METHODOLOGICAL RECOMMENDATIONS
FOR CO-OWNERS OF APARTMENT BUILDINGS:
DEVELOPMENT OF ENERGY EFFICIENCY PROJECTS

On behalf of:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany
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Items from named contributors do not necessarily reflect the views of GIZ
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<th>Full Name</th>
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<tr>
<td>DBN</td>
<td>state construction standards</td>
</tr>
<tr>
<td>ESC</td>
<td>energy service contract</td>
</tr>
<tr>
<td>ESCO</td>
<td>energy servicing company</td>
</tr>
<tr>
<td>HCC</td>
<td>housing construction cooperative</td>
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<tr>
<td>IHU</td>
<td>individual heating unit</td>
</tr>
<tr>
<td>Regional Development Ministry</td>
<td>the Ministry of Regional Development, Construction and Housing and Utility Sector of Ukraine</td>
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<tr>
<td>NAABC</td>
<td>non-associated apartment building co-owners</td>
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<tr>
<td>OSBB</td>
<td>apartment building co-owners association</td>
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<tr>
<td>PD</td>
<td>project documentation</td>
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<tr>
<td>TEF</td>
<td>technical and economic feasibility of energy efficiency measures</td>
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</table>
1. GENERAL PROVISIONS

The Methodological Recommendations are aimed to provide the apartment building co-owners with practical advice on the optimal organization of implementation of the projects for improvement of energy efficiency in their buildings. This advice deals with all phases of the project lifecycle: from the decision on the project development to its implementation and further maintenance of the building.

The Methodological Recommendations have been developed in accordance with the Civil Code of Ukraine, the Laws on Ukraine “On Specifics of Realization of Ownership Rights in Apartment Buildings”, “On Associations of Apartment Building Co-Owners”, “On Housing and Utility Services”, the Resolution of the Cabinet of Ministers of Ukraine of 11.10.2002 N 1521 “On Implementation of the Law of Ukraine “On Associations of Apartment Building Co-Owners”, the Resolution of the Council of Ministers of the Ukrainian SSR of 30.04.1985 N 186 “On Approval of the Model Charter of the Housing Construction Cooperative”, as well as the requirements of the state construction norms and state standards of Ukraine with regard to energy efficiency in buildings. At the same time, some terms and organizational approaches to the implementation of energy service in apartment buildings are presented taking into account the provisions of the Law of Ukraine “On Introduction of New Investment Opportunities, Guarantee of the Rights and Lawful Interests of Business Entities for the Large-Scale Energy Modernization”.

2. CONTENT AND MAIN STAGES OF THE PROJECT FOR IMPROVEMENT OF ENERGY EFFICIENCY IN APARTMENT BUILDINGS

Any project for improvement of energy efficiency in apartment buildings (hereinafter – the Project) provides for implementation of energy saving measures that ensure considerable reduction of energy consumption. The relevance of such projects is significantly increased with the view of the ongoing growth of energy costs. Implementation of energy efficiency projects allows the co-owners of apartment buildings to minimize payments for utility services (within the payback period of the Project’s capital investments) and significantly reduce them (upon completion of the payback period). At the same time, important arguments in support of such projects for the co-owners are:
- considerable improvement of the living conditions in apartments;
- increase of the market value of residential property in the buildings after the thermal modernization;
- increase of the term of efficient operation of such buildings approximately by 30 years.

The main reason for the high energy consumption by apartment buildings of mass series is excessive losses through the building envelope and poor efficiency of heating systems. This is due to the fact that most of buildings of this category were designed and built with low thermotechnical characteristics that do not meet today’s requirements. In addition, a part of the buildings require capital renovation. The need of capital renovation is determined based on the results of the assessment of the building’s technical condition.

The Project implementation includes additional heat insulation of the building with mandatory modernization of the heating system as it is this comprehensive approach that allows achieving the optimal result. Also, the co-owners may be offered the measures on modernization of the hot water and lighting systems, which would contribute to the increase of the Project’s productivity. At the same time, the optimal list of energy saving measures may be prepared and offered to co-owners only as a result of a detailed examination of the technical condition and the energy audit of the building, as well as relevant calculations.

The development and implementation of a project for improvement of energy efficiency in an apartment building may be conventionally presented as a consecutive scheme that includes the phases shown in Table 1 and described in detail in the following sections of the Methodological Recommendations. Good quality of implementation of each phase ensures minimization of risks for the entire Project and creates conditions for achievement of the set goals (namely, energy saving).
### Table 1. Implementation phases of the project for improvement of energy efficiency in apartment buildings

<table>
<thead>
<tr>
<th>№</th>
<th>Phase</th>
<th>Content of the Phase</th>
<th>Performance Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparatory</td>
<td>Formation of the Project’s concept:</td>
<td>Recorded resolution of the meeting on development and implementation of the project including:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- preliminary assessment of the energy saving potential including rough estimation of:</td>
<td>- appointment and authorization of persons in charge;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- saving of heat and funds;</td>
<td>- preliminary definition of funding sources and conditions;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- cost of the project;</td>
<td>- procedure for selection of contractors for works and services;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- payback period.</td>
<td>- procedure of reporting on implementation progress.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Elaboration on the options of possible funding of the project;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Presentation of the feasibility study of the project at the meeting of co-owners.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pre-project</td>
<td>Selection of service providers in technical examination and energy audit.</td>
<td>Reports on the results of technical assessment and energy audit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Assessment of the building:</td>
<td>Development of the TEF of measures (TEF of investments¹).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- collection and verification of data on operational characteristics;</td>
<td>Calculation of the tentative costs, sources and conditions of funding.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- evaluation of the technical condition of structures and engineering systems;</td>
<td>TEF and funding conditions are discussed and the decision is passed at the meeting to develop the project.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- energy audit;</td>
<td>Development of the design specifications.</td>
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<tr>
<td></td>
<td></td>
<td>- calculation of the forecast reduction of energy consumption and monetary savings.</td>
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<tr>
<td></td>
<td></td>
<td>- Calculation of the tentative cost of energy saving measures.</td>
<td></td>
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<tr>
<td>3</td>
<td>Development of the project documentation</td>
<td>Selection of developers of the project documentation.</td>
<td>Certificates on the delivered project works.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Development, approval and expert examination of the project documentation.</td>
<td>Development of PD, receipt of relevant expert opinions.</td>
</tr>
<tr>
<td>4</td>
<td>Execution of construction works</td>
<td>Selection of contractors for construction works, suppliers of equipment and materials.</td>
<td>Work completion certificates for individual phases of construction works.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Execution of construction works.</td>
<td>Executive documentation in accordance with DBN A.3.1-5, particularly, hidden work acceptance certificates, designer supervision log.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Technical supervision and designer supervision of the construction works.</td>
<td>Operational readiness certificate.</td>
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<tr>
<td></td>
<td></td>
<td>- Commissioning of the building.</td>
<td>Registration of the declaration or receipt of the operational readiness certificate.</td>
</tr>
<tr>
<td>5</td>
<td>Operation of the building during the post-project period</td>
<td>Monitoring of consumption of:</td>
<td>Achievement of the consumption indicators and monetary savings envisaged by the project.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- heat (GCal);</td>
<td>Guarantee of the return of borrowed/invested funds.</td>
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<td></td>
<td>- electricity (kW*hour);</td>
<td>Work completion certificates for the building’s current maintenance.</td>
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<tr>
<td></td>
<td></td>
<td>- cold water (m³);</td>
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<tr>
<td></td>
<td></td>
<td>- hot water (m³);</td>
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<tr>
<td></td>
<td></td>
<td>- Evaluation of the project results (achieved energy efficiency).</td>
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<tr>
<td></td>
<td></td>
<td>- Current maintenance of the building.</td>
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¹ TEF of investments (of banking TEF) is developed in the event of attraction of investment funds for the project implementation. More information on various types of TEF is presented in Section 2.2.3 of the Methodological Recommendations.
As may be seen from the Table above, certain tasks are being resolved at each phase of the project that require special skills. In the following sections of the Methodological Recommendations, the main content and specifics of each phase are discussed, which will allow the co-owners as the Project’s customers to organize the project process in a better way in order to achieve the set goals and minimize possible risks.

