

Study guide

ENERGY MANAGEMENT AND AUDIT

Kovrov A.V., Gerasymenko O.A., Elkin Y.G., Kroviakov S.O., Marianko Y.G., Kriukovska-Telezhenko S.A.

Co-funded by the European Union

UKRENERGY

Ministry of Education and Science of Ukraine

Odesa State Academy of Civil Engineering and Architecture

National Erasmus Office in Ukraine

Kovrov A.V., Gerasymenko O.A., Elkin Y.G., Kroviakov S.O., Marianko Y.G., Kriukovska-Telezhenko S.A.

ENERGY MANAGEMENT AND AUDIT

Study guide

Odesa 2025

UDK 697:620.9

**Recommended for publication by the Academic Council of
of the Odesa State Academy of Civil Engineering and Architecture
Minutes No. 10 of 27 March 2025**

Author's team:

Kovrov A.V.	Rector of the Odesa State Academy of Civil Engineering and Architecture, Head of the UKRENERGY project team from the Academy, PhD in Engineering, Professor
Gerasymenko O.A.	Senior Lecturer at the Department of Heat and Gas Supply and Ventilation of the Odesa State Academy of Civil Engineering and Architecture / Senior Expert and Lecturer at the Academy's Master's Programme of the UKRENERGY Project
Elkin Y.G.	Head of the Department of Heat and Gas Supply and Ventilation of the Odesa State Academy of Civil Engineering and Architecture, Senior Expert and Lecturer of the Academy's Master's Programme of the UKRENERGY Project, PhD in Engineering, Associate Professor
Kroviakov S.O.	Vice-Rector for Research of Odesa State Academy of Civil Engineering and Architecture, Senior Expert and Lecturer of the Academy's Master's Programme of the UKRENERGY Project, Doctor of Technical Sciences, Professor
Marianko Y.G.	Head of the Department of Foreign Languages at the Odesa State Academy of Civil Engineering and Architecture / Subject Expert, PhD in Philology, Associate Professor
Kriukovska-Telezhenko S.A.	Associate Professor of the Department of Heat and Gas Supply and Ventilation of the Odesa State Academy of Civil Engineering and Architecture, subject matter expert and lecturer of the Academy's Master's programme of the UKRENERGY project, PhD in Engineering, Associate Professor

Reviewers:

Mityuchenko I.V. Chairman of the Board of OdesaGas JSC

Titlov O.S. Doctor of Technical Sciences, Professor, Head of the Department of Oil and Gas Technologies, Engineering and Heat Power Engineering, Odesa National Academy of Food Technologies

Shekhorkina S.E. Doctor of Technical Sciences, Professor, Department of reinforced concrete and masonry structures REI «Prydniprovska State Academy of Civil Engineering and Architecture» Ukrainian State University of Science and Technologies

Energy Management and Audit: a study guide / Kovrov A.V., Gerasymenko O.A., Elkin Y.G., Kroviakov S.O., Marianko Y.G., Kriukovska-Telezhenko S.A. - Odesa, 2025. 158 p. (electronic edition).

The study guide was developed within the framework of the project 101082898 - UKRENERGY, co-funded by the European Union: “Innovative master»s courses to support the improvement of the energy and carbon footprint of the Ukrainian building stock”.

The project is co-financed by the European Union, but the views and opinions expressed are those of the authors of this project and do not necessarily reflect the views of the European Union or the European Executive Agency for Education and Culture. Neither the European Union nor the grantor can be held responsible for them.

The introductory guide deals with energy management and auditing. It describes aspects of the implementation and operation of an energy management system. It provides examples of calculations, guidelines and tools used in the energy audit process.

For scientists, teachers, students of technical specialities, energy auditors, representatives of business and government, as well as for a wide range of readers.

ISBN 978-617-8365-04-2

© A.V. Kovrov, O.A. Gerasymenko,
Y.G. Elkin, S.O. Kroviakov, Y.G. Marianko,
S.A. Kriukovska-Telezhenko, 2025

CONTENTS

INTRODUCTION ……..…….…….……... 7

Part 1: ENERGY MANAGEMENT

1. ESSENCE AND PRINCIPLES OF ENERGY MANAGEMENT .....…. 10

1.1. Tasks of energy management. Basic concepts ……..…. 10

1.2. Energy efficiency standards …….....…….…. 12

1.3. Problems of implementing energy management systems ……...…. 14

2. IMPLEMENTATION OF THE STRATEGY AND SYSTEM OF ENERGY MANAGEMENT AT THE ENTERPRISE AND ORGANIZATION ……..…. 18

2.1. Energy strategy of enterprise and organization ……..……...…..…… 18

2.2. Creation and improvement of energy management systems ……... 21

2.3. Organizational tools of energy management systems ……...…...…. 25

2.4. Methodical means of energy management systems ……..…. 26

3. IMPROVEMENT OF ENERGY MANAGEMENT SYSTEM ……. 31

3.1. Performance of energy management system functions ……..….. 31

3.2. Stimulation of energy management …….……...…. 33

3.3. Principles of financing energy saving measures …….……...…. 34

3.4. Analysis and evaluation of the energy management system performance . 35

3.5. Levels of energy management development …….…….…… 37

3.6. Using the energy management matrix …….……..…. 39

3.7. Energy management information systems …….……...…… 42

4. CONTROL AND NORMALIZATION OF ENERGY CONSUMPTION …… 44

4.1. Main provisions and basics of energy consumption control and normalization technology ……..…… 44

4.2. Building management system ……...…...…..…… 46

4.3. Changes in the use of fuel and energy resources ….…….. 49

4.4. Classification of specific consumption rates of fuel and energy resources 50

4.5. Specific indicators of fuel and energy resources consumption ……... 51
4.6. Sequence of determination of specific consumption rates of fuel and energy resources at the enterprise ……..…… 52
4.7. Certification and marking systems in energy conservation …… 54

5. BUSINESS PLANNING OF ENERGY SAVING PROJECTS ……..… 57
5.1. Financial and economic analysis of energy efficiency projects …… 57
5.2. Project Evaluation Methods ……..…….……. 58
5.3. Business plan and feasibility study of energy saving projects ……...…… 60
5.4. Procedure for development of feasibility study ……..…. 62
5.5. Fuel and energy balance ……..…. 63
5.6. Approaches to energy balance ……...……. 65

Part 2: ENERGY AUDIT

1. DEFINITION AND ALGORITHMS OF ENERGY AUDIT .....…. 67
1.1. General provisions. Objects of energy audit ……...… 67
1.2. Energy audit process ……..…….…… 70
1.3. Examples of industry-specific energy audit methodologies ……...…… 72

2. ENERGY AUDIT PLANNING PROCESSES ……..……...… 75
2.1. Preparation and purpose of the energy audit ……...…… 75
2.2. Define the boundaries, nature and scope of the energy audit …….. 75
2.3. Quality indicators of energy audit and qualification requirements for contractors ……...…… 78
2.4. Preparation of the terms of reference for energy audit work ……..…. 81
2.5. Organizational measures for planning an energy audit ……..…… 81
2.6. Development of energy audit schedule ……..……..….... 84
2.7. Master data collection and processing ……..……..……. 86
2.8. Processing and preliminary analysis of basic data on the object of energy audit ……...…….……. 91

3. METHODOLOGY OF ENERGY AUDIT ……... 94

3.1. Determination of energy consumption and its cost according to the facility documentation …….…….. 94
3.2. Facility energy survey and technological process …….. 94
3.2.1. Site visit ……..…….. 95
3.2.2. List of important energy consumers ……..……... 97
3.2.3. Site Energy Efficiency Analysis ……..……. 99
3.2.4. Elements of energy efficiency analysis ……. 100
3.2.5. Calculation of energy consumption at the facility ……..... 102
3.3.5.1. Seasonal fluctuations in energy consumption ……..… 102
3.3.5.2. Sankey diagram …… 104
3.3.5.3. Process bulb …….……. 106
3.3.5.4. Evaluation priorities ……...…….. 107
3.3. Planning and measurement ……. 108
3.3.1. Sequence of determining the appropriate place of measurement …. 109
3.3.2. Measurement methods and procedures ……..…….. 110
3.3.3. Measuring equipment used during the energy audit ……..……... 111
4. CERTIFICATION OF ENERGY EFFICIENCY OF BUILDINGS ……..….. 119
4.1. Key provisions on energy efficiency certification …….. 119
4.2. Data for energy efficiency assessment …… 120
4.3. Example of input data for energy efficiency assessment …… 121
4.4. Example of photo and video materials, thermal imaging results …… 123
4.5. Calculation of heat consumption through windows and doors ……..……. 127
4.6. Example of building description ……...…….. 128
4.7. Example of calculating heat losses through enclosing structures ……... 130
4.8. Example of description of engineering systems ……. 132
4.9. Analysis of actual energy consumption …….. 135
4.10. Example of heat input calculation …….…….. 136
4.11. Example of solar heat input ……..….. 139
4.12. Determination of energy consumption and use of energy …….……. 141

4.12.1. Transmission heat transfer characteristic ……..…….. 141
4.12.2. Characteristics of internal and solar heat input ……...… 146
4.13. Calculation of heat consumption …… 146
4.14. Total heating power consumption ……..……. 149
4.15. Cooling power consumption …….…….. 150
4.16. Lighting power consumption …….. 150
4.17. Determination of building energy efficiency ……..…… 151
4.18. Calculation of primary energy and greenhouse gas emissions …..……. 152
4.19. Conclusions on the results of the survey ……..…….. 153
REFERENCES……..……..……..…… 155
Attachment. An example of the first page of the building energy certificate is given in ……...…….. 158

INTRODUCTION

At the end of the twentieth century, the global economy was shaken by economic and energy crises, which led to a sharp decline in the rate of economic and social growth in many countries. In order to stabilize economic and social development, the United Nations adopted the Millennium Declaration in 2000, which reflected global directions and priorities until 2015.

In September 2015, the UN considered issues related to the sustainable development of countries and adopted a program to transform the development of countries by 2030. Each area was considered taking into account the national peculiarities of the countries.

In the early twenty-first century, Ukraine showed steady economic growth, which had a positive impact on the social situation.

GDP growth in the first seven years of the century was approximately 7.5%, and Ukraine's total GDP increased by almost 80%. At the same time, the development took place in the context of a predominantly raw material-oriented export-oriented socioeconomic model in Ukraine. This created the illusion of economic competitiveness, which led to a negative reaction to the global financial crisis of 2008-2009. Since 2010, the economy has been growing against the backdrop of a recovery in foreign markets. According to the State Statistics Service, Ukraine's exports of goods grew by almost 29.6% in 2010. This was also facilitated by the implementation and achievement of sustainable development strategies. The general goals of the country's sustainable development are: rational management, ecological balance and energy efficiency.

The basis of the state's energy security is the efficient functioning of the fuel and energy complex. The optimal operation of this sector has a significant impact on the country's economic performance and the welfare of its citizens.

Before the full-scale invasion, Ukraine had a strong energy generating potential. At the end of 2020, the total installed capacity of power generating plants in Ukraine was approximately 58 GW, of which about 47% were thermal power plants, 24% were nuclear power plants, 12% were combined heat and power plants, 8% were

hydroelectric power plants, 7% were power plants using non-conventional energy sources, and 2% were pumped storage power plants.

In recent years, there has been a downward trend in fuel consumption, and, accordingly, in heat and electricity. This was especially true during the last three years of the full-scale war with Russia. Over the past three years, Ukraine's energy sector has lost more than 40% of its generating capacity, up to 90% in the thermal power sector and up to 40% in the hydropower sector. The loss of capacity at the nuclear power units of the Zaporizhzhya Nuclear Power Plant had negative consequences for the entire Ukrainian energy system.

At the same time, power equipment is one of the main sources of environmental pollution. Emissions of harmful substances by energy companies reach approximately 40% of all other sources of pollution.

There is a need to overcome the backlog in the maintenance and modernization of the housing stock in Ukraine that has been accumulating for decades. The core of the problem lies not in rising energy prices, but in huge energy losses. Much of the heat supplied to residential consumers is lost due to the poor condition of utility networks and inefficient heat distribution in buildings. Judging by the results of comparable energy rehabilitation projects in the residential sector in other countries, we can expect heat energy savings of up to 70%. Further delays in solving this problem will lead to even greater heat loss and an increase in the cost of future rehabilitation measures. In addition, it is necessary to take into account the “normal” increase in the cost of construction work, as well as the increase in the cost of inflation, especially since some construction materials and production equipment have to be imported.

In order to improve energy efficiency in the housing and utilities sector, which is the largest consumer of energy (40% of total consumption), the following features should be highlighted

- heating and hot water supply systems have a great potential for energy savings (about 25%);
- losses for heat production and distribution in Ukraine amount to 60%;

- the experience of European countries with complete energy modernization of the housing stock shows that it is possible to achieve heat energy savings of up to 55%;
- the potential for reducing fuel consumption (gas imports) is about 60%.

Thus, improving energy efficiency in the housing stock is a priority area of sustainable development.

Therefore, the strategy of sustainable development in Ukraine should be based on a revision of the concept of energy and its need, and should be ensured by using significantly less energy.

Rational use of resources, especially fossil fuels, increased efficiency of energy consumption, and development of non-traditional energy sources can meet the necessary energy needs.

Energy saving is based on activities aimed at reducing the consumption of fuel and energy resources along the entire chain from production to use.

Ukraine has a systematic and effective approach to developing legislative and regulatory acts to improve energy efficiency and energy saving. Such measures include the development of the Concept of Sustainable Development of Ukraine in 2023, the Strategy for Thermal Modernization of Buildings for the period up to 2050. The Operational Action Plan prioritizes the coordination of goals at the national and local levels.

The second area is the introduction of strategic planning tools at all levels of the administrative and territorial structure, development and approval of local energy plans until 2030, coordination of long-term planning and implementation of energy-efficient measures for thermal modernization of buildings.

Thus, the priority area for the implementation of the long-term strategy for thermal modernization of buildings is the gradual introduction of energy management in the housing and utilities sector, as well as the improvement of energy efficiency audits of buildings.

Part 1: ENERGY MANAGEMENT

1. ESSENCE AND PRINCIPLES OF ENERGY MANAGEMENT

1.1. Tasks of energy management. Basic concepts

Drastic changes in legislation, inflation, doing business in new conditions and under martial law, exchange rate instability, rising energy and raw material tariffs are just some of the issues that require solutions.

Energy saving will make a significant contribution to their solution.

Reducing energy costs by improving energy efficiency will lead to a number of benefits:

- increased profitability;
- greater competitive ability;
- preservation of jobs;
- achieving the goal of survival in the current environment.

As an example, energy saving was implemented by enterprises in Western Europe in the 1980s, which to some extent is similar to the situation in Ukraine.

The rapid rise in energy prices in 1979-1982 (energy costs increased by 600%) led to a decline in production in Europe, many companies went bankrupt, and many jobs were lost.

Since then, the economies of Europe and America have been paying serious attention to energy management. To a large extent, this was achieved with little capital investment. The above-mentioned has made it possible to reduce energy costs by more than 30%. The typical cost of energy resources in a company's production now accounts for about 5% of total costs.

The main tasks of energy management are as follows:

- Analyzing energy use in general and by individual types of equipment,
- creating a fuel and energy balance of the enterprise;
- analysis of energy consumption efficiency;
- development of proposals for improving production processes, equipment, maintenance, utilization of secondary energy resources, etc;

- determination of the rational type of energy carriers for the enterprise;
- calculation and control of specific energy consumption rates for certain types of equipment and technologies;
- justification of sources of investment and financing of energy saving and energy efficiency measures;
- development of measures to encourage staff to save energy;
- creation of an energy accounting system at the enterprise and justification of the required level of its automation.

The following terms and concepts are used in energy management.

Energy saving is actions, processes and measures that accompany activities aimed at the reasonable use of energy resources.

Implementation of energy saving measures means the implementation of legislative, legal, organizational, technical, economic, scientific and informational measures aimed at efficient use of fuel and energy resources and improvement of the environment.

Energy efficiency is a characteristic of equipment, a technological process or a system in general, which reflects the degree of energy use per unit of output.

Energy management is an activity aimed at ensuring the rational use of fuel and energy resources and aimed at obtaining energy information through accounting, conducting standard energy and technological measurements and inspections, analyzing the efficiency of fuel and energy resources and implementing energy saving measures.

The energy management system is a part of the enterprise management system whose main task is to control the efficiency of fuel and energy resources consumption.

Energy management service is a business unit that ensures the development, implementation and achievement of energy saving goals.

Energy management matrix is a tool for visualizing and analyzing the state of functioning of the energy management system, which contains a set of audit criteria used to verify the energy management system.

Environmental management system is a part of the enterprise management system that includes organizational structure, planning, distribution of responsibilities,

practical methods, procedures, processes and resources necessary for the development, implementation, realization, analysis and development of environmental policy.

Energy use is a set of actions and operation of equipment and technologies related to the processes from energy generation to consumption.

Energy audit is a part of energy management aimed at inspecting a facility/enterprise in terms of its energy use, identifying facts of irrational energy use, determining energy saving measures, and assessing technical and economic opportunities for their implementation.

Energy consulting is an activity aimed at realizing the benefits of energy saving; solving customer's energy problems; selecting and justifying energy efficient solutions; disseminating knowledge and training personnel.

An energy service company is an organization that provides energy saving consulting services in combination with the search for investors for specific energy saving projects or acts as such an investor.

Energy balance is a system of indicators that reflects the quantitative correspondence between the receipt and consumption of energy resources.

1.2. Energy efficiency standards

Improving energy efficiency (of facilities, systems, processes, and equipment) is a very urgent task for Ukraine.

The implementation of international ISO standards in Ukraine can help solve the energy problem by improving energy efficiency and promote the development of renewable energy technologies.

Standards play an important role in the development of technical compatibility and global business competitiveness.

Currently, there are the following international standards (ISO) for energy management systems:

- ISO 50001:2011 - for the development of energy management systems (already adopted in Ukraine as a national standard and effective from 01.01.2015 DSTU ISO 50001: 2014);

- ISO 50002:2014 - on the basic principles and requirements for conducting energy audits;
- ISO 50003:2014 - requirements for bodies that audit and certify energy management systems;
- ISO 50004:2014 - for the implementation, maintenance and improvement of energy management systems;
- ISO 50006:2014 - basic principles and guidelines for measuring energy efficiency;
- ISO 50015: 2014 - on basic principles and guidelines for measuring and verifying energy performance in organizations.
- ISO 50001:2011 Energy management systems - Requirements with guidance for use has already been adopted in Ukraine as a national standard:
- DSTU ISO 50001:2014 “Energy saving. Energy management systems.

Requirements and guidance for use (ISO 50001:2011, IDT)”, effective from 01.01.2015, will provide organizations and companies with technical and managerial principles to improve energy efficiency, reduce costs and improve environmental performance.

Other standards in this series are also required to be implemented in Ukraine:

ISO 50002:2014 Energy audits - Requirements with guidance for use helps to make informed decisions about how to use your energy; it sets out the requirements for the process of conducting an energy efficiency audit, defines the principles of energy surveys, requirements for general processes during an energy audit and components of an energy audit. It is applicable to all types of institutions and organizations, as well as to all types of energy and energy use.

ISO 50003:2014 Energy management systems - Requirements for bodies providing audit and certification of energy management systems - will ensure the effectiveness of audit and certification and impartiality in the conduct of audit and certification. It is intended for use in conjunction with ISO/IEC 17021:2011 Conformity assessment - Requirements for bodies providing audit and certification of management systems. Requirements for bodies providing audit and certification of

management systems). This includes additional requirements for audit planning, initial audit, on-site audit, and ensuring that auditors have the necessary skills.

ISO 50004:2014 Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system. Guidance for the implementation, maintenance and improvement of an energy management system);

The examples and approaches presented in this standard illustrate possibilities and are not necessarily appropriate for every organization. In implementing, maintaining or improving an energy management system, it is important that organizations choose approaches that suit their own circumstances.

ISO 50004:2014 will help enterprises to use a systematic approach to continuously improve energy management and increase the effectiveness of green initiatives.

In order to effectively manage the energy efficiency of facilities, systems, processes and equipment, organizations need to know how energy is used and how much is consumed over time.

ISO 50006:2014 Energy management systems - Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) - General principles and guidance. provides practical guidance on how to meet the requirements of ISO 50001 and, as a result, achieve energy efficiency improvements.

1.3. Problems of implementing energy management systems

Implementation of energy management systems is accompanied by obstacles that can be conditionally classified into the following groups:

- Legal
- Social
- Administrative
- Production
- Financial
- market;

The list of the main obstacles to the implementation of energy saving policy by groups is presented in Table 1.1.

Table 1.1

Obstacles group	List of obstacles
Legal	• absence of normative acts on mandatory accounting of heat and electric energy costs; • lack of responsibility for non-payment of consumed energy. • ignoring consumer losses caused by outages and the supply of low-quality energy. • incomplete compliance with antitrust laws in the functioning of the energy market. • insufficiently developed system of responsibility of energy suppliers.
Social	• lack of awareness of the management of enterprises and citizens about the possibilities of saving energy, its real cost and alternative sources of supply; • poor use of Internet resources to disseminate information about energy saving; • low level of qualification in the fields of energy saving, energy marketing and energy management; • lack of demand for consulting services for energy efficiency assessment; • irrational methods of providing social benefits for energy consumption; • illegal use of energy resources; • lack of public understanding of the importance of energy efficiency and energy saving
Administrative	• opaque financial flows in the energy market, where decisions are made according to administrative criteria;

	• Determining the price of energy on the basis of political considerations, rather than market costs; • use of outdated regulatory framework of planned economy in market conditions; • outdated "Rules for the use of electric energy," which do not correspond to modern realities; • ignoring the rights of consumers in the documents and practices of energy supplying companies; • application of outdated methods of rationing from planned economy; • priority of goods with high liquidity in the foreign market over energy efficiency; • administrative restriction of energy supply to consumers
Production	• the advantage of investment in improving labor productivity over investment in energy efficiency; • imbalance between supply and demand for power and energy; • inefficient structure of generating capacities, in particular lack of maneuvering capacities; • slow pace of modernization of TPP equipment, which leads to an increase in energy prices; • high process losses in energy transmission and distribution; • unexpected or insufficiently prevented power outages; • low efficiency of equipment due to its deterioration; • significant commercial energy losses; • no choice of energy supplier; • the hidden monopoly of energy suppliers.
Financial	• lack of capital, especially working capital; • high interest rates on loans;

	• significant capital raising costs due to high credit rates; • non-payments for consumed energy; • opaque tariffs for power and energy that do not reflect the real costs of energy companies; • lack of investment in the energy sector.
Market	• unregulated market for energy-saving equipment and technologies; • lack of experience in marketing research, business planning and management of energy-saving projects; • shifting the costs associated with irrational use of energy to society; • ignoring the costs associated with environmental pollution in the production and consumption of energy; • covering excessive energy consumption through energy imports, which places a burden on society; • lack of ability to choose a supplier and type of energy carrier; • the hidden monopoly of energy suppliers; • opacity of privatization of energy facilities; • inconsistency in the regulation of the energy market; • inconsistency of benefits for the use of energy to market relations.

Knowledge and consideration of the above obstacles allows us to ensure the qualitative implementation of energy management systems.

2. IMPLEMENTATION OF THE STRATEGY AND SYSTEM OF ENERGY MANAGEMENT AT THE ENTERPRISE AND ORGANIZATION

2.1. Energy strategy of enterprise and organization

The energy strategy of the enterprise makes it possible to develop an effective energy efficiency program. This enterprise strategy defines general steps regarding the rational use of energy resources. It includes the following items:

- receipt (purchase) of primary energy resources;
- conversion of primary energy resources at the enterprise;
- distribution and supply of energy;
- use of energy;
- distribution of management responsibility for the use of energy resources.

The strategy focuses not only on the cost of energy, it is like a compass in energy efficiency. The energy strategy includes a number of goals, with the help of which the work of the enterprise will be adjusted, with the fulfillment of established tasks.

The energy strategy consists of developing an energy efficiency solution. The development and publication of corporate energy policy demonstrates that energy saving issues are common to all. Energy policy is developed for internal use purposes. The key role in this lies with the head of the enterprise and his determination in the issue of energy saving depends on the achievement of significant results in saving energy costs.

According to the ISO 50001 standard, top managers of an enterprise must demonstrate a commitment to the energy management system to continuously improve its efficiency by determining a certain energy policy.

Energy policy is the most important element of the energy management system. The duty of top managers of the enterprise is to determine and document the energy policy of the enterprise.

The sphere of energy policy includes:

- addressing all factors related to energy use;
- responsibility of the region and the boundaries of the energy management

system;

- appropriateness of the nature and scale of energy use;
- compatibility with the policies of other management systems.

Inefficient energy policy can be recognized in the case when the energy manager cannot control its implementation.

Evaluation of results and monitoring are necessary for management to receive information on the effectiveness of investments in energy efficiency, in particular financial and labor resources.

Monitoring data allow us to compare the performance of the enterprise with certain goals to improve energy efficiency.

Setting such goals serves as a benchmark for improving energy efficiency both in individual units and at the level of the entire enterprise.

Many enterprises managed to significantly reduce energy consumption and waste, which led to significant cost savings and confirmed that improving energy efficiency brings significant benefits.

The benefits of implementing an energy strategy can be divided into three main categories:

Environmental benefits - reducing negative environmental impacts both locally and globally.

Production benefits - increasing the efficiency of the company, improving staff productivity and product quality.

Financial benefits - direct reduction of costs and increase the financial stability of the enterprise.

When promoting energy efficiency, it is worth emphasizing its many advantages, but it is financial benefits that are usually the key factor on which attention should be focused.

Energy-saving policy in the production system (BC) should determine the goals, objectives, basic principles, as well as those responsible for its implementation.

The leadership of the Armed Forces forms a policy in the field of energy saving, approving it by order, and also appoints responsible persons, sets deadlines and

provides the necessary resources for the implementation of projects and events.

In accordance with the standard DSTU 4472:2005 "Energy management system. General requirements "energy saving policy of the production system shall ensure:

- compliance with the legislation of Ukraine in the field of energy saving, as well as compliance with technical regulations, norms and rules that must be performed by employees of the Armed Forces;
- consistency with the policy of the Armed Forces in the fields of ecology, labor protection and other related areas;
- cooperation with local and regional authorities in matters of energy saving;
- increasing the efficiency of use of fuel and energy resources;
- development of methods, models and tools for effective use of FEM in production processes;
- assessment of the effectiveness of the use of TX in accordance with the established criteria;
- creation of conditions for implementation of energy saving measures;
- improvement of energy saving policy;
- taking into account local and regional peculiarities in the implementation of energy saving measures;
- advanced training of energy management system personnel;
- encouraging employees to use energy resources rationally;
- promoting energy efficiency and informing staff about achievements in the field of energy saving.

The energy saving program should determine the goals, objectives, procedure for the development and implementation of energy saving measures.

Energy targets and indicators remain key elements of the energy management system and should correspond to the organization's energy policy.

Established energy targets and indicators should be:

- measured;
- documented;

- with certain deadlines for achievement.

To achieve these goals, ISO 50001 recommends the development and support of energy management action plans.

The power saving program must contain the following sections:

- general provisions with definition of goals and objectives;
- management responsibility;
- characteristics and prospects for the development of BC on the use of TR;
- current state of energy consumption;
- projected needs of the enterprise in the FEM;
- analysis of energy saving potential and identification of priority measures;
- a plan for the implementation of energy-saving measures indicating the deadlines and responsible persons;
- low-cost priority and promising energy-saving measures;
- feasibility study of implemented measures;
- tasks to units for the implementation of energy efficient equipment and technologies;
- document management, information flows;
- control of instrumentation systems;
- staff motivation for energy saving;
- personnel training;
- Monitor program execution
- program implementation mechanism (execution stages, performers, necessary resources and funding sources).

2.2. Creation and improvement of energy management systems

Energy management (EM) is a management system aimed at ensuring the rational consumption of fuel and energy resources (EE), which is based on conducting energy-technological measurements and inspections, analyzing the level of energy use and implementing energy-saving measures.

The energy management system (SEM) is a complex of organizational technical means, methodological and software, which together allows you to manage a particular process, so that only the minimum required amount of FOP is consumed to produce a certain amount of products or services.

The purpose of the implementation of SEM – to reduce the cost of payment PER.

Experience shows that the introduction of EMS allows you to reduce payments for energy resources by 10 - 30% tons due to cost-free and low-cost organizational and technical measures (payment only for the actual consumed FEM, improving the quality of work of operational personnel, optimizing the operating modes of equipment, timely technical and repair maintenance.

The introduction of EMS – a priority measure to reduce the cost of payment for PER in any organization, because:

- cost reduction is achieved with small investments and short terms of the event;
- possible phased implementation of SEM, which allows to carry out the event even in conditions of shortage of working capital;
- SEM is the basis for the following larger energy-saving projects, as it creates an information platform and motivation for its implementation.

EMS can be implemented at all power consuming facilities.

To form an EMS, a Concept for creating an EMS is created, which has the following structure:

- Control object;
- Purpose and criteria of management;
- Control actions;
- Limitations on the management process;
- Uncontrolled effects on the object;
- Controls.

The object of management is the enterprise or the organization as a whole, or their separate divisions, fuel and power-consuming units, as well as personnel related to issues of efficiency of using the FEM.

The purpose of management is to minimize the specific consumption of FEM per unit of product (services)

$$\text{P} = \frac{\text{E}}{\Pi} \rightarrow min,$$

where Π – the volume of production (service) for the reporting period in monetary terms;

E – PER consumption for the same period.

Control actions contain directly on the equipment and floats on the technical staff.

The following groups of control actions can be distinguished:

- administrative and organizational;
- technical;
- program-methodical, (Fig. 2.1).

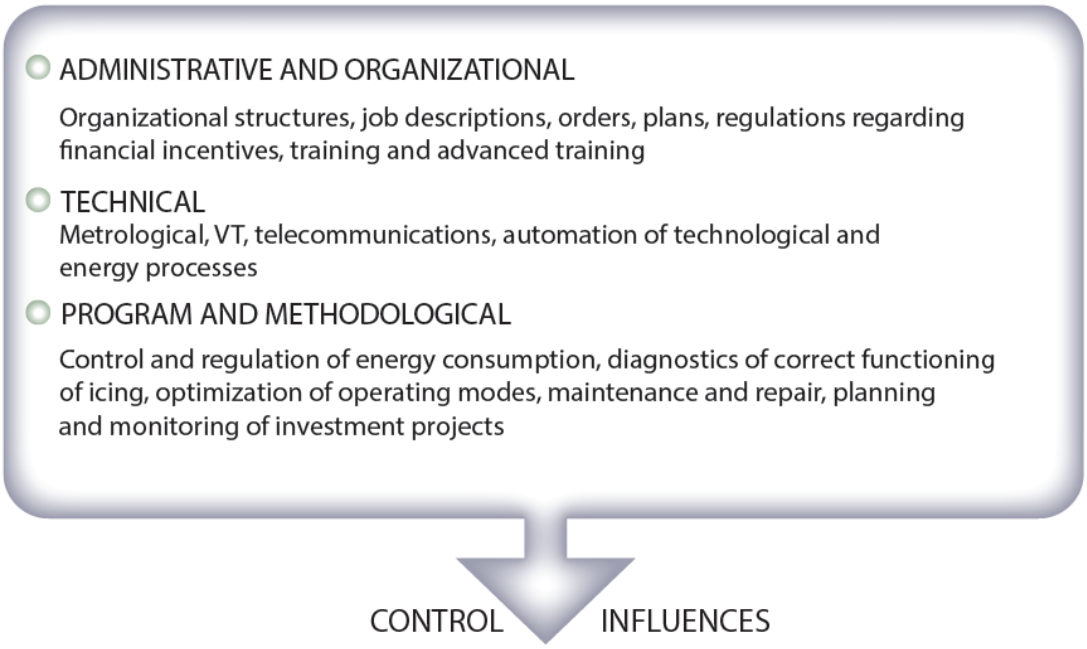


Fig. 2.1. Control action groups

The structure of impacts on objects is shown in Fig. 2.2.

