will be equal to:

(10)

Financing from own funds can be considered the option of using a savings account in a second-tier bank for capital repairs of apartment owners in a residential building. If the owners use their accumulated funds in their current account, then the payback period with and without installation will be 13.4 and 13.3 years, respectively.

When considering the option of financing with the help of borrowed funds, it should also be borne in mind that the money saved in subsequent years should be calculated based on the actual cost of money in n years, i.e. future cash flows must be discounted.

In this case, the formula for calculating the payback period should reflect the payback period of the considered renovation option, taking into account the total capital costs for its implementation, loan payments, the increase in the cost of heat tariffs, cash flow discounting achieved through savings as a result of the implementation of this energy-saving measure.

Since it is currently impossible to accurately predict how these variables will change over time in the future, several possible scenarios can only be constructed to solve the problem of assessing the predicted payback period of investments in energy saving.

There are also several cases when considering the use of borrowed funds:

- firstly, the possibility of obtaining a commercial loan from a second-tier bank;

- secondly, the possibility of obtaining a loan on a subsidized basis under government programs.

In either case, we will calculate the payback period with and without installation of a heat meter.

In case that borrowed funds are used for renovation, the total investment is considered as annuity payments. In this instant, loan payments and utility bills for heating are made monthly, which makes it possible to bring the calculation formula to the calculation of the period of permanent postnumerando rent with an equal number of charges m and the number of payments p.

The total investment in energy saving ∆К is determined by formula 11:

(11)

where m - number of loan repayment periods;

А – annuity coefficient;

ΔK – own funds for overhaul.

The annuity factor is calculated by the formula:

(12)

where – monthly interest rate on a loan.

We will calculate the payback period for the option of obtaining a loan in a second-tier bank for a period of 3 years, with an interest rate of 20.5% per annum, without installing a heat meter. At the same time, we will assume an average increase in tariffs of 18%.

The annuity factor is calculated using the formula 13:

(13)

We calculate the total investment in energy saving using the formula 14:

*=*36\*0,0374\*8431=11 234,4 тенге/м2 (14)

The payback period is calculated using the formula 15, while we consider the increase in tariffs on average 18%, the refinancing rate is 9.5%:

(15)

When calculating the payback period for the option of obtaining a loan in a second-tier bank for a period of 3 years, with an interest rate of 20.5% per annum, with installing a heat meter, we use the value = 8 725 tenge/m2, = 414 tenge/m2.

We calculate the total investment in energy saving using the formula 16:

*=*36\*0,0374\*8 725=11 747,3 tenge/м2 (16)

The payback period is calculated using the formula 17:

(17)

Thus, we got a difference of only 0.2 years.

We will calculate the payback period for the option of obtaining a subsidized loan under government programs in the amount of 6% per annum for a period of three years, with the same interest rate on the loan of 20.5% per annum, without installing a heat meter. Thus, the calculation will be made for a rate of 14.5% per annum.

We calculate the annuity factor using the formula 18:

(18)

In this case, the total investment in energy-saving measures will be calculated using the formula 19:

*=*36\*0,0344\*8431=10 329,5 tenge/м2 (19)

The payback period with the same increase in tariffs and the refinancing rate is calculated using the formula 20:

(20)

We will calculate the payback period for the option of obtaining a subsidized loan under government programs in the amount of 6% per annum for a period of three years, with an interest rate on the loan of 20.5% per annum, with the installation of a heat meter. The annuity factor remains at 0.0344.

In this case, the total investment in energy-saving measures will be calculated using the formula 21:

*=*36\*0,0344\*8 725=10 805 tenge/м2 (21)

The payback period is calculated using the formula 22:

(22)

Given the current economic and tariff situation in the Republic of Kazakhstan, the return on investment in the insulation of the facades of a 5-storeyed brick residential building for climatic conditions of Almaty will be no more than 16.2 years.

Annual cash savings for any nth considered year (first: n=1, second: n=2, third: n=3, etc. years), taking into account the growth of tariffs, is calculated using the formula 23:

(23)

However, when considering this formula, it should be borne in mind that the money saved in subsequent years should be calculated based on the actual value of money in n years (discounted), i.e. future cash flows must be multiplied by the discount factor kd. The formula 23 converts to the formula 24:

== (24)

where r – average annual increase in the cost of heat tariffs;

i – interest rate;

n – number of period.

Thus, the calculation of the annual savings, taking into account the growth of tariffs and discounting according to the formulas 25 and 26, will be:

(25)

= 1 270,6 (26)

To calculate the total savings from renovation, it is necessary to multiply the resulting savings per 1 m2 by the total area of the outer walls (the formulas 27 and 28):

(27)

(28)

In the first year, the savings from renovation per 1 m2 will be (the formulas 29 and 30):

(29)

(30)

The total annual savings are (the formulas 31 and 32):

(31)

(32)

Summarizing the above, the present value of the savings is 9,431,799 tenge, taking into account discounting and the concept of the modern value of money, it is 2,417,698 tenge. Discounted cash flow charts are presented in Appendix E. This value can be used in calculating the energy service contract.

The calculations presented above for improving the energy efficiency of buildings when insulating facades are applicable with the simultaneous installation of an Automatic heat station. Otherwise, the insulation of facades can only lead to an increase in the temperature of the internal premises and not provide an energy-saving effect. According to estimations, the simple payback period of an automated heat station together with the installation without loans due to energy saving measures is 4-5 years, with simultaneous installation with facade insulation - 16-17 years. Calculations were also carried out with loans for the purchase of an automated heating station for 10 years and heat modernization for a period of 20 years at an interest rate of 4.5% (the rate of House Construction Savings Bank) and 20% in a second-tier bank. According estimations, the installation of an AHS pays off at any interest rate, since the energy savings cover all interest payments with debt repayment and the cost of capital costs are not high (Table 15). Thermal insulation of a building and thermal insulation with AHS only pay off at a preferential rate, but at the same time it provides a technical increase in the energy efficiency class and the attainability of modern standards.

Calculations show that lengthening the maturity of borrowings helps to cover annual payments of principal and interest by saving energy consumption, while an increase in interest rates lengthens the payback period of the proposed major energy efficiency measures. Thus, measures to stimulate energy efficiency in buildings are impossible without government support for subsidizing the interest rate and extending the loan term.An algorithm for introducing energy efficiency tools in buildings for the Republic of Kazakhstan in the transition to a green economy is presented in Appendix F.

Table 15 - Financial indicators of energy efficiency measures

|  |  |
| --- | --- |
| Proposed measures | Payback period |
| Installation of an automated heat supply station with a heat meter | 4-5 лет |
| Thermal insulation of a building with mineral wool or expanded polystyrene | 13-14 лет |
| Combination of two measures | 16-17 лет |
| Note - compiled by the authors with the technical parameters of the DANFOSS | |

The proposed financial model requires the following proposals and recommendations:

- firstly, it is necessary to tighten the legal requirements for the energy efficiency of buildings and structures built before 2000. Therefore, it is necessary to develop and introduce mechanisms for state monitoring to comply with modern building codes and regulations in the field of energy efficiency through the mandatory implementation of the building's energy passport;

- secondly, it is required to introduce AHS and heat metering systems in the building as a whole and in apartments in particular in order to reduce the payment for utility services for heating and the transition from paying for the amount of heated area to a differentiated heat consumption metering system;

- thirdly, to use guidelines for calculating the economic effect and saving financial resources from the introduction of energy-saving measures. Since the indicator of the savings is the basis of the system of energy service contracts. The results of the payback period of investments in facade insulation were compared with the operational service life of the adopted design solution, which is at least 25-35 years with a technical correct solution and installation, which showed the payback period is less than the predicted service life of the design solution, therefore such a solution should be recognized economically appropriate.

**CONCLUSION**

At the present stage, there is a significant pool of financial instruments that can stimulate the growth of energy efficiency indicators by industry. Solutions and measures were studied in the research, especially in terms of identifying optimal conditions that can contribute to improving the energy efficiency of buildings. An important conclusion on the use of financial instruments is that the responsible government bodies need to radically rethink the very concept of energy efficiency, learning to treat it as an independent source of energy, the value of which is equal to the cost of saved energy resources.

The executors of the project "Improving energy efficiency of industry and housing in Kazakhstan using innovative technologies: standards and financial instruments" have achieved all tasks.

Among the recommendations for improving energy efficiency in Kazakhstan, we propose the following financial measures:

- creation of revolving energy saving funds and business development of energy service companies. The sphere of PPP has a significant number of risks, the regulation and minimization of which can be implemented based on the use of effective foreign experience in this area. Energy service contracts in the world are considered popular financial assets when potential investors can earn significant financial resources from participation in energy efficiency projects and are widely used in Russia, Ukraine and Belarus;

- an interesting tool could be the creation of a "green" bank that finances energy efficient projects through the accumulation of funds from international and Kazakhstani financial development institutions;

- a promising instrument is green bonds that can link debt capital markets through the AIFC and the Kazakhstan Stock Exchange with projects in the energy and other sectors that provide for increased energy efficiency in industry and housing and utilities, and environmental benefits;

- development of standardized banking products for financing energy efficiency programs;

- subsidizing the development of energy efficiency programs, and subsidizing or preferential taxation for the purchase of industrial equipment of high energy efficiency classes.