The list of key measures under each phase is contained in Table 4 of Annex 1.

Depending on the structural specifics and technical condition of an apartment building, as well as the co-owners’ capability to organize the process of preparation, development and implementation of the Project in an efficient way, implementation of each of the phases may be within the following timeframes:

- preparatory – 1-2 months;
- pre-project – 1-2 months;
- development of project documentation – 1-3 months;
- execution of construction works – 1-4 months.

The total duration of preparation, development and implementation of the project may be 6 to 12 months.

2.1. PHASE 1: PREPARATORY. CONTENT AND SPECIFICS

The preparatory phase allows the apartment building co-owners to form a common concept (idea) of the project of improvement of the building’s energy efficiency and take a principal decision as to the advisability of its implementation.

As a rule, this phase does not require the co-owners to have special knowledge in the areas of construction and operation of apartment buildings, as well as energy efficiency of buildings, because the methodology offered in the recommendations allows implementing necessary measures without any complex calculations and instrumental studies.

For implementation of the preparatory phase, it is recommended to establish a working group out of the building co-owners. If it is necessary to resolve (clarify) certain issues, the working group may apply to specialists for consultations.

At the preparatory phase, it is recommended for the working group to perform:

- preliminary assessment of the energy saving potential in the building through the tentative estimation of possible economy of thermal energy and its cost;
- preliminary assessment of the project cost;
- estimation of the simple payback period;
- elaboration on possible funding sources and conditions.

It is recommended that the results obtained should be presented by the working group at the meeting of co-owners with the justification of advisability of the project implementation in order to pass a relevant decision.

2.1.1. Legal and economic aspects of decision-making by the co-owners of apartment buildings with regard to development and implementation of energy efficiency projects

The legal grounds for the decisions to be passed by the co-owners of apartment buildings with regard to implementation of energy efficiency measures in their buildings are defined by the Civil Code of Ukraine, the Laws of Ukraine “On Specifics of Realization of Ownership Rights in Apartment Buildings” and “On Associations of Apartment Building Co-Owners”, the Model Charter of the Housing Construction Cooperative approved by the Resolution of the Council of Ministers of the Ukrainian SSR of 30.04.1985 N186.
2. Content and main stages of the project for improvement of energy efficiency in apartment buildings

Article 360 of the Civil Code of Ukraine\(^2\) obligates the apartment building co-owners to participate in accordance with each individual share in the joint shared property in the costs for management, maintenance and preservation of the joint property.

In accordance with Article 7 of the Law of Ukraine “On Specifics of Realization of Ownership Rights in Apartment Buildings”\(^3\) the co-owners are obligated to:

- ensure proper maintenance and proper sanitary, fire-prevention and technical condition of the apartment building’s joint property;
- ensure technical servicing and, if necessary, current repair and capital renovation of the apartment building’s joint property;
- implement resolutions of the meeting of co-owners;
- ensure compliance with the requirements of the housing and urban development legislation with regard to reconstruction, refurbishment, current and capital renovation, technical re-equipment of the premises or their parts;
- compensate the damages caused to the property of other co-owners or joint property of the apartment building.

Each co-owner has obligations concerning proper maintenance, operation, reconstruction, refurbishment, current and capital renovation, technical re-equipment of the apartment building’s joint property pro rata such co-owner’s share.

The owners of apartments and non-residential premises in an apartment building may be natural persons and legal entities, territorial communities or the state. All owners of apartments and non-residential premises in an apartment building are its co-owners based on their right of joint ownership to the apartment building’s joint property. At the same time, the procedure of decision-making on implementation of energy efficiency measures in multi-family buildings may have certain differences due to relevant specifics of realization of the ownership right in such buildings.

Due to the specifics of realization of the ownership right, multi-family buildings may be divided into:

- buildings where condominium co-owners associations have been established (hereinafter - OSBB);
- buildings constructed or purchased by housing construction cooperatives (housing cooperatives) (hereinafter - HCC);
- buildings where co-owners have not established OSBB (non-associated apartment building co-owners, hereinafter – NAABC).

2.1.2. Decision-making procedure

Decisions on reconstruction and renovation of multi-family buildings are made:

- **in OSBB buildings**, in accordance with Article 10 of the Law of Ukraine “On Associations of Apartment Building Co-Owners”\(^4\) by the general meeting of co-owners. The decision is deemed passed if at least two thirds of all co-owners voted in its favor. The decision of the general meeting passed in compliance with the charter is binding on all co-owners;

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\(^2\) Civil Code of Ukraine. Available at: http://zakon0.rada.gov.ua/laws/show/435-15/page7


\(^4\) Law of Ukraine “On Associations of Apartment Building Co-Owners”. Available at: http://zakon0.rada.gov.ua/laws/show/2866-14
2. Content and main stages of the project for improvement of energy efficiency in apartment buildings

- **in HCC buildings**, in accordance with Clause 60 of the Model Charter of the Housing Construction Cooperative approved by the Resolution of the Council of Ministers of the Ukrainian SSR dated 30.04.1985 N 186 by the general meeting of the cooperative members of their authorized representatives. The general meeting of the cooperative members (meeting of authorized representatives) are recognized quorate if at least 2/3 of the total number of cooperative members (authorized representatives) are present. The decision is deemed passed if at least 3/4 votes of the attending cooperative members (authorized representatives) were given in its favor;

- **in NAABC buildings**, in accordance with Article 10 of the Law of Ukraine “On Specifics of Realization of Ownership Rights in Apartment Buildings” by the meeting of co-owners. The decision is deemed passed by the meeting of co-owners if it was supported by the owners of apartments and non-residential premises whose total area exceeds 75 percent of the total area of all apartments and non-residential premises in the multi-family building. If one person owns an apartment (apartments) and/or non-residential premises with the total area of 50 percent or more of the total area of all apartments and non-residential premises in a multi-family building the decision is deemed passed by the meeting of co-owners if it was supported by more than 75 percent of the total number of co-owners.