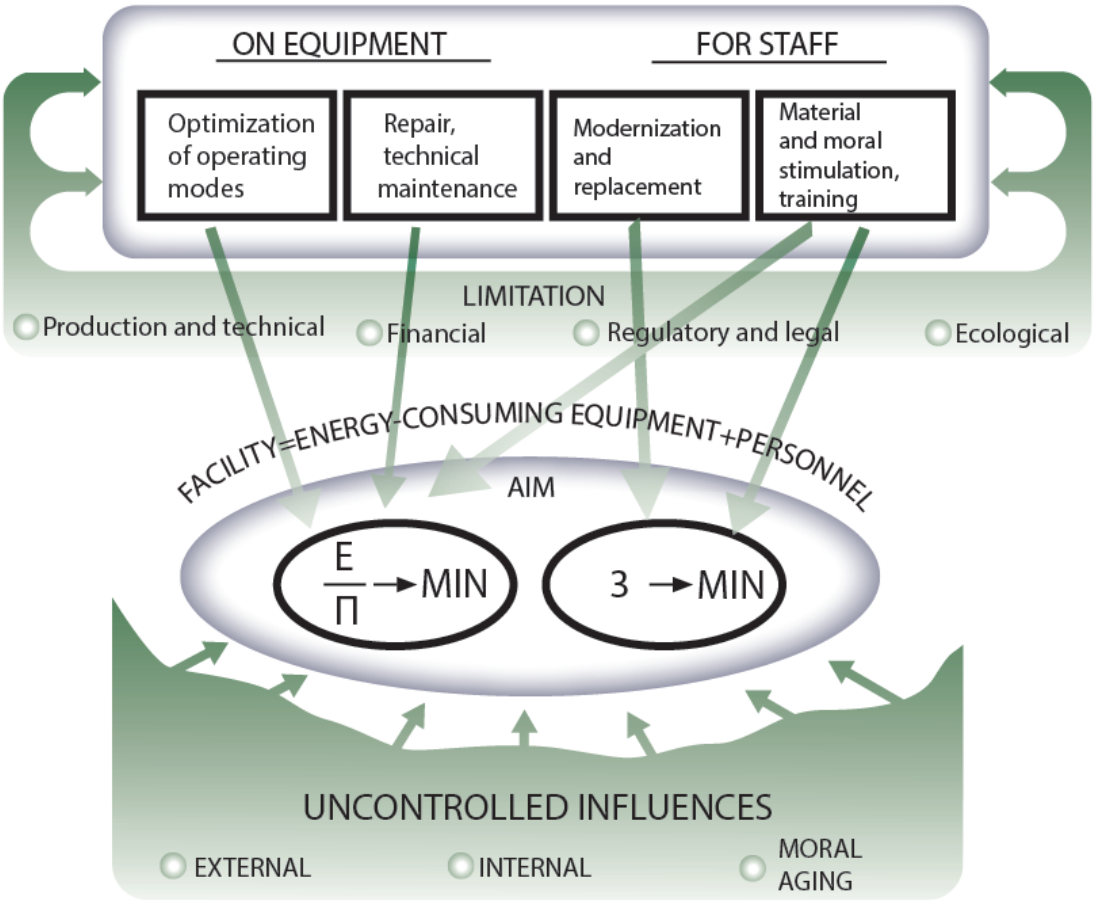


Fig. 2.2. Structure of effects on objects

Effects on equipment include:

- Optimization of operation modes;
- Maintenance modes;
- Repair service;
- Modernization or complete replacement of equipment.

Technical personnel can be influenced by material incentives, as well as using approaches to moral incentives.

Limitations on the management process. Any management process, including management of FP consumption, is associated with certain limitations. In general, it is

necessary to take into account the limitations of the planned production, financial, technical, regulatory and environmental nature.

Uncontrolled effects on the object should be considered the reason for the decrease in the effectiveness of the use of EPS. Although they cannot be completely eliminated, they must be compensated for by appropriate control actions.

Controls include organizational, methodological, software and technical areas.

2.3. Organizational tools of energy management systems

The SEM organizational means should regulate the actions of the operational and management personnel of the enterprise (organization) and create motivation to achieve the goal of minimizing the specific costs of FEM and the total costs of acquiring FEM and implementing energy-saving measures.

The EMS shall function on the basis of systematic execution of the defined sequence of actions and procedures (Fig. 2.3).

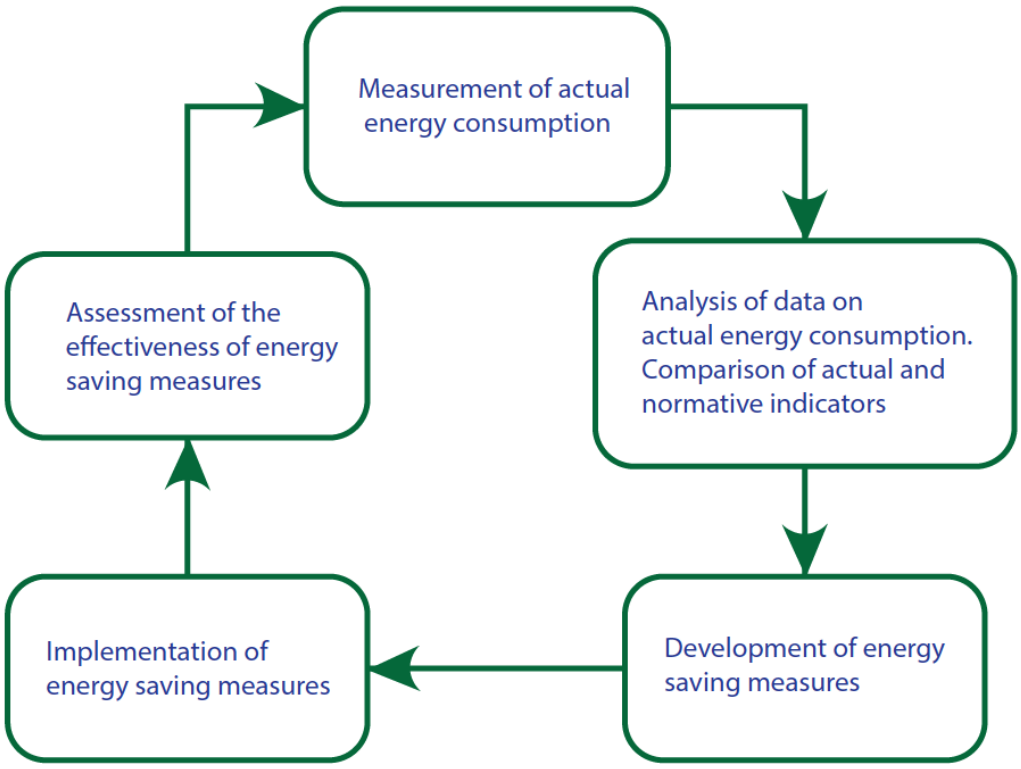


Fig. 2.3 Organization of EMS functioning

2.4. Methodical means of energy management systems

In accordance with the functions that the EMS should perform, the structure of its methodological means can be represented as a set of four interdependent subsystems, namely:

- Monitoring and normalization of energy consumption (KiN);
- Diagnostics of reasons for exceeding the actual energy consumption above the normative level;
- Optimization of operation modes, technical and repair maintenance;
- Planning and evaluating the effectiveness of energy saving measures.

The KiN subsystem is a basic subsystem that performs important independent functions, and also provides other EMS subsystems with output data.

KiN subsystem is functionally connected to the system of operational monitoring of process parameters.

KiN shall perform the following functions:

- Formation and preservation of a database of actual absolute indicators of energy consumption of objects and averaged values of the main technological parameters at daily time intervals;
- Preliminary control of the probability of daily data on actual energy consumption indicators;
- Performing the function of virtual counters;
- Calculation of actual absolute energy consumption indicators;
- Calculation of actual specific energy consumption indicators. The determining parameter is the parameter on which the amount of PER consumption depends, for example: the number of products produced or the number of degree days;
- Calculation of standard values of energy consumption indicators;
- Compilation of energy balances for various objects;
- Documentation of information.

The structure of methodological tools is shown in Fig. 2.4.

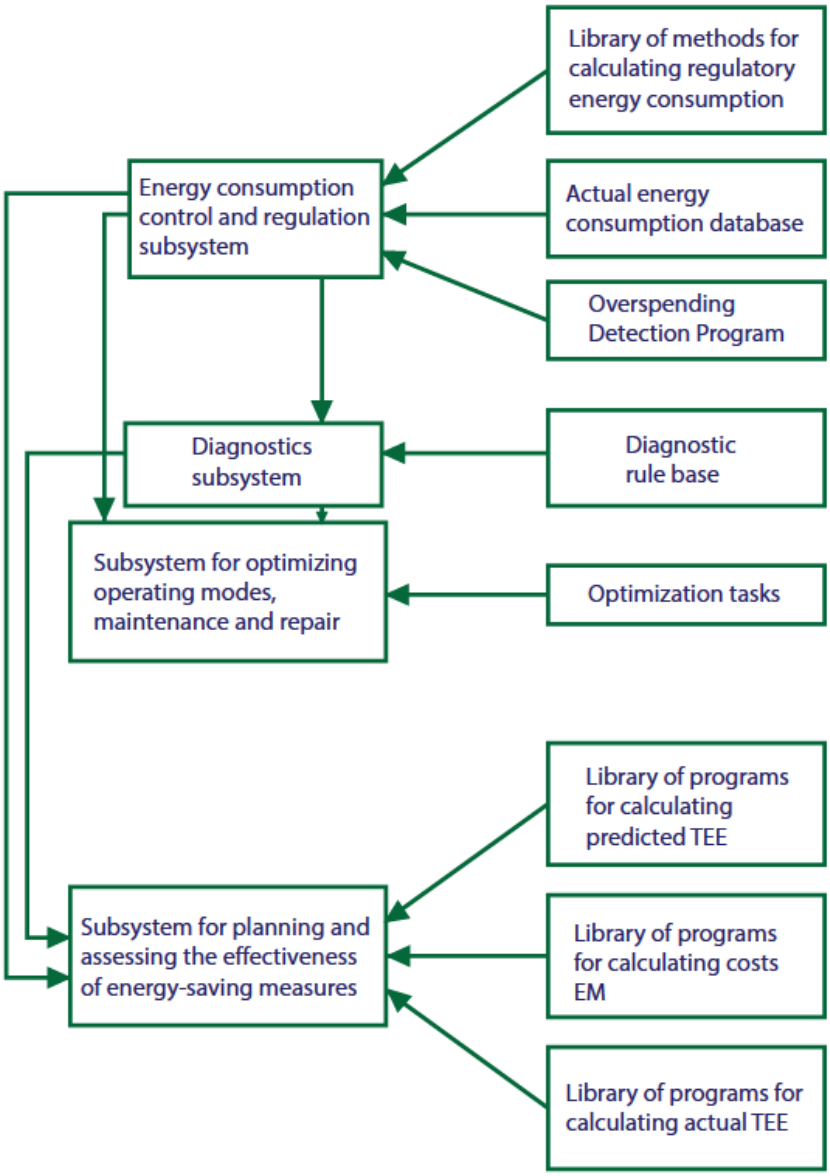


Fig. 2.4 Structure of methodical means

As part of the development of EMS, a general approach to solving the problem of diagnostics can be used based on the principles of building expert systems, which is widely used in systems for supporting management decision-making.

Diagnostics subsystem uses data on actual values of controlled process parameters and contains base of diagnostic rules and process situations interpreter (Fig. 2.5).

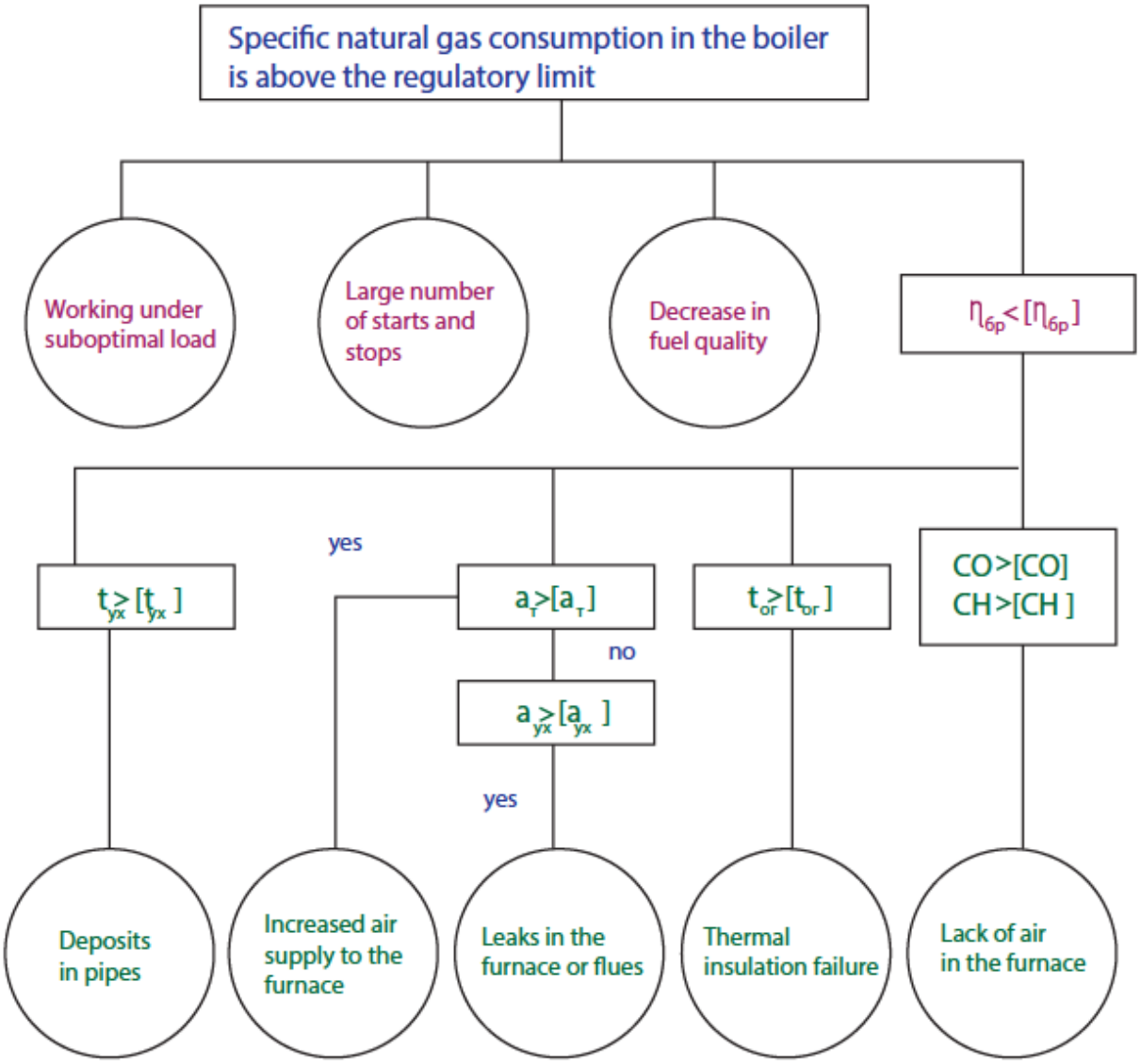


Fig. 2.5 Enlarged assessment tree

The rule base is open for new rules.

It should be continuously replenished by the energy manager in the process of accumulating experience in the operation of SEM.

The work of the process situation interpreter is to compare the actual values, diagnostic characteristics with the characteristic values specified in the rules and select those rules for which the characteristic designations coincide with the actual ones.

According to ISO 50001, the organization must:

- create, document, implement and maintain an energy management system in

accordance with the requirements of the current standard;

- identify and document the scope and boundaries of the energy management system;
- establish and record how the system meets the requirements of this standard to ensure continuous energy efficiency improvements.

According to the ISO 50001 standard, the top management of the organization is obliged to demonstrate commitment to continuous improvement of the efficiency of the energy management system, in particular by determining the energy policy.

The development and implementation of the energy management system (EMS) is a set of interrelated works, ordered in time and divided into stages and stages. Their implementation is a necessary and sufficient condition for creating an EMS that will meet the requirements of the technical assignment.

The ISO 50001 standard is also based on a continuous improvement known as the PDCA cycle (Plan-Do-Check-Act), which must be used by each company, regardless of type or size. Therefore, it is not enough to introduce an energy management system once. The goal should be its continuous improvement and control (Fig. 2.6).

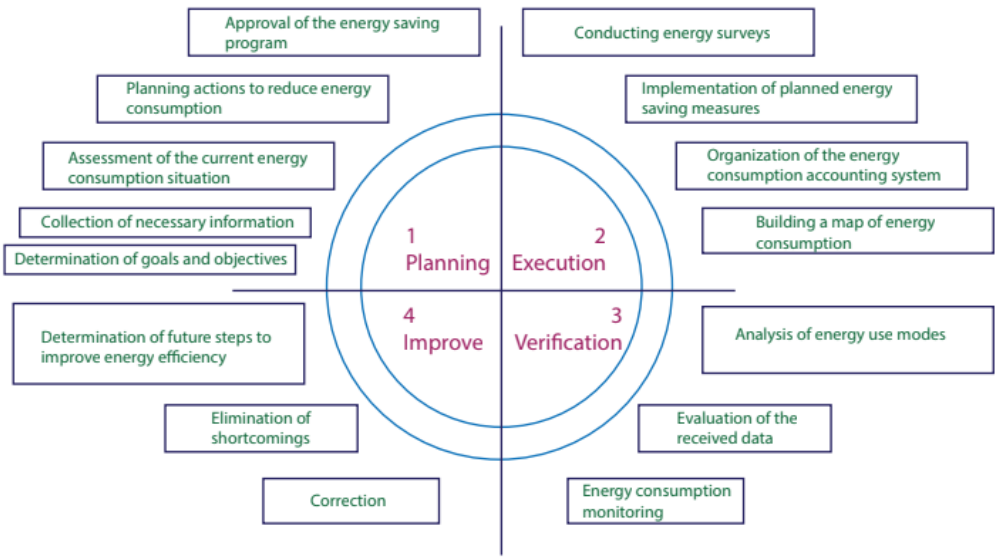


Fig. 2.6. Continuous Improvement Framework, PDCA Cycle

The phases are interconnected and thus provide constant movement and improvement.

Planning: In the beginning, there is always an energy assessment. Determine the starting point, including energy performance indicators (EnPIs), strategic and operational energy goals, and your approach. Here it is determined the energy consumption of various departments. This data forms the basis for further improvement processes and allows you to determine the potential for improving energy efficiency.

Execution: At this stage, actions are taken to improve and implement them. Based on the results of the energy assessment, energy efficiency indicators and goals are determined and action plans are drawn up to achieve energy efficiency goals.

Verification: The effectiveness of energy management plans at the "Execution" stage is constantly checked. To do this, it is necessary to monitor and measure the main processes that are important for energy efficiency. The obtained results are compared with previously set goals.

Improvement: The results of continuous measurements are broken down into reports. This will provide the basis for further steps to improve the energy management system.

3. IMPROVEMENT OF ENERGY MANAGEMENT SYSTEM

3.1. Performance of energy management system functions

At the initial stage of implementation of the energy management system (the first 1-1.5 years), the key tasks of the energy management service include:

- daily informing the management of the enterprise about:
    a) actual levels of unit costs of energy resources for production;
    b) the results of the analysis performed and recommendations for reducing specific energy consumption were developed;
    c) those responsible for inefficient use of FEM (if any);
    d) units demonstrating the best results (for further stimulation);
- development of energy consumption maps (energy balances) of all stages of the technological process to determine the main consumers of energy resources and identify bottlenecks;
- phased implementation of the energy consumption accounting and control system:
    a) at the level of individual structural divisions/workshops;
    b) within individual technological processes;
    c) for individual teams, shifts, and subsequently for individual employees;
- providing the company's management with visual information on energy efficiency;
- participation in improving the budgeting process in production;
- development, implementation and control over the implementation of energy saving measures (EZ);
- quality control of FEM coming from suppliers.

During the performance of its functions, the energy management service must adhere to the following principles:

- before investing in high technologies, you should first exhaust the possibilities of organizational measures that do not require costs, but contribute to effective management and control;

- the energy manager should analyze all personnel actions related to the use of TR;
- invest only in projects with the best economic performance, taking into account potential risks.

The content of management activities in accordance with management functions is given in Table 3.1.

Table 3.1

Control function	**Temporary function action interval**	**Content of management activities**
Current planning (business planning)	Short-term perspective (up to 1 year)	• prediction of environmental behavior; • determination of the composition and numerical values of indicators of annual, quarterly, monthly energy consumption plans; • internal energy audit for individual energy consumers; • management and maintenance of energy-saving projects
Coordination of activities	Short-term perspective (from 1 month to a year)	• defining a control structure; • establishing interaction between components; • separation of duties of personnel and coordination of actions
Coordination of activities	Short-term perspective (from 1 month to a year)	• defining a control structure; • establishing interaction between components; • separation of duties of personnel and coordination of actions

The main roles of the energy manager can be represented as follows:

- Development of energy management strategy within the organization;
- Product and process development;
- Monitoring and evaluation, stimulation of improving the energy efficiency of the organization;
- Management of financial aspects of energy supply and consumption;
- Consideration of various energy supply possibilities, including the creation of its own generating capacities.

3.2. Stimulation of energy management

High-quality and timely performance of work at the enterprise should be properly evaluated. It is important for the energy management service to develop a motivation system that will encourage effective activity in the field of energy saving. In assessing the efficiency of services and production units should focus on compliance with labor, production and planned discipline. It is important not only to exceed the planned indicators for energy saving, but above all to achieve them, because they are included in the budget of the enterprise, and their non-fulfillment can entail financial losses.

Management should encourage EMS personnel by:

- planning career development of service employees;
- introduction of a system for improving the professional skills of EMS personnel;
- bonuses and awards for specific achievements in energy conservation.

At the initial stage of the implementation of cost-free measures (those that require compliance with labor, technological and economic discipline), the heads of structural units that have achieved the best results (heads of workshops, shifts, sections, teams), as well as deputy energy managers, should receive encouragement if their activities were effective.

Motivation is a key factor that motivates people to act purposefully and remain persistent in overcoming difficulties.

When creating a motivation system, it should be borne in mind that:

- financial encouragement is not the only and best way to motivate;
- recognition of achievements and provision of responsibility can have a much greater impact;
- material incentives should be seen as a reward for a job well done;
- autonomy and personal accountability increase the level of motivation;
- without understanding and desire for change and internal motivation, learning will be ineffective.

3.3. Principles of financing energy saving measures

To form a financial policy in the field of energy saving abroad, the following tools are used: price regulation; financial support programmes, in particular grants; preferential lending; public procurement of technology; voluntary agreements between the public and private sectors; tax incentives such as energy taxes and tax credits.

All these mechanisms can be divided into two groups:

incentive (informational and financial support) and

restrictive (prohibitions, fees).

The most effective is their combination: stimulating measures form the policy, and restrictive ones ensure its implementation. The impact on the cost of energy resources or on the price of energy efficiency measures contributes to attracting investment in this area.

Examples of incentive measures are:

- financial support programs;
- preferential lending;
- tax incentives.

Fig. 3.1 shows the content of Art. 15 of the Law Sources of financing activities in the field of energy efficiency of buildings.

Strategy 15 Financing activities in the field of Energy efficiency of buildings.

2. State support for measures in the field of energy efficiency of buildings may be implemented through:

1) budget investment appropriations;
2) reduction in the cost of loans for energy efficiency measures (reimbursement of interest on loans and/or part of the loan amount);
3) reimbursement of part of the cost of energy efficiency measures;
4) preferential lending;
5) incentives in tariff and pricing for utility services and energy resources;
6) implementation of public-private partnerships, including energy services;
7) introduction of mechanisms to encourage recipients of social assistance to implement energy efficiency measures;
8) other forms of financing provided for by law.

Fig. 3.1 Sources of financing activities in the field of energy efficiency of buildings

In Western countries, there are a number of financial mechanisms that attract third parties to invest in projects aimed at energy saving. Such mechanisms include:

- energy service companies (ESCO);
- rotary loan funds;
- leasing programs;
- possibility of payment by parts;
- creation of joint ventures;
- venture funding;
- issue of municipal bonds for the implementation of infrastructure projects.

3.4. Analysis and evaluation of the energy management system performance

The main purpose of verifying and monitoring the efficiency of the energy management system is to develop optimal management decisions and recommendations aimed at improving its efficiency. This procedure is carried out in accordance with the requirements of DSTU 5077:2008 “Energy saving. Energy management systems of industrial enterprises. Inspection and control of the efficiency of functioning”.

The main tasks of the EMS verification and control are as follows

- ensuring compliance with regulatory requirements in the field of energy management;
- preparation of recommendations to improve the efficiency of the EMS;
- improving the mechanism of control over the EMS by the company's management;
- analysis of the level of EMS provision with labor, technical and financial resources;
- development of recommendations for training, retraining and advanced training of employees in the field of energy efficiency;
- development of staff incentives for efficient use of fuel and energy resources;
- coordination of actions aimed at supporting and improving the functioning of the EMS;
- preparing the system for certification.

The criteria for assessing the effectiveness of an energy management system are divided into **four groups:**

Criteria for the organization of the EMS component:

- Availability of documentation.
- Distribution of obligations and responsibilities.

Criteria for resource provision:

- Organizational aspects.
- Technical resources.
- Information support.
- Use of mathematical and software tools.
- Provision of material and financial resources.

Monitoring criteria:

- Conducting continuous observation.
- Audit check.
- Certification procedure.

Correction criteria:

- Implementation of corrective measures.
- Implementation of preventive measures.

3.5. Levels of energy management development

There are two main problems that hinder the development of energy management:

- Insufficient level of energy efficiency;
- low priority of financing in energy saving.

Key organizational aspects:

- Formation of energy policy;
- creation of appropriate management structures;
- organization of an energy reporting system.

These and other issues are systematized using the energy management matrix, which allows

- Identify and analyze the existing priorities of the enterprise in terms of energy management;
- find optimal options for organizational support of energy management.

Fig. 3.2 shows an example of an energy management matrix.

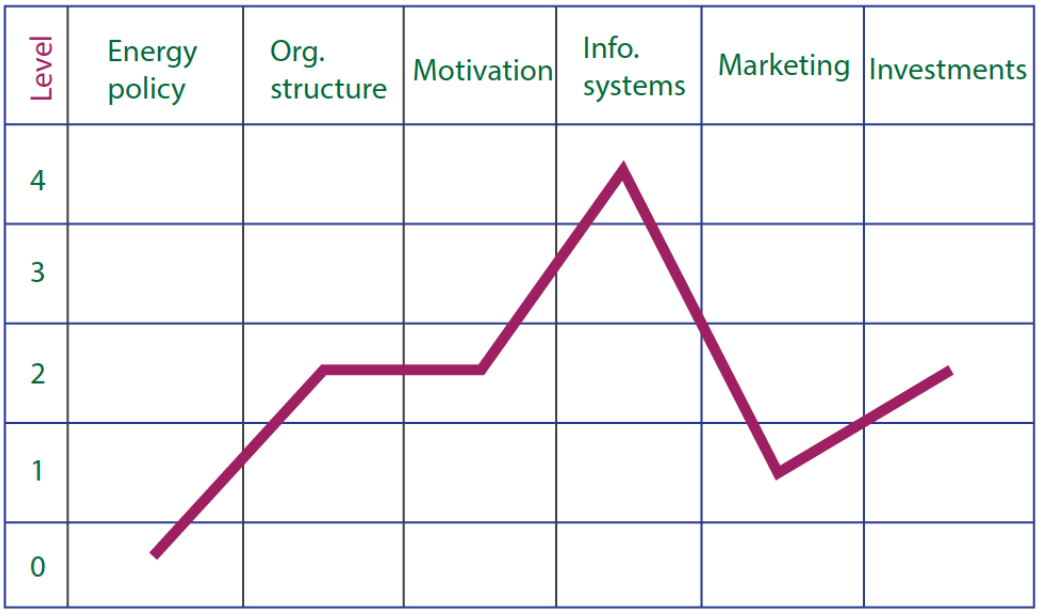


Fig. 3.2 Example of an energy management matrix

The horizontal rows of the matrix reflect the gradual complexity of the management level, and the vertical columns describe the key aspects of energy management Moving through the levels indicates an increase in the maturity of the system and its approximation to industry best practices. To apply the matrix effectively, it is necessary to identify the most critical issues that require more attention than others:

- determine the current level of the enterprise in the energy management system (on the matrix);
- focus on the areas (those columns of the matrix) that require the greatest improvement;
- identify the main barriers to improvement and develop ways to eliminate them;
- assess opportunities for improvement and find ways to implement them;
- involve the company's management and employees in the process.

Levels of energy management development:

Level 0: No energy management. The company does not have an energy policy, no responsible persons have been appointed, energy consumption is not monitored, and no efficiency measures are implemented.

Level 1: Initial level. There is no official policy, but there is a responsible specialist. He or she keeps track of energy costs and disseminates information through informal contacts.

Level 2: Partial integration. Top management recognizes the importance of energy management, but support is limited. The energy department reports to a committee whose interest determines the effectiveness of measures.

Level 3: Systematic approach. Energy management becomes part of the management structure. Energy consumption is integrated into cost accounting, an information system is in place, and an energy efficiency program is being implemented.

Level 4: High maturity of the system. Responsibility for energy consumption is distributed throughout the enterprise. Formal and informal communication channels are used, and the effectiveness of measures is monitored against targets. Energy achievements are widely publicized and management actively supports

energy saving initiatives. Energy saving achievements are widely publicized, and reducing energy consumption is viewed not only from the perspective of financial savings, but also from the perspective of impact on a wide range of issues, such as environmental. Senior management considers energy management to be important and is actively involved in energy saving issues.

3.6. Using the energy management matrix

To successfully implement organizational changes and improve energy management at the enterprise, it is necessary to:

- identify key issues that require the energy manager's priority attention;
- assess the effectiveness of the energy manager's activities;
- analyze the level of support provided to the energy manager;
- to determine the current situation and outline the directions of energy management development.

Table 3.2 shows the criteria for the state of the energy management system.

Table 3.2

Number of points/rating	Current situation	Possible improvements
22-24 Excellent	Energy management is a priority for the company. It is important to continue our activities following the principle that complacency is dangerous.	It is necessary to keep abreast of the latest achievements in the field of energy saving and energy management, and actively implement them in work processes
19-21 Good.	The company pays attention to energy management, but the management considers it mostly as a technical area rather than a part of overall management.	The main organizational approaches should be revised to include effective energy management in the strategic areas of cost control, and the

		structure and procedures of energy management should be improved
13-18 Medium	Energy consumption is managed in a haphazard manner. The management believes that this is a purely engineering and technical task, which is why the energy manager's potential is not fully utilized.	The main task is to raise the status of the energy manager, implement comprehensive monitoring of energy consumption, which will significantly improve the efficiency of its work
7-12 Poor	Certain elements of energy management are implemented in various departments, mainly in those dealing with equipment operation. However, the potential for effective energy management remains underutilized.	It is necessary to identify and eliminate key barriers to the development of energy management, as well as to integrate the energy management system into the overall management structure of the enterprise.
0-6 Very bad	The energy management system is absent or at an early stage of development. Due to inefficient use of energy resources, the company may lose 20% or more of their value.	A comprehensive energy management system, including technical support, organizational structure, regulated procedures, and staff training, should be established.

Determining the organizational profile of the enterprise. There are 10 steps that will help improve energy management at the enterprise:

1. Make a copy of the matrix and analyze each column. Mark the level that most accurately reflects the current state of your company. If necessary, you can make a

mark between levels for a more accurate assessment.

2. Connect the marked points to get a graphical representation of the organizational energy management profile. It will show the level of balance in energy management. Bumps in the profile are normal: peaks indicate strengths and dips indicate weaknesses.
3. Make a second copy of the matrix and ask your line manager to do the same.
4. Compare the resulting profiles. Discuss the differences in your assessments and try to find a compromise. If you come to an agreed solution, draw it on a third copy. If no agreement is reached, record both versions of the profile as different points of view. Additionally, you can involve other employees, especially those who work directly with energy management, to get a third-party assessment. This will help to identify strengths and weaknesses from an outsider's perspective.
5. Identify priority areas for improvement. Choose two areas that require the most attention. For each of them, make a list of the five main obstacles to development and identify three key opportunities for improvement. Keep in mind that sometimes it is worth focusing not on the most problematic areas, but on those where there is a real chance of making progress. That is, if the obstacles found are insurmountable or there are no obvious opportunities for improvement, it is better to spend resources on other aspects. In addition, employees in other departments or with a higher position may be able to overcome the identified obstacles or create opportunities for this. It is necessary to find out if this is possible and how they can be involved in this process.
6. Ask your line manager to perform a similar analysis.
7. Compare your lists of obstacles and opportunities. If you cannot agree, simply combine them into a common list.
8. Share the results with senior managers and ask them to perform the same analysis. Include the resulting profiles in the overall assessment.
9. Create a final report for management that includes:

- a graphical representation of the organizational profile;
- a list of identified obstacles and opportunities;

- recommendations for addressing the challenges and realizing the potential.

If it is difficult to find specific solutions, suggest key questions for management to discuss ways to improve the situation.

10. Develop an action plan for the next 12 months with management. The plan should include:

- responsible persons for each stage of implementation;
- intermediate goals and criteria for measuring progress.

One of the possible ways to track changes is to reuse the energy management matrix in a year, which will allow you to assess the dynamics of the company's energy management system.