Among the technical measures proposed for funding:

- Automation of heat energy consumption by apartment buildings (automation of heating stations, frontal regulation): installation of an automated heat supply point will reduce the specific energy consumption in winter from 180 kWh/m2 to 115, which will correspond to class C;

- insulation of the building, basement and attic with overhaul of the roof covering and replacement of external windows in public spaces, which will reduce energy consumption by another 20-25% to class B;

- thermal insulation of pipelines and an increase in the energy efficiency of the equipment of heat points, distribution pipelines for heating and hot water supply;

- restoration/implementation of hot water circulation systems, hydraulic adjustment, automatic / manual balancing of distribution heating systems and risers;

- installation of frequency regulation of pump drives in hot water supply systems;

- installation of automated control of lighting and replacement of incandescent lamps with energy-efficient lighting devices;

- relocation of electrical networks to reduce losses of electrical energy;

- development, together with local governments, of tools to stimulate separate waste collection.

Among the general recommendations:

1. Conducting an energy audit in a building, with obtaining an energy passport.

2. OSI (housing management company) must have a conclusion on energy audit with a list of energy saving measures and their feasibility study.

3. Careful maintenance of current documentation on the state of the engineering part and the building envelope, the availability of regulatory documents in electronic format.

4. Monitoring the state of the building heat supply system during the heating period, comparative analysis for 3-5 years.

5. Periodic thermal imaging inspection of the building envelope and heat supply system.

6. Local and individual regulation of the heating agent supply.

7. Installation of thermostats on heating devices in the apartments of the building.

8. Installation of general and individual metering devices.

9. Provision of lighting for courtyards and entrances with motion sensors and energy-saving lamps.

10. Use of renewable energy sources in the power supply of the building (photovoltaics, heat pumps).

11. Using the energy service approach when implementing energy saving measures.

The application of the financial principles mentioned above has the potential for commercialization within the framework of energy service contracts, as evidenced by the successful thermal modernization of buildings in Eastern Europe and Russia.

Significant investments in energy efficiency are required for the modernization of the housing on the example of a typical building of the 60s and 70s. A residential building located in Almaty was chosen for approbation; more accurate data are given in the report itself and its appendices. PPPs enable governments to avoid capital investment and balance energy investments, reduce energy costs and allocate their budgets appropriately. ESCO energy efficiency projects may face obstacles. Energy efficiency projects can only be implemented with a sustainable financing mechanism. A possible financing solution is the early involvement of banks in large-scale energy efficiency programs supported by a government agency through interest rate subsidies and financial injections. Moreover, in PPP projects, the public authority is a reliable contracting party as they will not shy away from their responsibilities. Entering into such partnerships generates additional revenues through increased private economic activity, profits from public good investments, new investment opportunities and new markets.

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**APPENDIX A**

**Classification of indicators of energy efficiency of buildings**

Natural

Conditionally natural

Cost

At the design stage

Under construction

At the operational stage

Throughout the entire life cycle

Energy efficiency of individual building elements

Energy efficiency of the outer shell of the building

Energy efficiency of the building as a whole

For residential buildings

For public buildings

For industrial buildings

Calculation and analytical

Experimental

Statistical

Instrument

Mixed

By type of measurements

By stages of the building life cycle

By building integrity

По типу зданий

By measurement methods

Figure A.1 - Classification of energy performance indicators for buildings

Note - compiled by the authors based on [10]

**APPENDIX B**

**Technical indicators of energy efficiency of buildings**

Table B.1 - Heat consumption of the building for 2016-2019

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Heat consumption of the building | Period days | Value, Gcal | | |
| 2016/17гг | 2017/18гг | 2018/19гг |
| ГВСср | 183 | 0,27 | 0,27 | 0,23 |
| (ОТ+ГВС) ср | 183 | 2,25 | 2,1 | 2,04 |
| ΣQГВС | 183 | 44,71 | 49,53 | 42,25 |
| ΣQОТ | 183 | 364,69 | 332,00 | 330,11 |
| ΣQОТ+ГВС | 183 | 409,4 | 381,53 | 372,36 |
| ОТ+ГВС год | 366 | 454,11 | 431,06 | 414,54 |
| (ОТ+ГВС) ср год | 366 | 1,31 | 1,19 | 1,14 |
| Norm (class of the ef. Building "D") |  | 148,3 | 148,3 | 148,3 |
| Excess, % |  | 146 | 124 | 123 |
| Norm (class ef. Building "D") +50% |  | 222,45 | 222,45 | 222,45 |
| Excess, % |  | 64 | 49 | 48 |
| Note - compiled by the authors based on [36-37] | | | | |

Table B.2 - Energy characteristics of a 5-storey building

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | The name of indicators | designation | Indicator value | |
| Without insulation | With insulation |
| 1 | Specific thermal performance of the building |  | 0,3964 | 0,0964 |
| 2 | Specific ventilation characteristics of the building, Wt/(m3·°С) | *kвент* | 0,1987 | 0,1987 |
| 3 | Average rate of air exchange in a building during the heating period, ch-1 | *пв* | 0,642 | 0,642 |
| 4 | Specific characteristic of the building's household heat emission, Wt/(m3·°С), | *kбыт* | 0,140 | 0,140 |
| 5 | Specific characteristic of heat input into the building from solar radiation, Wt/(m3·°С), | *Kрад* | 0,01215 | 0,01215 |
| 6 | Расчетная удельная характеристика расхода тепловой энергии на отопление и вентиляцию здания за отопительный период, Wt/(m3·°С), |  | 0,4839 | 0,1842 |
|  | | | | |
| 7 | Specific consumption of heat energy for heating and ventilation of the building during the heating period, kW \* h / (m3 / year) or, kWh / (m2 / year) | *q* | 42,1488 | 16,046 |
| 8 | Heat consumption for heating and ventilation of the building during the heating period, kW \* h / year |  | 318 621,9 | 121 309 |
| 9 | Total heat loss of the building for the heating period, kW \* h / year, |  | 391 841,1 | 184 783 |
| Note - compiled by the authors on the basis of the building's energy certificate | | | | |

**APPENDIX C**

**The energy passport of a residential 5-storey building without insulation**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. GENERAL INFORMATION | | | | | |
| Purpose of the building | | Residential | | | |
| Number of storeys, number of sections | | 5 | | | |
| Estimated number of residents | | 100 | | | |
| Position of the building | | Freestanding | | | |
| Constructive solution | | Wall: cement mortar 0.020 m. Ceramic hollow brick masonry 0.370 m, mortar - 0.020 m. Attic floor: leveling cement screed, reinforced with mesh Вр-1 D4.5 200x200. 0.030 m., screed cement M100 0.020 m., monolithic slab reinforced concrete 0.2 m. Basement: leveling cement screed, reinforced with mesh Вр-1 D4.5 200x200. 0.030 m., monolithic slab reinforced concrete 0.2 m. | | | |
| 2. CONDITIONS | | | | | |
| № | Name of  parameters | | Parameter | Unit. | Estimated value |
| 1 | Estimated outside air temperature for thermal protection design | | *t*н | °C | -28 |
| 2 | Average outdoor temperature for the heating period | | *t*от | °C | -1,8 |
| 3 | Duration of the heating period | | Zот | day/year | 168 |
| 4 | Heating degree-day period | | *ГСОП* | °C\* day/year | 3629 |
| 5 | Estimated indoor air temperature for design thermal protection | | *t*в | °C | +20 |
| 6 | Estimated attic temperature | | *t*черд | °C | 16 |
| 7 | Estimated temperature of the technical basement | | *t*подп | °C | 16 |