In accordance with the powers set by the above legislative acts, the co-owners/owners of apartment buildings are entitled to:

- act as a customer of capital renovation or reconstruction works in the multi-family building including implementation of energy efficiency measures;
- approve the budget estimate for energy efficiency measures, define the sources and procedures of their funding;
- set the procedure for payment, the list and amounts of contributions and payments including the deductions to the reserve fund and the repair fund;
- appoint contractors, enter into agreements with any natural persons or legal entities for reconstruction, current repair and capital renovation, technical re-equipment of property including implementation of energy efficiency measures;
- exercise control over execution of the agreements entered into.

Considering that the process of development and implementation of energy efficiency projects envisages resolution of a considerable number of organizational, legal, financial and technical issues the co-owners are recommended to ensure documentary recording of the decisions passed from the very beginning, as well as their systemization by topics in separate files. In particular, it is recommended to include into such files the documentary materials with regard to:

- making decisions on development of the project;
- preliminary assessment of the building’s technical condition and energy saving potential;
- appointment of providers/contractors of works;
- procurement of equipment and materials;
- implementation of individual phases of the project;
- financial issues, etc.

The subject list of such files has not been set by legislation but the main criterion of the advisability of formation of certain files consists in the convenience of use of the documentary materials in order to obtain necessary information with regard to all phases of the project.

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5 Resolution of the Council of Ministers of the Ukrainian SSR dated 30.04.1985 N 186 “On Approval of the Model Charter of the Housing Construction Cooperative”. Available at: http://zakon0.rada.gov.ua/laws/show/186-85-%D0%BF/page2

2.1.3. Assessment of the energy saving potential in a multi-family building

Assessment of the energy saving potential and economy of funds for the energy resources consumed (heat and electricity, etc.) in a multi-family building is a key factor that influences the decision to be taken by the co-owners with regard to implementation of energy efficiency measures.

At the initial stage of the preparation of the decision on implementation of energy efficiency measures, it is recommended that the co-owners of the multi-family building should use the simplified methodology for the preliminary assessment of the energy saving potential. The simplified methodology may be applied without a detailed energy audit of the multi-family building and does not require any special knowledge. However, it allows receiving estimated figures of the approximate (with possible deviations of 10-20%) reduction of energy consumption. Despite that, the figures obtained are sufficient for the co-owners to understand the energy saving potential and take a principal decision as to the implementation of energy efficiency measures, make the list of such measures and prioritize them, as well as estimate the expected economic effect.

The methodology of accurate calculation of the energy saving potential is based on the results of the energy audit performed by skilled specialists including the use of instrumental methods of research of thermotechnical and other energy indicators of the building.

At the same time, the co-owners have to understand from the very outset that the measures for energy efficiency improvement in the multi-family building by their nature are usually classified as technical re-equipment rather than reconstruction or capital renovation, as they result in the improvement of the operational and technical/economic characteristics of the building. This will require additional involvement of skilled specialists into development and implementation of the project in order to perform the necessary set of works and services.

Certainly, implementation of energy efficiency measures in multi-family buildings requires additional financial resources that usually exceed the aggregate maintenance costs. At the same time, considering the high energy saving potential in multi-family buildings existing mechanisms of funding of energy efficiency projects most often allow implementing them without additional monetary burden on the residents, that is, within the set current payments or, in some cases, even at a lower level. This is achieved due to the reduction of energy consumption as a result of implementation of energy efficiency measures and, accordingly, reduction of payments for them. It is the difference in the payments “before” and “after” the implementation of energy efficiency measures that is the basis for compensation of the costs for development and implementation of the projects for improvement of energy efficiency of buildings including the repayment of borrowed funds. The general scheme of achievement of the economic effect from implementation of energy efficiency measures is presented in Graph 1.

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7 Electricity: the calculation is based on the volume of electricity used for the building’s common needs.
8 Outlined in Section 2.1.5 of the Methodological Recommendations.
2. 2.1.4. List and contents of the input data for preliminary assessment of the energy saving potential in a multi-family building

For preliminary assessment of the energy saving potential in a multi-family building, it is necessary to collect data on the averaged volumes of consumption of energy resources and payments for them during the three previous years (baseline period) and compare them with the estimated (forecast) volumes of consumption of energy resources and energy costs after implementation of relevant energy efficiency measures. Data on energy consumption by a multi-family building during the baseline period is estimated based on the readings of the heat and electricity meters in the building.

Due to the fact that the cost of thermal energy is the most ponderable element in the structure of the cost incurred by the co-owners of the multi-family building for the consumed energy resources, it is recommended for understanding of the key indicators and justification of the project feasibility to compare primarily the figures of the current consumption of thermal energy ($Q_{\text{before}}$) during the baseline period and the estimated heat consumption ($Q_{\text{after}}$) that may be achieved as a result of the thermal modernization.

Upon availability of a per-building heat meter, the baseline current consumption of thermal energy before the thermal modernization ($Q_{\text{before}}$), which is used for further calculations of the energy saving potential, is determined as the arithmetic average of the actual readings of the meter for the last three years.

If a multi-family building is not equipped with a heat meter it is recommended to find the data on tentative volume of heat consumption ($Q_{\text{before}}$) during the baseline period from the heating service provider.

Further, if the principal decision is made to implement the project and involve specialists the estimated data of current consumption of thermal energy during the baseline period should be compared with the estimated data obtained taking into account the data of the assessment of the building’s technical condition, the energy audit data including application of the non-intrusive control devices, as well as thermometric and thermovision equipment.

The volume of thermal energy that will be used for heating in the building after the thermal modernization ($Q_{\text{after}}$) is determined by calculation. An example of the simplified calculation of the tentative heat consumption by the building after the thermal modernization is shown in Annex 2. The calculation is made using the data on the building’s operation characteristics specified in Table 6 of Annex 4.
2.1.5. Simplified methodology of assessment of the economic effect from implementation of energy efficiency measures

For the simplified assessment of economic effect from implementation of the energy efficiency improvement measures, averaged data of the energy saving potential can be used as shown in Table 2. The figures shown in the Table indicate how the implementation of an individual measure from the list could tentatively reduce the consumption of heat and electricity in comparison with the baseline consumption.