3.7. Energy management information systems

Traditionally, information should be **"accurate, timely and relevant"**. However, of these three criteria, relevance is the most important: the data must be relevant to the decision being made.

There are three levels of decision-making in an organization, each of which requires a different approach to information:

- operational control;
- management control;
- strategic planning.

Accuracy and timeliness also matter, but their level depends on the type of solution.

Accuracy determines the allowable error in measurements, and timeliness varies according to the management level.

Effective operational control requires immediate notification in case of deviations in performance. Management control is based on regular reports, usually corresponding to the monthly budget cycle.

Strategic planning requires **two types of information:**

- General annual data for annual analysis.
- rregular but often urgent information needed for strategic research.

The main groups that use energy data are:

- top management and senior executives;
- heads of departments (or those responsible for budgets)
- key specialists;
- employees of the energy management service;
- energy coordinators;
- general staff.

4. CONTROL AND NORMALIZATION OF ENERGY CONSUMPTION

4.1. Main provisions and basics of energy consumption control and normalization technology

Energy consumption control and normalization (ECN) is one of the most effective methods of managing energy use. This process allows you to explain actual energy consumption and assess deviations from the expected level in specific conditions.

KPIs are based on the analysis of historical data to determine “standard” (average) and “target” energy consumption levels against which future performance is compared. Regular monitoring of consumption levels allows you to quickly identify deviations in operation. Monitoring alone does not reduce energy consumption, but it helps determine where and when to take action to eliminate inefficient use of resources.

EE is a management tool based on monitoring energy consumption and process parameters at certain intervals (weekly, monthly, etc.). This allows you to analyze changes in energy efficiency using **energy metering centers (EMCs)** and implement corrective measures in a timely manner. The EMS is an integral part of the company's overall energy management system.

The main goals of KiN:

- detection of energy losses;
- preparation of corporate reports.

Types of comparisons in the KI system:

Fixed goal - defining a target level of energy consumption (for example, kWh per week or month);

Simple coefficient - used when energy consumption is directly proportional to a certain parameter, allowing you to evaluate the efficiency of work (for example, kWh/t);

The regression coefficient is similar to the simple coefficient, but takes into account the base load.

It is expressed by the equation:

$$y = ax + c \ ,$$

where y is a component of the y-axis;

x is a component of the x-axis;

a is the coefficient characterizing the slope of the line;

c - line segment on the y-axis.

It is the most suitable type of comparison of the factor relationship in the KPI system.

Types of energy loads

Baseload is the amount of energy consumed at zero variable (for example, the minimum consumption during equipment downtime).

Variable load is the additional amount of energy required for each new unit of production or change in operating conditions (for example, energy consumption depending on temperature or production load).

Specific and normalized energy efficiency indicators:

Specific performance indicator (SPI) - the ratio of energy consumption to the useful product/effect/work (e.g., kWh/m², kWh/t);

normalized performance indicator (NPI) is an indicator that takes into account the impact of external factors on energy consumption.

The PPR and NRP are calculated on the basis of energy audits and are used to assess efficiency across different enterprises of the same type.

Applied statistics is used to analyze energy consumption under conditions of random or unpredictable influences. Its methods allow you to identify hidden patterns, make forecasts and make informed decisions.

If a series of values of the resultant parameter and the factor are known, but it is unclear whether all factors affect this parameter and whether they should be taken into account in a simplified model, the most important factors are selected using factor analysis.

The use of regression analysis makes it possible to establish the relationship between energy consumption and its variable value (e.g., production volume), as well as to determine historical patterns of energy consumption under “base” and “variable” loads.

Since random factors affect the actual energy consumption, it always differs from theoretically calculated. Therefore, controlling and evaluating these deviations between actual and predicted consumption are key tasks of the I&C technology.

The information base of the energy management system can be an energy monitoring system. Energy monitoring can be carried out both on-site and remotely.

Advantages of remote monitoring :

- quick detection of cost overruns, minimization of losses
- increase the efficiency of equipment setup
- motivating staff to use energy efficiently
- Elimination of the human factor during the collection of primary data

Requirements for monitoring systems:

- work with the entire existing meter fleet
- the ability to expand the system
- the ability to exchange data with other systems
- the ability to work with different communication channels

4.2. Building management system

Building management systems are typically installed in public and office buildings; these systems allow you to control the building from a computer.

Such systems have not usually been installed in apartment buildings before, but nowadays, the most modern high-rise buildings also have a well-organized building management system.

Figure 4.1. shows the energy management system of buildings.

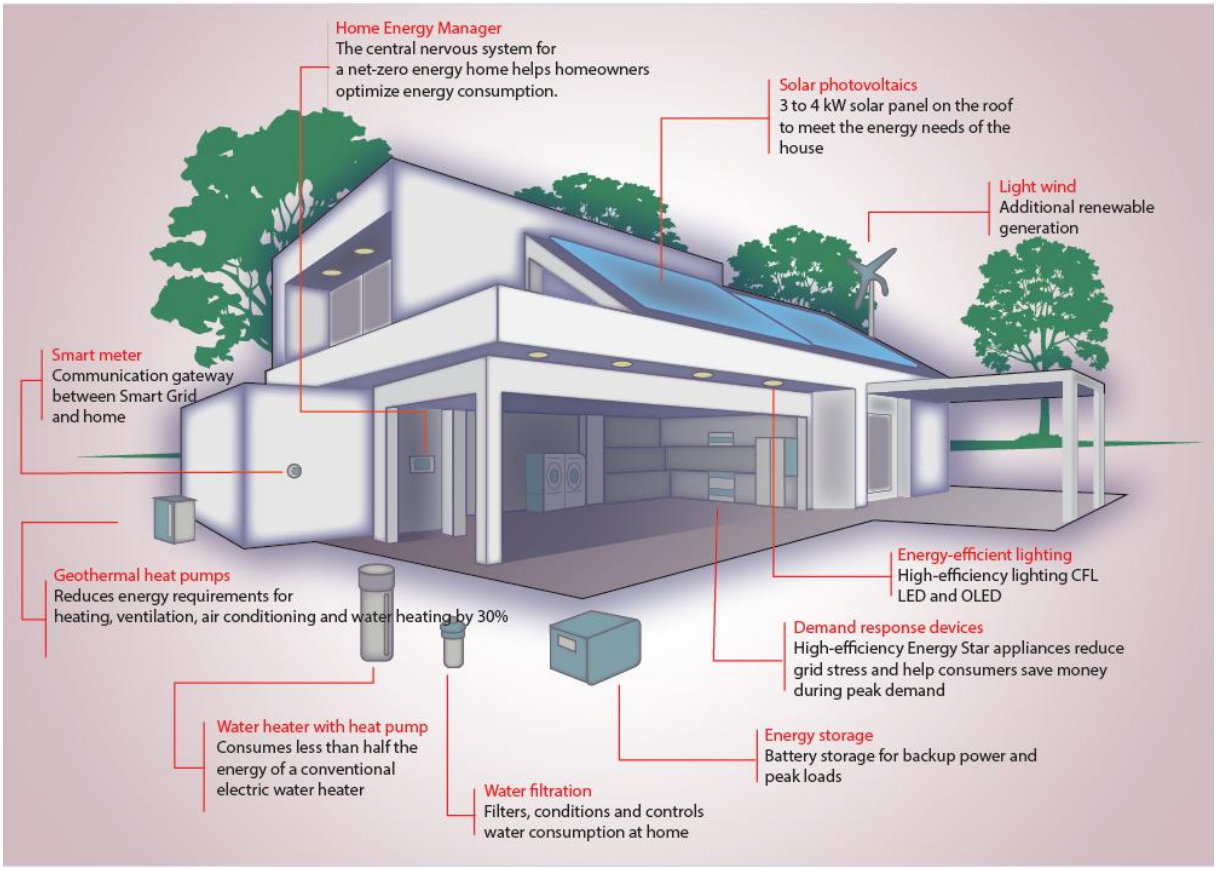


Fig. 4.1 Energy management system for buildings

Table 4.1 shows the system for setting goals, objectives, and action plans.

Table 4.1

OBJECTIVE	**TASKS**	**PROGRAM (action plan)**
Reducing energy consumption of building A by 10% in 2025	Reduce heat energy consumption for heating of building A by 7% in 2025 Indicative: energy consumption per square meter of floor space (kWh/^{m2})	Install an automatic regulator Improve thermal insulation Eliminate drafts/insulate windows and doors Adjust thermostats Eliminate shielding of the heat source

	Reduce electricity consumption in building A by 12% in 2025	Conduct staff briefings Analyze the lighting at workplaces Install energy-saving lamps Optimize the location of lighting sources Install motion-sensing circuit breakers

Table 4.2 shows an example of an Energy Efficiency Action Plan.

Table 4.2

Objectives	**Reduce electricity consumption in 2025 in building A by 12%.**
Indicator	Lighting energy consumption per 1 m2 (kWh/m2)
Investment is required Source Financing	500 Euro (Budget of the efficiency project)
Economy	300 Euro
Term	1.5 years
Reducing emissions CO_2	3.24 kg/year
Program/term	• Instruct staff (March 2025) • Analyze illumination (March 2025) • Install energy-saving lamps (August 2025) • Optimize the location of lighting sources (October 2025) • Install circuit breakers (October 2025)
Responsibilities and scope of work	• Head of the management company (0.5 days) • Electrician (2 days) • Electrician (1 day)

	• Electrician (1.5 days) • Electrician (5 days)

4.3. Changes in the use of fuel and energy resources

The main objectives of the adjustment are:

- analysis of existing positive and negative factors of energy consumption;
- assessing the impact of these trends in the future and taking into account their positive and negative consequences;
- analysis of new situations and problems, taking into account regional peculiarities, and ways to solve them;
- assessment of alternative means of development;
- monitoring the existing global experience to select the optimal solution that actively influences the development of energy consumption.

When planning the volumes of fuel and energy resources required for the use of fuel and energy resources, two directions can be used:

1. **Expert estimates** involve a comprehensive analysis and forecast of energy consumption development based on existing and new developments in this area.
2. **Modeling** is based on the development of statistical models for forecasting and utilizing energy resources

A comparison of the existing and proposed rationing system is shown in Table 4.3.

Table 4.3

The existing system	The proposed system
Activities required by existing legislation	Voluntary initiative activities
Annual nature of rationing	Control over actual energy consumption and prompt correction of energy consumption
Reports to the Chief Power Engineer	A separate energy management

Department	department is created
Existing energy consumption standards do not cover all factors	Takes into account all existing factors that affect energy consumption
There is no correlation between energy rationing and metering	Energy accounting and rationing are correlated with the energy management system
There is no system for analyzing the causes of energy resource overspending	solutions to overcome the identified causes of energy resource overspending

4.4. Classification of specific consumption rates of fuel and energy resources

Classification of specific consumption rates of fuel and energy resources:

- by the level of aggregation;
- by the composition of fuel and energy costs;
- by expiration date;
- by the level of management.

Depending on the level of aggregation, there are individual and group rates of specific fuel and energy consumption.

The individual rate determines the consumption of one or more types of FER per unit of product (work, service) for a specific technological facility (unit, plant, machine) under certain production conditions.

The group weighted average rate characterizes the consumption of one or more types of fuel and energy resources per unit of the same product at different levels of management, covering business units (sites, workshops, production facilities, enterprises, industries).

The norms are divided into **technological and general** production components of fuel and energy consumption.

The technological norm defines the consumption of one or more types of fuel and energy resources required for the production process, including unavoidable

technical losses associated with the performance of basic and auxiliary technological operations.

The general production rate covers not only production consumption and technological losses, but also the costs of additional needs, such as lighting, heating, ventilation, etc.

For the duration of the norms are divided into **annual, quarterly and monthly**.

In accordance with the level of management, norms differ in orientation to certain types of products and are divided into **differentiated and enlarged**.

The differentiated norm is established for a specific type, grade or type of product.

The enlarged norm is defined as the average value for a group of products of the same type, but of different varieties, or for a group of works and services for different purposes. Depending on the peculiarities of rationing, additional differentiation of norms by other criteria is possible, for example, taking into account the costs of one or more types of FEM for individual or consolidated needs.

4.5. Specific indicators of fuel and energy resources consumption

One of the key aspects of rationing is the definition of the unit of measurement of the rate of specific costs of fuel and energy resources (FEA) for the manufacture of products, the performance of work or the provision of services.

Technological standards of FEM costs in all cases are established exclusively on the natural unit of production. At the same time, general production standards can be determined for the same unit only if homogeneous products are produced. In some cases, it is more expedient to refer the PER costs not to the unit of finished products, but to the unit of raw materials. This approach is relevant for refineries, food industry enterprises.

If homogeneous products of different sizes are produced (and this is the vast majority of sub-sizes, for example, metal rolling), it is advisable to determine the rates of PER consumption per unit of reduced (conditional) products, that is, expressed in natural values, but adjusted to take into account a certain size.

If differentiated rates of PER unit costs are established, the volume of production is determined in natural units.

In the case of the use of enlarged norms for groups of products of the same type, but of different varieties or sizes, or for groups of works and services of different nature, conditional (consolidated) units of measurement of the volume of products/works/services are used, for example, a conditional sheet of paper.

For energy-intensive production processes (production of metals, thermal treatment of the material, production of liquefied gases, heating, production of artificial cold, etc.), the rates of unit costs of FEM should be determined per unit of output, work performed or service rendered in natural terms.

In enterprises with a wide range of products that is constantly changing, as well as, for example, in the construction sector, in experimental industries, as well as at the level of associations and regions, it is virtually impossible to choose a single indicator of the volume of output of products/works/services. In such cases, the rates of PER costs in natural or conventional units can be determined per unit of cost of net products, expressed in value measurement (reduced to unchanged prices).

Rationing of fuel and energy resources is carried out taking into account the following principles:

- coverage of all components and cost items of the FEM;
- compliance with the system of accounting and control over FER consumption adopted at the enterprise (in the organization);
- compliance with methodological consistency in the formation of norms and standards at different levels of management;
- ensuring the scientific and practical validity of norms and norms, their progressiveness, taking into account the latest achievements of science and technology, as well as advanced methods of organizing production and labor;
- formation of a single regulatory framework for all stages of production planning and management;
- regular review and adjustment of established norms.

Norms of specific consumption of fuel and energy resources have:

- be based on the plans of organizational and technical measures to improve the efficiency of the use of FEM;
- take into account the specifics of the production process, as well as the latest achievements of science and technology;
- contribute to the identification and mobilization of reserves of FEA savings in public production;
- create conditions for stimulating the conservation of energy resources.

4.6. Sequence of determination of specific consumption rates of fuel and energy resources at the enterprise

The process includes the following key steps:

1. Determination of the composition of technological processes and operations necessary for the manufacture of each type of product/performance of work/provision of services in which fuel and energy resources are used.
2. Establishment of units of measurement of products/works/services that must comply with the planned and regulatory documents in force at the enterprise, as well as statistical reporting.
3. Definition of the main sites and units, the consumption of FEM in which is directly related to the production of a particular type of product (or its analogue).
4. Identification of sites and units, the costs of which are distributed in proportion to the volume of services provided by them for the production of several types of products (works, services). Distribution of TOC consumption volumes can be carried out on the basis of actually used resources for a specific type of product or by differentiated analysis of TOC consumption in accordance with the structure of their use in individual technological processes.
5. Development of material balances for certain products and establishment of PER consumption rates. The material balance is based on the current regulatory basis for the consumption of material resources of the enterprise.

6. Formation of a list of equipment involved in the production of a certain type of product.
7. Development of a scheme for calculating technological and general production standards for specific costs of FEM for the manufacture of products (performance of work, provision of services). The calculation is carried out on the basis of the list of equipment, the energy consumption of which determines the process and auxiliary costs of the FEM.
8. Creation of a scheme for preparing initial data for calculating the rates of specific costs of FEM, collecting the necessary information and performing calculations.

All calculations of HR costs are carried out on the basis of production indicators for a predetermined conditional day, when the volume of HR consumption corresponds to the average value for the reporting period.

4.7. Certification and marking systems in energy conservation

Energy testing is a set of tests and measurements conducted by certified laboratories in order to establish the level of energy consumption of electrical appliances and other resources.

Energy label - a standard information card containing data on the level of energy efficiency of electrical equipment, including the class of energy consumption, indicators of resource efficiency, as well as additional information.

Energy labeling is a way to provide users with information about the efficiency of energy and resource use by electrical appliances by applying a special label.

A supplier is a manufacturer, its official representative or a person involved in the distribution of electrical equipment on the market.

Seller - a legal entity or an individual who sells, rents or demonstrates electrical appliances, including the option with payment in parts.

Energy certification of equipment (buildings) - the process of checking the compliance of energy characteristics of objects with the requirements of legislation in the field of energy conservation and rational use of resources.

Energy labeling is the process of informing consumers about the energy efficiency of products, equipment and technologies by entering relevant data into information available to users.

The International Organization for Standardization determines that all types of labeling have a common goal: "based on proven and reliable information, stimulate the supply of goods and services that have the least negative impact on human health and the environment, as well as increase demand for these goods, thereby stimulating environmental improvement through market mechanisms."

General principles of certification and marking

Certification is an official confirmation of compliance of products, enterprises, specialists or systems with the requirements established in national or international standards. Obtaining a certificate may grant a legal entity certain rights, for example, permission to install or use certain equipment or systems.

In some countries, in particular in Denmark, certification may be a prerequisite for obtaining state subsidies. This is especially important for the development of renewable energy and energy saving programs.

A recognized international initiative is the **US ENERGY STAR program**, which operates in the United States. In 2009, its participants achieved energy savings of $17 billion. Currently, more than 40 thousand products have this marking.

The US Department of Energy regularly purchases products of various brands to test the energy efficiency of the most common household appliances (refrigerators, freezers, dishwashers, etc.), which consume more than **25%** of household electricity. It is planned to expand testing to more goods. Inspections of 35 manufacturers that violated the requirements of the Energy Star program were also launched.

In Ukraine, the production of products and services are subject to certification (food industry, processing industry, metallurgical, chemical and energy).

A striking example of certification in Ukraine is the implementation of an event on energy efficiency of buildings (according to the Law of Ukraine on energy certification of buildings) with the provision of an appropriate certificate of energy efficiency of buildings with the definition of energy efficiency class.

Certification work is carried out in accordance with state norms and standards of Ukraine. As an example, the certification of energy efficiency of the building is carried out according to the requirements of GOST 9190:22 Energy efficiency of buildings.

This standard applies:

- for conformity assessment - according to DBN V.2.6-31;
- comparison of energy characteristics of alternative solutions for the building;
- energy certification of the building;
- establishing the effect of possible measures to improve the energy efficiency of the building;
- monitoring the energy efficiency of the building and its engineering systems;
- planning of thermal modernization activities;
- forecasting the necessary energy resources.

These are the goals and objectives for energy management of objects of housing and communal, social sector (building).

5. BUSINESS PLANNING OF ENERGY SAVING PROJECTS

5.1. Financial and economic analysis of energy efficiency projects

Energy saving in the enterprise can be achieved in two main ways:

- improving the efficiency of using existing equipment;
- investing in new equipment with higher energy efficiency.



The main purpose of the business is to make a profit and financial success. To achieve this, it is necessary to satisfy the interests of three key groups: customers, shareholders and employees.

However, profitability is not the only factor affecting the long-term development and stability of the company. Its sustainable success is influenced by other aspects that are reflected in the concept of "Business Circle." Some of these goals can be contradictory, but it is important to find a balance, since ignoring any of the important areas can lead to slower development and instability.

The concept of "Business Circle" emphasizes the importance of continuous improvement of the company, and this is possible only through investment. Therefore, the investment of capital is a key factor for the long-term growth and stability of the enterprise.

The main directions of investment:

1. **Development of new products** in order to improve the current range or enter new markets, which will contribute to the expansion or protection of the company's market share.

2. **Increase production capacity** to meet the growing needs of the market or expand the company's share in it.
3. **Upgrading existing equipment** for:
   - improving product quality and customer satisfaction;
   - reduced production costs.

A comprehensive analysis of the project involves its evaluation from various positions: technical, economic, financial, environmental and social.

However, since energy-saving projects are implemented at specific production facilities and financed by certain investors, it is usually enough to conduct a technical and financial assessment to decide on their feasibility.

The process of project analysis can be simplified by formulating six key questions, the answers to which will help determine its effectiveness (the same questions arise during financial evaluation):

1. What is the main purpose of the project?
2. What alternatives should be considered for comparison?
3. At what scale should the costs and benefits of the project be estimated?
4. What time horizon should be considered to assess the economic feasibility?
5. What are the benefits and costs of the project, and how can they be estimated?
6. What criteria should be applied to make a decision on the implementation or abandonment of the project?

5.2. Project Evaluation Methods

Payback Period (PBP). In many cases, this indicator is too simplistic to provide an objective assessment of the effectiveness of the project. If there are changes in costs in the future (for example, an increase in fuel prices), they can significantly affect the total cost of the project, which is not always taken into account when calculating the payback period.

A simple payback period does not allow you to correctly compare projects with different duration of operation. It also does not take into account the time factor when assessing the value of money and does not make it possible to compare the project with

alternative investments, where more accurate financial methods are used.

Despite these limitations, the payback period indicator remains popular in practice, especially at the initial stages of the analysis, when it is necessary to quickly assess the investment attractiveness of the project, in particular, when it comes to initiatives with a short return on investment

$$T_{ok} = \frac{I_o}{B},$$

where I_0 – initial investment;

B – net annual savings/income.

The shorter the investment return period, the more attractive the project looks. In general, it can be difficult to evaluate initiatives with a payback period of more than one or two years. However, there are exceptions: if costs are critical to the survival of the enterprise, for example, when replacing failed equipment, or if it is necessary to bring the activity in line with regulatory requirements (environmental standards, sanitary standards).

This method of evaluation is widely used in the analysis of projects, since it is noted:

- simplicity of calculation,
- availability for use.

Financial concepts in determining the effectiveness of investments.

Compounding (capitalization, expansion, compounding) is a process similar to depositing funds in a bank, when accrued interest is added to fixed capital, increasing it in the future. This is a method of bringing the value of assets (for example, capital expenditures) to the final investment period.

Discounting - a mechanism that allows you to determine the current (real) value of future cash flows. This process is used to evaluate investments, leading financial indicators from the future period to the current moment.

The discount rate is a key parameter for evaluating the effectiveness of a project, which allows comparing costs and revenues that arise at different times. It determines the minimum rate of return on investment that the investor expects to receive.

Inflation (b) is an indicator of average growth in prices for goods and services. Forecasting the level of inflation is difficult, since it can differ for different categories of products.

The real interest rate (r) is the nominal rate adjusted for the rate of inflation, taking into account changes in the cost of energy and other costs. The longer the economic life cycle of an investment, the more significantly this factor affects.

Main indicators of project evaluation.

Net Present Value (NPV) - the total discounted income of the project, defined as the difference between the revenues and expenses brought to date. If the NPV has a positive value at a given discount rate, the project is considered profitable.

Internal rate of return (IRR - Internal Rate of Return) - the level of profitability of the project, at which the discounted income is equal to the discounted costs. In fact, this is a discount rate that provides a break-even investment.

Net present value annuity is a method of converting NPV into average annual net income for the entire project implementation period. This is a convenient tool for comparing projects with different duration of action.

Evaluation of energy saving efficiency.

The official regulatory document regulating the procedure for assessing the economic efficiency of organizational and technical measures (OTZ) in the field of energy saving is the state standard GOST 2155-93 "Energy Saving. Methods for determining the economic effectiveness of energy saving measures. "

5.3. Business plan and feasibility study of energy saving projects

The implementation of the energy saving project goes through several key stages:

- definition and evaluation of the project;
- preliminary feasibility study (feasibility study);
- Business planning
- Search for financing;
- implementation of the project;

- results monitoring and reporting.

Energy saving measures are divided into three groups:

- cost-free (not requiring financial investments);
- low-cost (with minimal costs);
- projects that require significant funding, often involving external sources.

To attract financial support from outside, it is necessary to develop a business plan for the project. It should confirm its economic feasibility and interest potential investors or financial institutions.

Drawing up a business plan is preceded by a stage of generating ideas, among which the most promising is chosen. Providing public investment or obtaining a bank loan is possible only with a well-developed business plan. This document allows for a comprehensive analysis of the marketing and technical and economic aspects of the project. Its creation takes into account financial and economic indicators, regulatory requirements, availability of resources and other key factors of successful implementation.

Business plans in the field of energy conservation are usually developed for one year. They analyze in detail the energy saving measures (EPS) planned for implementation, and give an overall assessment of the measures, which are designed for 1-4 years. The business plan contains information about the enterprise, its financial condition, market analysis, marketing strategy and the expected economic effect of the implementation of energy-saving measures. Potential risks and mitigation strategies may also be considered.

The main reasons for developing a business plan:

- comprehensive business analysis;
- strategic planning of various aspects of the project;
- identification of financial needs and opportunities for raising funds;
- use as an argument in negotiations with potential investors and financial institutions.

A business plan is usually prepared for presentation to possible creditors or investors. It can be submitted to the following financial institutions:

- commercial banks;
- private investment funds.

Business plan structure for energy saving:

1. Executive summary (summary of the main provisions).
2. General information about enterprises.
3. Description of products, services and market opportunities.
4. Enterprise development plan.
5. Detailed description of the investment project.
6. Financial assessment and forecast.

5.4. Procedure for development of feasibility study

After an energy audit has been carried out at the facility and energy saving measures have been developed, it is important to assess their technical and economic efficiency, taking into account the costs and feasibility of implementation.

The feasibility study conducted after the energy audit of the facility should reflect the results of marketing and feasibility studies that prove the feasibility and feasibility of the project, the commissioning of new energy facilities and the modernization of existing ones, as well as the replacement or reconstruction of energy sources.

An example of the proposed structure of the feasibility study for the reconstruction of the heat supply of the city microdistrict:

1. General Information

1.1. General information that includes information about the implementing organization

2. Technical analysis of the project

2.1. Analysis of the existing power supply system and power consumption of the facility

2.2. Analysis of existing operating costs

2.3. Project Specifications

2.4. Technical solutions proposed for implementation

3. Financial and economic indicators of the project

3.1. Planned capital costs for the reconstruction of the facility

3.2. Planned operating costs of the facility

3.3. Indicators of the economic effect of modernization

4. Environmental Impact Assessment

In the case of using non-traditional energy sources, it is necessary to make comparisons with traditional sources.

5.5. Fuel and energy balance

Energy balance these are indicators showing the ratio between the intake and consumption of all types of energy resources at the facility.

The energy balance is compiled on the basis of project documentation, as well as on the results of measurements conducted during the energy audit.

There are several methods for **compiling the energy balance**, one of the most commonly used is the calculation and experimental method. using which the consumption and loss of energy resources are determined using analytical dependencies, and the results obtained are compared with the tests of energy equipment and measurements of accounting for the actual costs of energy resources.

Basic concepts and definitions

Actual energy balance reflects the current state of energy use (the achieved level of useful consumption of FEM), in addition, it shows energy losses (justified and unjustified).

Optimal energy balance is compiled to search for an option for providing an OOP facility, in which production can be carried out with minimal costs (the most economical energy resources, optimal operating modes of equipment, compatible operation of generating and power consuming plants, etc.).

Energy balance in working form reflects in the expenditure part the distribution of energy resources produced or received from other sources on a production-territorial and target basis, without division into what is useful and what is lost.

Partial energy balance consists for individual types of fuel, energy, energy

carriers both in monetary and natural forms (in tons of conventional fuel, kWh, kJ), and in shares (percentages).

Energy cost balance - energy balance in monetary form.

Consolidated energy balance is compiled on the basis of partial energy balances of all types of FEA in monetary form and in percentage. Additionally, if necessary, a summary energy balance in tones of conventional fuel, kWh, kJ or other units can be compiled.

Synthetic fuel and energy balance determines the distribution of extracted, summed up and produced fuel and energy resources at an industrial enterprise.

Experimental method of compiling the energy balance is based on conducting thorough tests of power equipment, accurate measurements and taking into account the actual costs of energy resources.

Estimated method of compiling the energy balance - a method in which the useful consumption and loss of energy resources are determined on the basis of appropriate physicochemical and empirical formulas.

Calculation and experimental method of compiling the energy balance provides for the combined use of both a calculated and an experimental approach to compiling an energy balance.

Conducting energy balance analysis is to identify the main consumers of energy resources in order to develop priority areas for energy conservation. In the presence of actual and optimal energy balances, the analysis consists in identifying places (subdivisions, technological processes) where energy resources are consumed least efficiently, after which the development of priority areas for energy conservation is carried out.

All energy losses are divided into **four groups** by the causes

The first group. Losses due to the equipment in the on state (for example, losses during rotation of the electric motor, from the equipment under voltage). These losses do not depend on the operating modes of the equipment, they are approximately constant (therefore they are called permanent losses). With unchanged technological parameters, these losses depend mainly on the technical condition of the equipment.

Reduction of energy losses of this group is possible by improving its technical condition, repair.

The second group. These are energy dissipation losses caused directly by the operation of the equipment. Depends on the modes. They are called variable losses (for example, loss of active energy in electrical equipment).

The third group. Losses from underutilization of energy, due to the physics of technological processes and the degree of their imperfection. These losses depend on the load, so they are similar to the previous ones also variable (most characteristic of thermal systems, mainly associated with the presence of secondary energy resources).

The losses of the second and third groups depend on the load on the equipment, but this dependence is not always linear.

The fourth group. Additional energy losses, they are associated with the impossibility of ensuring the normal course of the technological process in the areas of underload and forced mode of equipment operation. It is clear that these are loss variables.

5.6. Approaches to energy balance

When conducting an energy audit, it is advisable to draw up an energy balance in a working format. At the request of the customer, the audit may include the calculation of the optimal energy balance for its comparison with the actual one. In this case, the main discrepancies between the two balances are analyzed in order to determine the areas with the greatest losses and to prioritize the effectiveness of the use of FEM.

The process of compiling energy balances usually involves an assessment of the level of PER consumption both in physical quantities and in financial equivalent, with distribution by departments or technological processes of the enterprise.

The calculation of energy balances is based on the documentation of the enterprise, which has the necessary measuring equipment, as well as on the results of direct measurements made during the audit. In the absence of measuring instruments

at the enterprise, it is allowed to use calculation methods to determine the consumption of FEM for individual processes or subdivisions.

When compiling energy balances, both calculation and calculation and experimental methods are used. The latter is the most common, because it allows you to find the optimal balance between the cost of measurements and the cost of accounting and consumption of energy by the enterprise.

The calculation and experimental approach is the most universal and the most accessible. Within the framework of this method, the useful part of energy consumption is determined by calculation, and energy losses are determined both experimentally and through calculations, after which all indicators are analyzed and agreed in the overall energy balance of the installation.

In the practice of energy audit, this method is most often used.

Depending on the classification characteristics, fuel and energy balances are divided into the following types:

1. By types of air conditioning: electric, thermal, fuel, general energy.
2. By functional purpose: reporting, planning, project, research, regulatory.
3. By the level of use: actual, economically justified, optimal, project, planned.
4. By time period: seasonal, quarterly, annual, monthly, daily, variable, hourly.
5. According to the object of study: workshop, production site, installation, unit, apparatus, structural element.
6. By level of detail: synthetic (generalized), analytical (detailed).
7. By the number of stages of energy processes: one-stage, two-stage, multi-stage.

Part 2: ENERGY AUDIT

1. DEFINITION AND ALGORITHMS OF ENERGY AUDIT

1.1. General provisions. Objects of energy audit

According to ISO 50002, an energy audit is a systematic analysis of energy use and consumption within the limits defined by the nature and scope of the energy audit work, with the aim of identifying, quantifying and reporting on opportunities to improve the level of energy efficiency achieved/attainable.

In other words, an energy audit is an assessment of the energy characteristics of an audited entity.

Energy audit is aimed at reducing energy consumption by business entities by increasing the efficiency of their use. The main tasks of an energy audit are:

- analysis of the state of energy resources use at the audited object;
- Identification of potential energy saving opportunities;
- development of organizational and technical measures aimed at reducing energy costs;
- economic justification of the developed organizational and technical measures.

The audit process analyzes energy flows in a process or system (for example, a building), which allows minimizing energy consumption without reducing, but improving, if possible, technological parameters, as well as the level of comfort and safety.

The objects of energy audit are:

- separate divisions of the organization;
- significant consumers of the organization's FER;
- energy supply systems;
- buildings and structures;
- system of accounting and control over the use of FER;
- energy management system.

The subjects of energy audit are the customer and the energy audit contractor.