3. GEOMETRIC INDICATORS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | Indicator | Unit | Standardized value | Estimated design value |
| 8 | The sum of the areas of the floors of the building | *Аот*, м2 | **-** | 3220 |
| 9 | Residential area | *Аж*, м2 | **-** | 2725 |
| 10 | Estimated area | *Ар*, м2 | **-** | 2725 |
| 11 | Heated volume | *Vот*, м3 | **-** | 7560 |
| 12 | Glazing ratio  building facade | ƒ | - | 0,12 |
| 13 | Building compactness index | *Kкомп* | - | 0,425 |
| 14 | Total outdoor area  building envelope,  including: | *Ансум*, м2 | **-** | 2150,5 |
| facades | *Афас* | **-** | 1774,2 |
| walls (separately by type designs) | *Аст* | **-** | 1700 |
| windows and balcony doors | *Аок.1* | **-** | 71,2 |
| windows of staircase and elevator nodes | *Аок.4* | **-** | 18 |
| west | *Аок.1* | **-** | 35,6 |
| south | *Аок.1* | **-** | 35,6 |
| entrance doors and gates | *Адв* | **-** | 12,5 |
| attic floors | *Ачерд* | **-** | 115 |
| floors over technical  underground or over unheated basements | *Ацок1* | **-** | 115 |
| walls in the ground and floor on the ground | *Ацок3* | **-** | 363,8 |
| 15 | Reduced resistance  heat transfer of external fences, including: | *Rопр,*  м2х°С/Вт |  |  |
| walls (separately by type of construction) | *Roпр,ст* | 2,67015 | 0,998 |
| windows and balcony doors | *Roпр,ок1* | 0,340725 | 0,5 |
| windows of staircase and elevator nodes | *Roпр,ок4* | 0,340725 | 0,5 |
| entrance doors and gates | *Roпр,дв* | 0,8 | 0,8 |
| attic floors | *Roпр,черд* | 3,53305 | 0,354 |
| ceilings over technical undergrounds or over unheated basements (equivalent) | *Roпр,цок1* | 3,53305 | 0,354 |
| walls in the ground and floor on the ground (I zone) general | *Roпр,цок3* | 2,67015 | 0,998 |
| № | Indicator | Unit | Standardized value | Estimated design value |
| 16 | Total heat transfer coefficient of the building | *Кобщ*  Вт/(м2 х °С) |  | 0.932 |
| 17 | Average rate of air exchange in a building during the heating period at a specific rate of air exchange | nв, ч-1 |  | 0,642 |
| 18 | Specific heat emission in the building | qбыт, Вт/м2 |  | 0,140 |
| 22 | Specific thermal performance of the building | *kоб,* Вт/(м3\*°С) | 0,225 | 0.3964 |
| 23 | Specific ventilation characteristics of the building | *kвент,* Вт/(м3\*°С) |  | 0,1987 |
| 24 | Specific characteristic of the building's household heat emission | *kбыт,* Вт/(м3\*°С) |  | 0,140 |
| 25 | Specific characteristic of heat input into a building from solar radiation | *kрад,* Вт/(м3\*°С) |  | 0,01215 |
| 29 | Coefficient taking into account the decrease in the use of heat gains during the period when they exceed heat losses | *ν* |  | 0,765725 |
| 30 | Coefficient of accounting for additional heat losses of the heating system | *bh* |  | 1,11 |
| 31 | Estimated specific characteristic of heat energy consumption for heating and ventilation of the building for the heating period | *qрот*  Вт/(м3\*°С) |  | 0.4839 |
| 32 | Normalized specific characteristic of the consumption of heat energy for heating and ventilation of the building during the heating period | *qтрот*  Вт/(м3\*°С) |  | 0,359 |
| 33 | Energy efficiency class of the building |  |  | Пониженный"D" |
| 34 | Does the building design comply with the regulatory requirement for  heat protection |  |  | Нет |
| 35 | Specific consumption of heat energy for heating and ventilation of the building during the heating period , kW \* h /  m 3 year | q | кВт\*ч/  м3 год | 42.1488 |
| 36 | Heat consumption for heating and ventilation of the building during the heating period , kW \* h /  (year) | *Qгодот* | кВт\*ч/  (год) | 318621.90326 |
| 37 | Total heat loss of the building for the heating period , kW \* h /  (year) | *Qгодобщ* | кВт\*ч/  (год) | 391841.07177 |

**Heat engineering calculation of enclosing structures.**

I. Calculation of the required heat transfer resistance of the enclosing structures Rtr, at the request of sanitary and hygienic and comfortable conditions.

Calculation of the required heat transfer resistance of the enclosing structures:

Wall: Rтр = [n (tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 4· 8,7 ) = 1,379 м2С / Вт

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 4 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 Вт/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

Attic floor:

Rтр = [n(tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 3· 8,7 ) = 1,839 м2С0 / Вт

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 3 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 Вт/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

Basement overlap:

Rтр = [n(tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 2· 8,7 ) = 2,758 м2С0 / Вт

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 2 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 Вт/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

**II . Calculation of the reduced resistance of heat transfer of enclosing structures R pr, at the request of energy-saving conditions.**

Degree-day of the heating period according to SN RK 2.04-21-2004\* (ГСОП):

ГСОП = ( tв - tот )· Zот = ( 20 – (–1,8) )· 168 = 3629

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tот= –1,8 0С – the average temperature of the outside air, the period with the average daily temperature of the outside air no more than 8 0 С according to SP RK 2.04-01-2017 table. 3.1;

Zот = 168 – the duration of the heating period with an average daily outside air temperature of no more than 8 0 С according to SP RK 2.04-01-2017 tab. 3.1;

The normalized value of the reduced resistance to heat transfer of the enclosing structure:

Walls: Rпр = а·ГСОП+b = 0,00035·3629+1,4 = 2,67015 м2С/W

a – 0,00035 according to SP RK 2.04-107-2013 tab. 4;

b – 1,4 according to SP RK 2.04-107-2013 tab. 4.

Attic floors: Rпр = а·ГСОП+b = 0,00045·3629+1,9 = 3,53305 м2С/W

a – 0,00045 according to SP RK 2.04-107-2013 tab. 4;

b – 1,9 according to SP RK 2.04-107-2013 tab. 4.

Unheated basement:

Rпр = а·ГСОП+b = 0,00045·3629+1,9 = 3,53305‬ м2С/W

a – 0,00045 according to SP RK 2.04-107-2013 tab. 4;

b – 1,9 according to SP RK 2.04-107-2013 tab. 4.

Windows, balcony doors and stained glass:

Rпр = а·ГСОП+b = 0,000025·3629+0,25 = 0,340725 м2С/W

a – 0,000025 according to SP RK 2.04-107-2013 tab. 4;

b – 0,25 according to SP RK 2.04-107-2013 tab. 4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Buildings and  premises | Heating degree-day, оС**·** сут/год (ГСОП) | The above heat transfer resistance  Rпр , м2С/W according connstructions | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Walls | Coverings and ceilings over driveways | Attic ceilings, over unheated undergrounds and basements | Windows, balcony doors and stained glass | Lanterns |
| Public, administrative and household | 3629 | 2,67015 | - | 3,53305 | 0,340725 | - |

the heat transfer resistance of the enclosing structures is the reduced Rпр according to the II calculation.

**III . Calculation of the actual resistance to heat transfer of enclosing structures Rф.**

Calculation of the actual resistance to heat transfer of enclosing structures: R**ф =** 1/αв + Rсл + 1/αн

αв = 8,7 W/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. 5;

αн = 23 W/(м2·0С)– heat transfer coefficient for winter conditions JV RK 2.04-107-2013 Table. 7.

αн = 12 W/(м2·0С)– Перекрытий чердачных и над неотапливаемыми подвалами. по СП РК 2.04-107-2013 табл. 7

Rсл = δ / λ

δ – layer thickness;

λ – the calculated coefficient of thermal conductivity of the material

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Designed structures: wall | | | | | | | | | |
| Material | Layer thickness, (δ) | | The calculated thermal conductivity material,(λ)W/(м2·0С) | | | Rсл = δ / λ | | Rф = 1/αв+Rсл+1/αн | |
| Cement mortar | 0,020 м | | 0,76 | | | 0,020/0,76 = 0,0263 | | 1/8,7+0,0263+0,78+0,0263+1/23 = 0,998 | |
| Hollow ceramic brickwork | 0,370 м | | 0,47 | | | 0,370/0,47=0,787 | |
| Cement mortar | 0,020 м | | 0,76 | | | 0,020/0,76 = 0,0263 | |
| structures: attic floor | | | | | | | | | |
| Material | | Layer thickness, (δ) | | The calculated thermal conductivity material,(λ)W/(м2·0С) | | | Rсл = δ / λ | | Rф = 1/αв+Rсл+1/αн |
| Leveling screed reinforced with mesh Вр-1 D4,5 200х200. | | 0,030 м | | 0,76 | | | 0,030/0,76 = 0,0394 | | 1/8,7+0,0394+0,117+1/12=0,354 |
| Monolithic reinforced concrete slab | | 0.2 м | | 1,7 | | | 0,2/1,7=  0,117 | |
| structures: glazing | | | | | | | | | |
| Material | | | | | Rф | | | | |
| Double-glazed window | | | | | 0,500 | | | | |

We check the condition: R**ф ≥** Rпр

The condition is fulfilled:

Wall: Rф (0,998)> Rпр(2,67015)

Attic floor: Rф (0,354)> Rпр (3,53305)

Windows: Rф (0,500)> Rпр (0,340725)

Basement: Rф (0,354)> Rпр (3,53305)

**Calculation of the energy passport**

1.1 Specific heat-shielding characteristic of a building, is calculated by the formula:

= 0,425 × 0.932 = 0.3964

where:

|  |  |
| --- | --- |
| — | reduced resistance to heat transfer of the i -th fragment of the heat-protective envelope of the building, m 2о С / W |
| Aф,i — | area of ​​the corresponding fragment of the building's heat-shielding envelope, m 2 |
| Vот — | heated building volume, м3 |
| nt,i — | the coefficient taking into account the difference between the internal or external temperature of the structure from those adopted in the calculation of the GSOP, is determined by the formula: |
| Kобщ – | total heat transfer coefficient of the building, W / (m 2 ⋅° C), determined by the formula: |
| Kкомп – | coefficient of compactness of the building, m -1 , determined by the formula: x |

1.2 The specific ventilation characteristic of the building, *k vent* , W / (m 3 o C ), should be determined by the formula:

=0,28×1×0,642×0,85×1,301×(1 - 0) = 0,1987

where:

|  |  |  |
| --- | --- | --- |
| *с* — | specific heat capacity of air equal to 1 kJ / (kg ° С) | |
| *nв* — | average rate of air exchange in a building during the heating period, ч−1, *nв* = 0,642; | |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data, take β*v* = 0,85; | |
| — | average density of the supply air during the heating period, kg / m 3  = 353 / [273 + (-1,8)] = 1,301 | |
| *tот* — | average outside air temperature for the heating period, °С; *tот* = - 1,8 °С. |
| *kэф* — | recuperator efficiency factor, 0 | |