<table>
<thead>
<tr>
<th>Structural element</th>
<th>Technical solution</th>
<th>Energy saving potential</th>
<th>Averaged payback period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Heat insulation</td>
<td>18-25%</td>
<td>7-10</td>
</tr>
<tr>
<td>Windows, entrance doors</td>
<td>Replacement</td>
<td>15-20%</td>
<td>15</td>
</tr>
<tr>
<td>Attic and attic floor</td>
<td>Heat insulation</td>
<td>5-15%</td>
<td>10-12</td>
</tr>
<tr>
<td>Basement floor</td>
<td>Heat insulation</td>
<td>5-10%</td>
<td>7-10</td>
</tr>
<tr>
<td>Ventilation systems</td>
<td>Installation of input-extract valves; Installation of heat recovery units; Change for the mechanical exhaust ventilation</td>
<td>5-35%</td>
<td>5-8</td>
</tr>
<tr>
<td>Per-building heating system</td>
<td>Installation of IHU with the weather regulator</td>
<td>15-20%</td>
<td>2-4</td>
</tr>
<tr>
<td></td>
<td>Hydrochemical cleaning and balancing</td>
<td>5-10%</td>
<td>1-2</td>
</tr>
<tr>
<td>Per-building electricity systems</td>
<td>Replacement of incandescent lamps</td>
<td>5-7%</td>
<td>2-3</td>
</tr>
<tr>
<td></td>
<td>Installation of lighting regulators</td>
<td>5%</td>
<td>2-3</td>
</tr>
</tbody>
</table>

Source: Authors

Table 2. Averaged data of the energy saving potential of the multi-family building

When using the data from the above Table for calculation of the energy saving potential, one should bear in mind that the priority must be given to comprehensive solutions that ensure higher and longer effects than individual measures. At the same time, it would be a mistake simply to add up the indicators when calculating the forecast result of implementation of the set of measures for improvement of the building’s thermotechnical characteristics. Experience has shown that the comprehensive implementation of such measures allows achieving the total reduction of heat consumption of 30% to 70% depending on the list of measures and technical solutions selected, as well as the initial technical condition of the building. Examples of the forecast results of the combination of individual measures are shown in Table 3.

At the same time, if the decision is made on advisability of modernization of electricity systems the result of implementation of relevant measures will not have a considerable impact on the building’s thermotechnical characteristics. Therefore, the volume of possible reduction of electricity consumption for the building’s general needs and saving of the funds paid for it will be calculated separately while the forecast indicators may be thus compared with the relevant indicators of the baseline period of consumption.
### 2. Content and main stages of the project for improvement of energy efficiency in apartment buildings

<table>
<thead>
<tr>
<th>Set of technical solutions of the thermal modernization</th>
<th>Energy saving potential as a result of implementation</th>
<th>Averaged payback period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation of walls, replacement of windows, insulation of the roof (roofing) without modernization and automation of the heating system</td>
<td>10-35%</td>
<td>7-10 years</td>
</tr>
<tr>
<td>Modernization of the heating system (cleaning, automatic hydraulic balancing, automatic control and regulation)</td>
<td>10-25%</td>
<td>2-5 years</td>
</tr>
<tr>
<td>Modernization of the heating system (cleaning, automatic hydraulic balancing, automatic control and regulation) + insulation of walls and replacement of windows</td>
<td>35-45%</td>
<td>7-10 years</td>
</tr>
<tr>
<td>Modernization of the heating system (cleaning, automatic hydraulic balancing, automatic control and regulation) + insulation of walls, basement floor, roof (roofing)</td>
<td>35-45%</td>
<td>5-8 years</td>
</tr>
<tr>
<td>Insulation of walls, replacement of windows, insulation of the roof (roofing) + IHU with weather regulation + automatic hydraulic balancing</td>
<td>35-50%</td>
<td>6-9 years</td>
</tr>
<tr>
<td>Modernization of the heating system (cleaning, automatic hydraulic balancing, IHU with weather regulation) + insulation of walls and replacement of windows + ventilation with humidity regulation</td>
<td>45-60%</td>
<td>7-10 years</td>
</tr>
<tr>
<td>Replacement of the heating system with a two-pipe system with IHU with weather regulation + insulation of walls, roof (roofing), basement floor (over the unheated cellar), replacement of windows + ventilation with heat recovery (individual heat recovery units with at least 75% efficiency)</td>
<td>65-85%</td>
<td>10-12 years</td>
</tr>
<tr>
<td>Replacement of the heating system with a two-pipe system with IHU with weather regulation + insulation of walls, roof (roofing), basement floor (over the unheated cellar), replacement of windows + ventilation with heat recovery (individual heat recovery units with at least 75% efficiency) + renewable energy sources (solar collectors, solar batteries, etc.)</td>
<td>70-100%</td>
<td>10-15 years</td>
</tr>
</tbody>
</table>

Source: Authors

Table 3. Examples of achievement of possible reduction of heat consumption depending on combinations of energy saving measures

Thus, effect from implementation of energy efficiency measures is determined by the reduction of consumption of energy resources ($\Delta Q$) and the achieved saving of funds ($\Delta E$). Calculation of the approximate effect from implementation of energy saving measures in physical (GCal, kW*hour) and money terms may be made according to Formulas 1 and 2.
2. Content and main stages of the project for improvement of energy efficiency in apartment buildings

\[ \Delta Q = Q_{\text{before}} - Q_{\text{after}} \]

where \( \Delta Q \) – effect from reduction of heat consumption by the building, GCal;
\( Q_{\text{before}} \) – volume of heat consumed by the building before implementation of energy saving measures, GCal;
\( Q_{\text{after}} \) – volume of heat consumed by the building after implementation of energy saving measures, GCal.

\[ \Delta E = \Delta Q \times T \]

where \( \Delta E \) – effect from reduction of heat consumption by the building in money terms – annual money savings, UAH;
\( T \) – thermal energy tariff, UAH/GCal.

Approximate total cost of the project (PC) on improvement of the building’s energy efficiency may be calculated according to Formula 3 based on the open data on the cost of individual services and works disseminated by professional organizations\(^{10}\), as well as the companies specializing in their delivery. An example of such a calculation is shown in Annex 3. If necessary, it is recommended in the course of the calculation to seek consultations of relevant specialists (energy auditors, providers of design and construction works, suppliers of energy saving equipment and materials, etc.).

\[ PC = C_{\text{tech.assessment}} + C_{\text{audit}} + C_{\text{design}} + \sum_{j=1}^{k} C_{ij} \]

where \( C_{\text{tech.assessment}} \) – cost of works on assessment of the building’s technical condition;
\( C_{\text{audit}} \) – cost of energy audit of the building;
\( C_{\text{design}} \) – cost of development of the design documentation;
\( C_{ij} \) – cost of implementation of the j measure on improvement of energy efficiency, UAH (including the cost of equipment, materials and works for each individual measure);
\( k \) – number of measures.

The costs of services on technical assessment and energy audit depend upon the size of the multi-family building (area/volume) and are determined on a contractual basis by the customer and potential contractors.

The cost of development of the design documentation is set within 3-7% of the total cost of the works on energy efficiency improvement of the multi-family building (construction project).