In many countries, energy audit activities are carried out in accordance with the international standard ISO 50002:2014. This standard has been harmonized in Ukraine in the form of the national standard DSTU ISO 50002:2016 (ISO 50002:2014, IDT) “Energy audits. Requirements and guidelines for their conduct”. This standard is based on best practices for conducting energy audits. It contains the basic requirements for the key stages: development of the terms of reference, performance of work, approval of the results and completion of the audit. The standard provides for the possibility of using different approaches depending on the specifics, scope of work, boundaries and objectives of the audit.

Depending on the scope and level of detail, energy audits are divided into three types:

Type 1. Express energy audit. This is the minimum scope of work that provides a general idea of the energy saving potential. It involves the analysis of energy and process data, as well as a visual assessment of the facility's condition. This approach is best suited for micro and small businesses.

Type 2. Detailed energy audit. This is a detailed inspection of the facility with measurements of energy performance of systems and processes. This type of audit provides an understanding of the efficiency of each significant energy consumer and allows for a technical and economic analysis of both organizational and technological solutions with different payback periods.

Type 3. Comprehensive energy audit. It consists of an in-depth study and technical and economic assessment of the audit object using a variety of different measuring devices. A detailed study provides an understanding of the problems that arise and affect the efficiency of the energy consumer. This type of audit is more typical for large enterprises with a large number of staff.

Table 1.1 shows the breakdown of the cost and duration of an audit by the size of the enterprise.

Table 1.1

Type of audit	The scale of the enterprise	Results	Cost of the audit	Duration of the audit
Type 1	Micro or small	Organizational and standard energy efficiency measures. An aggregate assessment of their effectiveness. The accuracy of the assessment is low, as it is based on empirical and statistical data	Low	Low 1 - 5 days
Type 2	Average	Organizational, standard and specialized energy efficiency measures. Standard technical and economic assessment of their effectiveness. The accuracy of the assessment is average, as it is based on both experience and statistical data, as well as on individual measurements.	Medium or high	Medium or high 3 - 6 months (for enterprises without seasonal dependence) 6 - 12 months (for enterprises with seasonal dependence)
Type 3	Big	Development of energy saving projects with technical and financial assessment of their effectiveness. The accuracy of the assessment is high, as it is based on measurements and modeling.	Medium or high	Medium or high Up to 6 months (for energy saving projects without seasonal dependence) Up to 12 months (for energy saving projects with seasonal dependence)

According to the ISO 50002 standard, the level of detail required for an audit is determined by the characteristics of the facility, the types of energy use and consumption, and the resources available. At the preliminary preparation stage, the client and the contractor should assess the availability of data for the energy audit and find out whether it is sufficient to conduct a more detailed analysis. If additional measurements are required, the parties usually agree on their scope before the audit begins.

For Level 2 and Level 3 audits, it is advisable to agree on the current or base tariff that will be used for financial analysis.

Depending on your needs, you can choose one or more types of energy audits. Annex A (Table A.1) of DSTU ISO 50002:2016 (ISO 50002:2014, IDT) “Energy audits. Requirements and guidelines for their conduct” provides a comparative table describing the main differences between these types. The types of audits listed in Table A.1 (DSTU ISO 50002:2016) are not strictly regulated, so the company can determine the level of detail of the energy audit within the range from type 1 to type 3 according to its own needs. In this case, type 1 is the least detailed and can be considered as the basic level of energy audit.

The following key points should be considered when choosing the appropriate type of energy audit:

- Type 1 audit is mandatory;
- Type 1 energy audit requires minimal costs and is usually used for further planning of a more detailed audit of the enterprise or its individual units, installations, etc. (taking into account the results of the rapid audit);
- more detailed audits are advisable only if the company's management intends to implement energy efficiency measures (or at least part of them) that meet the agreed investment attractiveness criteria.

1.2. Energy audit process

In accordance with DSTU ISO 50002:2016 (ISO 50002:2014, IDT), the energy audit process consists of the following stages:

1) energy audit planning;
2) preliminary meeting and data collection;
3) planning of measurements;
4) inspection of the facility
5) analysis;
6) presentation of the energy audit report;
7) final meeting.

The algorithm of the energy audit process is shown in Fig. 1.1.

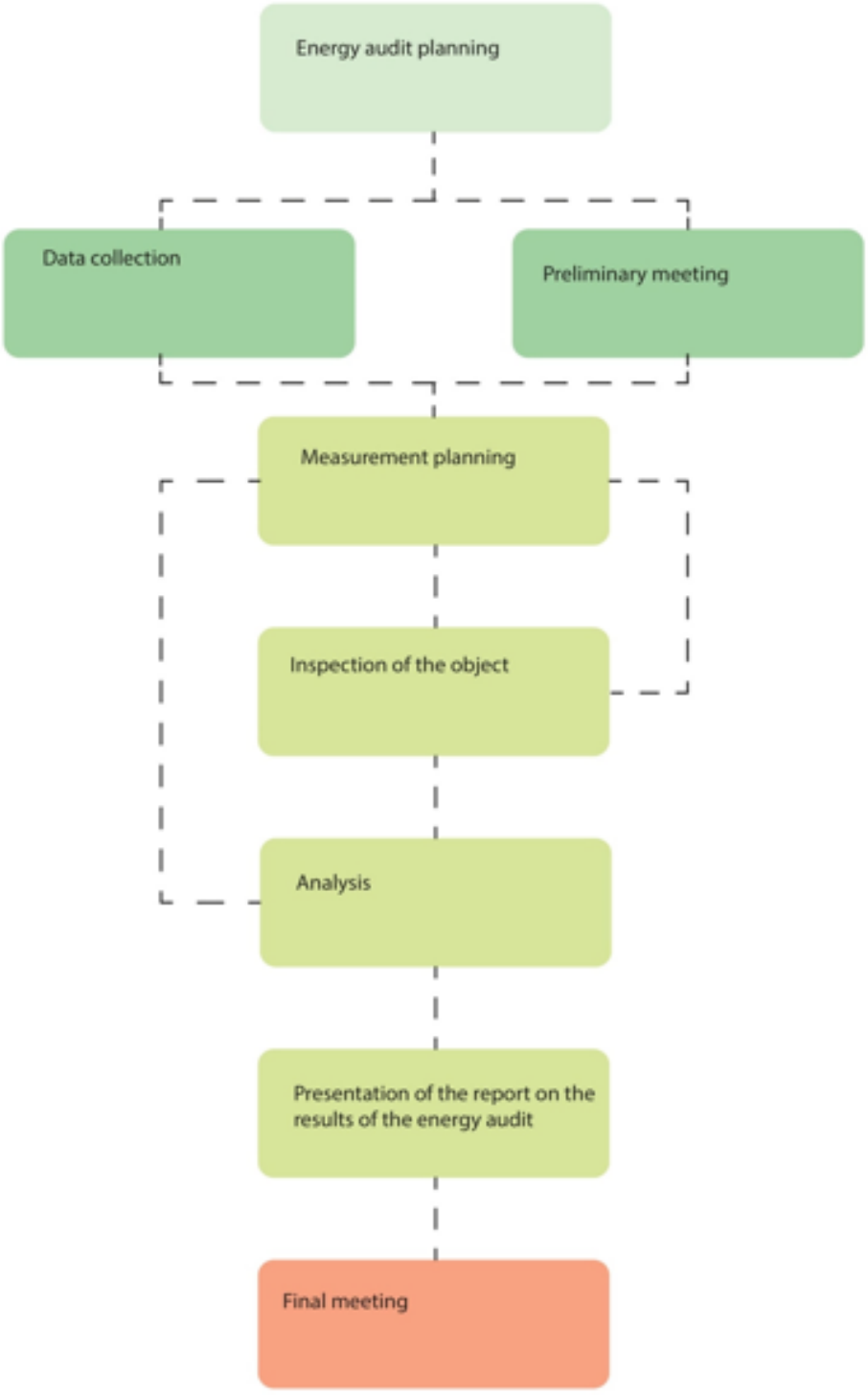


Fig. 1.1 Algorithm of the energy audit process

The types and stages of energy audits, as well as the duration of the work stage for different types of energy audits are shown in Table 1.2.

Table 1.2

Energy audit stage	Duration of the work stage for different types of energy audits, %.		
	Type 1	*Type 2*	*Type 3*
Planning the energy audit process	10	10	5
Preliminary meeting, collection of necessary data	30	25	15
Measurement planning	0	10	25
Site inspection	25	15	5
Analysis of information	20	30	30
Reporting	5	5	10
Closing meeting	10	5	10

In addition to DSTU ISO 50002:2016 (ISO 50002:2014, IDT), which defines the general principles of energy audits, appropriate methodologies are used that describe in detail the procedure for performing individual stages or a set of tasks during the audit. These can be both universal methods suitable for any enterprise (for example, the typical methodology "General Requirements for Organizing and Conducting an Energy Audit") and industry-specific methods that take into account the specifics of a particular industrial sector.

1.3. Examples of industry-specific energy audit methodologies

Examples of industry-specific methods for conducting energy audits include:

- methodology for conducting energy audits of oil and gas companies;
- Procedure for organizing an energy audit of Ukrzaliznytsia facilities;
- DSTU B V.2.2-39:2016 Methods and stages of energy audit of buildings;
- Methodology for conducting energy audit of housing and communal services facilities;
- Methodology for conducting energy audits of enterprises and organizations in the coal industry, etc;
- Methodology for conducting a building inspection for the purpose of drawing up a building energy certificate.

Experienced energy audit companies usually have their own corporate energy audit methodologies based on the requirements of the current legislation, the international standard ISO 50002:2014, and the company's internal standards. Such methods include:

1) Methods of measurement, including:

- quality indicators of different types of fuels for steam and hot water boilers;
- electricity quality indicators;
- the amount of electricity consumed;
- fuel consumption by heat generating units;
- water consumption in streams (both pressurized and non-pressurized);
- indoor air quality;
- air exchange rate in the premises;
- lighting level in the premises;
- temperature of heated surfaces and their thermal imaging inspection;
- electrical parameters of electrical installations, etc.

2) Visual inspection methods, including the condition of

- enclosing structures of buildings and structures;
- pumping stations and hydraulic structures;
- engineering systems of the building;
- heat generating installations;
- heating mains, etc.

3) Methods of calculation, evaluation, and analysis that allow determining

components of the balance of fuel, electricity and heat consumption by the enterprise;

- energy efficiency indicators of individual installations, technological lines, processes and the enterprise as a whole;
- energy saving potential for various facilities and systems.

After the final version of the report is prepared, it is presented to the representatives and top management of the customers at the final meeting.

The duration of an energy audit depends on the type and object of the audit, the size of the enterprise and the volume of fuel and energy consumption.

If necessary, the timeframe can be adjusted by increasing the number of energy auditors or reducing the scope of work, as agreed with the customer.

An energy audit can be used to conduct energy analysis, facilitate monitoring, measurement and analysis in accordance with ISO 50001, or be used independently.

2. ENERGY AUDIT PLANNING PROCESSES

2.1. Preparation and purpose of the energy audit

Preparatory work for an energy audit is carried out by the customer before signing a contract with the contractor. They include:

1) determining the purpose of the energy audit;

2) determining the boundaries, nature and scope of audit work;

3) development of the terms of reference;

4) determining the qualification requirements for the audit contractor;

5) preparation of tender documentation.

To ensure the effectiveness of an energy audit and the ability to evaluate its performance, it is necessary to clearly define the purpose of the audit.

The purpose of the energy audit should be agreed between the organization and the energy auditor.

The main purpose of an energy audit is to help the management of an industrial enterprise determine the level of FER consumption, energy saving potential, sources of energy losses and the amount of irrational use of FER by production and auxiliary units, technological processes and individual consumers. The audit also contributes to the development of energy saving measures, their feasibility study and environmental impact assessment. The objectives of an energy audit can be aligned with the company's energy goals and used to improve any aspect of the level of achieved or potential energy efficiency in accordance with the commitments set out in its energy policy. In accordance with the SMART concept, these goals should be specific, measurable, achievable, relevant and time-bound (according to ISO 50002).

Typically, the goals of an energy audit are expressed in the following indicators:

- percentage increase in the level of achieved or achievable energy efficiency;
- improvement of energy consumption;
- other energy efficiency indicators.

Goals can relate to specific equipment, systems, or processes.

An example is the following energy audit goal: to develop a set of energy efficiency measures that will reduce the annual electricity consumption of a compressor station by 5% in 2025 compared to its baseline energy consumption.

2.2. Define the boundaries, nature and scope of the energy audit

According to ISO 50002, energy audit boundaries are physical or site boundaries and/or organizational boundaries as defined by the organization.

An energy auditor can cover one or more borders.

A clear definition of the boundaries, nature and scope of energy audit work allows energy auditors to focus their efforts and resources on improving the level of achieved or potential energy efficiency of those systems and processes that are most critical from this point of view.

Typically, most or all significant energy consumers are analyzed in an energy audit. According to the ISO 50001 standard, the volume of energy consumption is considered significant if it accounts for 80% of the total level. Therefore, as a rule, all energy-intensive consumer groups that collectively use 80% of a certain type of energy (gas, heat, electricity, etc.) are considered. At the same time, small individual consumers whose total consumption does not exceed 20% are usually not included in the analysis.

To determine the nature and scope of energy audit work, a list of tasks to be performed during the audit process and objects to be analyzed is formed.

One of the key tasks of an energy audit is to establish a baseline of energy consumption for further comparison with the indicators of the following reporting periods. This allows us to assess the efficiency of FER use and develop a strategy for improving the energy efficiency of the enterprise.

In addition, the main tasks of an energy audit may include:

- Assessment of the general condition of the enterprise, its divisions, and technological processes of the enterprise as consumers of fuel and energy resources;

- analysis of the terms and conditions of energy supply contracts, including an assessment of their reliability and the main risks associated with energy supply;
- study of the energy efficiency of the building, preparation of a certificate of energy efficiency of the building;
- Assessment of the possibility of implementing the use of alternative and renewable energy sources (introduction of cogeneration units, heat pumps, solar collectors, photovoltaic systems, etc.), as well as secondary energy resources (heat recovery from flue gases or compressors, etc.)
- analysis of the state of energy monitoring and metering systems for FER consumption with determination of the required level of their detail and accuracy;
- assessment of FER consumption balances by their individual types;
- analysis of energy-intensive technological installations, production processes and subdivisions of the enterprise in terms of the balance of FER consumption;
- identification of FER losses at the energy audit objects;
- assessment of the share of FER costs in the overall structure of production costs;
- determination of energy saving potential for energy audit objects;
- assessment of the efficiency of FER use;
- analysis of the effectiveness of the energy management system (EMS), provided that there is a certified auditor who meets the requirements of DSTU ISO 50003:2016;
- development of recommendations for energy efficiency measures, assessment of the amount of possible energy savings from their implementation;
- assessing the impact of the proposed measures on the company's forecasted FER costs and the terms of contracts for their purchase;
- Calculation of financial savings from the implementation of energy efficiency measures, taking into account factors (changes in energy tariffs, inflation, exchange rates, etc.) that affect the amount of financial savings;

- analysis of cash flows over the life of the energy efficiency measures, calculation of profitability and net present value of each measure;
- Identification of key financial and energy indicators to be monitored throughout the project implementation period;
- Developing an energy efficiency implementation plan with timelines, estimated costs of each component, and overall estimates.

The degree of detail in this list of tasks and objects of energy audit directly affects the accuracy of the audit cost estimate. The more detailed the tasks and objects of the energy audit are, the easier it is for the contractor to conduct the analysis and for the customer to assess whether the results obtained meet their expectations.

2.3. Quality indicators of energy audit and qualification requirements for contractors

Energy audits are not subject to licensing, and there are no approved qualification requirements for energy auditors; the key factor for the customer when choosing a contractor is often the cost of services.

In this regard, there is a problem of ensuring the qualification requirements for contractors, which in turn leads to the following threats:

- the purpose of the audit may be not so much to identify problem areas of the enterprise in terms of energy efficiency as to sell its own products.
- The determined indicators of investment attractiveness of the proposed energy efficiency measures may be overestimated compared to the actual ones.

To evaluate the quality of energy audits, it is advisable to use certain indicators, an indicative list of which is presented in Fig. 2.1.

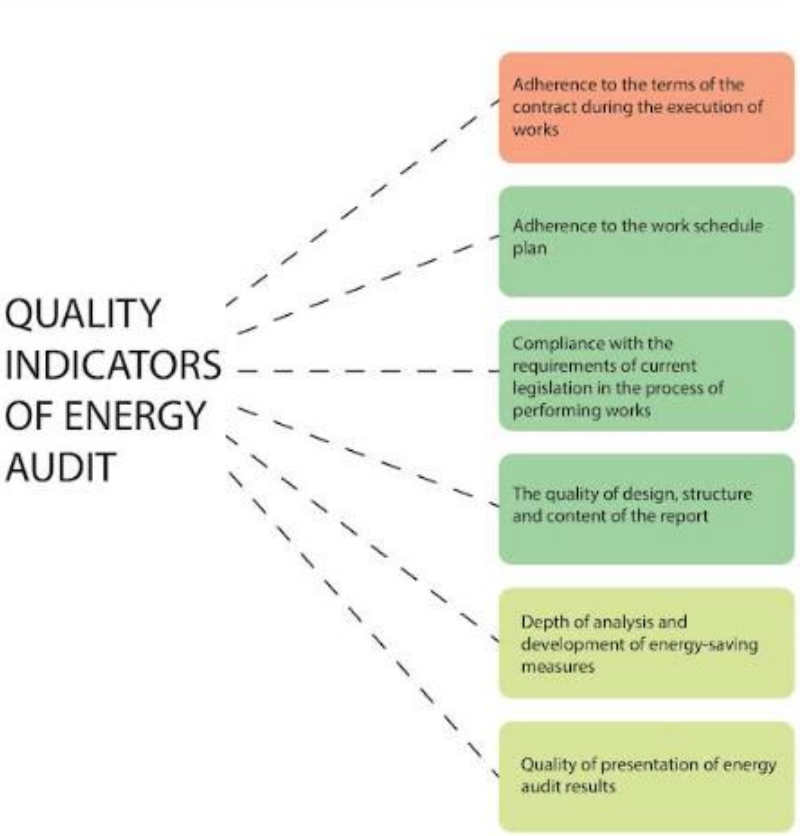


Fig. 2.1 Energy audit quality indicators

If necessary, these indicators can be included in the energy audit contract as criteria for assessing the quality of the work performed.

This will help to improve the level of audits conducted and ensure a clearer understanding between the customer and the contractor regarding the expected results of the energy audit.

One of the key principles of energy audit activities is the competence and objectivity of the performers during the energy audit. Compliance with this principle implies that energy auditors must have an appropriate level of qualification, which includes both relevant professional education and the necessary work experience.

The energy auditor shall have the knowledge and skills necessary to perform the energy audit work of the nature and scope specified.

The competence of an energy auditor can be evidenced by testimonials:

- appropriate level of education, skills and experience, taking into account national guidelines and recommendations;

- Possession of technical skills appropriate to the specifics of energy use, the nature of the work, and the scope and objectives of the energy audit;
- knowledge of relevant legal and regulatory requirements;
- understanding of the specifics of the types of energy used or subject to inspection;
- familiarity with ISO 50002, as well as national energy audit standards.

A Lead Energy Auditor requires the managerial, professional and leadership skills necessary to effectively lead a team of energy auditors (according to ISO 50002).

In addition to the qualifications of auditors, other factors can affect the quality of energy audit results (Figure 2.2).

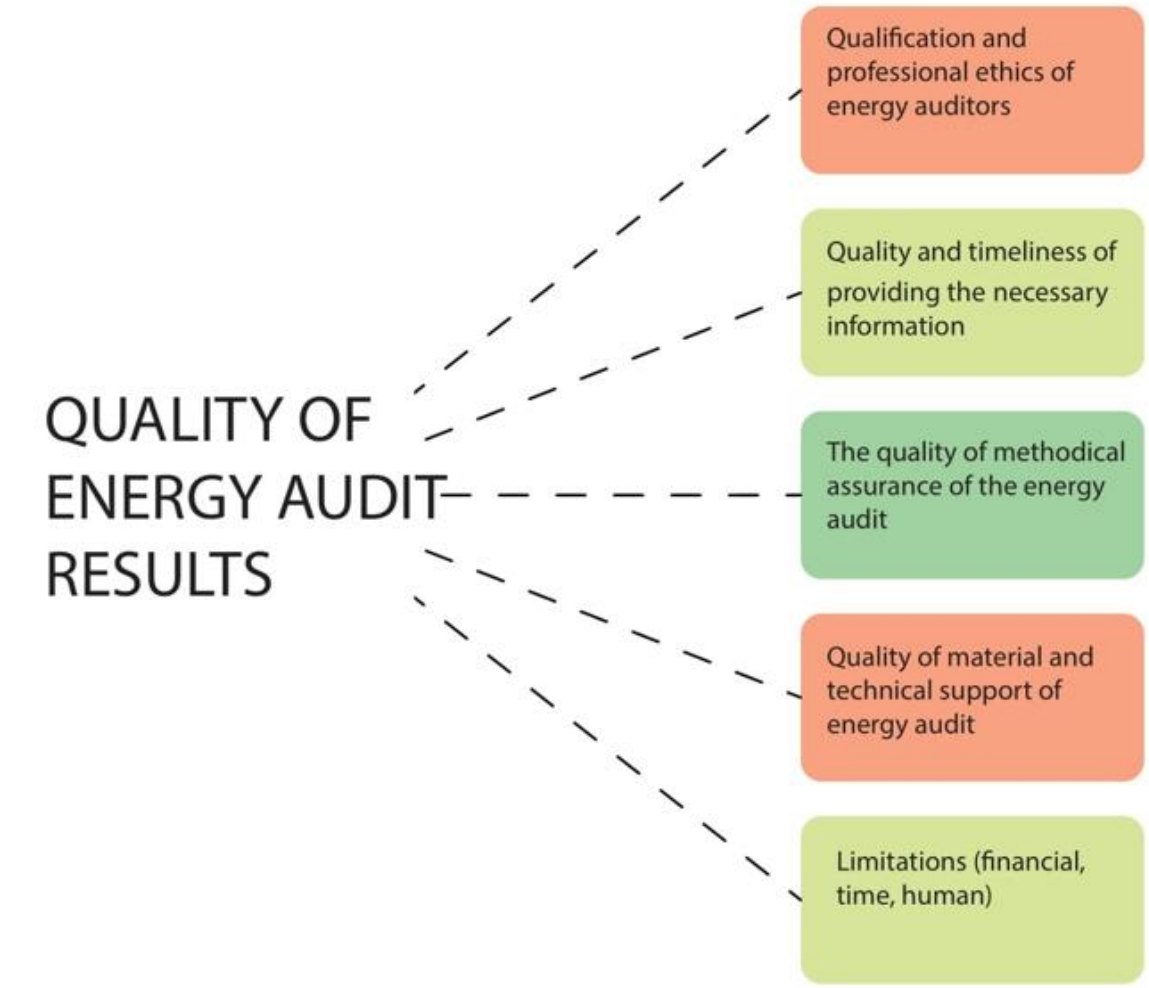


Fig. 2.2 Factors affecting the quality of energy audit results

2.4. Preparation of the terms of reference for energy audit work

A detailed list of tasks for an energy audit is usually defined by the customer in the form of a technical assignment. The terms of reference should clearly address the following issues:

- energy audit objective - defining the main objectives and areas of the audit to be achieved;
- list of energy audit objects (boundaries) - a clear definition of the audit boundaries, including specific objects, systems and processes to be assessed;
- list of tasks (nature and scope of work) - a detailed description of the work to be performed, including methods of measurement, performance evaluation and analysis;
- stages of work performance and their expected completion date - a breakdown of the entire process into stages, with the timing of each stage determined;
- list of expected results and the procedure for their evaluation by the customer - determination of what results should be obtained upon completion of the energy audit and how they should be evaluated;
- reporting form - requirements to the structure and content of the report to be submitted to the customer;
- regulatory and methodological support for the performance of work - a list of regulatory documents, standards, recommendations and methodologies to be used in the course of the energy audit.

Additionally, the terms of reference may specify qualification requirements for the contractor. Usually, these requirements are included in the tender documentation for the work.

2.5. Organizational measures for planning an energy audit

To ensure an objective assessment of the cost of energy audit work, as well as to conduct an effective energy audit, the following should be taken into account.

The energy auditor and the company's authorized representatives should agree on the following:

1. Nature and scope of work, boundaries and purpose of the energy audit;
2. Needs and expectations for achieving the audit objectives;
3. The required level of detail of the audit results;
4. Time frame of the energy audit;
5. Criteria for evaluating and ranking opportunities to improve the level of achieved / achievable energy efficiency;
6. The need to involve staff and other resources of companies;
7. What data should be provided by energy auditors before the start of the energy audit;
8. Expected results and reporting form;
9. Whether the draft final report should be presented to the company's top management for discussion;
10. Company representative responsible for conducting the energy audit;
11. Procedure for approving any changes to the nature of the energy audit work.

The energy auditor shall request information to determine the factors that may affect the energy audit process, including based on the actual situation:

1. Existing regulatory requirements or other constraints that affect the nature and scope of the energy audit;
2. Existing strategic plans that may affect the level of energy efficiency of the enterprise;
3. Existing management systems, for example: environment, quality, energy management, etc;
4. Any considerations, even subjective ones, including existing opinions, ideas and constraints, related to potential energy efficiency measures.

The energy auditor should inform the organization about:

1. Tools, equipment and services required to conduct an energy audit and how to engage them;
2. Commercial or other process that may affect his/her conclusions and recommendations;
3. Any other questions regarding the conflict of interest

The work of energy auditors is often carried out under certain resource constraints - time, financial, human and material.

In addition, there may be difficulties in obtaining all the necessary information and its uncertainty. Most energy audits require the involvement of several specialists from different fields, such as electricians, heat engineers, technologists, metrologists, and others. Thus, an energy audit is a team effort that requires clear organization and planning.

First of all, when forming a team to conduct an energy audit, it is necessary to identify the head of the energy audit team. This person is responsible for planning and organizing the work of the entire team. The efficiency and effectiveness of the energy audit depends largely on his or her experience and professional qualities.

Companies should take into account that the scope and nature of energy audit work, as well as the requirements for the depth of energy efficiency analysis, can significantly affect the cost of the audit.

Therefore, the customer needs to discuss with the energy auditor both the details and the total amount of work to ensure the right balance between the complexity and level of detail of the energy audit, as well as the costs of its conduct.

Given this, this section provides requirements and recommendations for planning an energy audit. Planning consists in developing a strategy and choosing approaches to determining the nature, timing and time of the energy audit.

The planning process allows the energy auditor to focus on the most important areas of audit, identify problems that require the most careful analysis and verification.

Planning helps to properly organize their work, and supervise the work of specialists involved in energy audit, as well as coordinate the work carried out by other energy auditors and specialists of other professions.

The nature of the planning largely depends on the organizational form, size and type of activity of the enterprise, the type of energy audit, the correct representation of the energy auditor about the state of use of fuel and energy resources.

When planning an energy audit, it is advisable to pay special attention to the issues of energy analysis of energy audit facilities.

To this end, the following procedures are defined during planning:

- identification of available energy sources used in the enterprise;
- evaluation of directions of energy use and consumption both in the past and in the present;
- evaluation of energy consumption directions in accordance with the requirements of ISO 50001:2018;
- identification of areas of significant energy consumption, which allows to identify objects (buildings, structures, equipment, systems, technological processes), as well as personnel that significantly affect the energy consumption of the enterprise;
- identification of other variable factors that can significantly affect energy consumption;
- determining basic energy consumption levels for each area of significant energy consumption;
- assessment of the current level of energy intensity of individual objects (buildings, structures, equipment, systems and processes) related to identified areas of significant energy consumption;
- estimating projected future energy use and consumption;
- identifying and identifying priorities and opportunities to improve energy efficiency in the enterprise.

2.6. Development of energy audit schedule

The energy auditor should prepare an energy audit plan, which lists the actions that need to be performed during the energy audit.

The energy audit schedule should include:

- the composition of energy auditors and customer personnel involved in certain stages of energy audit work;
- measures to train the customer's personnel involved in the energy audit;
- briefing on occupational safety for the energy audit team;

- a list of planned energy audit works at the facility (specific objects and the essence of the work within the framework of the energy audit), the period of their implementation and responsible performers of the work both on the part of the contractor and on the part of the customer.

The energy audit plan usually consists of three sections.

In the first section of the plan, the personal composition of the group is determined with the distribution of functions among its members. The effectiveness of energy audit largely depends on the specialists involved in its conduct. It is better to start the formation of an energy audit group by identifying the head of the energy audit group - a key figure in any energy audit activity. The team leader should have experience in energy saving, energy audit and energy measurements.

The personal composition of the group of energy auditors and their specialization, which also includes the company's specialists, should fully cover all the relevant requirements for energy auditors to solve the problems of energy audit. All specialists should have a high level of professional training and the necessary practical experience. It is mandatory for them to understand the methods and procedures of energy audit and the ability to use it in practice, as well as knowledge of the technological process in which the energy audit will be conducted.

The second section of the plan defines the schedule of the energy audit. The schedule defines the list of planned energy audit work, the timing of their implementation and the performers of the work and serves as a means of monitoring the audit. When scheduling, customer requirements must be taken into account. If necessary, a network schedule for conducting an energy audit at the enterprise is drawn up.

The start and end dates of each stage of the energy audit are determined by the head of the group of energy auditors together with the responsible person from the customer, taking into account the expected scope of work to be performed and the resources to be involved for this.

The third section of the plan contains organizational and technical measures to ensure a successful energy audit. The form of this section of the plan is the same as the previous one.

It indicates all the measures for the implementation of which the administration of the enterprise is responsible. In particular, these are measures for transport, household and housing support for the work of energy auditors, as well as meeting the needs of energy auditors in work premises, communication services, copying equipment, if necessary, in safety equipment.

The prepared energy audit schedule is agreed with the customer, who can make the necessary adjustments to it. You can adjust the plan on each

Energy Audit Stage. The energy audit plan must be approved simultaneously with the signing of the energy audit contract.

A copy of the energy audit schedule approved by the head of the energy audit group and agreed with the customer is transmitted to the customer and communicated to each of the energy auditors, and its compliance is mandatory.

2.7. Master data collection and processing

Collection and generalization of basic data (information) about the object of energy audit, as well as their corresponding assessment is one of the important stages of energy audit. As a rule, the enterprise has accumulated significant amounts of documentary information about the actual consumption of FEM, production technology, etc.

Depending on the source of information, the entire array of information about the object of energy audit can be divided into primary and secondary.

Primary information means such information that is collected for the first time to achieve the goal and solve the tasks of energy audit.

To obtain the necessary primary information about the object of the energy audit, it is necessary to use the following information collection tools:

survey (questionnaire) of the company's employees and external experts;

- interviewing employees and external experts;

- use of photo and video;
- carrying out the necessary measurements.

Questionnaire in the process of energy audit is one of the main means of obtaining primary information about the company. The essence of the method is to conduct an absentee survey of employees of the enterprise and external experts to obtain information on the effectiveness of the use of FEM in the enterprise. To conduct a survey, energy auditors prepare questionnaires (questionnaires) in advance, which provide a list of questions to which respondents should answer.

Interviewing is used throughout all stages of the energy audit and is associated with direct contacts of energy auditors and representatives of the enterprise.

As during the questionnaire, a pre-prepared set of questions is used in the interview, but the difference is that the question is asked directly by the energy auditor. This fact makes it possible to avoid ambiguous interpretation of questions (since there is an opportunity to clarify them).

In the process of energy audit can be used the following types of interviewing:

- personal:
  - an individual interview with each member of the staff responsible for the effectiveness of the use of FEM in the enterprise (or an external expert);
  - a collective interview with all the personnel responsible for the effectiveness of the use of HR in the enterprise (or all external experts);
- telephone;
- postal.

Interviewing external experts allows you to study the essence of the problem, find as many solutions as possible. Interviews with experts require little time, financial and labor resources. Criteria for the selection of experts can be the level of education, work experience, position, etc.

Under secondary information mean such information that exists in published form and was not collected for the purposes of this energy audit. This type of information, in turn, can be divided into external and internal.

External Information – it is enterprise data that is collected outside the enterprise and can be published in periodicals, reference books, books, computer databases, the Internet, etc. It includes:

- normative and reference information;
- scientific and technical literature;
- information from the Internet.

Internal Information – These are data that are collected and analyzed directly by the personnel of the enterprise in accordance with Table 2.1.