1.2.1 The average rate of air exchange in a building during the heating period, *n in* , ч −1 , is calculated from the total air exchange due to ventilation and infiltration by the formula: =

= [(10900 × 56) / 168 + (642,6 × 168) / (168 × 1,301)] / (0,85 × 7560) = 0.642

where:

|  |  |  |
| --- | --- | --- |
| Lвент — | the amount of air supplied to the building with an unorganized inflow or a standardized value with mechanical ventilation, m 3 / h, equal to: 4 × Ар= 4 × 2725 = 10900 | |
| Ар; Аж; | for public and office buildings - estimated area, м2, Ар = 2725 м2 |
| hэт — | floor height from floor to ceiling, m |
| nвент — | number of hours of operation of mechanical ventilation during a week, equal to 8 hours × 7 days = 56 | |
| 168 — | number of hours per week | |
| Gинф — | the amount of air infiltrated into the building through the enclosing structures, kg / h: Gинф = 0,1 × βv × Vобщ = 0,1 × 0,85 × 7560 = 642.6 | |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data β*v* = 0,85 |
| Vобщ — | heated volume of the public part of the building, м3, Vобщ = 7560 м3 |
| nинф — | the number of hours of accounting for infiltration during the week, h, equal to 168 for buildings with balanced supply and exhaust ventilation and (168 - n ventilation ) for buildings in the premises of which air pressure is maintained during the operation of supply mechanical ventilation, nинф = 168 | |
| — | average density of the supply air during the heating period, kg / m 3: = 353 / [273 + (-1,8)] = 1,301 | |
| *tот* — | average outside air temperature for the heating period, °С; *tот* = - 1,8 ° |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data β*v* = 0,85 | |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, m 3, Vот = 7560 м3 | |

1.3The specific heat generation characteristic of household buildings, k life , W / ( m 3 to C) should be determined by the formula: =  = 0.140

where:

|  |  |
| --- | --- |
| qбыт — | the value of household heat dissipation per 1 m 2 of the area of ​​residential premises (A g ) or the estimated area of ​​a public building (A p ), W / m 2 , taken for: a) residential buildings with an estimated occupancy of apartments less than the total area per person: q life = 17 W / m2;  b) residential buildings with an estimated occupancy of apartments with a total area and more per person q life = 10W / m2;  qбыт = 56×((100×10+2725×15+2725×10)/2725))/168 = 8.45 |
| Ар; Аж; — | calculated area for public and administrative buildings м2; Ар = 2725м2 |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, Vот = 7560 м3 |
| *tв* — | temperature of the internal air for the design of thermal protection, °С, *tв* = +20 °С |
| *tот* — | average outside air temperature for the heating period, °С, *tот* = - 1,8 °С |

1.4The specific characteristic of heat input into the building from solar radiation, kрад, Wt/(m3 оС), should be determined by the formula:



where:

|  |  |  |
| --- | --- | --- |
| — | heat gain through windows and lanterns from solar radiation during the heating period, MJ / year, for two building facades oriented in two directions, determined by the formula: =  = 0,8 × 0,68 × (71,2 × 659 + 18 × 330) = 28756.2752 МДж/год | |
| τ1ок, τ1фон — | coefficients of the relative penetration of solar radiation for light-transmitting fillings, respectively, of windows and skylights, taken according to the passport data of the corresponding light - transmitting products; in the absence of data should be taken according to a set of rules; roof windows with an angle of inclination of the infills to the horizon of 45 ° and more should be considered as vertical windows, with an angle of inclination less than 45 ° - as skylights |
| τ2ок, τ2фон — | coefficients that take into account the shading of the skylight, respectively, of windows and skylights by opaque filling elements, taken according to design data; in the absence of data should be taken according to a set of rules |
| Аок1, Аок2, Аок3, Aок4 | the area of ​​the windows of the building facades (the blind part of the balcony doors is excluded), respectively, oriented in four directions, m 2 |
| Aфон — | area of skylights of the building, m 2 |
| I1, I2, I3, I4 — | the average value of solar radiation for the heating period on vertical surfaces under actual cloudiness conditions, respectively, oriented along two facades of the building, MJ / (m 2 ⋅year), is determined by the methodology of the set of rules |
| Note - for intermediate directions, the value of solar radiation should be determined by interpolation | |
| Iгор — | the average value for the heating period of the solar radiation on a horizontal surface when the actual cloud conditions MJ / (m 2 ⋅year) determined by the set of rules. |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3 | |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, GSOP= 3629 оС⋅сут/год. | |

1.5 The calculated specific heat characteristic energy consumption for heating and ventilation of the building during the heating period, W / (m 3 · ° C) should be determined by the formula: [0.3964 + 0,1987 - (0,140 + 0,01215) × 0,765725 × 0,95] × (1 - 0,1) × 1,11 =0.4839W/(м3·°С)

where:

|  |  |  |
| --- | --- | --- |
| *kоб* — | specific heat-shielding characteristic of the building, W/(м3 оС), *kоб* = 0.3964; По by volume and GSOP at the intersection we find the normalized value of t / building protection characteristics | |
| *kвент* — | specific ventilation characteristic of the building, W / (m 3 о С ), *kвент* = 0,1987 | |
| *kбыт* — | specific characteristic of the building's household heat emission, W / (m 3 о С ), *kбыт* = 0,140; | |
| *kрад* — | specific characteristic of heat input into the building from solar radiation, W / (m 3 оС), *kрад* = 0,01215; | |
| ν — | coefficient of heat gain reduction due to thermal inertia of enclosing structures; recommended values ​​are determined by the formula: = 0,7 + 0,000025 × (3629 - 1000) = 0,765725 | |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, ГСОП = 3629 оС⋅day/year. |
| ζ — | coefficient of efficiency of automatic regulation of heat supply in heating systems; recommended values: ζ= 0.95 - two-pipe system with thermostats and with central automatic regulation at the inlet | |
| ξ - | the coefficient taking into account the decrease in the heat consumption of residential buildings in the presence of apartment accounting of heat energy for heating, is taken before obtaining statistical data on the actual decrease ξ = 0,1 | |
| β*h* — | coefficient that takes into account the additional heat consumption of the heating system associated with the discreteness of the nominal heat flux of the range of heating devices, their additional heat losses through the radiator sections of the fences, increased air temperature in the corner rooms, heat losses of pipelines passing through unheated rooms for: tower-type buildings β*h* = 1,11; | |

1.6 Specific consumption of heat energy for heating and ventilation of the building for the heating period q , kWh / (m 3 year) or, kWh / (m 2 year) should be determined by the formulas: = 0,024 × 3629 × 0.4839= 42.1488кW ч/(м3год)

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, ГСОП = 3629 оС⋅сут/год; |
| — | calculated specific characteristic of the consumption of heat energy for heating and ventilation of the building during the heating period, W / (m 3 ° С),, = 0.4839. the normalized specific characteristic of heat energy consumption for heating and ventilation of the building during the heating period |

1.7 The consumption of heat energy for heating and ventilation of the building during the heating period , kWh / year, should be determined by the formula:

 = 0,024×3629×7560×0.4839=318621.903264 кW ч/год

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, GSOP = 3629 о С ⋅day / year. |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3 |
| — | calculated specific characteristic of the consumption of thermal energy for heating and ventilation of the building during the heating period, W/(м3·°С), = 0.4839 |

**Energy efficiency classes of residential and public buildings**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | Class designation | Energy efficiency class name | The deviation of the calculated (actual) value of the energy efficiency indicator for heating and ventilation of the building from the standard, % | |
| new and renovated buildings | | | | |
| 1 | А++ | Very  high | below -60 | |
| А+ | from -50 to -60 | |
| А | from -40 to -50 | |
| 2 | B+ | high | from -30 from -40 |
|  | B | from -15 to -30 |
| 3 | C+ | Normal | from - 5 to - 15 |
|  | C | from + 5 to - 5 |
|  | C- | from + 15 to + 5 |
| existing buildings |  |  |  |
| 4 | D | Reduced | from + 15,1 to + 50 |
| 5 | E | Low | 50 |

1.8 The total heat loss of the building for the heating period, kWh / year, should be determined by the formula: =

= 0,024 × 3629 × 7560 × (0.3964 + 0,1987) = 391841.071776 кW ч/год

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year,, ГСОП = 3629 оС⋅сут/год; |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3; |
| *kоб* — | heat-shielding characteristic of the building, W/(м3 оС), *kоб* = 0.3964; |
| *kвент* — | ventilation characteristics of the building,W/(м3 оС), *kвент* =0,1987; |