The cost of individual energy saving measures is calculated on the basis of the data on the scope of work (area, volume, linear meters, number of units, etc.), cost of materials and equipment, as well as the cost of works (mounting).

In addition, it is necessary to provide for additional costs under the project that are connected with the expert examination of the design documentation (0.5 - 1.0%), technical supervision (to 2.5%) and design supervision\(^{11}\) (to 2.5% of the total cost of the project).

The results of the rough estimation of the cost of measures and expected financial result from their implementation is the basis for the principal decision to be made by the building co-owners on the commencement of implementation of the project of improvement of the building’s energy efficiency and relevant capital investment in the future. For that purpose, it is necessary to compare the volumes of consumption of energy resources (\( Q_{\text{before}} \)) and their costs (\( C_{\text{before}} \)) during the current baseline period and the relevant expected indicators after the project’s implementation (\( Q_{\text{after}} \), \( C_{\text{after}} \)).

Comparison of the annual money savings from energy saving measures and the total cost of their implementation allows calculating the approximate simple payback period of capital investment \( T_{pb} \) using

\(^{10}\) Relevant monitoring is performed, for instance, by the Association of Energy Auditors of Ukraine. Available at: [http://aea.org.ua/projects/price-monitoring/](http://aea.org.ua/projects/price-monitoring/)

\(^{11}\) The volume of design supervision measures is determined by the customer taking into consideration the project specifics.
Formula 4 (without taking into account the changes of the tariffs for energy resources and other investment indicators).

\[ T_{pb} = \frac{PC}{\Delta E} \]  

where \( PC \) – total cost of the project; 
\( \Delta E \) – annual money savings.

At further stages of the project implementation, relevant specialists may be involved for relevant calculations – energy auditors, certified experts in assessment of the building’s technical condition, designers. In addition to the assessment of the potential of saving of heat and electricity, the specialists may perform additional assessment of the possibilities to save energy and funds of the residents of the multi-family building on condition of implementation of the measures for more rational use of cold and hot water.

2.1.6. Presentation of justification of expediency of implementation of energy efficiency measures

It is recommended to present the results of the preliminary assessment of the energy saving potential of the multi-family building at the meeting of co-owners.

In the course of the presentation, it is worth highlighting the following aspects that influence the co-owners’ understanding of the content of the project of improvement of the building’s energy efficiency and their decision as to the necessity of its implementation:

- information on the building’s technical condition (taking into account the year of construction and, possibly, current repairs or capital renovations conducted earlier);
- information on current volume of consumption of energy resources (heat and electricity) during the three previous years and amounts of payments for them;
- goal and contents of measures for improvement of the building’s energy efficiency, examples of their positive implementation and economic effect;
- a tentative list of energy saving measures proposed for implementation in the building and expected result of reduction of the consumption of energy resources;
- projected reduction of the funds paid for the consumed energy resources;
- tentative estimated cost of the project and its approximate payback period;
- how implementation will influence the co-owners’ fees for maintenance of the building and utility services;
- justification of the expediency of development and implementation of the project taking into account the above factors.

If the co-owners approve the decision on development and implementation of the project for energy efficiency improvement of the multi-family building it is also recommended to discuss and take a decision on other organizational issues during the meeting:

- appointment of the co-owners to be in charge of further organization of the project’s development and implementation;
- authorization of people in charge to hold the procedures for selection of providers of works and services (consulting, technical assessment and energy audit, preparation of design and budget documentation, repair and construction works, procurement/supply of materials and equipment, etc.);
- preliminary determination of the sources and conditions of funding of the project development;
- approval of the procedure for selection of the service and work contractors;
procedure and frequency of reporting of the persons in charge to the co-owners on the project implementation progress (it is recommended to report upon completion of each phase but at least once a month; reports may be presented at the meeting of co-owners or through dissemination of relevant reporting data, in particular concerning the works completed, funds spent and the contents of the project’s current measures/phases).

Of course, the list of the above issues is not exhaustive and may include other issues connected with the project development.

2.2. PHASE 2: PRE-PROJECT PHASE. CONTENTS AND SPECIFICS OF THE PHASE

At the pre-project phase, the assessment of technical condition and the energy audit of the multi-family building are conducted, and based on their results the TEF of energy saving measures is developed (in case of necessity, the TEF of investments), as well as the design specifications.

2.2.1. Assessment of technical condition of the multi-family building

Technical assessment is a process of obtaining of the quality and quantity figures with regard to the operational suitability of the building, its parts and structures through a visual inspection, instrumental measurements in the natural conditions and laboratory studies by certified experts.

Thus, the purpose of the assessment and evaluation of the technical condition of buildings and engineering networks is to make the list, estimate the volumes and costs of the works needed to restore the normal operational suitability of the building. If the cost of such works is insignificant (the works are mainly of a “cosmetic” nature) the decision is made to commence the project.

If the technical condition of the building proves its unsuitability for normal operation or the state of emergency and the building’s restoration requires significant costs as compared to the energy efficiency measures it is recommended in such cases to start with implementation of the measures for repair of the damaged structural elements and then to return to the project of energy efficiency improvement.

The content and volumes of the assessment works (selective or full assessment) should be determined in accordance with the program of assessments developed on the basis of the technical specification attached to the agreement between the co-owner/owner of the property (customer) and the organization performing the assessment. It is recommended to set the cost of the assessment of technical condition of the multi-family building according to the established standards12.

Based on the results of the technical assessment, the Report on Assessment of Technical Condition is prepared to describe the technical condition of the structures and the building as a whole, as well as provide recommendations for implementation of the measures (if necessary) to restore (replace) individual structural elements.

2.2.2. Energy audit of the multi-family building

The purpose of energy audit is to evaluate the efficiency of use of the energy resources in a multi-family building and to prepare the proposals for efficient measures for the reduction of the co-owners’ expenses. In the course of energy audit, the energy examination is performed including the use of instrumental methods and analysis of the performance of the energy consumption systems, and on this basis the energy saving potential

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12 SOU (Standard of Organization of Ukraine) D.1.2-02495431-001:2008 “Standards of labor costs for determination of the cost of works on assessment of the technical condition and operational suitability of the buildings and structures”. Available at: http://dbn.at.ua/load/normativy/61-1-0-930
and possible saving of the costs for energy resources are estimated.

Energy audit performed by qualified specialists allows:

- detecting the sources of irrational excessive consumptions and unjustified losses;
- developing of recommendations for elimination of unjustified costs and losses based on the technical and economic analysis;
- proposing a program for saving of energy resources and rational energy consumption;
- setting the order of implementation of the proposed measures with the technical and economic analysis of the implementation costs and payback periods.

Based on the results of the energy audit, a report must be prepared including:

- information on the results of technical and energy assessment;
- conclusions as to the expedience of the thermal modernization of the building (based on the calculations of economic efficiency of the energy efficiency measures taking into consideration all factors, in particular, payback of the costs for the measures and reduction of operation costs after the thermal modernization);
- description of the recommended measures of thermal modernization.