Table 2.1

List of internal information

№ s/p	Information Source Name	Availability mark
1	Description of the production structure of the enterprise	
2	General plan of the enterprise with operation of buildings/structures (Fig. 2.3)	
3	Single-line power supply diagram and brief description of the enterprise power supply system with indication of places of installation of electricity meters	
4	Heat supply scheme of the enterprise with indication of places of heat energy installation (if any)	
5	Enterprise Energy Passport	
6	Steam-condensate balance of the enterprise	
7	Data on monthly consumption of fuel and energy resources for the last three years. If there are several counters, then separately for each counter	
8	Data on output by product group for three years and plan for 2017	
9	Plans for reconstruction and modernization of the enterprise	
10	Data on measures to save fuel and energy resources planned for implementation in the current year (name and brief description of the event, where it is planned to implement, the value of the planned savings)	
11	Data on the main technologies, administrative and auxiliary buildings and structures of the enterprise: name of the building, purpose, construction volume, number of floors, material of enclosing structures, glazing area, temperature regime, availability of heating and ventilation systems, number of showers and washbasins using hot water	
12	Data on heat-generating equipment: name, brand, quantity, place of installation, operating mode, as well as technical documentation for equipment (regime maps, technical passports)	

№ s/p	Information Source Name	Availability mark
13	Data on the main technological fuel consumption of equipment: name, brand, regime maps, technical passports, quantity, purpose, place of installation, duration of work for the year, what products are planned to be produced on it	
14	Data on the main technological heat-consuming equipment: name, brand, quantity, purpose, place of installation, duration of work for the year, what products are planned to be produced on it	
15	Data on main process power consumption	
16	Equipment: name, brand, quantity, power (electric), purpose, place of installation, duration of work for the year, what products are planned to be produced on it	
17	Data on power consumption of equipment of auxiliary workshops (pumping, boiler houses, compressor, mechanical and tool shops, car parks, etc.): name, brand, quantity, power (electricity), purpose, place of installation, duration of work per year	
18	Data on the lighting system of shops and premises: name, brand, quantity, capacity (electric), place of installation, duration of work per year	
19	Data on the outdoor lighting system: name, brand, quantity, power (electric), duration of work per year	

The main advantages and disadvantages of secondary information are given in Table 2.2.

Table 2.2.

Main advantages and disadvantages of secondary information

Advantages	*Disadvantages*
With a large number of information has a relatively cost	May not be fully fit for purpose (incomplete, general)
Relatively quickly going	May be obsolete
Often there are many sources of information that allow you to identify different approaches and compare data, as well as get more information	The methodology underlying the data collection may be unknown (sample size, due date)
Information collected from independent sources has significant reliability	May be incomplete, contradictory, its reliability is not always known



Fig. 2.3 Example of the general plan of the enterprise
(with explication of buildings)

The energy auditor should collect and summarize relevant energy data that provide the objectives of the audit:

1. List of energy-intensive systems, processes and equipment;
2. Detailed characteristics of energy use within a certain nature and scope of energy audit work, including relevant changes, as well as how they, in the opinion of the organization, affect energy efficiency;
3. Data on the level of achieved efficiency for the previous and current periods, including:

– energy consumption;
– relevant changes;
– corresponding adjacent measurements;

– previous and recent operational events that may have affected energy consumption for the period covered by the data collected.

4. Monitoring of equipment information, configuration and analysis;
5. Future plans that may affect the level of achievable energy efficiency;
6. Design, operation and maintenance documents;
7. Results of previous energy audits or studies;
8. Current rates rates (or tariffs) for energy resources or the base rate (or tariff) that will be used for financial analysis;
9. Other relevant economic data;
10. Information on how the organization manages its own use and consumption of energy;
11. Energy distribution and management system.

2.8. Processing and preliminary analysis of basic data on the object of energy audit

The process of processing and primary analysis of basic data involves the implementation of a set of measures aimed at the initial study of the key parameters of the energy audit object, which allows a better understanding of its specifics.

The most common actions within this analysis include:

1) *Identification of the main species* – is carried out in order to determine the types of energy resources used at the enterprise.

2) *Identification of energy sources and analysis of existing energy supply systems* – allows you to determine the origin of the EE (whether it is its own sources, or purchased), as well as to make an inventory of all energy sources (electricity, gas, steam, secondary energy resources, water, wastewater) in physical units of measurement (kWh, MJ, m × ³, etc.) and in value terms. Sources of energy resources are grouped by types of FP. At this stage, energy supply schemes within each power system (heat supply, power supply, fuel supply, water supply, compressed air supply, etc.) are also analyzed. A brief description of each system is carried out and the availability of appropriate power supply schemes, as well as contractual relations

regarding the purchase of TP, is noted. In the case of the presence of subabonents, notes are made on the conditions for their connection, methods of accounting and calculation for consumed energy resources.

Analysis of the functioning of energy supply systems may include:

- list of metering devices with indication of the type, place of installation, method of accounting and data transfer;
- characteristics of energy resources accounting (commercial, technical, shop, aggregate, etc.);
- places of installation of measuring instruments (pressure gauges, thermometers, flow meters, etc.), which makes it possible to determine the key technical parameters of objects using the simplest dependencies between the analyzed values.

3) Study of process flow diagrams – is executed in the form of a schematic diagram, which reflects the main stages of providing production with energy resources and raw materials. The scheme indicates the points of supply and consumption of FEP, as well as the possibility of waste disposal as part of the technological process.

4) Assessment of PER consumption level – is carried out to analyze the dynamics of changes in energy consumption both at the level of the entire enterprise and in its individual structural divisions. This analysis allows you to determine the main directions of the use of FEP and identify areas with the highest return on investment in energy efficiency. In the course of this study, daily schedules of energy consumption (if any) can be considered. Particular attention should be paid to the electric load schedules, as well as the power factor for the entire enterprise, as well as for individual transformer substations or large electricity consumers. Graphical analysis of electrical loads helps to estimate the load level (coefficient) of supply lines and transformers in relation to their maximum power. Active energy (power) is directly used to perform useful work, in particular mechanical or thermal. Reactive energy is not involved in the performance of useful work, but is spent on the formation of electromagnetic fields in engines, transformers, induction furnaces, welding machines and lighting devices. Since reactive power entails additional energy costs, it must be compensated. Reactive

power compensation is an efficient and low-cost way to optimize power supply, which helps to reduce electricity losses and improve technical and economic indicators.

5) Formation of the list of main consumers of FEM – involves the identification of the main consumers of energy resources through a detailed study of technological processes. To this end, lists of energy-consuming equipment are compiled, indicating their key technical parameters. Equipment is classified by:

- type of PC consumed;
- location (building, shop, production area);
- Role in the process;
- the nature of the allocation of PER consumption (own or economic needs).

3. METHODOLOGY OF ENERGY AUDIT

3.1. Determination of energy consumption and its cost according to the facility documentation

Energy audit begins with determining the current energy consumption, its cost. This information allows you to imagine the extent of the problem and shows where efforts should be focused to achieve the best results.

Information about the current state of energy consumption is collected as a rule for one year, to assess the impact on energy consumption of climatic conditions and the seasonal nature of the object's activities, this requires monthly data of all types of energy and energy carriers.

It is also necessary to obtain information about the outside air temperature during this period and preferably the average monthly.

Find out how costs and energy are formed, get acquainted with the system of tariffs and energy and energy carriers.

The energy auditor needs to receive information about the full connected power of energy receivers and the maximums of power consumption, to receive characteristic load graphs. As a result of processing the accounting and financial documentation of the object, the following information will be obtained:

- total cost of energy resources consuming the facility;
- distribution of costs between types of fuel;
- seasonal changes in fuel consumption;
- tariff system information.

3.2. Facility energy survey and technological process

Knowing the cost and consumed amount of each type of energy consumed, you can proceed to determine the places of their consumption, for each type of energy to determine the most important consumers by volume and cost.

The energy auditor gets a clear idea of technological processes and specific equipment.

To obtain information about exactly where and in what amount of energy is consumed, it is necessary to familiarize yourself as thoroughly as possible with the production process at the facility. Particular attention should be paid to large energy consumers. A small relative saving for a large consumer is more likely to be significant than a large relative saving for a small consumer. Consider each step in more detail.

3.2.1. Site visit

Visiting an object (enterprise) is a very important stage for obtaining reliable information, in particular about the production cycle. In the process, it is necessary to find out all the stages of technological production processes, paying attention to the following issues:

- the input and output energy streams of each stage;
- feedstock and material flows;
- loss and branch flows.

Communication with practicing managers, technologists, process managers. It is interesting to find out whether workers see opportunities to influence energy consumption. The energy auditor needs in his survey to be guided by the existing scheme of engineering networks (heating, electricity, compressed air, steam, water, etc.) of the enterprise. This allows the energy auditor to have an idea of the flow patterns of energy resources (Fig. 3.1).

Having familiarized with the energy supply system of the enterprise as a whole, the energy auditor should proceed to a detailed acquaintance with the work of each technological process which has significant energy consumption flows and large energy consumption figures.

The process flow diagram conventionally shows the main stages through which the raw material passes before becoming the final product of production and the connections between these stages.

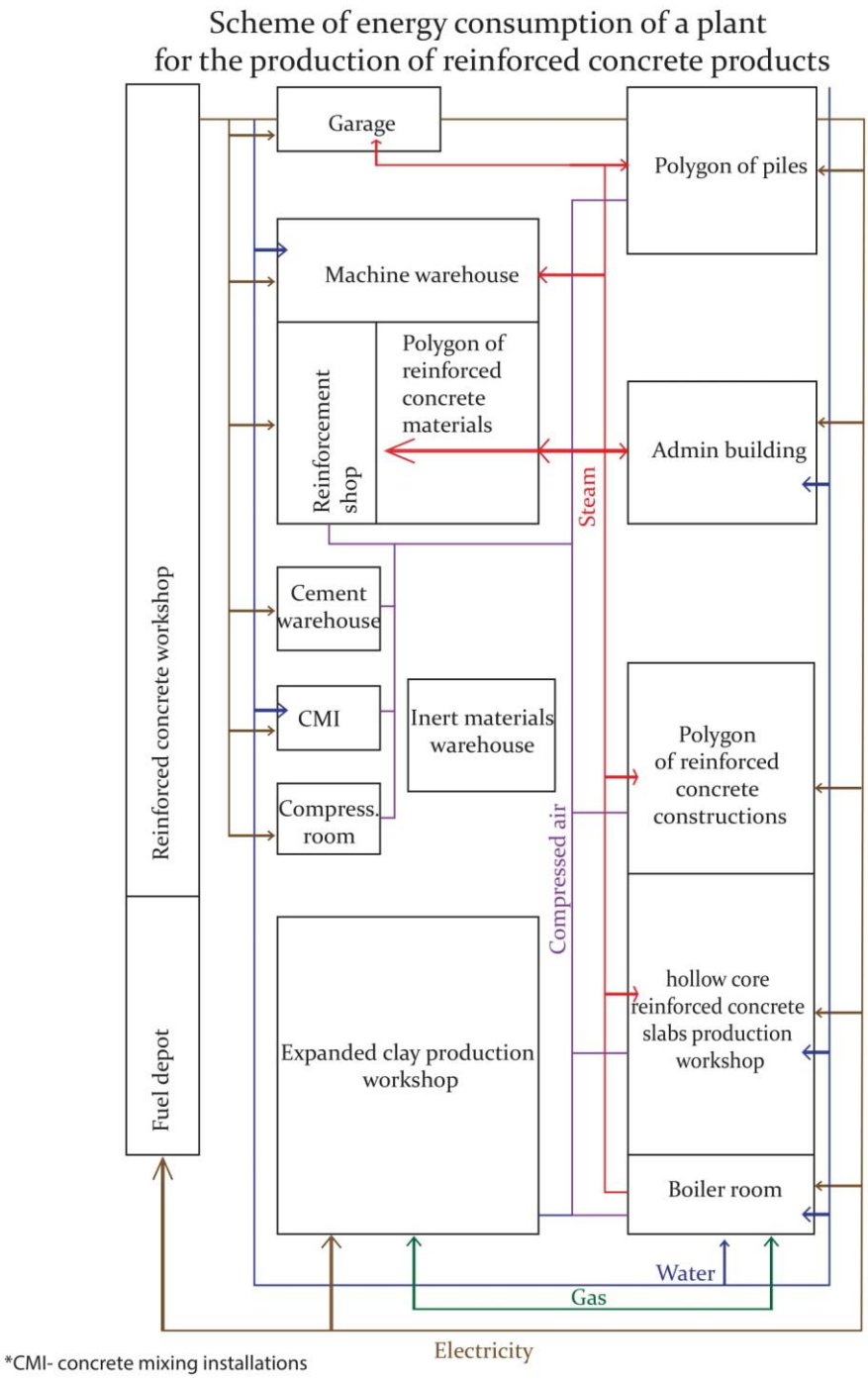


Fig. 3.1 Power consumption diagram

The main inputs and types of energy used must be shown. Each of these stages is considered as a separate object of examination.

As an example, Fig. 3.2 shows a diagram of the technological process for the production of floor slabs. Please note that the waste of the molding and heat treatment processes is supplied as a secondary raw material after secondary treatment.

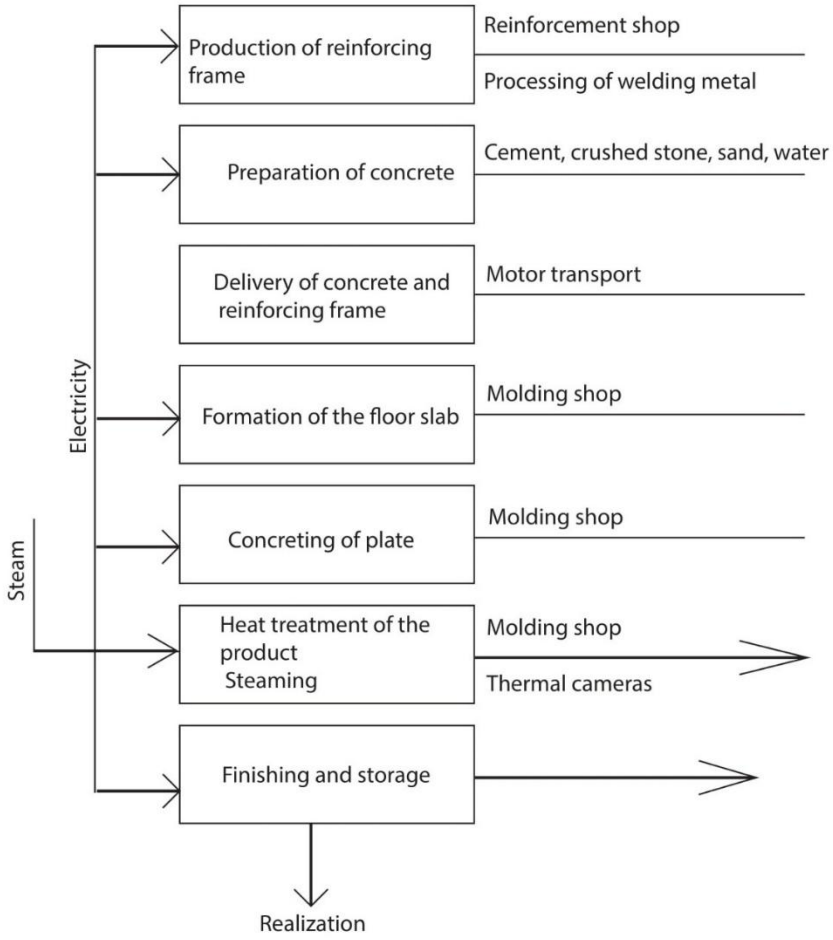


Fig. 3.2 Process flow diagram

3.2.2. List of important energy consumers

Using the example of the production of reinforced concrete products in Table 3.1, we will consider a list of important energy consumers in particular:

- the enterprise must have an account of the energy flows used;
- current power usage status.

Table 3.1

Energy consumers on the example of production of reinforced concrete products

Types of consumption	*Steam energy*	*Fuel energy (gas)*
– Lighting – electric furnaces – heating of premises – air conditioning – air compressors – refrigerator compressors	– thermal chambers – Heating – processing of materials before mixing in winter – liquid heaters – drying cabinets	– steam boilers – hot water boilers – steam generators – thermal liquid heaters – furnaces – Garbage burners

Types of consumption	*Steam energy*	*Fuel energy (gas)*
– pumps of water and process fluids – fans – production machines and mechanisms, electric drives, process heating – vacuum pumps – mixers		

The amount of energy consumed is estimated by a combination of measurement, estimation and calculation. We must try to get the most accurate result.

Figure 3.3 illustrates the methods used to determine the amount of energy consumed.

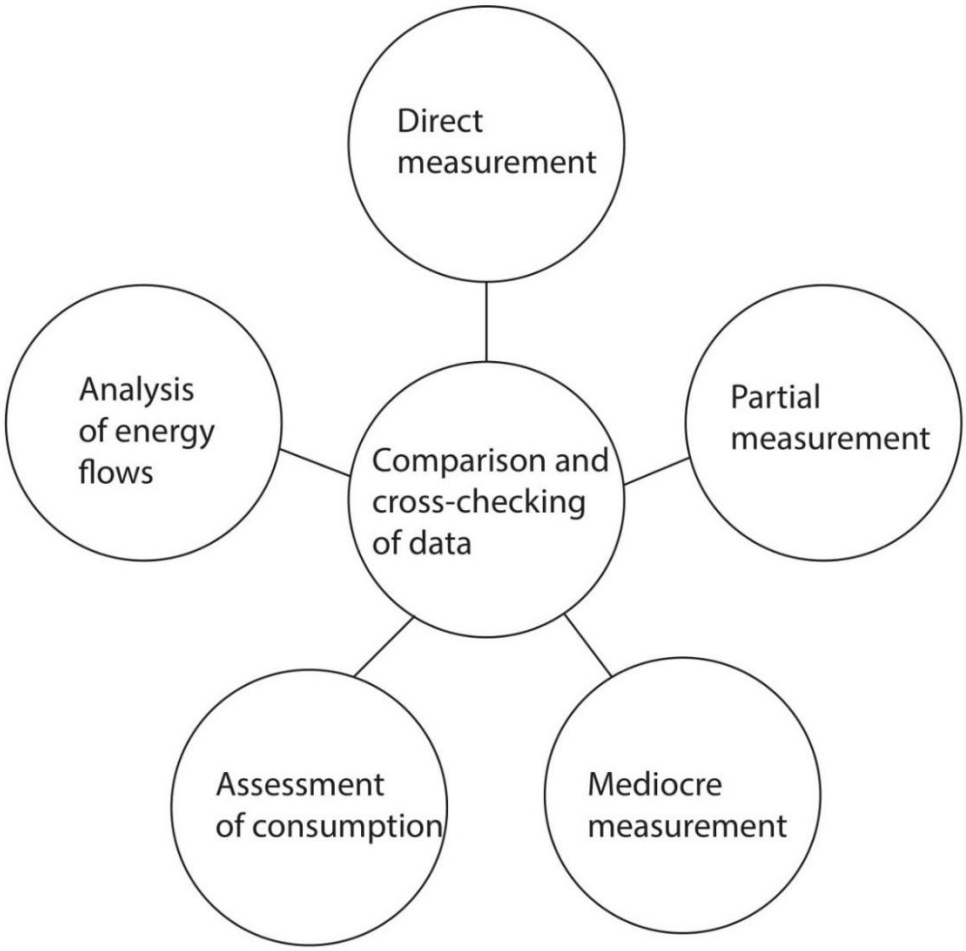


Fig. 3.3 Methods used to determine the amount of energy consumed

5 keels concentrated around the central circle of comparison and cross-checking the data provide different methods of measuring and estimating the amount of energy

consumed by different categories of energy receivers. The obtained values of singing are put grouped into separate categories of consumers.

Cross-checking is performed to refine the data. Enterprises must have a developed network of meters. In addition, you need to be prepared to use portable measuring devices. Even when direct measurement of energy expenditure is impossible, mediocre methods exist to estimate it. These methods are based on the elementary laws of physics and are carried out using simple and inexpensive equipment.

3.2.3. Site Energy Efficiency Analysis

The end of the site energy survey for the auditor is the stage of analyzing energy use and flow distribution at the site. In order to improve the analysis for the energy auditor, it is more convenient to use tables, graphs and a short comment.

The goal analysis should address the following issues:

- calculate the amount of energy consumption by different consumers within the facility;
- distribute the financial costs of energy proportional to all consumers;
- Compare energy consumption with product release
- determine deviations from the norm regarding energy consumption (unexpectedly high or low levels of consumption, or erroneously determined during regressive analysis).

This information is very important for the audit customer because it confirms or refutes the established opinion about the size of energy consumption within the facility.

Especially important is the fact that this information is prepared by professional energy consultants who took a fresh look at the object.

In the process of analysis, deviations from the norm are revealed, which can be caused by incorrect bills of energy suppliers. The auditor in this case should clearly outline this negative practice, prompting the management of the enterprise to take appropriate measures.

3.2.4. Elements of energy efficiency analysis

Figure 3.4 shows a line graph of monthly gas consumption by the heating system and indicators of the external temperature of degree-days.

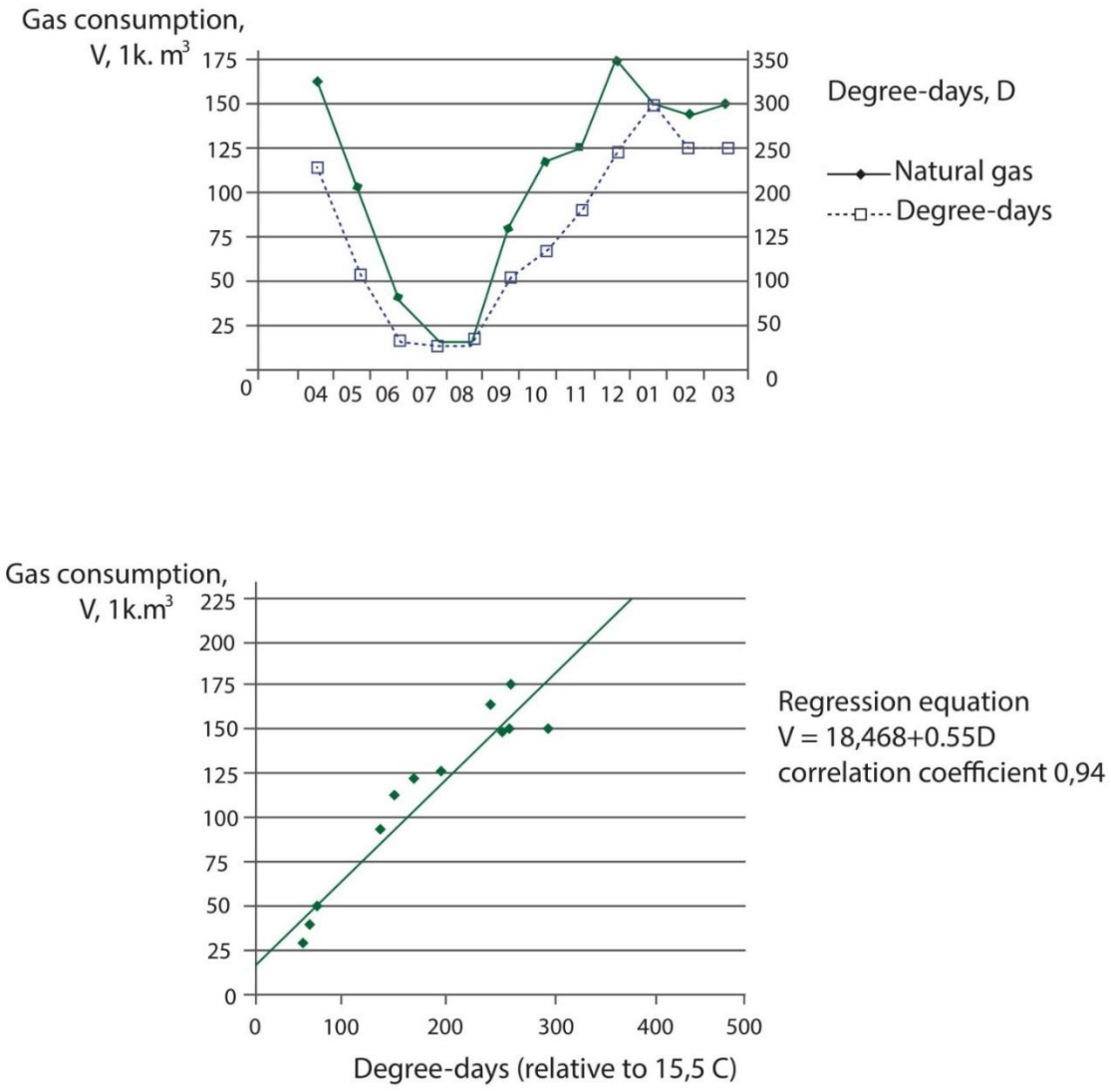


Fig. 3.4 Schedule of regressive analysis of gas consumption for heating

The energy auditor uses all or part of the following elements to achieve the above objectives:

- annual energy purchase report;
- regression analysis graph;
- energy audit table;

- fuel cost factors;
- Sankey diagram;
- power consumption pie charts.

Energy consumption can also be measured indirectly. Analysis of data obtained for variable production conditions often provides quantitative indicators for the distribution of measured energy costs to energy components. More often, the regressive analysis method and the test control method are used for this.

A regressive analysis method is a mathematical technique based on comparing the amount of energy used with another variable on which energy consumption may depend. For example: we compare the value of monthly energy consumption with the release of products for the same period.

Regressive analysis divides the amount of energy consumed into sustainable consumption and variable consumption.

Regressive analysis also gives the nature of the dependence of the change in the amount of energy on the amount of production.

The simplest diagram is a linear dependence - the so-called linear regression. There are also various kinds of nonlinear dependencies.

Namely, quadratic, exponential, exponential, logarithmic regression.

Regressive analysis establishes ways to save energy, as well as justifies the levels of energy consumption and use.

The position of the asterisks corresponds to the amount of production for a certain period of time and the amount of energy consumed during the same time.

With maximum approximation, a regression line was drawn - the so-called standard line.

The segment OA which cuts off the standard line along the energy axis corresponds to the consumed electricity of the enterprise.

The BC segment corresponds to consumption, which is due to the release of a certain volume of products.

The report on the purchase of fuel and energy is usually presented in tabular form.

Tables are compiled on the basis of monthly reports on accounts of fuel and energy suppliers.

From these tables clearly shows what proportion of a particular type of fuel, energy is in the total energy consumption.

During the analysis and in reports, energy auditors most often use two types of schedules:

- schedule of energy consumption change over time (linear schedule of energy consumption) on which, in addition to monthly energy consumption, data on the volume of production, on the ambient temperature can be entered;
- a regression analysis plot.

3.2.5. Calculation of energy consumption at the facility

The calculation of consumption should take into account seasonality, measurements (assessment), calculation, it must be borne in mind that there will be no coincidence between these approaches. The seasonal nature of the energy demand can help the energy auditor separate the load of the technological process from the load associated, for example, with the heating of the room. Consumption calculation is a combination of estimation and calculation measurements, although it is always necessary to be as accurate as possible, but inconsistencies can occur. The accuracy of the figure is not as important as the scale of consumption itself.

3.2.5.1. Seasonal fluctuations in energy consumption

Figures 3.5 and 3.6 show seasonal variations that may assist in assessing process load. The first graph (Fig. 3.5) reflects the monthly load due to heating of premises, where the dependence of heating volumes on the outside air temperature is clearly established. The graph shows the period of lack of heating.

The second schedule (Fig. 3.6) takes into account the added constant load associated with the production process. If the process load is relatively constant, then an assessment of its determination can be obtained by measuring the fuel consumption at the facility during the period when there is no heating.

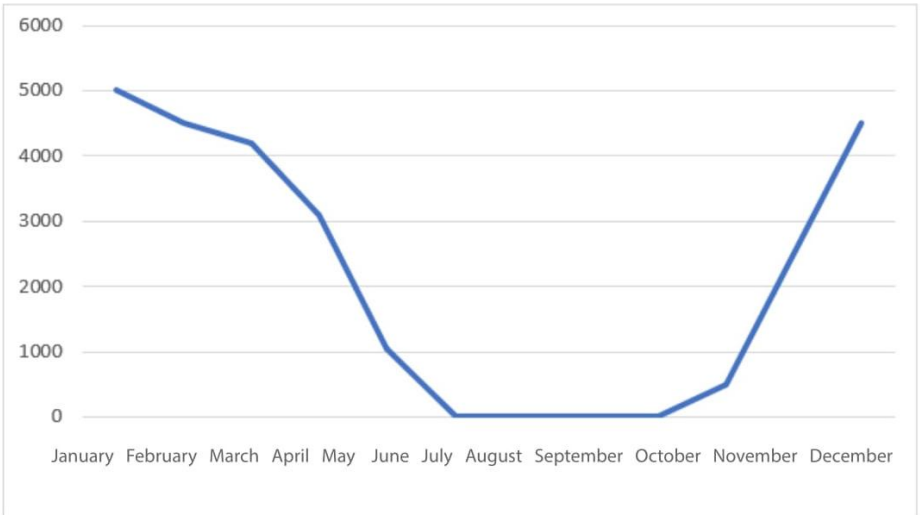


Fig. 3.5 Room heating

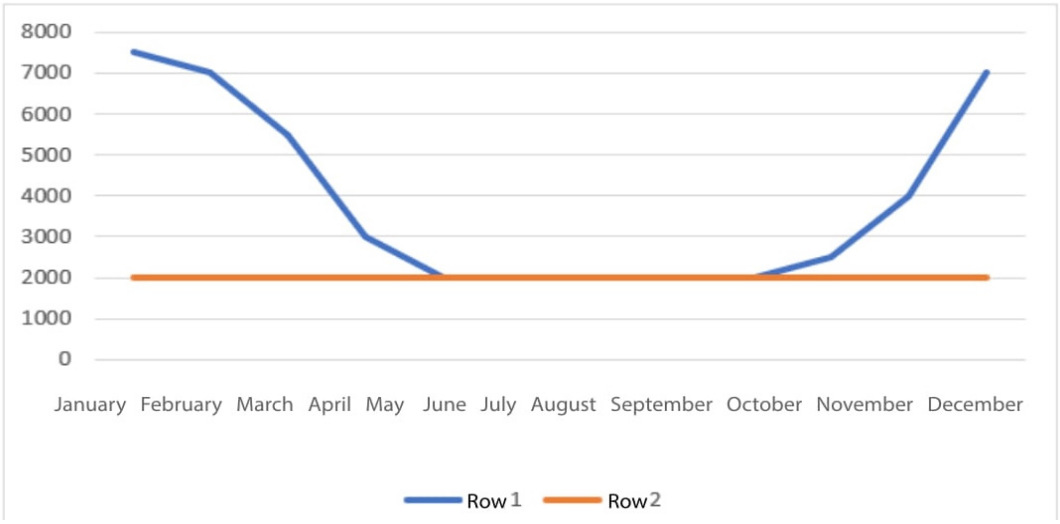


Fig. 3.6 Technical needs (row 1) and heating of premises (row 2)

An example of a daily load graph is shown in Fig. 3.7.

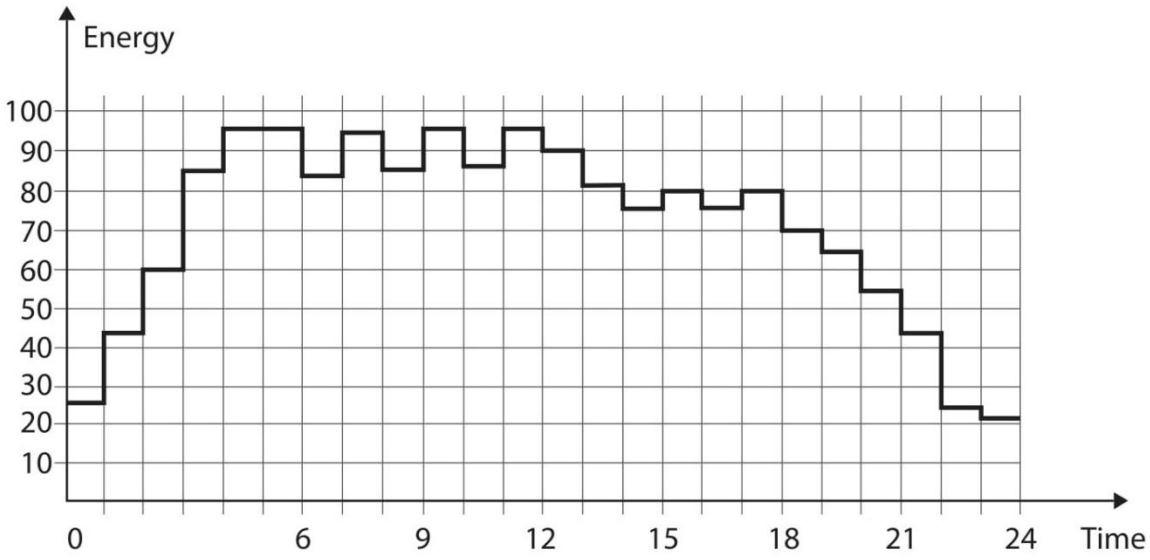


Fig. 3.7 Daily load schedule

3.2.5.2. Sankey diagram

A Sankey diagram is a graphical representation of energy flows in which the thickness of different elements of the diagram is proportional to the corresponding amount of energy. Some Sankey diagrams reflect the cyclic movement of energy flows, for example, the return of condensate to the boiler room.