**APPENDIX D**

**The energy passport of a residential 5-storey building with insulation**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. GENERAL INFORMATION | | | | | |
| Purpose of the building | | Residential | | | | |
| Number of storeys, number of sections | | 5 | | | | |
| Estimated number of residents | | 100 | | | | |
| Position of the building | | Freestanding | | | | |
| Constructive solution | | Wall: cement mortar 0.020 m., Insulation "Penoplex" 0.1 m. Ceramic hollow brick masonry 0.370 m, mortar 0.020 m. Attic floor: leveling cement screed, reinforced with mesh Вр-1 D4.5 200x200. 0.030 m., Insulation - "Penoplex" 0.1 m. Screed c-p, М100 0.020 m., Monolithic reinforced concrete slab 0.2 m. Basement: cement leveling screed, reinforced with mesh Вр-1 D4.5 200x200 0.030 m., Penoplex insulation 0.1 m., Monolithic reinforced concrete slab 0.2 m. | | | | |
| 2. CONDITIONS | | | | | |
| № | Name of  parameters | | Parameter | Unit. | Estimated value | |
| 1 | Estimated outside air temperature for thermal protection design | | *t*н | °C | -28 | |
| 2 | Average outdoor temperature for the heating period | | *t*от | °C | -1,8 | |
| 3 | Duration of the heating period | | Zот | day/year | 168 | |
| 4 | Heating degree-day period | | *ГСОП* | °C\* day/year | 3629 | |
| 5 | Estimated indoor air temperature for design thermal protection | | *t*в | °C | +20 | |
| 6 | Estimated attic temperature | | *t*черд | °C | 16 | |
| 7 | Estimated temperature of the technical basement | | *t*подп | °C | 16 | |

3. GEOMETRIC INDICATORS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | Indicator | Unit | Standardized value | Estimated design value |
| 8 | The sum of the areas of the floors of the building | *Аот*, м2 | **-** | 3220 |
| 9 | Residential area | *Аж*, м2 | **-** | 2725 |
| 10 | Estimated area | *Ар*, м2 | **-** | 2725 |
| 11 | Heated volume | *Vот*, м3 | **-** | 7560 |
| 12 | Glazing ratio  building facade | ƒ | - | 0,12 |
| 13 | Building compactness index | *Kкомп* | - | 0,425 |
| 14 | Total outdoor area  building envelope,  including: | *Ансум*, м2 | **-** | 2150,5 |
| facades | *Афас* | **-** | 1774,2 |
| walls (separately by type designs) | *Аст* | **-** | 1700 |
| windows and balcony doors | *Аок.1* | **-** | 71,2 |
| windows of staircase and elevator nodes | *Аок.4* | **-** | 18 |
| west | *Аок.1* | **-** | 35,6 |
| south | *Аок.1* | **-** | 35,6 |
| entrance doors and gates | *Адв* | **-** | 12,5 |
| attic floors | *Ачерд* | **-** | 115 |
| floors over technical  underground or over unheated basements | *Ацок1* | **-** | 115 |
| walls in the ground and floor on the ground | *Ацок3* | **-** | 363,8 |
| 15 | Reduced resistance  heat transfer of external fences, including: | *Rопр,*  м2х°С/W |  |  |
| walls (separately by type of construction) | *Roпр,ст* | 2,67015 | 4,459 |
| windows and balcony doors | *Roпр,ок1* | 0,340725 | 0,5 |
| windows of staircase and elevator nodes | *Roпр,ок4* | 0,340725 | 0,5 |
| entrance doors and gates | *Roпр,дв* | 0,8 | 0,8 |
| attic floors | *Roпр,черд* | 3,53305 | 3,619 |
| ceilings over technical undergrounds or over unheated basements (equivalent) | *Roпр,цок1* | 3,53305 | 3,579 |
| walls in the ground and floor on the basement | *Roпр,цок3* | 2,67015 | 4,459 |
| № | Indicator | Unit | Standardized value | Estimated design value |
| 16 | Total heat transfer coefficient of the building | *Кобщ*  W/(м2 х °С) | - | 0,226 |
| 17 | Average rate of air exchange in a building during the heating period at a specific rate of air exchange | nв, ч-1 | - | 0,642 |
| 18 | Specific heat emission in the building | qбыт, W/м2 | - | 0,140 |
| 22 | Specific thermal performance of the building | *kоб,* W/(м3\*°С) | 0,225 | 0,0964 |
| 23 | Specific ventilation characteristics of the building | *kвент,* W/(м3\*°С) | - | 0,1987 |
| 24 | Specific characteristic of the building's household heat emission | *kбыт,* W/(м3\*°С) | - | 0,140 |
| 25 | Specific characteristic of heat input into a building from solar radiation | *kрад,* W/(м3\*°С) | - | 0,01215 |
| 29 | Coefficient taking into account the decrease in the use of heat gains during the period when they exceed heat losses | *ν* | - | 0,765725 |
| 30 | Coefficient of accounting for additional heat losses of the heating system | *bh* | - | 1,11 |
| 31 | Estimated specific characteristic of heat energy consumption for heating and ventilation of the building for the heating period | *qрот*  W/(м3\*°С) | - | 0,1842 |
| 32 | Normalized specific characteristic of the consumption of heat energy for heating and ventilation of the building during the heating period | *qтрот*  W/(м3\*°С) | - | 0,359 |
| 33 | Energy efficiency class of the building | - | - | Высокий "А" |
| 34 | Does the building design comply with the regulatory requirement for  heat protection | - | - | Да |
| 35 | Specific consumption of heat energy for heating and ventilation of the building during the heating period , kW \* h /  m 3 year | q | - | 16,046 |
| 36 | Heat consumption for heating and ventilation of the building during the heating period , kW \* h /  (year) | *Qгодот* |  | 121309 |
| 37 | Total heat loss of the building for the heating period , kW \* h /  (year) | *Qгодобщ* |  | 184783 |

**Heat engineering calculation of enclosing structures.**

I. Calculation of the required heat transfer resistance of the enclosing structures Rtr, at the request of sanitary and hygienic and comfortable conditions.

Calculation of the required heat transfer resistance of the enclosing structures:

Wall: Rтр = [n (tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 4· 8,7 ) = 1,379 м2С / W

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 4 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 W/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

Attic floor:

Rтр = [n(tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 3· 8,7 ) = 1,839 м2С0 / W

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 3 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 W/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

Basement overlap:

Rтр = [n(tв - tн)]/(Δtн .αв) = [ 1· ( 20 – (– 28 ) ]/( 2· 8,7 ) = 2,758 м2С0 / W

where: n = 1 - coefficient adopted according to SN RK 2.04-21-2004 Table 1;

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tн = – 28 0С – is the design temperature of the outside air of the coldest five-day period with a provision of 0.92 according to SP RK 2.04-01-2017 table. 3.1;

∆tн = 2 0С – standard temperature difference according to SP RK 2.04-107-2013 table. 6;

αв = 8,7 W/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. five.

**II . Calculation of the reduced resistance of heat transfer of enclosing structures R pr, at the request of energy-saving conditions.**

Degree-day of the heating period according to SN RK 2.04-21-2004\* (ГСОП):

ГСОП = ( tв - tот )· Zот = ( 20 – (–1,8) )· 168 = 3629

tв = 20 0С – design temperature of internal air according to SN RK 2.04-21-2004 table. 3.2;

tот= –1,8 0С – the average temperature of the outside air, the period with the average daily temperature of the outside air no more than 8 0 С according to SP RK 2.04-01-2017 table. 3.1;

Zот = 168 – the duration of the heating period with an average daily outside air temperature of no more than 8 0 С according to SP RK 2.04-01-2017 tab. 3.1;

The normalized value of the reduced resistance to heat transfer of the enclosing structure:

Walls: Rпр = а·ГСОП+b = 0,00035·3629+1,4 = 2,67015 м2С/W

a – 0,00035 according to SP RK 2.04-107-2013 tab. 4;

b – 1,4 according to SR RK 2.04-107-2013 tab. 4.

Attic floors: Rпр = а·ГСОП+b = 0,00045·3629+1,9 = 3,53305 м2С/W

a – 0,00045 according to SP RK 2.04-107-2013 tab. 4;

b – 1,9 according to SR RK 2.04-107-2013 tab. 4.

Unheated basement:

Rпр = а·ГСОП+b = 0,00045·3629+1,9 = 3,53305‬ м2С/W

a – 0,00045 according to SR RK 2.04-107-2013 tab. 4;

b – 1,9 according to SR RK 2.04-107-2013 tab. 4.

Windows, balcony doors and stained glass:

Rпр = а·ГСОП+b = 0,000025·3629+0,25 = 0,340725 м2С/W

a – 0,000025 according to SP RK 2.04-107-2013 tab. 4;

b – 0,25 according to SR RK 2.04-107-2013 tab. 4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Buildings and premises | Heating degree-day, оС**·** сут/год (ГСОП) | The above heat transfer resistance  Rпр , м2С/W according connstructions | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Walls | Coverings and ceilings over driveways | Attic ceilings, over unheated undergrounds and basements | Windows, balcony doors and stained glass | Lanterns |
| Public, administrative and household | 3629 | 2,67015 | - | 3,53305 | 0,340725 | - |

the heat transfer resistance of the enclosing structures is the reduced Rпр according to the II calculation.

**III . Calculation of the actual resistance to heat transfer of enclosing structures Rф.**

Calculation of the actual resistance to heat transfer of enclosing structures: R**ф =** 1/αв + Rсл + 1/αн

αв = 8,7 W/(м2·0С) – heat transfer coefficient of the inner surface of the enclosing structure of the PO RK 2.04-107-2013 Table. 5;

αн = 23 W/(м2·0С)– heat transfer coefficient for winter conditions JV RK 2.04-107-2013 Table. 7.