Based on the results of energy audit, the **technical and economic feasibility study** (TEF) of energy efficiency measures is prepared.

### 2.2.3. Technical and economic feasibility of energy saving measures. Why is it needed?

The selection of the optimal set of measures on the energy efficiency improvement of the multi-family building is only possible at the phase of the technical and economic feasibility of the measures (TEF) based on the results of the detailed technical assessment and energy audit of the building conducted by the specialists of relevant qualifications.

In the course of the selection of measures for improvement of the building’s energy efficiency, the co-owners should take into consideration that the optimal level of consumption of energy resources is achieved not only through the combination of energy saving measures (heat insulation of the building envelope, replacement of windows, modernization of engineering systems) but also due to the use of various structural solutions and equipment with different technical and economic characteristics. That is, in the course of the project development it is possible to apply different variants of technical solutions that allow achieving different levels of heat energy savings with relevant costs spent. An example of application of the variants of technical solutions is shown in Graph 2.

![Graph 2. Illustration of possible variants of heat insulation of the building to achieve the optimal level of energy efficiency](source: Authors)
In this example, the possibility of use of several variants of technical solutions is shown with regard to the heat insulation of the roof, façade and windows using the structures with different thermotechnical characteristics within the normative heat transfer resistance (R)\(^{13}\).

According to the calculations the difference in the total cost of thermal modernization of the façade, for instance, using the structures with 0.8 R, 1R and 1.3 R ranges from 8% to 15% because it is only the thickness of the insulation layer and the length of mechanic fixtures that is changed in these structures, and their cost has an insignificant impact on the cost of the system as a whole. At the same time, the cost of windows of 0.8 R, 1R and 1.3 R differs considerably (within the range of 30-50%) as the construction of windows differs significantly.

Considering the fact that the relation of the areas of individual elements of the building envelope to the total envelope area is different in each individual building this allows estimating optimal variants of technical solutions for insulation of facades. For instance, to obtain a normative value of the specific heat consumption in the course of a comprehensive thermal modernization it is possible to select windows with a low heat transfer resistance (0.8 R) and a façade structure with a higher value (1.3 R). In this case, the necessary result will be achieved at the minimum possible price.

Thus, modeling of different variants of the structure of a building’s heat cover allows finding an option with a sufficient level of energy efficiency and the lowest capital investment into comprehensive modernization. An example of such modeling is shown in Graph 3 demonstrating the dependence of the heat saving indicator upon the volume of capital investments in an individual apartment building.

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\(^{13}\) Standard heat transfer resistance (R) is an indicator that characterizes the ability of a material (structure) to retain heat. The higher the resistance, the better the heat insulation characteristics of the material (structure). It is established by DBN B.2.6-31:2006 “Constructions of buildings and structures. Heat insulation of buildings”. Available at: http://eurobud.ua/uploads/files/pinoplast_norm_doc/4%20DBN%20B.2.6-31-2006.pdf
The diagram of dependence of the annual heat savings upon the cost of thermal modernization measures allows selecting the optimal variants of the thermal modernization simultaneously by the criteria of economic and energy efficiency by way of comparison of the pairs of variants.

In particular, the variants of comprehensive thermal modernization that ensure approximately the same saving of heat are divided in the Graph into 7 groups: A, B, C, D, E, F and G. Analysis of the variants within each group allows selecting the most efficient variant in a group.

In Group A, for example, the most efficient variant is 44 that ensures the heat saving of 1346 GCal, which is the group’s maximum (other variants in the group are 1346, 1347, 1341, 1336, 1331). However, the cost of implementation of this variant is the lowest.

Using this diagram, it is possible to made decisions based on:

- the target (desirable) level of energy efficiency – to find a variant that would be cheaper with the same level of energy efficiency. For instance, the best variant to achieve the savings of 1370 GCal is 17;
- out of the target (desirable) level of the costs for energy efficiency measures, to select the variant that would ensure the largest heat savings. For instance, the most efficient variant with the cost of about UAH 6,000,000 will be 18.

Thus, the main goal of **TEF of the measures** for improvement of energy efficiency of a multi-family residential building is to select the optimal combination of energy saving measures and technical solutions that allow achieving the target levels of reduction of the consumption of energy resources (the maximum energy efficiency of the building) with minimum possible costs.

The co-owners have to bear in mind that if the project of energy efficiency improvement of the multi-family building is implemented involving investment funds there may be a need to prepare **TEF of investments**, which is different from TEF of measures by its content. In the course of preparation of the Investment TEF, the project’s development is modeled with the influences of different factors (organizational and legal, technical, financial and economic, etc.) Based on the data obtained, the optimal conditions for the project implementation are defined.

On the basis of such analyses, the organizational and financial model of the project implementation is developed (the phased detailed plan with the sequence of steps for the project’s implementation taking into consideration the technical and legal aspects of the relations between the project participants, implementation schedule and the structure of funding of each step, ways to neutralize the risks found in the course of the analysis, as well as the guarantees of preservation of the forecast indicators and investment return, etc.).

The Investment TEF contains a detailed justification of the project concept, describes its technical, economic, financial and social characteristics. The Investment TEF describes the main aspects of the project, analyzes all of its problems and defines the solutions for them. The Investment TEF makes it possible to evaluate the project’s viability and serves as a ground for receipt of financial support from external investors.

2.2.4. Design assignment

An important component of the pre-project phase is development of a **design assignment** based on the results of the assessment of technical condition and energy audit of a multi-family building.

The design assignment sets the customer’s justified requirements as to the planning, architectural, engineering and technological solutions for the construction project, its key parameters, costs and organization of its construction, and is prepared taking into account the technical specifications, urban planning conditions and restrictions.

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14 DBN A.2.2-3-2014 “Composition and contents of design documentation for construction”. Available at: http://minregion.gov.ua/attachments/files/bydivnitsvo/uxnichne-regulyuvannya/normuvannya/DBN_A22_3_2012_1.pdf
At the same time, the design assignment sets the criteria of complexity of the construction project in order to set the design stages. For apartment buildings, the determining criterion for inclusion of a project into a certain category is the number of people who permanently live in the building. In particular, buildings with the number of residents to 50 are included into the 2nd category of complexity, 50 to 300 people – the 3rd category, 300 to 400 people – the 4th category and over 400 people – the 5th category15.

The main risks at the phases of preparation of the thermal modernization project are limited to the incorrect preparation of input data for the design. This is connected with possible errors in the course of assessment of technical condition and energy audit of the building (poor quality of measurements of the building’s geometric parameters, examination of the structural elements, definition and calculation of thermotechnical indicators, etc.).

Consequently, these factors will further result in the design mistakes, failure to achieve expected indicators, as well as energy efficiency, saving of heat, water and electricity. In particular, negligent assessment of the building’s technical condition may fail to envisage the measures for restoration of the operational suitability of the building’s structural elements. The mistakes made in the development of the organizational and financial mechanism and the business plan may principally put the possibility of the project’s implementation at risk.