An example of a Sankey diagram for a modern power plant is shown in Fig. 3.8.

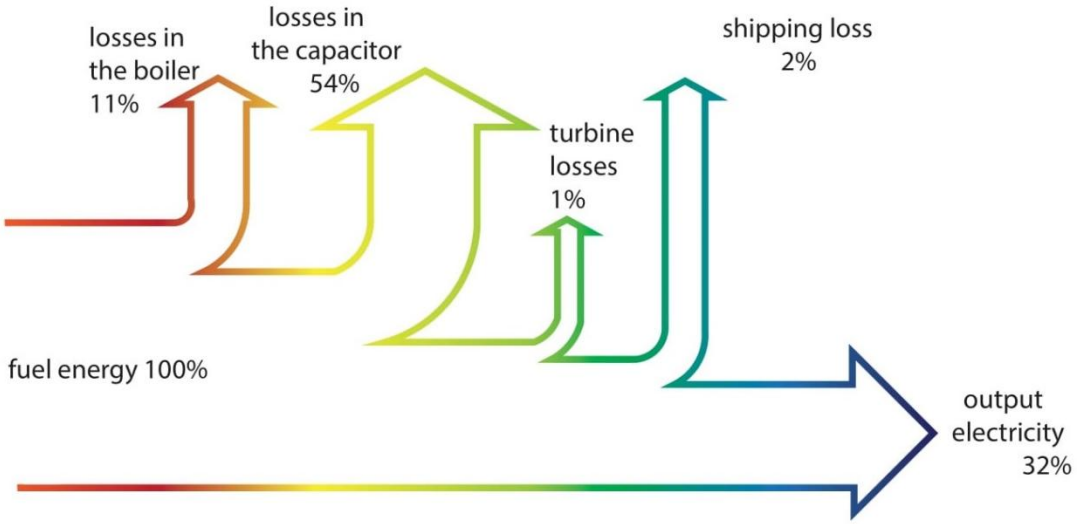


Fig. 3.8 Sankey diagram for modern power plant

In addition to the Sankey diagram, the energy audit uses pie charts with which you can graphically depict energy consumption in both natural and relative units (Fig. 3.9).

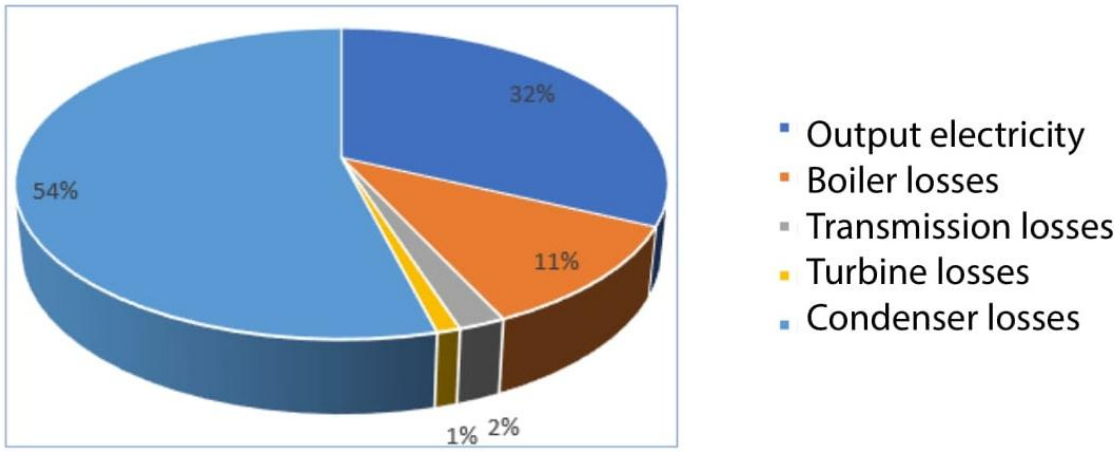


Fig. 3.9 Pie chart for modern power plant

The importance of such graphs is that they clearly demonstrate the change in the amount of energy consumed over time. This information helps to compare the actual change in the amount of energy consumed with the expected. Load schedules contain signs of potential energy savings and may indicate the following factors:

- damage control system;
- losses and leaks;
- manual control systems;
- differences in energy efficiency between different work shifts.

Load schedules are an integral part of the energy survey. Energy flows are estimated by:

- use of various existing additional meters and meters;
- analysis of nominal data of the equipment, care should be taken to use the information given the large discrepancies in energy consumption, if this equipment was modified;
- analysis of maximum actual fuel movement speed.

Improve current power consumption

Critical analysis of energy flows consists of analyzing the current energy consumption at the facility and identifying processes where energy consumption needs to be improved.

There are three approaches:

– from the place of direct use (compressed air for vibration mechanisms);

– from the place of loss (excessive steam or compressed air pressure, operating equipment, conveyor lines, welding transformers, excessive overheating of furnaces, excessive steam temperature in the heat chambers);

– at low conversion efficiency (combustion processes in boilers and furnaces, cooling processes, compressed air production).

Existing systems should be taken critically. The design of the system may not be optimal. It often happens that the advantage belongs to the easiest option with the lowest capital costs. At this stage, it is necessary to establish whether the energy flows

are purposeful, whether there is a better way. The information available in the industry and the available specific energy costs should help in this task.

To determine the best options requires an understanding of technological processes and knowledge of available technology and technologies.

3.2.5.3. Process bulb

When considering energy consumption, a good analogy of the consumption system is given by the bulb (Fig. 3.10). The explicit requirement for energy is based on the transformation of energy of one type into another. So things are in the production of steam, compressed air, refrigerants. If we remove the energy generation (conversion) efficiency layer, we get the energy consumed by the distribution system. By removing the layer of distribution inefficiency, we get the energy consumed by the final consumer.

Order of analysis. Once in the middle of the bulb, we must focus on minimizing final consumption. Where final consumption is impractical, as an example of using compressed air for cleaning, it is possible to remove such a load. Where this is not possible, a reduction in energy consumption can be made by reducing losses or improving insulation. Reducing consumption by the end user can reduce distribution losses. It may also be possible to make a more rational distribution system. Thus, we have an idea of a potentially new equipment capacity caused by a decrease in needs. This has a major impact on the evaluation of options for improving equipment efficiency.

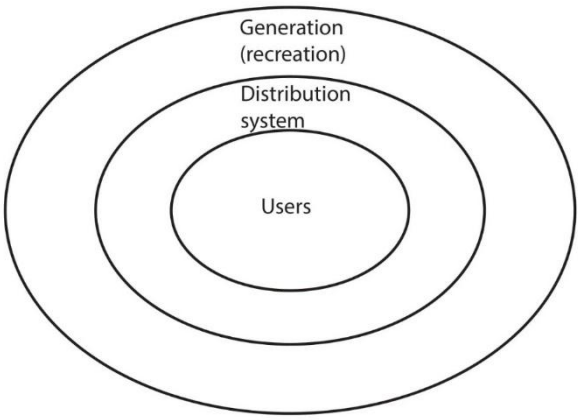


Fig. 3.10 Process bulb

3.2.5.4. Evaluation priorities

In example (A) in Fig. 3.11, the final consumption is 60 GJ. This is due to the need to enter 100 GJ into the distribution system at 60% distribution efficiency to service the required load. A total energy input of 167 GJ is required.

In example (B) in Fig. 3.12, the final consumption decreased to 40 GJ. To ensure such power, 67 GJ must be supplied. At the same time, the total energy input is reduced to 111 GJ, the distribution efficiency is unchanged.

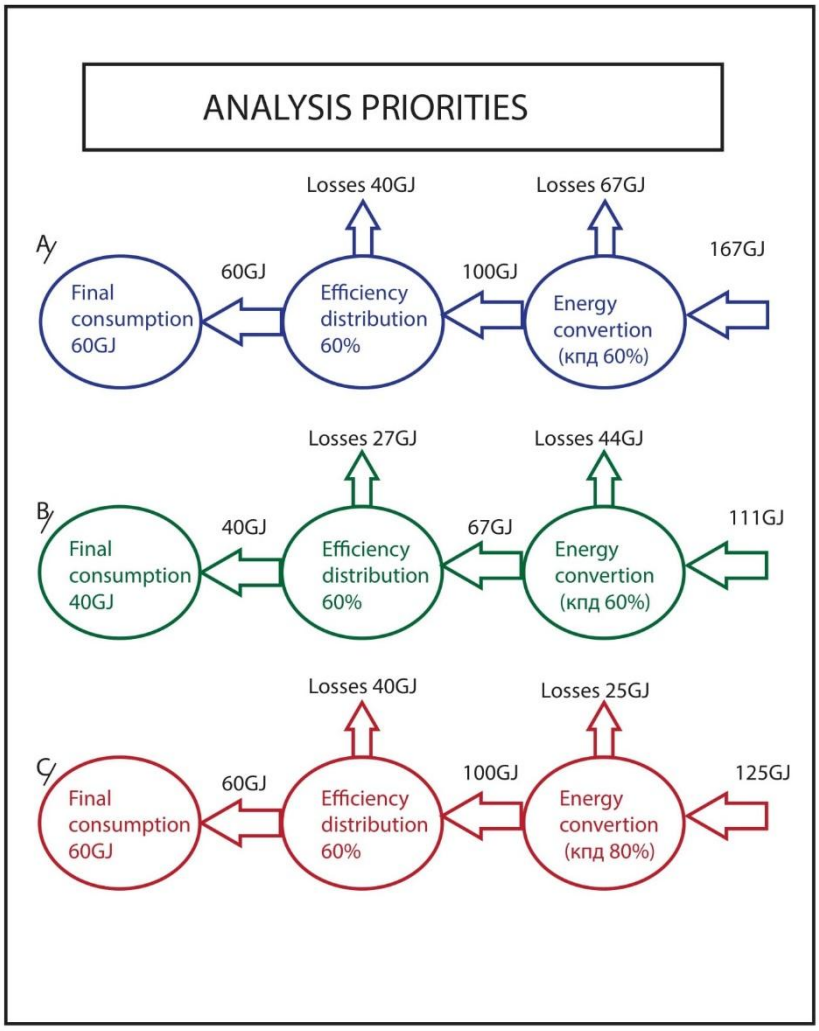


Fig. 3.11 Examples of analysis priorities

In example (C) in Fig. 3.12, the final consumption at 60 GJ and the conversion efficiency is increased from 60% to 80%. The total energy consumption is 125 GJ. Thus, we see that with a decrease in final consumption by 1/3, we save more energy than with an improvement in efficiency by 1/3.

Analysis of energy use.

In the process of work, the energy auditor should highlight the following goals

- what requires the energy that exactly carries out this process;
- whether this consumption is necessary;
- the possibility of reducing power;
- alternative options for satisfying energy requirements.

Energy or energy consumption can also be determined by readings of stationary or temporary measuring instruments. For example: stationary electro or heat meters.

3.3. Planning and measurement

In accordance with the Law of Ukraine "On Metrology and Metrological Activity," the term "measurement" means the reflection of physical quantities by their values through experiment and calculations using special technical means.

Measurement is an integral part of the process of collecting information during the energy audit. They are performed in cases where it is necessary to verify the reliability of information obtained from documentary sources, to supplement or clarify the statistical data on the object of the energy audit, as well as during the analysis of the real parameters of the functioning of individual energy consumers. Power metering and control systems available at the facility, stationary and portable instrumentation are used for measurements.

The amount of information that needs to be obtained through measurements is determined by energy auditors in accordance with the characteristics of the energy audit object, as well as depending on the goals and objectives set. Measurements, the results of which will not be used to form energy audit conclusions, are impractical. That is why the measurement process requires careful planning.

During preparation for measurements, the following errors shall be avoided:

- *Insufficient data, which makes it impossible to perform accurate energy analysis of specific installations, processes, systems or buildings, which leads to a decrease in the quality of analysis;*
- *An excessive amount of data that will never be used to estimate the energy consumption of an object, which causes an unreasonable increase in the cost of an energy audit, without improving the quality of the findings.*

To avoid such problems, the energy auditor during the planning of measurements should determine the most appropriate places for their conduct. To do this, you need to answer the following key questions:

- Which parameter or indicator should be measured?
- What level of accuracy, measurement method and type of measuring equipment should be applied?
- What should be the duration and frequency of measurements?
- Where is the best place for measurements?

3.3.1. Sequence of determining the appropriate place of measurement

According to ISO 50002 For any measurement and data collection on site, the energy auditor and the organization must agree on a measurement plan. The measurement plan, if necessary, is reviewed based on the results obtained by the energy auditor during the energy audit. The main elements to be included in the measurement plan are:

1. List of relevant (control) measurement points, related processes and measuring equipment;
2. Identification of any additional measurement points, respectively measuring equipment, related processes and the possibility of installing equipment;
3. Required accuracy and repeatability of measurements, and associated uncertainty (measurement instability);
4. Duration and frequency of measurement, i.e. individual data points or continuous monitoring;
5. Purity of data collection for each measurement;
6. Appropriate time period when the activity is representative;
7. Relevant variables provided by the organization, such as operating parameters and manufacturing data;
8. Responsible for carrying out measurements, including a list of persons working for the organization or on its behalf. The responsible person may be from an organization, energy auditor or external body, such as a subcontractor;

9. Calibration and traceability of measuring equipment (if real or practical).

It is important that some necessary data, such as monthly performance and utility bills for previous periods, be provided by the organization itself. The organization clarifies the reliability of its own data on energy, production, etc. The auditor confirms that the analysis is based on correctly measured data and indicates how the information was obtained. It should be shown that the data sets are comparable (taken from the counter, nominal or calculated in another way).

Selective research techniques may be required when, from a practical and economic point of view, it is inappropriate to study all available information during an energy audit.

The sample study is described in ISO 19011-2011, point V.3. Procedures and methods should be chosen based on their suitability to the nature and scope of work on energy audit.

3.3.2. Measurement methods and procedures

Measurement method – is a combination of measuring principles and means of using measuring equipment. The chosen method should provide the minimum permissible error and help eliminate systematic errors or transfer them to the category of random ones.

The level of reliability of information obtained during measurements directly depends on the applied method. Therefore, when planning measurements, it is necessary to determine in advance the most appropriate methods for their implementation. Depending on the specifics of the measurements performed, various methods can be used, which must be indicated in the corresponding section of the energy audit report.

When choosing the optimal measurement method, the following main factors should be taken into account:

- Compliance of the method with a specific task - ensuring the necessary accuracy of measuring a physical quantity;

- Availability of legitimate measuring instruments (FTA) - the possibility of using certified and properly calibrated devices;
- Ease of implementation and efficiency - the convenience of using a method that provides high performance during measurements.

Preference is given to direct measurements (for example, with direct evaluation), automated methods.

According to the Law of Ukraine "On Metrology and Metrological Activity": the measurement technique is a set of procedures and rules, the implementation of which ensures the receipt of measurement results with guaranteed accuracy.

The use of appropriate methods for performing measurements in energy audit activities is associated with the need to ensure the unity of measurements, namely: the measurement results should be expressed in units of physical quantities.

3.3.3. Measuring equipment used during the energy audit

One of the main tasks in organizing the activities of the energy auditor is the correct and effective choice of equipment. Devices for conducting an energy audit are a set of measuring instruments that must meet certain requirements, namely:

- no impact of measuring instruments on the operation of the studied electrical networks during the measurement of their operation mode;
- portability. The weight of the device should be no more than 15 kg, the device should be made in a protected case or with an existing protective case;
- autonomy. The presence of a built-in power supply that provides several hours of operation;
- ability to register data. The presence of an internal drive or the ability to connect an external drive;
- communication with the computer. Availability of port and software for data transfer to the computer;
- availability of a Certificate of metrological certification of measuring equipment in Ukraine (if provided for by applicable law).

To conduct an energy audit of industrial enterprises, it is necessary to have a minimum set of measuring equipment, the main characteristics of which are given in Table 3.2

Table 3.2

Main characteristics of the minimum set of measuring instruments

Instrument type	Purpose	Additional features
Ultrasonic flowmeters	For non-destructive measurement of liquid flow in fully filled pipes and in the absence of gas bubbles and suspension in the flow	Availability of a data storage device and a port for connecting to a computer
Gas analyzers	To determine the composition of gases in the sample. Used for flue gas analysis, adjustment of heat-generating equipment consuming fuel, technical and environmental monitoring	Measurement of gas temperature, determination of SO1 concentration, availability of memory and printing devices
Thermal imager	To obtain a visual display in the form of a thermogram of the temperature distribution on the surface of the object. The temperature distribution is shown on the thermal imager display as a color field, with each color reporting its own temperature. A thermal imager in an energy audit allows you to remotely detect heat leaks from window blocks and building doors, on the surfaces of heat-generating equipment and heating mains	Thermal imagers are equipped with software necessary for storing and analyzing infrared images and for preparing informative and high-quality reports
Infrared thermometers	For contactless temperature measurement	Availability of adjustment of surface radiation coefficient
Digital thermometers	For temperature measurement by contact in a wide range of installations and ranges	Can be used with different types of thermocouples
Air thermocouples	To measure ambient temperature	Used with digital thermometer
Overhead thermocouples	To measure the temperature of the medium through the metal wall	Used with digital thermometers
Contact thermocouples	For contact measurement of medium temperature	Used with digital thermometer
Analysers and/or Electrical Data Loggers	To measure and record for a long time the parameters of three-phase and single-phase electrical networks, as well as equipment for obtaining graphs of electrical loads of technological equipment	The presence of an optical sensor (for reading the indicators of counters with switch or disk mechanisms), as well as a data storage device and a port for connecting to a computer
Current-measuring shaft mites	For instantaneous measurements of parameters of three-phase and single-phase electrical networks (current, voltage, power, power factor)	Availability of a data storage device and a port for connecting to a computer

Instrument type	Purpose	Additional features
Data loggers	For registration at certain time intervals of numerical values characterizing one or another parameter. The device is universal performs recognition and processing of incoming signals in digital and analog form	Port to connect to computer
Power Quality Analyzer	To record a wide range of electrical network parameters such as current strength, voltage, power, power factor, nonsonuidality, etc.	
Ultrasonic thickness gauges	To determine wall thicknesses of pipes and other objects	Typically used with a flowmeter
Rangefinders (roulette, laser rangefinder)	To measure distances to objects as well as linear dimensions of objects	Diapwzon distances - 0 ÷ 200 m; accuracy + 2-3mm;
Anemometers	To measure the flow rate at	—
Tachometer	open access	Measurement can
Pressure gauges and	To measure angular velocity	be a contact or
differential	rotating body (rotation speed	—
pressure gauges	machine parts and mechanisms)	—

Depending on the type of energy audit object, a set of measuring equipment can be supplemented with the following devices:

– devices for measuring compressed air leaks in pipelines;
– hygrometer;
– Pitot tube;
– correlation determiner of pipeline damage points;
– leak detectors and gas detectors;
– flow meter for effluents;
– water quality determinant (salt content, pH);
– dynamometers for measuring force and moment;
– autonomous devices for long-term recording of air temperature;
– equipment for measuring air infiltration in rooms;
– other devices.

Heat energy meters are the energy boundary of a building. During an energy audit, you need to take into account everything that affects the energy consumption of

the building after the ITP. Thermal energy consumption must be measured in each apartment, this can be done in two ways:

- installation of heat energy meters in each apartment can be done if each apartment has an individual heating system. For example: heating system on the floor with a comb on the floor branch to each apartment;
- installation of heat distributors on each heating device in the building. This option is suitable for any building heating system. The heat distribution device does not measure the amount of energy consumed, but only the temperature on the surface of the radiator, thereby fixing a certain amount of heat energy distributed between all heating devices. When using distributors, a common home heat meter is installed.

The main measuring equipment is shown in Fig. 3.12).

Thermal counter



Pyrometer



Thermal imager

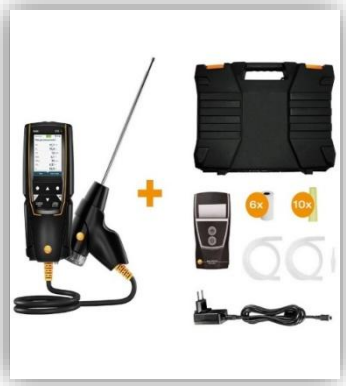


Thermoanemometer



Fig. 3.12. Basic measuring equipment

Flow meter



Gas analyzer



Flowmeter



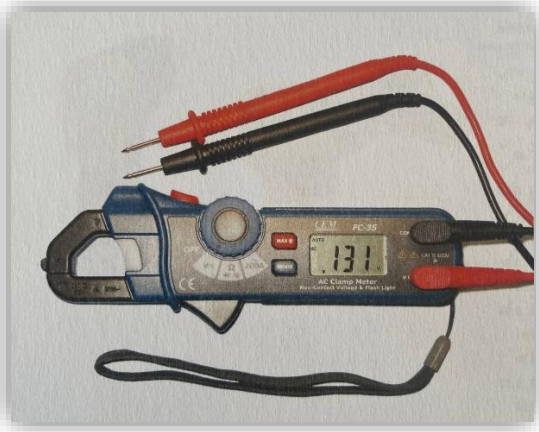
Pressure gauge



Pyranometer



Current mites



Luxmeter

Roulette

Fig. 3.12. Basic measuring equipment (continued)





Fig. 3.12 Measuring equipment (continued)

In an energy audit, temperature measurement is common. It should be understood that temperature sensors must be in contact with the surface for some time to achieve equilibrium. More often, contactless temperature measurement and optical methods are used when the instruments read the amount of electromagnetic measurement of the equipment under study. Most often used infrared thermal camera or pyrometer.

Air exchange in the building is the main criterion for determining the thermal loss of the building. Airflow can be measured using an anemometer, which are divided into two classes:

- with a turbine, where the air flow rate is measured depending on the turbine speed;
- where the air flow speed is determined depending on the temperature of the filament, which decreases or increases depending on the air speed.

  More convenient are thermoanemometers.

If there is no anemometer at hand, use flame or smoke. Air leaks through the building shell are determined to determine the air permeability. This measurement is carried out laboratory and to determine the air permeability, two methods are used: laboratory and design. The air permeability test is carried out to ensure a pressure difference between air in the middle and outside the room, with a pressure difference

of 50 Pa. The pressure drop occurs when one or more fans are operating, depending on the area of the room.

With an energy audit, it is very important to obtain data on the level of carbon dioxide pollution of the room. This makes it possible to analyze the quality of the ventilation system. Air quality meets the standards if the SO2 level is below 1000 ppm.

Heat transfer coefficient of building shell elements is calculated due to thickness and thermal conductivity of building shell layers. The thickness is measured at the time of inspection of the building, and the thermal conductivity values are taken from the tables of GOST 9191. Measurements are performed in accordance with international standards.

To measure the heat transfer coefficient of building elements, it is necessary to measure the heat flux density (W/m2). Heat flux density is measured using ball-shaped sensors on one side of red color on the other of blue color. At the heart of such a sensor is used thermal battery.

The heat transfer coefficient can also be calculated by knowing the heat flux density and temperature difference. This process is stretched in time and can last from 3 to 7 days.

A number of gas analyzers are used to assess the quality of combustion processes. More often devices are used, which include programs for assessing the quality of gases, analyzing the combustion process, detecting the excess air coefficient and calculating the efficiency of the combustion processes and the efficiency of the equipment.

The energy auditor must be able to use portable devices to control the flow of gas, liquid, steam, etc. The most common are ultrasonic portable flow meters.

At the disposal of the energy auditor should be pressure gauges that allow you to quickly establish pressure indicators in pipelines.

It is advisable for an energy auditor to be able to work with devices such as a pyranometer. These instruments are used to measure solar radiation. With its help, you can determine the value of the permeability of solar radiation through windows and enclosing structures.

In the practical work of the energy auditor, the ability to work with devices for analyzing the quality and power of power supply systems is of great importance. Such devices include current portable ticks, ammeter, voltmeter and power quality analyzers.

The level of illumination in the premises is determined using luxometers.

The most important device of the energy auditor is a laser or ordinary roulette.

In the absence of information on the dimensions of buildings, windows, doors, etc., measuring work is performed. As a result of measurement work, the customer receives dimensional geodetic drawings in two- or three-dimensional form, which contain information on the height and planned location of structures of buildings or structures. When performing certain measurements, it is important to evaluate their accuracy. The term "measurement accuracy" defines the level of approximation of the measurement results to the actual value.

The key to correct conclusions from the analysis of information of temporary measuring instruments is common sense and cross-checking the results. The first step in generalizing the information received from the measuring instruments is to build a change in loads over a certain time - load graphs. To do this, use the readings of those measuring instruments that can measure energy consumption for a certain period of time (electricity meter or ultrasonic flow meter).

4. CERTIFICATION OF ENERGY EFFICIENCY OF BUILDINGS

4.1. Key provisions on energy efficiency certification

Under the energy efficiency of the building refers to the property of the building, characterized by the amount of energy required to create proper living conditions or life of people in such a building.

The Law of Ukraine "On Energy Efficiency of Buildings" defined the minimum requirements for energy efficiency of buildings for the implementation of which it is necessary to conduct an energy audit of the building, as well as develop energy efficiency measures on its basis.

A professional approach to solving energy saving problems can significantly, and in some cases, 2-3 times reduce the cost of operating buildings.

Energy consumption in residential buildings depends on:

– local climatic conditions;
– building shell characteristics;
– designed internal environment conditions;
– characteristics of settings parameters of building technical systems;
– works and processes in the building;
– behavior of building users, as well as operating mode.

According to clause 7.2 of GOST B V.2.2-39:2016 the purpose of energy audit in this case may be:

– verification of compliance with current regulatory documents in the field of energy efficiency;
– reduction of energy consumption and expenses for payment of consumed energy in the building;
– reducing the impact of energy consumption waste on the environment;
– preparation and receipt of the building energy certificate.

According to the Law of Ukraine "On Energy Efficiency of the Building," energy efficiency certification is understood as a type of energy audit during which information is analyzed on the actual or design characteristics of enclosing structures and engineering systems.

The compliance of the calculated level of energy efficiency with the established minimum requirements for the energy efficiency of buildings is assessed and recommendations are made to increase the level of energy efficiency of the building.

4.2. Data for energy efficiency assessment

In accordance with the provisions of DSTU B V.2.2-39: 2016, when determining the energy efficiency of buildings, it is necessary to take into account:

– local climatic conditions;

– normative sanitary and hygienic parameters of the microclimate of the premises of the building;

– geometric, thermal and energy indicators of buildings;

– functional purpose, type, architectural planning solution of the building;

– indicators of energy characteristics of engineering equipment;

– service life of the building.

Depending on the purpose of the energy audit and the terms of reference, the following methods for assessing the energy characteristics of the building are used, namely:

– design method based on design data;

– design method based on design data and results of technical surveys;

– calculation and measurement method;

– operational method (measuring).

General requirements for energy audit are defined in:

– DSTU ISO 50002:2016 "Energy audits. Requirements and guidelines for its implementation (ISO 50002:2014, IDT);

– DSTU EN16247-2:2015 Energy Audit - Part 2. Buildings energy audit buildings;

– GOST 9190:2022 Energy efficiency of buildings. Method of calculating energy consumption during heating, cooling, ventilation, lighting and hot water supply.

The information contained in these standards is the cornerstone of energy audit of buildings, in particular requirements, methodology, models, algorithms for energy audit of buildings.

4.3. Example of input data for energy efficiency assessment

Figure 4.1 shows the building plan.



Fig. 4.1. Building plan

Table 4.1 gives the data on the monthly consumption of electricity, heat or (fuel), hot water, cold water of the embedding for three years.

Table 4.1

Statistics of heat energy consumption for 2016 - 2018

Thermal energy						
Months	2016		2017		2018	
	Gcal	UAH.	Gcal	UAH.	Gcal	UAH.
January	108	74718,72	110,7	148192,98	80,2	119830,83
February	67,1	46422,46	93	124498,17	58,2	86959,53
March	55,7	38535,49	40,2	53815,34	81	121026,15
April	3,8	2628,99	-	-	12,1	18299,44
October	42,9	57429,8	19,7	26372,19	7,5	11342,63

November	76,9	102945,26	54	72289,26	57,8	87413,83
December	97,5	130522,28	87,2	130289,88	74,4	137472,6
Total	451,9	453203	404,8	555457,8	371,2	582345

Table 4.2 shows the actual consumption of hot water during 2018

Table 4.2

Months	2018				
	accrued	Benefits	total	Gcal	Tariff, UAH.
January	17482,4	2570,61	20053,01	13	1494,15
February	15383,9	2898,68	18282,58	12	1494,15
March	16623,5	3134,41	19757,91	13	1494,15
April	22140,2	2754,48	24894,68	17	1494,15
May	10379,3	1893,32	12272,62	8	1512,35
June	8732,94	1085,25	9818,19	6	1512,35
July	9664,09	2380,21	12044,3	8	1512,35
August	11124,9	2465,95	13590,85	9	1512,35
September	15688,4	2278,88	17967,28	12	1512,35
October	25384,8	2769,26	28154,06	19	1512,35
November	13989,6	2633,04	16622,64	11	1512,35
December	18962,2	2897,13	21859,33	13	1631,36
Total	185556,23	29761,22	215317,45	141	

Table 4.3 shows the actual electricity consumption during 2018

Table 4.3

The Moon	2018		2019	
	тис. кВт·год	UAH	тис.кВт·год	UAH
January	1,477	4298,07	1,821	5299,11
February	2,130	6198,3	2,814	8188,74
March	1,803	5246,73	2,257	6567,87
April	1,431	4164,21	2,639	7679,49
May	1,791	5211,81	1,593	4635,63
June	0,510	1484,1	-	-
July	0,245	712,95	-	-
August	0,700	2037	-	-
September	1,523	4431,93	-	-
October	2,097	6102,27	-	-
November	1,457	4239,87	-	-
December	3,100	9021	-	-
Total	18,264	53148,24	11,124	32370,84

Climatic design parameters of the external environment according to DBN N B V.1.1-27:2010 "Construction climatology" (for Odessa, Odessa region):

- design temperature for heating design..... - 18 ° C;
- duration of heating period..... 165 days;
- average temperatures of the heating period..... 1.0 ° C;

Design average monthly outdoor air temperatures, ° C and duration of heating period are given in Table

Monthly external air temperature

month	Janu ary	Febr uary	Mar ch	April	Octob er	Nove mber	Dece mber	**per year**
average monthly	-1,3	-0,6	2,9	9,2	17	11,3	5,8	+3
temperature, ° C	29	26	29	12	13	28	28	165

4.4. Example of photo and video materials, thermal imaging results

To fix and graphically depict the state of energy audit objects of their individual components, it is necessary to use means of photo and video shooting and thermal imaging fixation of the object.

Photo and video materials, thermal imaging obtained during the energy audit in the first place can be used in the presentation and analysis of the state of the object of energy audit. Often it is these materials that can quite clearly and informatively characterize the existing state of the object. The advantages of this approach include:

– documentation of actual state fixation;
– easy production of materials;
– a short time is required to obtain materials.

Photo fixation can be:

– orientation;
– overview;
– Nodal;
– detailed.