Rсл = δ/λ

δ – layer thickness;

λ – the calculated coefficient of thermal conductivity of the material

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Designed structures: wall | | | | | |
| Material | Layer thickness, (δ) | The calculated thermal conductivity material,(λ)W/(м2·0С) | | Rсл = δ / λ | Rф = 1/αв+Rсл+1/αн |
| cement mortar | 0,020 м | 0,76 | | 0,020 / 0,76 = 0,0263 | 1/8,7+0,0263+3,225+0,787+0,0263+1/23 = 4.459 |
| Insulation "Penoplex" | 0,1 м | 0,031 | | 0,1/0,031= 3,225 |
| Hollow ceramic brickwork | 0,370 м | 0,47 | | 0,370/0,47=0,787 |
| cement mortar | 0,020 м | 0,76 | | 0,020 / 0,76 = 0,0263 |
| structures: attic floor | | | | | |
| Material | Layer thickness, (δ) | The calculated thermal conductivity material,(λ)W/(м2·0С) | | Rсл = δ / λ | Rф = 1/αв+Rсл+1/αн |
| Leveling screed reinforced with mesh Вр-1 D4,5 200х200. | 0,030 м | 0,76 | | 0,030/ 0,76 = 0,0394 | 1/8,7+0,0394+3,225+0,0394+0.117+1/12 = 3,619 |
| Insulation "Penoplex" | 0,1 м | 0,031 | | 0,1/0,031= 3,225 |
| cement mortar М100 | 0,020 м | 0,76 | | 0,020/0,76 = 0,0394 |
| Monolithic reinforced concrete slab | 0.2 м | 1,7 | | 0,2/1,7=  0.117 |
| structures: unheated basement | | | | | |
| Material | Layer thickness, (δ) | The calculated thermal conductivity material,(λ)W/(м2·0С) | | Rсл = δ / λ | Rф = 1/αв+Rсл+1/αн |
| Leveling screed reinforced with mesh Вр-1 D4,5 200х200. | 0,030 м | 0,76 | | 0,030/0,76 = 0,0394 | 1/8,7+0,0394+3,225+0,117+ 1/12 =3,579 |
| Insulation "Penoplex" | 0,1 м | 0,031 | | 0,1/0,031= 3,225 |
| Monolithic reinforced concrete slab | 0.2 м | 1,7 | | 0,2/1,7=  0,117 |
| structures: glazing | | | | | |
| Material | | | Rф | | |
| Double-glazed window | | | 0,500 | | |

We check the condition: Rф ≥ Rпр

The condition is fulfilled:

Wall:Rф (4,459)>Rпр(2,67015)

Attic floor: Rф (3,619)>Rпр (3,53305)

Windows: Rф (0,500)>Rпр (0,340725)

Basement: Rф (3,579)>Rпр (3,53305)

**Calculation of the energy passport**

1.1 Specific heat-shielding characteristic of a building, is calculated by the formula:

 = 0,425 × 0,226 = 0,0964

где:

|  |  |
| --- | --- |
| — | reduced resistance to heat transfer of the i -th fragment of the heat-protective envelope of the building, m 2о С / W |
| Aф,i — | area of ​​the corresponding fragment of the building's heat-shielding envelope, m 2 |
| Vот — | heated building volume, м3 |
| nt,i — | the coefficient taking into account the difference between the internal or external temperature of the structure from those adopted in the calculation of the GSOP, is determined by the formula:: |
| Kобщ – | total heat transfer coefficient of the building, W / (m 2 ⋅° C), determined by the formula: |
| Kкомп – | coefficient of compactness of the building, m -1 , determined by the formula: x |

1.2 The specific ventilation characteristic of the building, *k vent* , W / (m 3 o C ), should be determined by the formula:

 = 0,28 × 1 × 0,642 × 0,85 × 1,301 × (1 - 0) = 0,1987

where:

|  |  |  |
| --- | --- | --- |
| *с* — | specific heat capacity of air equal to 1 kJ / (kg ° С) | |
| *nв* — | average rate of air exchange in a building during the heating period, ч−1, *nв* = 0,482 | |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data, take β*v* = 0,85 | |
| — | average density of the supply air during the heating period, kg / m 3  = 353 / [273 + (-7,0)] = 1,327 | |
| *tот* — | average outside air temperature for the heating period, °С; *tот* = - 7,0 °С. |

1.2.1 The average rate of air exchange in a building during the heating period, *n in* , ч −1 , is calculated from the total air exchange due to ventilation and infiltration by the formula:

= [(10900 × 56) / 168 + (642,6 × 168) / (168 × 1,301)] / (0,85 × 7560) = 0.642

where:

|  |  |  |
| --- | --- | --- |
| Lвент — | the amount of air supplied to the building with an unorganized inflow or a standardized value with mechanical ventilation, m 3 / h, equal to 4 × Ар = 4 × 2725 = 10900 | |
| Ар; Аж; — | for public and office buildings - estimated area, м2, Ар = 2725 м2 |
| hэт — | floor height from floor to ceiling, m |
| nвент — | number of hours of operation of mechanical ventilation during a week, equal to 8 hours × 7 days = 56 | |
| 168 — | number of hours per week | |
| Gинф — | the amount of air infiltrated into the building through the enclosing structures, kg / h: Gинф = 0,1 × βv × Vобщ = 0,1 × 0,85 × 7560 = 642.6 | |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data β*v* = 0,85 |
| Vобщ — | heated volume of the public part of the building, м3, Vобщ = 7560 м3 |
| nинф — | the number of hours of accounting for infiltration during the week, h, equal to 168 for buildings with balanced supply and exhaust ventilation and (168 - n ventilation ) for buildings in the premises of which air pressure is maintained during the operation of supply mechanical ventilation, nинф = 168 | |
| — | average density of the supply air during the heating period, kg / m 3  = 353 / [273 + (-1,8)] = 1,301 | |
| *tот* — | average outside air temperature for the heating period, °С; *tот* = - 1,8 °С. |
| β*v* — | coefficient of air volume reduction in the building, taking into account the presence of internal enclosing structures, in the absence of data β*v* = 0,85 | |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, m 3, Vот = 7560 м3 | |

1.3The specific heat generation characteristic of household buildings, k life , W / (m 3 to C ) should be determined by the formula: =  = 0.140

where:

|  |  |
| --- | --- |
| qбыт — | the value of household heat dissipation per 1 m 2 of the area of ​​residential premises (A g ) or the estimated area of ​​a public building (A p ), W / m 2 , taken for: a) residential buildings with an estimated occupancy of apartments less than the total area per person: q life = 17 W / m2;  b) residential buildings with an estimated occupancy of apartments with a total area and more per person q life = 10W / m2;  qбыт = 56 × ((100 × 10 + 2725 × 15 + 2725 × 10) / 2725)) / 168 = 8.45 |
| Ар; Аж; — | calculated area for public and administrative buildings, Ар = 2725м2 |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3, Vот = 7560 м3 |
| *tв* — | temperature of the internal air for the design of thermal protection, °С, *tв* = +20 °С |
| *tот* — | average outside air temperature for the heating period, °С,  *tот* = - 1,8 °С |

1.4The specific characteristic of heat input into the building from solar radiation, kрад, Wt/(m3 оС), should be determined by the formula:



where:

|  |  |  |
| --- | --- | --- |
| — | heat gain through windows and lanterns from solar radiation during the heating period, MJ / year, for two building facades oriented in two directions, determined by the formula:  = 0,8 × 0,68 × (71,2 × 659 + 18 × 330 )= 28756.2752 МДж/год | |
| τ1ок, τ1фон — | coefficients of the relative penetration of solar radiation for light-transmitting fillings, respectively, of windows and skylights, taken according to the passport data of the corresponding light - transmitting products; in the absence of data should be taken according to a set of rules; roof windows with an angle of inclination of the infills to the horizon of 45 ° and more should be considered as vertical windows, with an angle of inclination less than 45 ° - as skylights |
| τ2ок, τ2фон — | coefficients that take into account the shading of the skylight, respectively, of windows and skylights by opaque filling elements, taken according to design data; in the absence of data should be taken according to a set of rules |
| Аок1, Аок2, Аок3 Aок4 — | the area of ​​the windows of the building facades (the blind part of the balcony doors is excluded), respectively, oriented in four directions, m 2 |
| Aфон— | area of skylights of the building, m 2 |
| I1, I2, I3, I4 — | the average value of solar radiation for the heating period on vertical surfaces under actual cloudiness conditions, respectively, oriented along two facades of the building, MJ / (m 2 ⋅year), is determined by the methodology of the set of rules |
| Note - for intermediate directions, the value of solar radiation should be determined by interpolation | |
| Iгор — | the average value for the heating period of the solar radiation on a horizontal surface when the actual cloud conditions MJ / (m 2 ⋅year) determined by the set of rules. |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3 | |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, GSOP= 3629 оС⋅сут/год. | |

1.5 The calculated specific heat characteristic energy consumption for heating and ventilation of the building during the heating period, W / (m 3 · ° C) should be determined by the formula:

 [0,0964 + 0,1987 - (0,140 + 0,01215) × 0,765725 × 0,95] × (1 - 0,1) × 1,11 =0.1842

where:

|  |  |  |
| --- | --- | --- |
| *kоб* — | specific heat-shielding characteristic of the building, W/(м3 оС), *kоб* = 0,0964;  by volume and GSOP at the intersection we find the normalized value of t / building protection characteristics | |
| *kвент* — | specific ventilation characteristic of the building, W / (m 3 о С ), *kвент* = 0,1987 | |
| *kбыт* — | specific characteristic of the building's household heat emission, W / (m 3 о С ), *kбыт* = 0,140; | |
| *kрад* — | specific characteristic of heat input into the building from solar radiation, W / (m 3 оС), *kрад* = 0,01215; | |
| ν — | coefficient of heat gain reduction due to thermal inertia of enclosing structures; recommended values ​​are determined by the formula: = 0,7 + 0,000025 × (3629 - 1000) = 0,765725 | |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, ГСОП = 3629 оС⋅сут/год. |
| ζ — | coefficient of efficiency of automatic regulation of heat supply in heating systems; recommended values: ζ= 0.95 - two-pipe system with thermostats and with central automatic regulation at the inlet | |
| ξ - | the coefficient taking into account the decrease in the heat consumption of residential buildings in the presence of apartment accounting of heat energy for heating, is taken before obtaining statistical data on the actual decrease ξ = 0,1 | |
| β*h* — | coefficient that takes into account the additional heat consumption of the heating system associated with the discreteness of the nominal heat flux of the range of heating devices, their additional heat losses through the radiator sections of the fences, increased air temperature in the corner rooms, heat losses of pipelines passing through unheated rooms for: tower-type buildings β*h* = 1,11; | |

1.6 Specific consumption of heat energy for heating and ventilation of the building for the heating period q , kWh / (m 3 year) or, kWh / (m 2 year) should be determined by the formulas: = 0,024 × 3629 × 0,1842 = 16.046

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, ГСОП = 3629 оС⋅сут/год. |
| — | calculated specific characteristic of the consumption of heat energy for heating and ventilation of the building during the heating period, W / (m 3 ° С),  = 0, 1842, the normalized specific characteristic of heat energy consumption for heating and ventilation of the building during the heating period |

1.7 The consumption of heat energy for heating and ventilation of the building during the heating period, kWh / year, should be determined by the formula: = 0,024 × 3629 × 7560 × 0,1842 = 121309

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, for a specific point, GSOP = 3629 о С ⋅day / year. |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3 |
| — | calculated specific characteristic of the consumption of thermal energy for heating and ventilation of the building during the heating period, W/(м3·°С) = 0,1842 |

**Energy efficiency classes of residential and public buildings**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| № | Class designation | Energy efficiency class name | The deviation of the calculated (actual) value of the energy efficiency indicator for heating and ventilation of the building from the standard, % | |
| new and renovated buildings | | | | |
| 1 | А++ | Very  high | below -60 | |
| А+ | from -50 to -60 | |
| А | from -40 to -50 | |
| 2 | B+ | high | from -30 from -40 |
|  | B | from -15 to -30 |
| 3 | C+ | Normal | from - 5 to - 15 |
|  | C | from + 5 to - 5 |
|  | C- | from + 15 to + 5 |
| existing buildings |  |  |  |
| 4 | D | Reduced | from + 15,1 to + 50 |
| 5 | E | Low | 50 |

1.8 The total heat loss of the building for the heating period, kWh / year, should be determined by the formula:  = 0,024 × 3629 × 7560 × (0,0964 + 0,1842) = 184783

where:

|  |  |
| --- | --- |
| ГСОП — | Degree- days of the heating period, о С ⋅day / year, ГСОП = 3629 оС⋅сут/год |
| Vот — | heated volume of the building, equal to the volume limited by the inner surfaces of the outer fences of buildings, м3; Vот = 7560 м3 |
| *kоб* — | heat-shielding characteristic of the building, W/(м3 оС), *kоб* = 0,0964 |
| *kвент* — | ventilation characteristics of the building, W/(м3 оС), *kвент* = 0,1842; |

**APPENDIX E**

**Financial indicators of energy efficiency measures**

Figure E.1 - Discounted cash flows when installing ATP taking into account energy savings

Note - compiled by the authors

Figure E.2 - Discounted cash flows for building insulation, taking into account energy savings

Note - compiled by the authors

Figure E.3 - Discounted cash flows for building insulation and installing ATP, taking into account energy savings

Note - compiled by the authors

**APPENDIX F**

**Algorithm of the implementation of energy efficiency tools in buildings for the Republic of Kazakhstan in the transition to a green economy**

Yes

Yes

No

No

Yes

No

Yes

No

No

Yes

Yes

Introduction and dissemination of experience

Figure E.1 - Algorithm of the implementation of energy efficiency tools in buildings

**APPENDIX G**

**List of published works**

Publications: published 20 articles, one study guide and one monograph.

In the journals recommended by the Ministry of Education and Science of the Republic of Kazakhstan: 7 articles.

2020 year:

1 Tleppaev A.M., Zeinolla S.Zh. Analysis of costs in a green economy on the example of the European Union and the Republic of Kazakhstan // Economy: strategy and practice. - 2020. - №1 (15). - P. 101-111 (rus.)

2 Tleppaev A.M., Abishova S.S. Green bonds as a tool for achieving energy efficiency goals // Statistics, Accounting and Audit. - 2020 - №1 (76). - P. 177-180 (rus.)

2019 year:

1 Lokhmann B., Tleppaev A., Azhibaeva A., Omarov T. International experience in the implementation of innovative financial instruments to improve the energy efficiency of buildings//Bulletin of the Al-Farabi Kazakh National University, Economic series. - 2019. - №1 (127). - P. 89-99 (rus.)

2 Tleppaev A., Suleimenov J. International experience of investment incentives for energy efficiency projects in housing and communal services and industry//Statistics, accounting and audit. - 2019. - №1 (72). - P. 187-190 (rus.)

2018 year:

1 Mohamed El-Hoderi, Tovma N.A., Tleppayev A.M., Ussabayev A. Foreign experience of using energy saving technologies and Kazakhstan practice // Bulletin of the Al-Farabi Kazakh National University, Economic series. - 2018. - №1 (123). - P. 59-69 (rus.)

2 Tleppaev A.M., Zeinolla S.Zh. The role of energy efficiency standardization in achieving sustainable economic development // Central Asian Economic Review (CAER). - 2018. - №5. - P. 232-242 (rus.)

3 Tleppaev A.M. Investment incentives for energy efficiency projects // Science and Life of Kazakhstan. - 2018. - №5 (65). - P. 189-192 (rus.)

6 articles have been published in journals in the Scopus database.

2020 (in press):

1 Tleppayev A., Zeinolla S. Digitalisation and energy: world experience and evidence of correlation from Kazakhstan // Economic Annals-XXI. -2020. – Vol. 176, Issue 3-4 (engl.). SJR 2019 - 0.234, SNIP 2019 - 0.519, percentile 69%.

2 Sharipov R., Kudrevich O., Yerzhanov S., Shavdinova M., Tyulyubayeva D. Further improvement of methods for determining energy efficiency of buildings and structures in the Republic of Kazakhstan // Journal of Applied Engineering Science. – 2020. - Vol. 18, Issue 4 (engl.). SJR 2019 - 0.35, SNIP 2019 - 0.9, percentile 45%. DOI: 10.5937/jaes0-27202

## 3 Shavdinova M., Aronson K., Borissova N. Development of condenser mathematical model for research and development of ways to improve its efficiency// Journal of Applied Engineering Science. – 2020. - Vol. 18, Issue 4 (engl.). SJR 2019 - 0.35, SNIP 2019 - 0.9, percentile 45%. DOI: 10.5937/jaes0-27517

2019 year:

## 1 Tleppayev A. Digitalisation and energy: world experience and evidence of correlation from Kazakhstan // Economic Annals-XXI. -2019. – Vol. 176, Issue 3-4. – P. 56-64 (engl.). SJR 2018 - 0.210, SNIP 2018 - 0.319, percentile 40%.

## 2 Alibekova, G., Tleppayev, A., Medem, T.D., Ruzanov, R. Determinants of technology commercialization ecosystem for universities in Kazakhstan// Journal of Asian Finance, Economics and Business. – 2019. - №6(4). - P. 271-279 (engl.). SJR 2018 - 0.192, SNIP 2018 - 1.219, percentile 20%.

2018 year:

## 1 Tleppayev A., Zeinolla S., Abishova S. Kazakhstan's Energy Efficiency Policy Via Dea Approaches// The Journal of Social Sciences Research. -2018. – Vol. 4, Issue 12. – P. 509-514 (engl.). SJR 2018 - 0.188, SNIP 2018 - 0.320.

6 articles have been published in the materials of international conferences in the Scopus database.

2020 year:

1 Tleppayev A., Zeinolla S. Rating Methodology for Kazakhstan's Energy Efficiency Projects // 35th international IBIMA conference. - Seville. -2019. - P. 894-902 (engl.).

2 Tleppayev A., Zeinolla S. Financial Efficiency of Kazakhstan's Energy Efficiency Projects // 35th international IBIMA conference. - Seville. -2019. - P. 5383-5389 (engl.).