2.3. PHASE 3: PREPARATION OF DESIGN DOCUMENTATION

Due to the fact that energy efficiency improvement of a multi-family building is a complex set of measures, preparation of the good-quality design documentation is an important factor of achievement of the expected effect of reduction of the consumption of energy resources. The energy saving measures should not only be based upon the optimal technical solutions but also be justified from the economic viewpoint.

The design documentation is prepared on the basis of the design assignment. Construction project is a set of documents with all necessary information to conduct all stages of construction works. That is why development of the design is primarily necessary for proper implementation of the co-owners’ ideas and preferences. The procedure for preparation of design documentation for construction is approved by the Regional Development Ministry16.

It should be noted that the cost of the full set of design documentation may account for only 3-7% of the total construction cost. Therefore, it is not recommended to ignore this important stage as the mistakes in organization of the construction process, excessive use of materials and improper equipment may unreasonably increase the cost of the projects, on one hand, and cause the failure to achieve the expected reduction of the consumption of energy resources, on the other hand.

Design documentation should meet the requirements of legislation, construction norms, standards and rules17. It is not allowed to prepare design documentation without the energy assessment and energy audit, as well as mechanic and thermotechnical calculations in compliance with relevant DBN requirements18,19,20.

The developed design documentation is subject to expert examination21 in order to evaluate the quality

15 DBN B.1.2-14-2009 “General principles to ensure reliability and constructive safety of buildings, structures, constructions and foundations”. Available at: http://dbn.at.ua/load/normativy/dstu/5-1-0-1032
17 DBN A.2.2-3-2014 “Composition and contents of design documentation for construction”. Available at: http://minregion.gov.ua/attachments/files/bydivnitstvo/texnichne-regulyuvannya/normuvannya/DBN_A22_2_3_2012_1.pdf
18 DBN A. 2. 1-1-2014 “Engineering research for construction”. Available at: http://dbn.at.ua/load/normativy/dbn_a_2_1_1_1_2014/1-1-0-1167
19 DBN B.2.6-31:2006 “Heat insulation of buildings”. Available at: http://dbn.at.ua/load/normativy/dbn/1-1-0-13
of design solutions through detection of possible deviations from the requirements of Ukrainian legislation in the area of construction, building norms, standards and rules. The expert examination is the completion stage of development of construction projects. Design documentation is submitted for expert examination by the customer or by the design organization authorized by the customer. The cost of the examination services is 0,5 - 1% of the total cost of construction.

Mandatory expert examination is established for the construction projects that:

- belong to the 4th and the 5th complexity categories, with regard to the compliance with the standards of sanitary and epidemiological safety of the population, energy saving, fire safety, durability, reliability, sustainability of buildings, their operational and engineering safety;

- are constructed using the budget funds, monies of the state-owned and municipal companies, institutions and organizations, as well as the loans issued against state guarantees, if their estimated cost exceeds UAH 300,000, with regard to the estimated cost of design documentation.

In addition, it is recommended to perform the expert examination in case of occurrence of disputable situations between the customer (investor) and the works contractor in order to verify the compliance of the budget documentation with the existing design, correctness and justification of application of the ratios, prices and volumes of the planned works at any stage of the works.

Expert examination of the projects for improvement of energy efficiency of buildings is conducted by organizations irrespective of the ownership form that meet the criteria set by the central executive authority in the area of construction, urban development and architecture. At the same time, expert examination of the construction projects of the 4th and the 5th categories of complexity constructed at the cost of budget funds, the funds of the state-owned and municipal companies, institutions and organizations, as well as the loans issued against state guarantees, is conducted by the state-owned expert organizations.

2.3.1. Framework conditions and requirements to implementation of energy efficiency measures in multi-family buildings

Design documentation is prepared in compliance with the requirements of a number of state regulatory technical documents that set the framework conditions and requirements to the thermotechnical indicators of the building envelope (heat insulation cover, windows) of the buildings, heating systems, ventilation and hot water supply. Compliance with these requirements in the course of the project implementation ensures reduction of the consumption of energy resources for heating, maintenance of the standard sanitary and hygienic parameters of the microclimate in the premises, durability of the structures in the course of the building operation, as well as achievement of the expected economic effect from energy saving measures.

The provisions of the above regulations have to be applied in the course of design of the heated buildings and structures in the cases of new construction, technical re-equipment, reconstruction and capital renovation (thermal modernization), preparation of the energy certificate, estimation of consumption of the fuel and energy resources for heating with the use of the calculation and analytical methods, energy audit of buildings and structures. It is established also that these provisions are binding on all legal entities in the territory of Ukraine irrespective of the form of ownership or departmental subordination.

Certainly, it is very difficult for the co-owners of apartment buildings who do not have special skills to get oriented in the whole mass of the regulatory and technical documents that regulate the technical aspects of implementation of the projects of energy efficiency improvement of buildings. With this view, Table 6 of Annex 4 systemizes and presents the framework conditions and requirements to the operational characteristics

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21 Article 31 of the Law of Ukraine “On Regulation of Urban Development Activities”. Available at: http://zakon0.rada.gov.ua/laws/show/3038-17/page2

of the building envelope, systems of heating, ventilation and hot water supply. In addition, the Table indicates possible technical solutions aimed to achieve these indicators, possible risks in the course of implementation of relevant measures and practical recommendations as to their mitigation.

2.4. PHASE 4: PERFORMANCE OF CONSTRUCTION WORKS

Effective legislation defines construction works as the works on new construction, reconstruction, technical re-equipment of active enterprises, restoration, capital renovation. The customer has the right to perform the construction works after:

- the registration by the authority in charge of the state architectural and construction control of the declaration on commencement of the construction works - with regard to the construction projects of the 1st through the 3rd categories of complexity;
- issuance by the authority in charge of the state architectural and construction control of the permit to the customer to perform the construction works - with regard to the construction projects that belong to the 4th and the 5th categories of complexity.

The construction works on thermal modernization of residential buildings are performed taking into account the provisions of DSTU-H Б.3.2-3:2014 “Recommendation for thermal modernization of residential buildings”.

It is recommended to perform the construction works in the following sequence:

- preparatory works;
- repair or replacement of windows, entrance doors, exit ways and balcony doors;
- repair or replacement of windows on staircases, corridors and halls in common use, technical floor and attics;
- modernization of internal engineering systems in the building;
- heat insulation of the outer elements of the building envelope and waterproofing of the roof.

The sequence of the works may be different depending upon the previously implemented measures for improvement of energy efficiency.

At the stage of the preparatory work, the following measures are implemented:

- analysis of technical documentation and results of the site assessment;
- detailed examination of the site and local work conditions by the contractor’s specialists;
- determining the duration of the works;
- conciliation of the contractual price;
- formalization and entry into agreements;
- entry into agreements for the supply of materials and goods, lease of equipment.