Examples of survey results obtained using photofixation and thermal imager are presented in Fig. 4.2

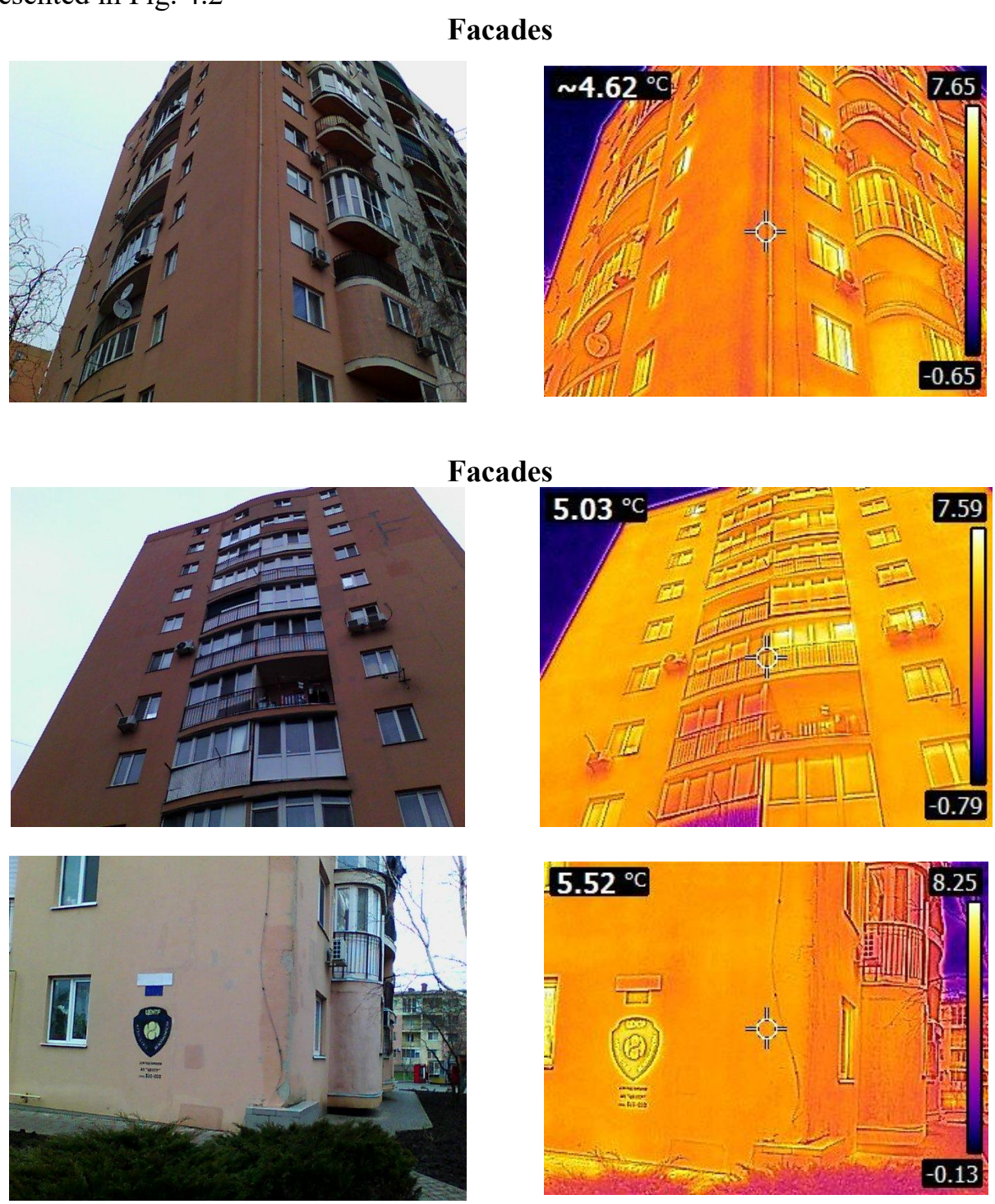
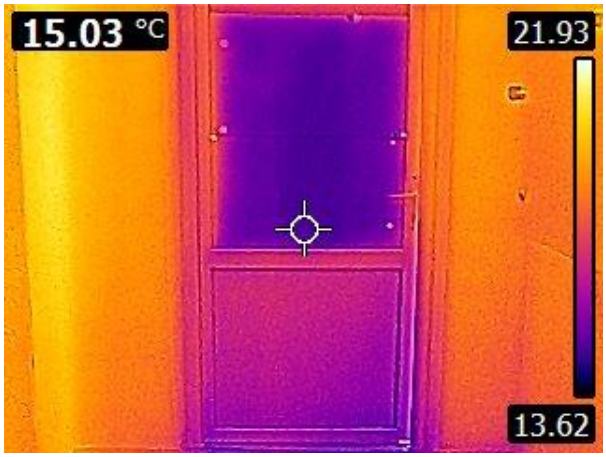


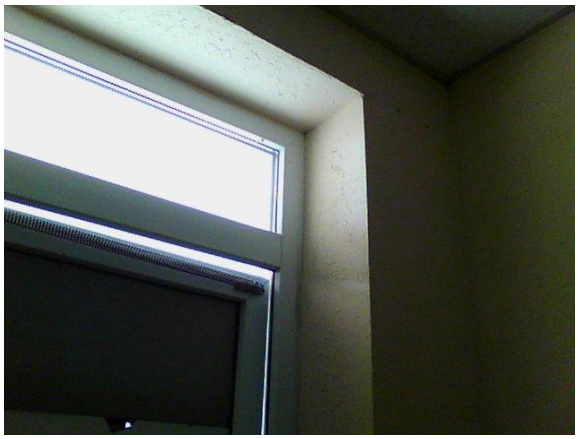
Fig. 4.2 Examples of results of inspection of buildings by thermal imager (beginning)

Doors





Doors



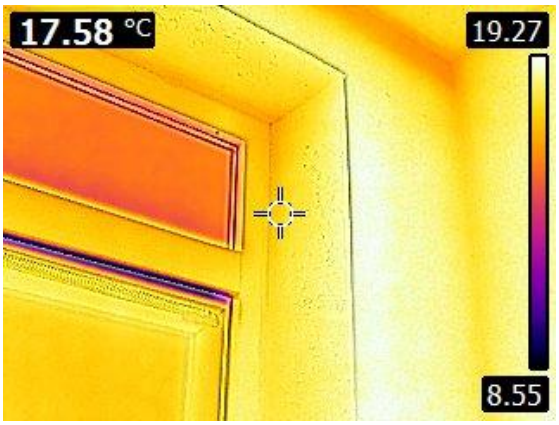
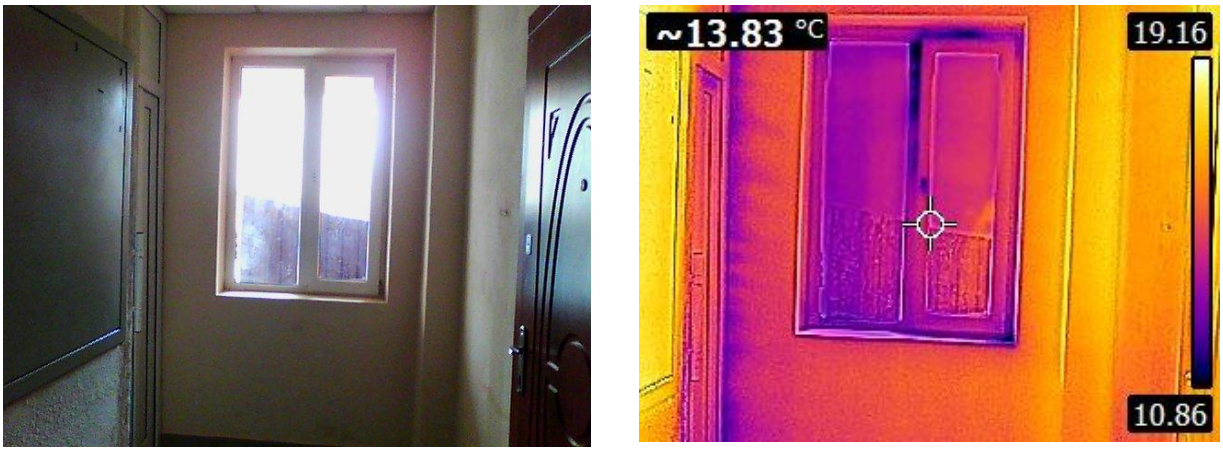




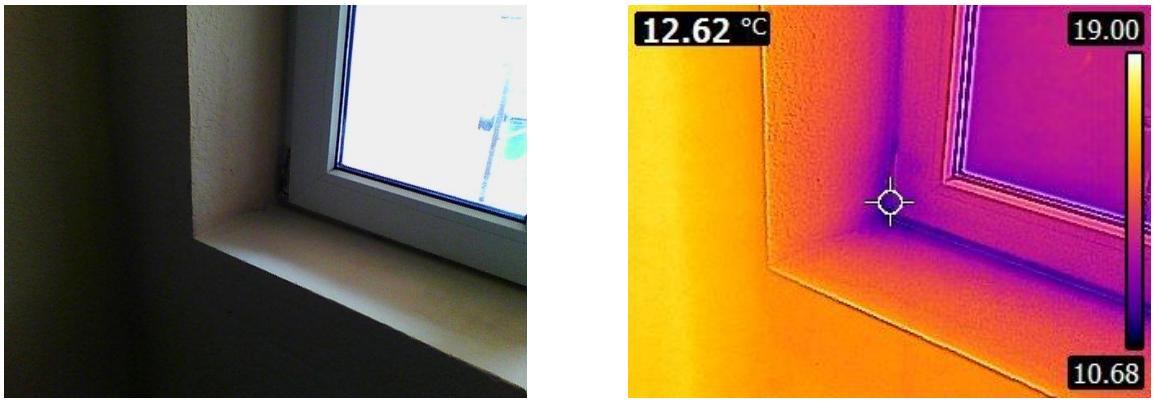


Fig. 4.2 Examples of results of inspection of buildings by thermal imager (continued)

External windows



External windows



Balconies and loggias



Fig. 4.2 Examples of results of inspection of buildings by thermal imager (continued)

Base and scaffold

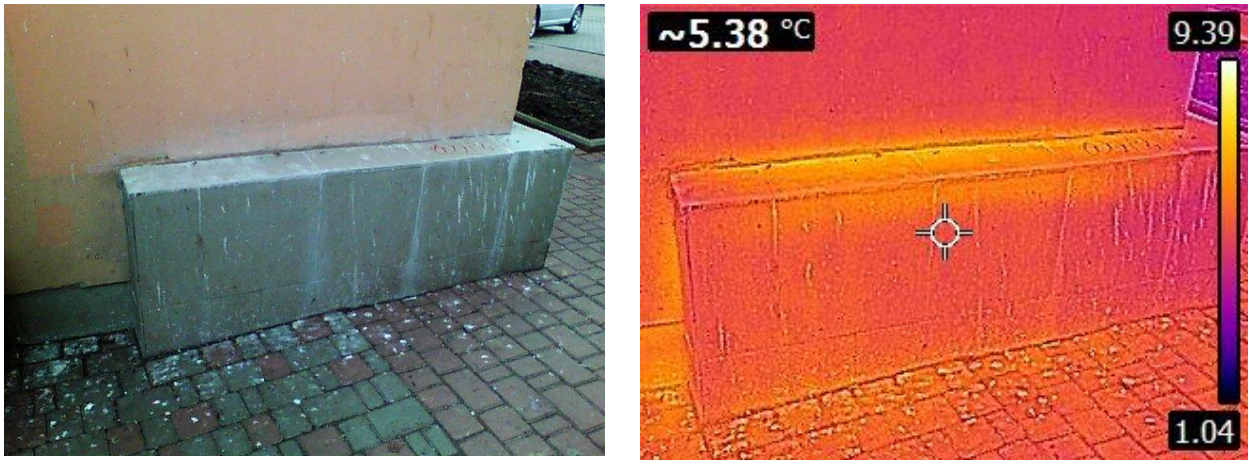


Fig. 4.2 Examples of results of inspection of buildings by thermal imager (continued)

4.5. Calculation of heat consumption through windows and doors

The method for calculating heat consumption is defined in ISO 10077-1: 2017 "Thermotechnical properties of windows, doors and blinds. Calculation of heat transmittance. Part 1: General Provisions (ISO 10077-1: 2017).

Approximate heat transfer of windows:

– Windows with one glass panel:

$U_ф$=5,7 Вт/м^{2}К;

– Old windows with double glazing in the frame:

U_w=2,8 Вт/м^{2}К;

– Old windows with double glazing in separate frames:

U_w=2,4 Вт/м^{2}К;

– New windows with double glazing in a plastic frame:

U_w=1,3-1,8 Вт/м^{2}К;

– Three-chamber new window in a plastic frame:

U_w=0,7-1,1 Вт/м^{2}К;

– Manufacturers usually indicate U_w windows.

Types of typical existing old windows:

– windows with one glass panel;

– two window glasses in one frame;

– two window glasses in different frames.

Heat transfer through windows and doors is calculated by the formula:

$$\mathbf{U_W = \frac{\sum A_g\ U_g + \sum A_f\ U_f\ + \sum l_g \Psi g}{\sum A_g + \sum A_g}}$$

- When determining the heat transfer coefficient of the window (UW - window), the following parts are taken into account:
- Glazing (U_g - glazing)
- Rama (U_f - rama)
- Window sealing gasket (thermal bridges)

4.6. Example of building description

Apartment building.

The 10-storey building has a basement and technical floor, a floor height of 3 meters, the total area of the building is 4910 m2, the total volume is 14730 m3, the heating area is 3803 m2, the heating volume is 11410 m3, the basement is unheated. It was put into operation in 2000.

Type of construction: monolithic frame, wall filling - aerated concrete, 400 mm thick. It has internal and external decoration, which is partially broken.

Typical examples of violation of walls and finishing revealed during the examination are given in Fig. 4.3.





Fig. 4.3 Examples of breaking walls and finishing



Fig. 4.3 Examples of breaking walls and finishing (continued)

Examples of patchwork insulation of walls detected during the survey are given in Fig. 4.4.



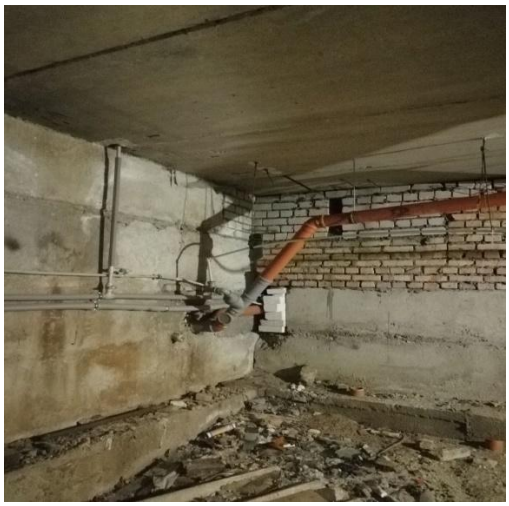
Fig. 4.4 Examples of patched wall insulation

Examples of photographic recording of the condition of basements of surveyed buildings are shown in Fig. 4.5.

Condition of basement slab



Non-insulated floor (heat loss through the ground)



Basement windows or ventilation blowouts



Heated or unheated basement



Fig. 4.5 Examples of photographic recording of the condition of basements of surveyed buildings

4.7. Example of calculating heat losses through enclosing structures

The calculation method is defined in EN ISO 13370 "Thermal characteristics of buildings. Heat loss through the ground. Methodology of calculation. "

Not insulated floor. If dt < B ":

$$U = \frac{2\lambda}{\pi B + dt} \ln\left(\frac{\pi B`}{dt} + 1\right)$$

Where λ – earth thermal conductivity, W/mK

Heat loss due to:

- Floor on the ground
- Ventilated floor
- Heated basement
- Unheated basement

Insulated floor. If dt ≥B'

$$U = \frac{\lambda}{0.457B` + d_t}$$

Where λ - earth thermal conductivity, W/m· K

Ventilated floor

$$\frac{1}{U} = \frac{1}{Uf} + \frac{1}{Ug + Ux}$$

Where Uf – heat loss through the floor, Ug – heat loss through the ground, Ux – heat loss through walls and ventilation

Unheated basement

$$\frac{1}{U} = \frac{1}{Uf} + \frac{A}{(AUbf + (zPUbw) + (hPUw) + (0.33nV)}$$

Where Uf - heat loss through the floor, Uw - heat loss through the walls below ground level, Ubw - heat loss through basement walls above ground level, Ubf - heat loss through the basement floor.

An example of the erected heat transfer resistance of the building envelope is given in Table 4.4.

Table 4.4

Heat transfer resistance of building enclosing structures

№	Name of enclosing structures	Thermal resistance of enclosures R, м^2·К/Вт	
		Actual value	Normative values according to DBN B.2.6-31:2021
1	Exterior walls	3,8	3,5
2	Windows	0,7	0,7
3	Doors	0,6	0,6
4	Covering heated attics (technical floors), attics, attic floors of unheated attics	3,7	5,5
5	Unheated basement	3,5	-

4.8. Example of description of engineering systems

The heat supply source is a roof boiler house where two boilers with a capacity of 200 kW each are installed. Two-pipe heating systems are closed, with pump circulation, with horizontal dilution of pipelines, with distribution combs in common corridors.

Shutoff valves are installed in front of each comb.

Allotments for apartments are equipped with metering units. Pipelines are made of plastic pipes with a gasket in the floor.

The main risers pass in isolation through common corridors. The heating devices are steel radiators in the amount of 208 pcs.

Distribution pipelines of the heating system are laid along the perimeter of the room. In the room, the specified air temperature is automatically maintained by adjusting the coolant flow in the heating device by automatic thermostats.

Heating system equipment is shown in Fig. 4.6, 4.7.



Fig. 4.6. Heating boiler



Fig. 4.7. Heat point

Ventilation of premises is due to natural convection and air permeability of enclosing structures (due to leakiness of door structures). Air is removed through ventilation ducts placed in bathrooms, baths and kitchens.

Exits of ventilation shafts are located on the roof of the building (Fig. 4.8).



Fig. 4.8. Outputs of ventilation shafts

Accounting for electricity consumption for the needs of lighting common areas is carried out by electric energy metering units. Common areas are illuminated by incandescent lamps. Adjustment of lighting in apartments is carried out in manual mode.

An example of the characteristics of automation of engineering systems is given in Table 4.5.

Table 4.5.

Characteristics of automation of engineering systems

Characteristics	Feature Detail Options	Energy efficiency class
Heating systems		
Regulation of heat energy supply to the room	No automatic adjustment	D
Adjustment of distribution by coolant temperature in supply or return pipeline	No automatic adjustment	D
Adjustment of circulation, mixing and circulation mixing pumps (at different system levels)	No automatic adjustment	D

Characteristics	Feature Detail Options	Energy efficiency class
Regulation of the frequency of reduction of energy consumption by the system and/or distribution of the coolant	No automatic adjustment	D
Relationship between regulation of energy consumption and/or distribution of coolant in the heating system	No automatic adjustment	D
Ventilation and air conditioning systems		
Indoor air flow control	No automatic adjustment	D
Lighting systems		
Regulation in the presence of people in the room	Manual on/off	C
Outdoor lighting adjustment	Manual	C and below

4.9. Analysis of actual energy consumption

It is important and responsible to determine and analyze the actual energy consumption. The most acceptable period that most objectively characterizes energy consumption is a year. In turn, annual energy consumption is formed by analyzing monthly consumption. It is necessary to analyze energy consumption three years before the audit.

An example of the analysis is shown below.

Thermal energy. There is no information on the actual consumption of thermal energy in the building being analyzed for the last three years. Therefore, correct information about its actual consumption is available only for 2023 - 2024.

For 2023-2024, the building consumed 324 Gcal of thermal energy.

The actual consumption of thermal energy in 2022, reduced to the design conditions, is determined by the formula:

$$Q_{year}^{p.y} = [324/(19+0,6)/155]\cdot(21-0,3)\cdot 180 = 398 \text{ Gcal /year}$$

Where: – average design temperature of the heating period, $t_{ср}$ = +0,3°C;

– actual average heating temperature in 2023,

$t_{ср}^{ф}$ = -0,6 °C;

– average actual internal temperature in the building premises,

$t_{в}^{ф}$ = 21 °C;

– design internal temperature in the building premises, $t_{в}^{р}$ = 20 °C;

– actual duration of the heating period, $n_{о}^{ф}$ = 155 days;

– estimated duration of the heating period, $n_{о}$ =n 168 days.

Розрахунок проведемо за класичною методологію.

The calculation will be carried out according to the classical methodology.

According to the requirements of the GOS V.2.5-67:2013 "Heating, ventilation and air conditioning" in determining the estimated heat consumption for heating buildings and heat loads on heating systems should take into account the heat balance between heat losses and thermal revenues. Therefore, the calculation is made in accordance with DSTU NBA.2.2-5:2007 "Guidelines for the development and compilation of energy passport of buildings."

Table 4.6 shows an example of an analysis of actual thermal energy consumption.

Table 4.6

Actual thermal energy consumption

Name of the building	Heating area, м^2	Heating volume, м^3	Actual annual consumption warm, Gcal		
			measured	reduced	calculated
Residential building	4070	12210	324	511	511

4.10. Example of heat input calculation

Types of heat input are shown in Fig. 4.9.

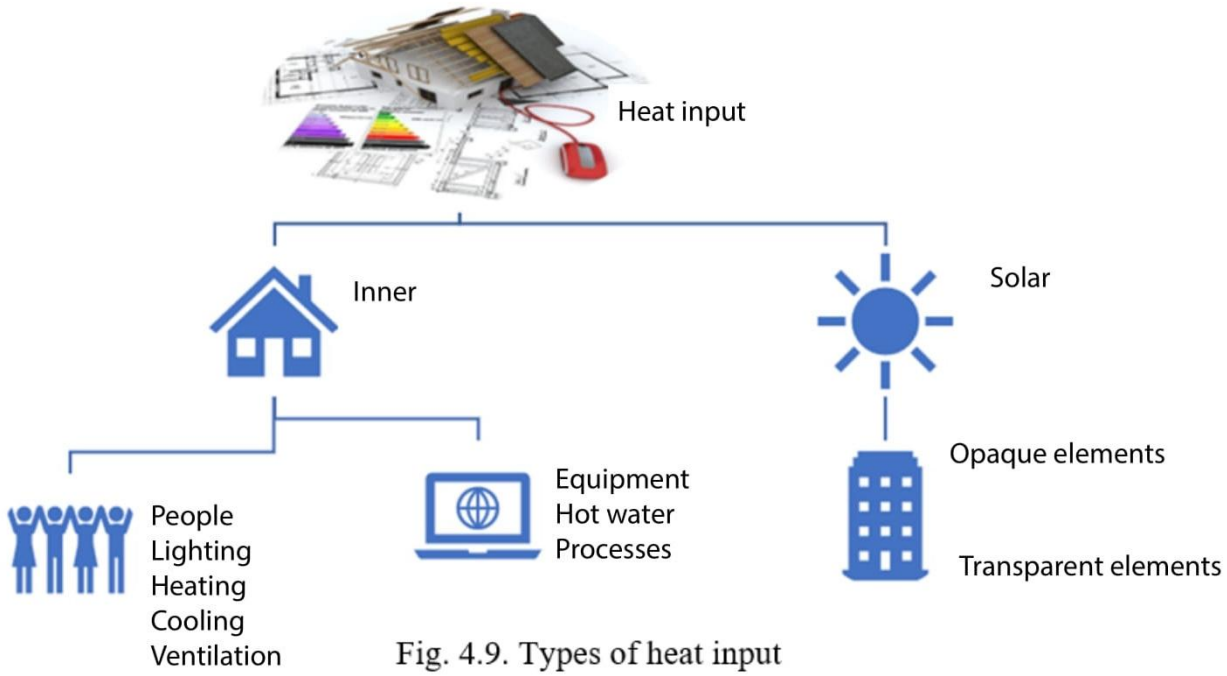


Fig. 4.9. Types of heat input

An example of internal heat input of the surveyed building is given in Table 4.7.

Table 4.7

Internal heat input

EQUIPMENT ↓ Φint=Φint.oc+Φint.A+Φint.L ↓ ↓ Inhabitants of Lighting	**Purpose of the building**	**Schedule of use Hour/week**	**Metabolic heat Fint.oc, W/m ^{2}**	**Lighting Fint.L, W/m ^{2}**	**Equipment Fint.A, W/m ^{2}**
	Single-family houses	112	1,2	2,0	2,0
	Apartment buildings, dormitories	112	1,8	2,0	2,0
	Public administrative buildings, offices	50	4,0	7,0	6,0
	Buildings of educational institutions	50	7,0	7,0	6,0
	Buildings of preschool institutions	50	7,0	7,0	3,0

	Buildings of health care institutions	168	2,7	7,0	6,0
	Hotels	168	4,0	8,0	2,0
	Restaurants	84	5,0	8,0	4,0
	Sports facilities	84	5,0	8,0	1,0
	Buildings of wholesale and retail trade establishments	84	7,0	12,0	2,0
	Buildings of cultural and entertainment institutions and leisure facilities	56	5,0	8,0	2,0
	Other types of buildings	60	3,0	7,0	2,0

4.11 Example of solar heat input

Calculation of solar heat input is shown in Fig. 4.10.

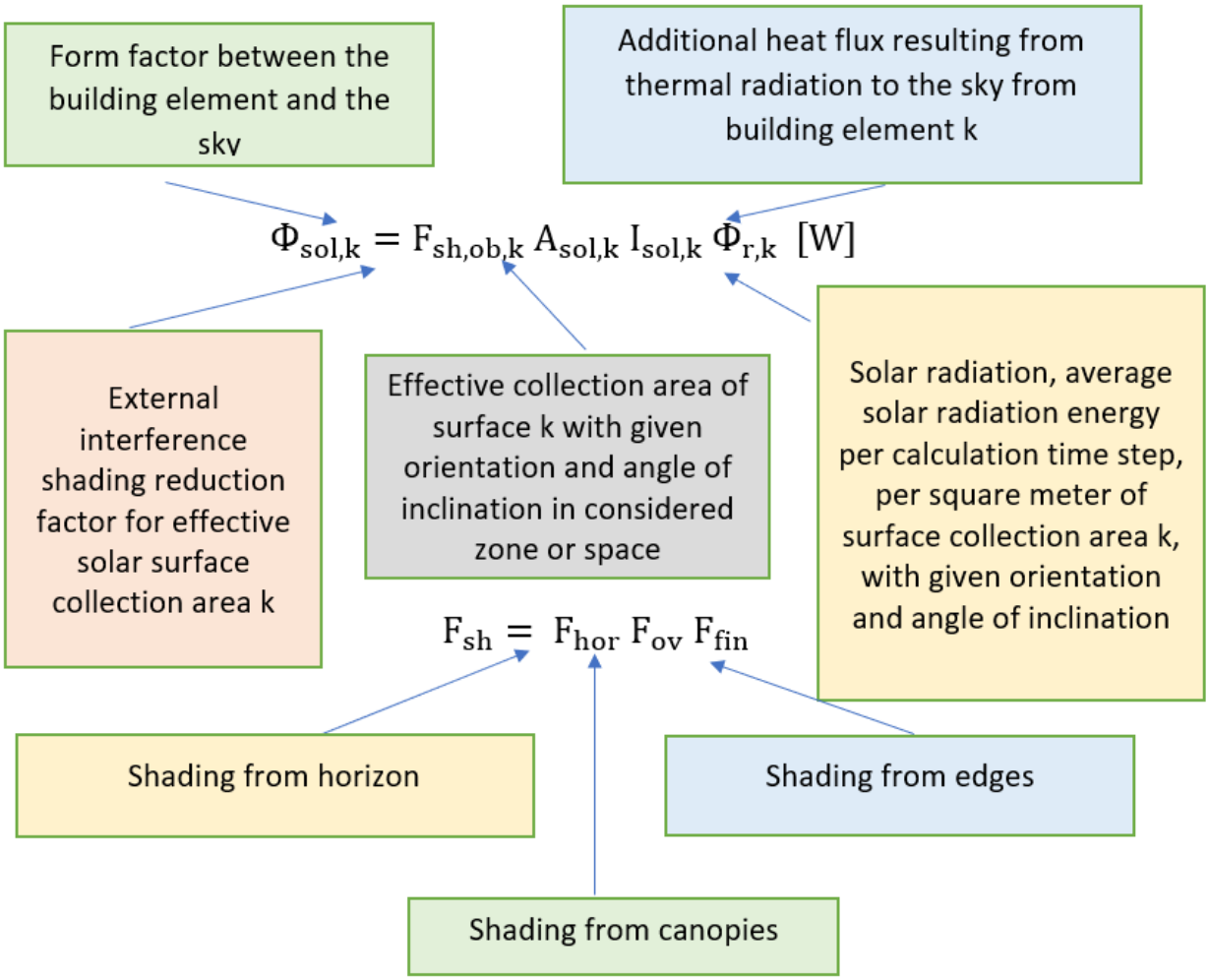


Fig. 4.10 Calculation of solar heat input

The transmittance of solar energy by windows taken into account in the calculation is given in Table 4.8.

Table 4.8

Solar energy transmittance by windows

	Types of windows	Solar energy transmittance
1	Single glazing	0,85
2	Double glazing	0,75
3	Double glazing with selective coating	0,67
4	Triple glazing	0,7
5	Triple glazing with two selective coatings	0,5

An example of calculating the coefficient of use of heat of entry is given in Fig. 4.11.

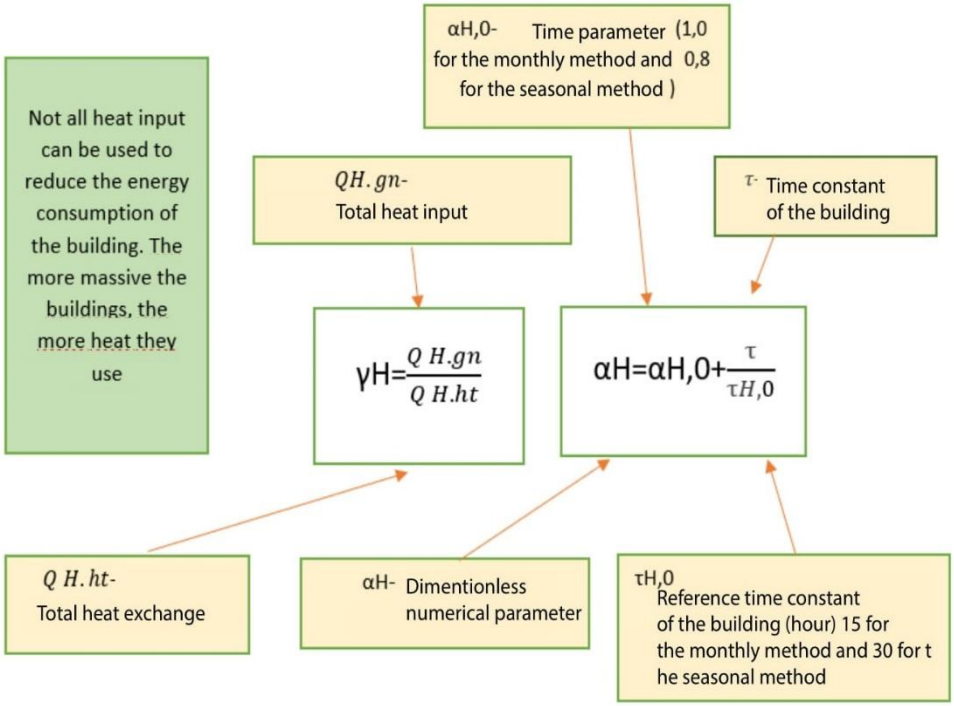


Fig. 4.11. Calculation of heat input utilization factor

Heat input utilization factor is calculated by the formula:

$$\eta H, gn = \frac{1 - \gamma_H^{\alpha H}}{1 - \gamma_H^{\alpha H+1}}$$

Example of calculation of energy consumption of premises heating is shown in Fig. 4.12.

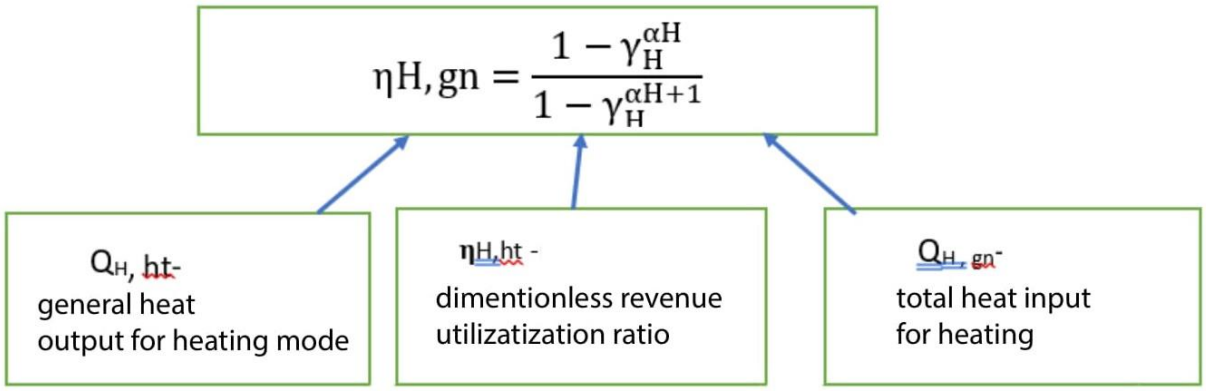


Fig. 4.12 Energy consumption of premises heating

4.11. Determination of energy consumption and use of energy

According to DSTU B A.2.2-12:2015:

- Energy consumption of the building shows how much energy the building needs to heat the premises;
- Energy consumption is based on building envelope elements, air exchange and heat supply;
- Energy consumption is less important than energy use;
- The use of energy in a building also includes energy used not only to cover the energy needs of the building and energy used to supply energy to the building;
- During the power supply of the building, part of the energy is lost in the heat supply system.

The calculation should be carried out in accordance with section 15 of DSTU B 9190:2022.

An example of determining the energy performance of the building is given below.

4.11.1. Transmission heat transfer characteristic

Estimated heat energy consumption for heating the house during the heating period Qyear, kWh, according to GOST 9190:2022.