2019 year:

1 Tleppayev A. Financing Models for Energy Efficiency Buildings // 33rd International IBIMA Conference. - Madrid.-2019.- P. 3897-3903 (engl.).

2 Tleppayev A. Cost-Optimal methodology for Kazakhstan's energy efficiency projects // 33rd international IBIMA conference. - Madrid.-2019.- P. 4603-4608 (engl.).

2018 year:

1 Tleppayev A., Zeinolla S. The role of energy efficiency standards in achieving sustainable economic development // 32nd international IBIMA conference. - Seville. -2018. - P. 6816-6821 (engl.).

2 Tleppayev A. Improving Energy Efficiency of Buildings for Kazakhstan's Economic Development // 32nd international IBIMA conference. - Seville. -2018. - P. 7475-7482 (engl.).

1 article was published in the materials of international conferences.

1 Tleppaev A.M., Zeinolla S.Zh. Improving energy efficiency of buildings in Kazakhstan as a factor in achieving sustainable development // Materials of the XIV Annual International Scientific Conference of the Kazakh-German University «Modern global trends: challenges and risks for Central Asia». - Almaty, 2018 .- P. 150-159 (rus.).

Published monographs:

- Tleppaev A.M., Azhibaeva A.A., Omarov T.K. Financial instruments to improve the energy efficiency of buildings. - Almaty. -2020. - 144 p. (rus.)

Textbook published:

- Tleppaev A.M. Public-private partnership in reforming the housing and communal services of Kazakhstan. - Almaty. -2019. - 140 p. (rus.)

**APPENDIX H**

**List of copyright certificates**

Received 3 copyright certificates:

1 Certificate of entering information into the state register of rights to objects protected by copyright N. 11285 dated July 08, 2020, Republican State Enterprise National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan: «Financial instruments and standards for improving the energy efficiency of buildings».

2 Certificate of entering information into the state register of rights to objects protected by copyright N. 4695 dated July 26, 2019, Republican State Enterprise National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan: «Methodology of rating evaluation of energy efficiency projects».

3 Certificate of state registration of rights to the copyright object No. 2729 dated August 23, 2018, state number IS 3936 in the Department for Intellectual Property Rights of the Ministry of Justice of the Republic of Kazakhstan: «Investment incentives for energy efficiency projects in housing and communal services and industry».

**APPENDIX I**

**List of acts - implementation of the result**

The following results of the project were introduced:

- analysis of financial instruments for improving energy efficiency;

- analysis of energy consumption by buildings;

- partnership tools for improving building energy efficiency.

Table I.1 - List of acts on implementation of the project

|  |  |  |  |
| --- | --- | --- | --- |
| N | Name of implementation | Type of implementation (technology, standard, recommendation, methodology, other) | Place of implementation |
| 1 | Act - implementation | methodology, recommendation | LLP Tabiya-consult |
| 2 | Act - implementation | methodology, recommendation | LLP MKA Engineering |

**APPENDIX J**

**Calendar plan**

Appendix 1.1  
to Agreement of grant funding No. 244, March 27, 2018

TECHNICAL SPECIFICATIONS AND  
CALENDAR WORK PLAN  
  
Under contract No. 244, March 27, 2018  
  
1. "Kazakh-German University in Almaty"

1.1 Priority: 5. Scientific foundations of "Mangilik el" (education of the XXI century, fundamental and applied research in the humanities)

1.2 Sub-priority: 1. Fundamental and applied research in the field of socio-economic and humanitarian sciences sub-priority: 1. Fundamental and applied research in the field of socio-economic and humanitarian sciences

1.3 Title of project: AP05131192 «Повышение энергоэффективности промышленности и жилищного хозяйства в Казахстане с использованием инновационных технологий: стандарты и финансовые инструменты»

1.4 The total amount of the project is 18 893 500 (eighteen million eight hundred ninety three thousand five hundred) tenge, for the research work in accordance with article 3:

- for 2018 - in the amount of 6 195 456 (six million one hundred ninety five thousand four hundred fifty six) tenge;

- for 2019 - in the amount of 6,274,025 (six million two hundred seventy-four thousand twenty-five) tenge;

- for 2020 - in the amount of 6 424 019 (six million four hundred twenty four thousand nineteen) tenge.

*2.* **Characteristics of scientific and technical products by attributes and economic indicators**

2.1 Field of research: in the field of energy, statistical and mathematical modeling and economics

2.2 Scope: the study is aimed at developing the concept of a green economy, and its significance is the development of mathematical models and planning techniques, laws governing the "green economy".

2.3 Final results:

- for 2018: problems of energy efficiency of buildings in housing and industry were identified by collecting and processing data on the actual energy consumption of buildings;

- for 2019: a methodology for rating assessment of energy efficiency projects and proposals for activating a green economy based on the PPP principle and the implementation of energy service contracts were developed;

- for 2020: tools for innovative services and business models and an algorithm for the implementation of energy efficiency tools in buildings for the Republic of Kazakhstan for the transition to a green economy have been developed.

2.4 Patentability: patentable.

2.5 Scientific and technical level (novelty): for the first time, an algorithm will be developed for the implementation of financial instruments for increasing energy efficiency in buildings for the transition to a green economy, according the economic, social and investment parameters of the Republic of Kazakhstan.

2.6 The use of scientific and technical products is carried out: by the contractor

2.7 Type of use of the result of scientific and (or) scientific and technical activities: publications in international and Kazakhstan’s journals, materials of international conferences, copyright certificate.

*3.* ***Name of work, terms of their implementation and results***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Code | | Name of work under the Agreement and the main stages of its implementation | Period of execution | | | Expected Result |
| beginning | | ending |  |
| 1 | | will be identified problems of "energy efficiency" of buildings in the residential sector and industry, its features, strengths and weaknesses | Febrary 2018 | | April 2018 | The problems of energy efficiency of buildings in the residential sector and industry, its features, strengths and weaknesses will be identified, 1 article will be published in the journal recommended by the CCSES MES RK |
| 2 | | will be considered international experience of investment incentives for energy efficiency projects in housing and industry | May 2018 | | August 2018 | International experience of investment incentives for energy efficiency projects in housing and industry will be considered, 1 copyright certificate received |
| 3 | | will collect and process the data on the actual energy consumption of the buildings, including an expertise of the building; | September 2018 | | November 1, 2018 | The collection and processing of data on the actual energy consumption of buildings will be carried out, including an expertise of the building, 1 article will be published in the journal recommended by the CCSES MES RK |
| 4 | | will be collecting and processing data about financial indicators of investments in energy efficiency in buildings for a list of applicable financial products | January 2019 | | April 2019 | The collection and processing of data on financial indicators of investments in energy efficiency in buildings will be carried out for a list of applicable financial products, 1 article will be published in the journal recommended by the CCSES MES RK |
| 5 | | will provide the methodology of rating evaluation of the energy efficiency projects | May 2019 | | August 2019 | A methodology for rating evaluation of energy efficiency projects will be developed, a educational textbook "PPP in reforming the housing and communal services of Kazakhstan" will be issued and 1 copyright certificate will be obtained |
| 6 | | will develop proposals for enhancing the green economy based on the PPP principle and implementation of energy service contracts, including proposed business plan; | September 2019 | | November 1, 2019 | Proposals for enhancing the green economy based on the PPP principle and implementation of energy service contracts will be developed, including a proposed business plan, published 2 articles in a peer-reviewed foreign scientific publication indexed in the Scopus database |
| 7 | | tools of innovative services and business models will be developed | January 2020 | | April 2020 | Tools of innovative services and business models will be developed, 1 article will be published in the journal recommended by the CCSES MES RK |
| 8 | | will introduce new standards in the energy efficiency of buildings | May 2020 | | August 2020 | New standards in the energy efficiency of buildings will be proposed, the monograph "Financial instruments of improving the energy efficiency of buildings" will be published and 1 copyright certificate will be received |
| 9 | | will be the algorithm of implementation of energy efficiency tools in buildings in Kazakhstan for transition to green economy | September 2020 | | November 1, 2020 | An algorithm of implementation of energy efficiency tools in buildings for the Republic of Kazakhstan for the transition to a green economy will be proposed, 1 article was published in a peer-reviewed foreign scientific publication, indexed in the Scopus database |
|  | | | | | | |
| From client: The chairman "Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan"  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Abdrasilov B.S.  м.п. | | | Contractor:  President  Kazakh-German University in Almaty  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Marcus Kaiser  м.п.  Familiarized with: Scientific supervisor of the project  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Tleppayev A.M.  (signature) | | | |

**APPENDIX K**

**List of used foreign information resources**

The following foreign information resources were used by the executors of the project:

- SpringerLink, which is one of the leading databases on information data, journals and books on science, technology and medicine (http://link.springer.com/);

- Science Direkt database, which provides access to more than 2,500 magazine titles and more than 11,000 books from the Elsevier Publishing Collection (http://www.sciencedirect.com);

- Scopus, which presents a database that indexes more than 21,000 scientific and technical and medical journals for about 5,000 international publishers (http://www.scopus.com/);

- ThomsonReuters - the Web of Knowledge a multidisciplinary electronic research platform (http://apps.webofknowledge.com) /