The overall energy efficiency indicator of the ER building shall be determined by the following condition:

$$EP \leq EP_{max},$$

Where EP – design specific annual power consumption of the building, determined by the formula (3) DBN B.2.6-31:2021;

EP_{max} – maximum permissible value of specific annual energy consumption of the building, kWh/m^2.

$$EP = (Q_{H,\,nd} + Q_{C,\,nd})/A_f,$$

Where $Q_{H,\,nd}$, $Q_{C,\,nd}$, $Q_{DHW,\,nd}$ - annual energy consumption of the building for heating, cooling and hot water supply, respectively, kWh, is determined according to GOST 9190:2022

A_f – conditioned (heated) area, m^2.

Annual power consumption for heating (cooling) is determined by the formula (65) GOST 9190:2022:

$$Q_{H,C\ nd,an}=\sum Q_{H,\,nd,I}/1000,\ \text{kWh},$$

Where $Q_{H,C\ nd,I}$ – energy consumption for heating (cooling) of the 1st month, kWh, which is determined according to the formula (3):

$$Q_{H,C\ nd} = Q_{H,C\ nd,\,cont}= Q_{H,C\ ht} - \eta_{H,C\ gn} \cdot Q_{H,C\ gn}\ ,$$

Where $Q_{H,\ C\ ht}$ – total heat transfer in heating (cooling) mode, kWh, which is determined according to formula (7):

$$Q_{H,C\ ht} = Q_{H,C\ tr} + Q_{H,C\ ve}\ ,$$

Where $Q_{H,C\ tr}$ – total heat transfer by transmission, kWh;

$Q_{H,\ C\ ve}$ – total heat transfer by ventilation, kWh;

$Q_{H,\ C\ gn}$ – smart heat input in heating (cooling) mode Wh, for each month we determine by formula (8):

$$Q_{H,\ C\ gn} = Q_{int} + Q_{sol}\ ,\ \text{Wh}$$

Q_{int} – sum of internal heat input W/h;

Q_{sol} – sum of solar heat input W/h;

$\eta_{H,C,gn}$ – dimensionless coefficient of utilization of receipts, which is determined depending on the ratio of receipts and heat losses $\gamma_{н,с}$ and the numerical parameter $a_{н,с,}$ which depends on the inertia of the building.

The coefficient of use of receipts for heating is found by the formula:

if $\gamma_H > 0$ та $\gamma_H \neq 1$: $\eta_{H,gn} = \dfrac{1-\gamma_H^{a_H}}{1-\gamma_H^{a_H+1}}$,

if $\gamma_H = 1$: $\eta_{H,gn} = \dfrac{a_H}{a_H+1}$,

if $\gamma_H < 0$ та $Q_{H,gn} > 0$: $\eta_{H,gn} = 1/\gamma_H$,

if $\gamma_H \leq 0$ та $Q_{H,gn} \leq 0$: $\eta_{H,gn} = 1$

Where γ_H – dimensionless ratio of heat receipts and losses for heating mode:

$$\gamma_H = \frac{Q_{H,gn}}{Q_{H,ht}}$$

Where $Q_{H,gn}$ - total heat input for heating mode, Вт·год;

$Q_{H,ht}$ - total heat transfer for heating mode, Вт·год;

a_H - dimensionless numerical parameter depending on the building time constant τ_H.

$$a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$$

Where $a_{H,0}$ - reference dimensionless numerical parameter equal to 1.0;

τ - time constant of the building zone, h;

$\tau_{H,0}$ - reference time constant taken at 15 h.

The coefficient of use of receipts for cooling is found by the formula (51a):

if $\gamma_C > 0$, $\gamma_C \neq 1$ та $Q_{C,ht} > 0$: $\eta_{C,ls} = \frac{1-\gamma_C^{-a_C}}{1-\gamma_C^{-(a_C+1)}}$,

if $\gamma_C > 0$, $\gamma_C \neq 1$ та $Q_{C,ht} \leq 0$: $\eta_{C,ls} = 1$,

if $\gamma_C = 1$: $\eta_{C,ls} = \frac{a_C}{a_C+1}$,

if $\gamma_C < 0$: $\eta_{C,ls} = 1$,

Where γ_C – dimensionless ratio of heat inflow and loss for cooling mode:

$$\gamma_C = \frac{Q_{C,gn}}{Q_{C,ht}}$$

Where $Q_{C,gn}$ - total heat input for cooling mode, Вт·год;

$Q_{C,ht}$ - total heat transfer by transmission and ventilation for cooling mode, Вт·год;

a_C - dimensionless numerical parameter depending on the building time constant τ_H.

$$a_C = a_{C,0} + \frac{\tau}{\tau_{C,0}}$$

Where $a_{C,0}$ - reference dimensionless numerical parameter equal to 1.0;

τ - time constant of the building zone, h;

$\tau_{C,0}$ - reference time constant taken at 15 h.

The time constant of the building zone according to GOST 9190:2022 is calculated by the formula:

$$\tau = \frac{C_m}{H_{tr,adj} + H_{ye,adj} + H_{ye,extra,adj}}$$

Where C_m – building internal heat capacity, W h/K;

$H_{tr, adj}$ – representative value of the total transmission heat transfer coefficient, W/K, calculated according to GOST 9190:2022:

$$H_{tr, adj} = H_D + H_g + H_u + H_A$$

Where H_D – direct generalized coefficient of heat transfer by the transmission to the external environment, W/K;

H_g – stationary generalized coefficient of heat transfer by the transmission to the soil, W/K is calculated in accordance with the methodology for calculating heat transfer to the soil (paragraph B.1.1. "Soil floor" Appendix B GOST 9190:2022).

H_u – generalized coefficient of heat transfer by the transmission through substandard volumes, in our case there are no;

H_A – generalized coefficient of heat transfer by the transmission to the combined buildings, in our case there are no.

In our case, H_x, reflecting H_D, H_g is calculated according to the formula GOST 9190:2022:

$$H_x = b_{tr,x} \sum_i A_i \, U_i$$

Where A_i – area of the building shell element, m^2;

U_i - reduced heat transfer coefficient of the building shell element i, W/(m^2 K), which is $U_i = 1/R_{\sum пр i}$;

For existing buildings, in the absence of information or its insufficient amount regarding heat-conducting inclusions in the structure, it is necessary to add a corrective correction to the heat transfer coefficient of the ΔU to take into account the effect of heat-conducting inclusions, according to Table 4 of GOST 9190:2022.

$R_{\Sigma np}$ – reduced heat transfer resistance of the building shell element, m^2 К/Вт;

$b_{tr,x}$ – correction factor, according to Table 3 of GOST 9190:2022

An example of the calculated heat transfer characteristics of the transmission is given in Table 4.9

Table 4.9

Transmission heat transfer characteristics

month	**год., t**	**θ_C**	**$\theta_{int,set,H}$**	**$H_{tr,adj}$**	**Q_{tr}**
January	744	-1,3	19	2360,072	35644,64051
February	672	-0,6	19	2360,072	31084,98126
March	744	2,9	19	2360,072	28269,8873
April	720	9,2	19	2360,072	16652,66853
May	744	15,3	19	2360,072	6496,806397
June	720	19,6	19	2360,072	-1019,55113
July	744	22,0	19	2360,072	-5267,68086
August	744	21,6	19	2360,072	-4565,32341
September	720	17,0	19	2360,072	3398,503782
October	744	11,3	19	2360,072	13520,38088
November	720	5,8	19	2360,072	22430,12496
December	744	1,1	19	2360,072	31430,49581
Total					178075,9

Then, the representative value of the total transmission heat transfer coefficient for the heating and cooling period, respectively, is:

$$H_{tr,\ adj} = 2360{,}072 \text{ Вт/К}$$

The internal heat capacity of the building according to GOST 9190:2022 is calculated by the formula:

$$C_m = C \times A_f, \text{ Вт год/ К},$$

Where C – internal heat capacity of the building per unit area, we accept according to Table 15 of GOST 9190:2022;

A_f – air-conditioned building area, m^2.

We calculate according to the section 12.4

$$C_m = 35 \times 4070 = 142450 \text{ Вт ·год/ К}$$

4.11.2. Characteristics of internal and solar heat input

The sum of internal heat inputs according to GOST 9190:2022 is determined by the formula:

$$Q_{int} = (\sum \Phi_{int,\, mn,\, k} \times A_f)\, t, \quad \text{Вт/ год},$$

Where $\Phi_{int,\, mn,\, k}$ – time-averaged heat flux from the k-th internal source, W/m^2;

A_f – conditioned heating area, m^2;

t – duration of the period of use, expressed in hours per month.

The following heat input is taken into account:

- internal heat flow from people, $\Phi_{int,Oc}$;
- internal heat flow from lighting, $\Phi_{int,L}$.
- internal heat flow from the equipment,$\Phi_{int,A}$;
- usage schedule - 112 h/week;
- metabolic heat, $\Phi_{int,Oc}$ – 1,8 $Вт/м^2$;
- lighting, $\Phi_{int,L}$ - 2 $Вт/м^2$;
- equipment $\Phi_{int,A}$ - 2 кВт.

The heat input from the sun for each month is calculated in accordance with GOST 9190:2022.

Information on climatic data and characteristics of internal and solar heat revenues for each region of Ukraine is given in GOST 9190:2022.

4.12. Calculation of heat consumption

An example of calculating the thermal consumption of a building is given below.

The calculation was carried out in accordance with the "Methodology for the distribution between consumers of the volumes of utilities consumed in the building"

approved by order of 22.11.2018 No. 315 of the "Ministry of Regional Development of Ukraine".

Output data:

$T_п$ = 80ºC design coolant temperature in the supply pipeline

T_o = 60ºC design coolant temperature in return pipeline

$t_{под}$ ºC, c average coolant temperature in the supply pipeline during the heating period

$$t_{под} = t_{вн} + 0{,}5 \cdot (t_п - t_0) \cdot q + 0{,}5 \cdot (t_п + t_0 - 2t_{вн}) \cdot q^{[1/(1+3)]}$$

Relative heat flow

$$q = (t_{вн} - t_{ср.о}) \div (t_{вн} - t_{р.о}) = (22 - 2) \div (22 + 18)$$

$t_{под}$ = 22+0,5·(80-60)·0,5+0,5·(80+60-2·22)·0,5(1/(1+0,3)) = 55,16 ºC

$t_{зв}$ ºC, average temperature of return water during the heating period.

$t_{зв} = t_{вн}$ -0,5·($t_п$ - t_o) ·q+0,5·($t_п$ +t_o -2$t_{вн}$) · q(1/1+0,3))

$t_{зв}$ = 22-0,5·(80-60)·0,5+0,5·(80+60-2·22)·0,5(1/1+0,3)) = 45,16ºC

Thermal costs are:

$Q_{рік}$ = $Q_{год}$ · 24 · n Гкал/рік

n – number of days of pipelines operation (for heating pipelines n = 168 days)

$Q_{год}$ = ∑β·q·L, Gcal/year

β – coefficient taking into account additional heat consumption by the reinforcement of supports and compensators is 1.25

q – heat consumption rate for insulation pipelines, kcal/m· g

The rate of heat consumption is determined by the formula:

$$q = \frac{t - t_0}{R_t} \frac{ккал}{м \cdot г}$$

t – average annual coolant temperature in the pipeline, ºC

t_o – indoor air temperature, ºC (for furnace + 18 ºC, for corridors + 16):

R_t – total thermal resistance,м·г·ºC/ккал

Thermal consumption boilers indirect heating installed in the furnace, model EV12S800 99 F43 TP determine according to the passport data.

The heat consumption of one boiler is 3.7 kVt/24rik, or 0.00318143 Gcal/day, respectively for two boilers:

$Q_{рік}$ бойл = 2·0,00318143·365 = 1,255374 Гкал/рік

An example of a summary calculation is given in Table 4.10.

Table 4.10

Heating flows of furnace No. 1 Heating flows of furnace No. 2

Топочна № 1	Котловий контур	Котловий контур	Розп. гребенка	Опалюв. контур
t под˚С	65.00	65.00	65.00	55.16
t обр˚С	50.00	50.00	50.00	45.16
β	1.25	1.25	1.25	1.25
t °С	18	18	18	18
d зов	57	76	219	76
d вн	50	69	207	69
λгр	50	50	50	50
Rmp	0,0004	0,0003	0.0002	0,0003
Rв	0,0055	0.0040	0.0013	0.0040
Товщ. ізоляц. матер	20	20	20	20
λиз	0.045	0.045	0.045	0.045
Rиз	1.8813	1.4963	0.5936	1.4963
Rвн	0.3648	0.3050	0.1366	0.3050
R t	2.2520	1.8056	0.7317	1.8056
q под	20.870	26.030	64.230	20.582
q обр	14.210	17.772	43.731	15.043
L под	2.70	2.50	2.00	5.80
L обр	2.70	6.80	2.00	5.80
Q под	70.437	81.343	160.575	149.217
Q обр	47.957	150.640	109.328	109.065
Q год	118.394	231.982	269.903	258.283
Q рік Гкал/рік	1.037	2.032	2.363	0.979
Q бойл Гкал/рік	1.255374			

Топочна № 2	Котловий контур	Котловий контур	Розп. гребенка	Опалюв. контур
t под˚С	65.00	65.00	65.00	55.16
t обр˚С	50.00	50.00	50.00	45.16
β	1.25	1.25	1.25	1.25
t °С	18	18	18	18
d зов	57	76	219	76
d вн	50	69	207	69
λгр	50	50	50	50
Rmp	0.0004	0.0003	0.0002	0.0003
Rв	0.0055	0.0040	0.0013	0.0040
Товщ. ізоляц. матер	20	20	20	20
λиз	0.045	0.045	0.045	0.045
Rиз	1.8813	1.4963	0.5936	1.4963
Rвн	0.3648	0.3050	0.1366	0.3050
R t	2.2520	1.8056	0.7317	1.8056
q под	20.870	26.030	64.230	20.582
q обр	14.210	17.772	43.731	15.043
L под	2.70	2.50	1.60	6.80
L обр	2.70	6.80	1.60	6.80
Q под	70.437	81.343	128.460	174.945
Q обр	47.957	150.640	87.462	127.870
Q год	118.394	231.982	215.922	302.814
Q рік Гкал/рік	1.037	2.032	1.891	1.148
Q бойл Гкал/рік	1.255374			

Топочна № 1	Котловий контур	Котловий контур	Розп. гребенка	Опалюв. контур
Q топ Гкал/рік	15.908			

Топочна № 2	Котловий контур	Котловий контур	Розп. гребенка	Опалюв. контур
Q топ Гкал/рік	15.477			

4.13. Total heating power consumption

The total heat loss of the subsystem of production/generation and accumulation of heat is determined for each month by the formula:

$$Q_{H,gen,ls.i} = Q_{H,gen,out.i} \cdot (1 - \eta_{H,gen})/\eta_{H,gen}$$

where $\eta_{H,gen}$ - efficiency of the subsystem of production/generation and accumulation of heat;

$Q_{H,gen,ls.i}$ – energy of output from the heat production subsystem during the first month is equal to the energy of input to the distribution subsystem $Q_{H,dis,in,I}$, Вт·год;

Efficiency of the heat generation subsystem is taken according to the data of Table 27 of GOST $\eta_{H,gen}$= 77 % (ККД котла).

An example of calculation of energy consumption during heating is given in Table 4.11

Table 4.11

Calculation of energy consumption during heating

The Moon the Year	Parameter					
	$Q_{H,nd}$, кВт·год	$Q_{H,em,ls}$, кВт·год	$Q_{H,em,ls}=Q_{H,dis,out}$, кВт·год	$Q_{H,dis,in}=Q_{H,gen,out}$, кВт·год	$Q_{H,gen,ls}$, кВт·год	$Q_{H,use}$, кВт·год
January	56465,6	13513,38	69978,98	107446,6	32094,43	139540,99
February	46385,8	11101,07	57486,87	90223,71	26949,94	117173,655
March	36379,8	8706,432	45086,23	62318,57	18614,64	80933,208
April	12669,3	3032,023	15701,32	42221,9	12611,74	54833,6416
October	9601,1	2297,74	11898,84	36297,34	10842,06	47139,4067
November	30578,1	7317,966	37896,07	64684,88	19321,46	84006,3359
December	48942,2	11712,87	60655,07	92160,72	27528,53	119689,243
Total	***241022***	***57681,48***			***147962,8***	***643316***

4.14. Cooling power consumption

Total energy of output from production/generation and accumulation subsystems, kWh, is calculated by formula

$$Q_{C,gen,out} = Q_{C,\ dis,\ in} / \eta_{C,ac} = 68269 / 0{,}93 = 73407{,}5 \text{ кВт·год.}$$

At the same time, the efficiency of the production/generation subsystem is accepted in accordance with Table 31 of GOST 9190:2022 and is $\eta_{C,gen} = 2{,}25$:

$$Q_{C,gen,ls} = Q_{C,gen,out} \cdot (1 - \eta_{C,gen}) / \eta_{C,gen} = 73407{,}5 \cdot (1\text{-}2{,}25)/2{,}25 = -40781{,}9 \text{ кВт·год.}$$

Total power consumption during cooling is determined according to the formula:

$$Q_{C,use} = Q_{C,gen,out} + Q_{C,gen,ls} = 73407{,}5 - 40781{,}9 = 32625{,}6 \text{ кВт·год.}$$

Specific energy consumption of the building during cooling is:

$$Q_{C,use} / A_f = 32625{,}6 / 4070 = 8{,}0 \text{ кВт·год/м}^2.$$

4.15. Lighting power consumption

Annual power consumption during lighting W, kWh is determined according to GOST 9190:2022:

$$W = W_L + W_P$$

Where W_L– енергія, необхідна для виконання функції штучного освітлення в будівлі кВт· год;

W_P – parasitic energy required to charge the batteries of emergency lighting fixtures and energy to control/adjust the lighting in the building, kWh.

The value W_L is determined by the formula:

$$W_L = (P_N \cdot F_c) \cdot [(t_D \cdot F_O \cdot F_D) + (t_N \cdot F_O)] \cdot A_f / 1000,$$

Where P_N – specific power of installed artificial lighting in the building, W/m^2;

F_c - constant brightness coefficient;

F_O – lighting utilization rate;

F_D - natural light coefficient;

t_D – time of natural light use during the year, h;

t_N - time of using artificial lighting during the year, h;

A_f – air-conditioned building area, m^2.

In our case: $F_c = F_O = F_D = 1$; $t_D = 2250$ год; $t_N = 250$ год.

According to the actual data $P_N = 5$ Вт/м^2.

$$W_L = 50875 \text{ кВт·год.}$$

Значення W_P визначаємо за формулою:

The value W_P is determined by the formula:

$$W_P = (P_{em} + P_{pc}) \cdot A_f ,$$

Where P_{em} – total installed specific power of batteries of emergency lighting luminaires, according to Table 36 of GOST 9190:2022 is 1 kWh/m^2;

P_{pc} – the total installed specific power of all control systems of zone lighting devices at the time when lamps are not used, according to Table 36 of GOST 9190:2022 is 5 kWh/m^2.

$$W_P = (1 + 5) \cdot 4070 = 24420 \text{ кВт год.}$$

$$W = 75295 \text{ кВт год.}$$

4.16. Determination of building energy efficiency

Calculation of energy losses is calculated by the formula:

$$[(EP - EP_{max}) / EP_{max}] \times 100\% = [(76 - 70) / 70] \times 100 = 75 \%$$

Thus, energy loss is 75%.

We determine the value of the general display of specific energy consumption during heating, cooling (EP), kWh/m3, for the energy efficiency class of residential buildings from 10 to 16 floors (by energy consumption according to the Order of 27.10.2020 № 260):

$$EP_p = 70 \text{ кВт·год/м}^2.$$

That is, in accordance with the annex to the Minimum Energy Efficiency Requirements for Buildings of the Order of 27.10.2020. No. 260 the building belongs to the energy efficiency class **«G»** EP = 166,1 кВт·год/м^2 ≥ EP_{max} = 105 kWh/m^2.

Classification of buildings by energy efficiency is carried out in accordance with the GOS V.2.6-31:2021 "Thermal insulation and energy efficiency of buildings" (Table 4.12).

Table 4.12

Classification of buildings by energy efficiency (DBN V.2.6-31:2021)

Energy efficiency classes at home by specific energy consumption	Difference of design or actual value of specific power consumption, ER and maximum permissible value, EP_{max} % $[(EP-EP_{max})/EP_{max}]*100\%$
A	Minus 50 and below
B	From minus 49 to minus 10
C	From minus 9 to 0
D	From 1 to 25
E	From 26 to 50
F	From 51 to 75
G	76 and above

Conclusion: ***The building belongs to class G***

4.17. Calculation of primary energy and greenhouse gas emissions

1. The primary energy (E_p), кВт·год, is calculated for each energy carrier and is calculated by the formula

$$E_p = \sum (E_{del,i} \times f_{P,del,i}),$$

Where $E_{del,i}$ - supplied energy, кВт·год;

$f_{P,del,i}$ - primary energy factor for the i-th delivered energy carrier.

Supplied energy ($E_{del,i}$) is calculated by the formula

$$E_{del,i} = Q_{H,use} + Q_{C,use} + Q_{DHW,use} + Q_{V,use} + Q_{W,use},$$

2. The specific indicator of primary energy consumption (e_p), кВт·год/м^2, is calculated by the formula

$$e_p = E_p / A_f,$$

Where A_f - conditioned (heated) building area, m^2.

3. The mass of greenhouse gas emissions (mso2), kg, is calculated from the supplied and exported energy for each energy carrier using the formula

$$mco_2 = \sum (E_{del,i} \times K_{del,i}) / 1000,$$

Where $E_{del,i}$ - supplied energy and-th energy carrier, кВт·год;

$K_{del,i}$ - emission factor CO_2 for the supplied and-th energy carrier, г/кВт·год.

The specific indicator of greenhouse gas emissions (mco_2), kg/m^2, is calculated using the formula

$$mco_{2\,num} = \sum (E_{del,i} \times K_{del,i}) / A_f$$

4. Greenhouse gas emission factors (CO_2) include all greenhouse gas (CO_2) emissions associated with the primary energy used in a building.
5. Primary energy factors ($f_{P,nren}$) and greenhouse gas emission factors (CO_2) (K) are г/кВт·год taken according to the indicators of primary energy factors and greenhouse gas emission factors (CO_2).

An example of calculations of primary energy and greenhouse gas emissions is given in Table 4.13.

Table 4.13

Calculation of primary energy and greenhouse gas emissions

	Energy carrier	E_{deli}	$f_{P,del,i}$	E_p
$Q_{H,use}$	1	643316,48	1,1	707648,128
$Q_{C,use}$	1	32625,6	2,3	75038,88
$Q_{DHW,use}$	1	83061	1,1	91367,1
$Q_{V,use}$	1	12210	2,3	28083
$Q_{W,use}$	1	75295	2,3	173178,5
	E_{deli}	**846508,08**	**E_p**	**1075315,61**

4.18. Conclusions on the results of the survey

An example of conclusions on the results of the building inspection is given below

Conclusions on the inspection of the building.

1. Thermal insulation of the building requires repair and decoration of facades. There is a separate destruction of insulation. Insufficient level of thermal insulation of the building roof. In this regard, heat loss due to enclosing structures of the building is 15%.

2. The heating system has significant disadvantages, namely: low efficiency of boilers and heating systems in general (efficiency 77%). The schematic diagram of the piping of four gas boilers in two furnaces does not correspond to the design solution, which leads to gas overexpenditure. There is no water treatment system.
3. During the operation of the building, repair of pipelines of the heating and thermal insulation system was not carried out. The building's hydraulic heating system is unbalanced. Heating devices and pipelines of the heating system are contaminated. On the pipeline system there is a narrowing of the diameter of the conditional passage.
4. There is no possibility to adjust the heat transfer of heating devices depending on the outside air temperature.

The following measures are proposed to modernize the heating system:

- return to the design solution with parallel operation of all four boilers;
- replace distribution pipelines in the basement and thermal insulation;
- replace existing boilers with modern condensing ones;
- balance the heating system and increase the capacity of the pumps;
- replace heating appliances;
- perform chemical washing of the heating system;
- install thermostats on heating devices.

According to the results of the survey and calculations, an energy certificate of the building is drawn up.

An example of the first page of the building energy certificate is given in attachment.

REFERENCES

1. Bozhenko M. Systemy opalennia, ventylatsii i kondytsiuvannia povitria budivel: navch. posib. – Kyiv: KPI im. Ihoria Sikorskoho, 2019. – 380 s.
2. DBN V.2.5-39:2008. Inzhenerne obladnannia budynkiv i sporud. Zovnishni merezhi ta sporudy. – Na zaminu SNiP 2.04.07-86; chynnyi vid 2009-07-01. – Vyd. ofits. – Kyiv: Minrehionbud Ukraine, 2009. – 56 s.
3. DBN V.2.5-39:2008. Inzhenerne obladnannia budynkiv i sporud. Zovnishni merezhi ta sporudy. Teplovi merezhi. Zi zminoiu № 1. – Na zaminu SNiP 2.04.07-86; chynnyi vid 2018-07-01. – Vyd. ofits. – Kyiv: Minrehionbud Ukraine, 2018. – 5 s.
4. DBN A.3.1-5:2016. Orhanizatsiia budivelnoho vyrobnytstva. – Na zaminu DBN A.3.1-5:2009; chynnyi vid 2017-01-01. – Vyd. ofits. – Kyiv: Minrehionbud, 2016. – 51 s.
5. DBN V.2.5-67:2013. Opalennia, ventylatsiia ta kondytsionuvannia. – Na zaminu SNiP 2.04.05-91; chynnyi vid 2014-01-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2013. – 147 s.
6. DBN V.2.6-31:2021. Teplova izoliatsiia ta enerhoefektyvnist budivel. – Na zaminu DBN V.2.6-31:2016; chynnyi vid 2022-09-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2022. – 156 s.
7. DBN V.2.5-41:2009. Inzhenerne obladnannia budynkiv i sporud. Zovnishni merezhi ta sporudy. Hazoprovody z polietylenovykh trub. Chastyna I. Proektuvannia. Chastyna II. Budivnytstvo. – Na zaminu DBN V.2.5-20-2001; chynnyi vid 2010-08-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2010. – 149 s.
8. DBN V.2.5-20:2018. Hazopostachannia. Z urakhuvanniam Zminy № 1. – Na zaminu DBN V.2.5-20-2001; chynnyi vid 2020-06-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2019. – 115 s.
9. DBN V.2.5-39:2008. Inzhenerne obladnannia budynkiv i sporud. Zovnishni merezhi ta sporudy. Teplovi merezhi. Zi Zminoiu № 1. – Na zaminu SNiP 2.04.07-86; chynnyi vid 2018-07-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2018. – 56 s.
10. DBN V.2.5-39:2008. Teplovi merezhi. Chynnyi vid 2009-07-01. – Vyd. ofits. – Kyiv: Minrehionbud Ukraine, 2018. – 72 s.

11. DSTU B V.2.2-39:2016. Metody ta etapy provedennia enerhetychnoho audytu budivel. – Chynnyi vid 2017-01-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2016. – 48 s.
12. DSTU B V.2.7-182:2009. Budivelni materialy. Metody vyznachennia terminu efektyvnoi ekspluatatsii ta teploprovidnosti budivelnykh izoliatsiinykh materialiv u rozrakhunkovykh ta standartnykh umovakh. – Chynnyi vid 2010-08-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2010. – 56 s.
13. DSTU-N B V 2.2-27-2010. Budynky i sporudy. Nastanova z rozrakhunku insolatsii obiektiv tsyvilnoho pryznachennia. – Chynnyi vid 2011-01-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2010. – 56 s.
14. DSTU 9190:2022. Enerhetychna efektyvnist budivel. Metod rozrakhunku enerhospozhyvannia pry opalenni, okholodzhenni, ventylatsii, osvitlenni ta hariachomu vodopostachanni. – Na zaminu DSTU B A.2.2-12:2015; chynnyi vid 2023-03-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2022. – 156 s.
15. DSTU 9191:2022. Teploizoliatsiia budivel. Metod vyboru teploizoliatsiinoho materialu dlia uteplennia budivel. – Na zaminu DSTU B V.2.6-189:2013; chynnyi vid 2023-03-01. – Vyd. ofits. – Kyiv: DP «UkrNDNTs», 2023. – 60 s.
16. DSTU EN ISO 52003-1:2022. Enerhetychni kharakterystyky budivel. Pokaznyky, vymohy, reitynhy ta sertyfikaty. – Na zaminu DSTU B EN 15217:2013 (EN 15217:2007, IDT); chynnyi vid 2024-04-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2023. – 73 s.
17. DSTU ISO 50001:2020. Systemy enerhetychnoho menedzhmentu. Vymohy ta nastanova shchodo vykorystannia (ISO 50001:2018, IDT). – Na zaminu DSTU ISO 50001:2014; chynnyi vid 2020-09-15. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2020. – 33 s.
18. DSTU ISO 50015:2016. Systemy enerhetychnoho menedzhmentu. Vymiriuvannia ta veryfikatsiia rivnia dosiahnutoi/doziazhnoi enerhoefektyvnosti orhanizatsii. Zahalni pryntsypy ta nastanova (ISO 50015:2014, IDT). – Chynnyi vid 2016-09-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2016. – 69 s.

19. DSTU-N B V.2.5-73:2013. Nastanova z montazhu vnutrishnikh sanitano-tekhnichnykh system. – Na zaminu SNiP 3.05.01-85; chynnyi vid 2014-01-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2013. – 29 s.

20. DSTU-N B V.2.5-73:2013. Nastanova z montazhu vnutrishnikh sanitano-tekhnichnykh system (SNiP 3.05.01-85, MOD). – Na zaminu SNiP 3.05.01-85; chynnyi vid 2014-01-01. – Vyd. ofits. – Kyiv: Minrehion Ukraine, 2013. – 22 s.

21. Enerhozberezhennia v promyslovosti. Chastyna 1: Navchalnyi posibnyk / A.V. Prakhovnyk, O.M. Sukhodolia, S.P. Denysiuk, V.V. Prokopenko. – Elektronne navchalne vydannia. – NMU №E11/12-104. – Kyiv: NTUU «KPI», 2011. – 517 s.

22. Enerhozberezhennia v promyslovosti. Chastyna 2. Enerhetychne obladnannia: Navchalnyi posibnyk / A.V. Prakhovnyk, O.M. Sukhodolia, S.P. Denysiuk, V.V. Prokopenko. – Elektronne navchalne vydannia. – NMU №E12/13-024. – Kyiv: NTUU «KPI», 2012. – 230 s.

23. Prokopenko V.V. Enerhetychnyi audyt. Navch. posib. – Kyiv: Kyivskyi politekhn. in-t, 2015. – 88 s.

24. Tsentralizovane teplopostachannia [Elektronnyi resurs] / Danfoss District Energy, URL: https://assets.danfoss.com/documents/192363/AR397130606552uk-UA0101.pdf

25. Directive 2012/27/EU of the European Parliament and of the Council on energy *efficiency*. Brussels: European Union, 2012. 56 p.

26. Doty S., Turner W. C., Roosa S. A. Energy Management Handbook. – 9th ed. – London: Routledge, 2017. 900 p.

27. Dongellini M., Marinosci C., Morini G. L. Energy Audit of an Industrial Site: A Case Study. Energy Procedia. 2014. Vol. 45, no. 68. P. 424–433.

28. ISO 50001:2018. Energy management systems – Requirements with guidance for use. Geneva: ISO, 2018. 35 p.

29. Thumann A., Niehus T., Younger W. J. Handbook of Energy Audits. – 9th ed. – New York: Taylor & Francis, 2020. 460 p.

ЕНЕРГЕТИЧНИЙ СЕРТИФІКАТ БУДІВЛІ

Адреса (місцезнаходження) будівлі:	вул. Торгова, 11, м. Одеса, Одеська область
Ідентифікатор об'єкта будівництва:	-
Відомості про об'єкт сертифікації	існуюча будівля
Функціональне призначення та назва будівлі:	Житловий будинок (секція 1.2)

Відомості про конструкцію будівлі

Загальна площа, (м²):	4867,8
Загальний об'єм, (м³):	14603
Опалювана площа, (м²):	4070
Опалюваний об'єм, (м³):	12210
Кількість поверхів:	10
Рік прийняття в експлуатацію:	2012
Кількість під'їздів або входів:	32



Шкала класів енергоефективності		Клас енергетичної ефективності та питоме енергоспоживання
A	< 35,0	
B	< 56,0	
C	≤ 70,0	
D	≤ 84,0	
E	≤ 94,5	
F	≤ 105	
G	> 105	166,1

G

2021

Питоме споживання первинної енергії: **264,2**

0 50 100 150 200 250 300 350 400 >450

0 10 20 30 40 50 60 70 80 >90

Питомі викиди парникових газів: **50,1**

Дані енергоаудитора:	Номер та дата реєстрації:
Герасименко О.А. ОД № 000003	*1 листопада 2023 р.*