The site prepared for the works on improvement of energy efficiency should have:

- fully completed works on replacement of individual structures and elements (in the cases of reconstruction or capital renovation to be performed at the site), repair works;
- selected and equipped places for warehousing of materials and goods (warehouses, platforms for

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23 Resolution of the Cabinet of Ministers of Ukraine of 13 April 2011 N 466 “Some Issues of Performance of Preparatory and Construction Works”. Available at: http://zakon2.rada.gov.ua/laws/show/466-2011-%D0%BF
storage of materials and goods); 
- defined places for keeping and collecting of the waste; 
- installed rafting; delivered materials and goods, tools and equipment; 
- equipped areas for preparation of the elements for mounting; 
- installed lifting equipment at the work places (if necessary); 
- inscriptions and signage that warn of the danger.

The following sequence is recommended for the heat insulation of the outer elements of the building envelope:

1. outer walls and external wall structures that contact with the soil; 
2. other structures in any sequence:
   - built-up roofs; 
   - attic roofs and roofing over unheated attics; 
   - roofing over passages and unheated cellars; 
   - heat insulation of the floor over the ground.

It is recommended to start the works on heat insulation of outer walls and external wall structures that contact with the soil after the modernization and testing of internal engineering systems.

The works on heat insulation of outer walls and external wall structures that contact with the soil and heat insulation and waterproofing of the roof could be performed simultaneously.

2.4.1. Technical and designer supervision of the construction works

The quality of the works on improvement of energy efficiency depends upon the following factors:
- justification of the design solutions; 
- qualification of the work performers; 
- compliance of the materials, goods and equipment with the indicators set for the project; 
- compliance with the work technologies; 
- technical supervision at all stages of the works on improvement of energy efficiency.

The technical and designer supervision of the construction is envisaged by the Law of Ukraine “On Architectural Activities” and its procedure is established by the Cabinet of Ministers of Ukraine.

The technical supervision measures in the course of implementation of the project of thermal modernization of the multi-family building are aimed to ensure ongoing control of the quality of works on improvement of energy efficiency in compliance with the design solutions, requirements of the state standards, construction standards and rules. The technical supervision measures should provide for the verification and expert assessment of all processes, terms and costs of works. The measures have to be performed at the necessary quality level.

Technical supervision should be ensured by the customer (developer) throughout the entire period of construction and performed by the person who has a qualification certificate issued in accordance with the law by the architecture and construction attestation commission.

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The results of the technical supervision over the performance of the construction and renovation works are made available to the customer, among other ways, through execution of the reports on the works performed with defects. In case of detection of deviations from the design solutions in the course of the works and the contractor’s refusal to eliminate them, the customer and a relevant inspectorate of the State Architecture and Construction Control Authority are notified to that effect for the measures to be taken in compliance with legislation.

During acceptance of the phases of the works on improvement of energy efficiency and evaluation of the work quality, the following elements are checked:

- compliance of the materials and goods with the requirements of design solutions, instructions and recommendations as to their application, as well as the regulatory and technical documentation for the materials and goods;
- compliance of the content and volume of the works with the design solutions and effective regulatory documents;
- degree of compliance of the controlled physical and mechanic, geometric and aesthetic indicators with the requirements of structural solutions by the corresponding works;
- timeliness and correctness of keeping the logs of works and the logs of hidden works;
- elimination of the defects indicated in the work logs in the course of the technical supervision over the works.

**Designer supervision** provides for the control of the compliance of construction works with the project’s design\textsuperscript{27}. The designer supervision measures are taken by the project’s designer or its authorized representative in compliance with legislation and the agreement with the customer during the entire period of construction.

2.4.2. **Commissioning of the building upon completion of construction works**

Upon completion of the construction works for improvement of energy efficiency of the multi-family building, it is necessary to fulfill the commissioning procedure set by legislation\textsuperscript{28}.

Commissioning of the finished construction projects that belong to the 1st through 3rd categories of complexity implies registration of the declaration on the readiness of the object for operation submitted by the customer to the state architecture and construction control authority free of charge within ten working days of registration of the application.

Commissioning of the finished construction projects that belong to the 4th and the 5th categories of complexity is based on the certificate of readiness of the object to operation according to the relevant certificate issued by the state architecture and construction control authorities.

The certificate of readiness of the object to operation shall be signed by the customer, the general designer, the general contractor or the contractor (if the construction works are conducted without subcontractors), subcontractors, insurers (if the project is insured).

2.5. **PHASE 5: EVALUATION OF THE PROJECT PERFORMANCE AND FURTHER OPERATION OF THE OBJECT**

Operation of the multi-family building after the project’s implementation provides for:

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\textsuperscript{28} Article 39 of the Law of Ukraine “On Regulation of Urban Development Activities”. Available at: http://zakon4.rada.gov.ua/laws/show/3038-17/page3
3. Sources of funding of the measures for improvement of the building’s energy efficiency

- monitoring of consumption of energy resources for the purpose of evaluation of the project performance;
- implementation of the measures for operation of energy equipment and structural elements of the building.

The key indicators used for the monitoring and evaluation of the performance of the project for energy efficiency improvement of a residential building are those of the building’s annual consumption of:

- thermal energy, GCal;
- electricity, kW*hour;
- hot water, m$^3$;
- cold water, m$^3$.

It is recommended to use these indicators with the project data. It is also recommended to compare the current indicators with the baseline period indicators on the annual basis. If deviations are detected it is necessary to find out the reasons and take corrective measures in cooperation with the specialists of relevant profiles.

It is recommended to perform further operation of the multi-family building in compliance with the established Rules for Maintenance of Residential Buildings and Adjacent Areas$^{29}$. Compliance with those Rules ensures normal functioning of residential buildings through implementation of a set of measures aimed to maintain the operability of the building elements or set parameters and work modes of technical equipment.

Compliance with said rules will ensure further efficient operation of the building.

3. SOURCES OF FUNDING OF THE MEASURES FOR IMPROVEMENT OF THE BUILDING’S ENERGY EFFICIENCY

In today’s Ukraine, the following financial mechanisms$^{30}$ are used within the effective legislative framework for implementation of energy efficiency projects:

- direct investments of the co-owners including those through special funds;
- borrowed funds from banking institutions, private investors, etc.;
- co-funding from the local and/or state budget;
- agreements with other parties on funding of energy efficiency measures (for example, with a business entity that provides energy services$^{31}$);
- involvement of grant funds from international donor organizations.

These financial mechanisms may be used both separately and in combinations. It is recommended to select the specific mechanism for the project’s funding taking into account the following factors:

- financial indicators and payback period of the energy saving project;
- paying capacity of co-owners of the multi-family building;
- terms of borrowing from banking institutions, private investors, etc.;
3. Sources of funding of the measures for improvement of the building’s energy efficiency

- existence of relevant state and/or local programs for support of energy efficiency measures and the terms of co-funding (compensation of costs) under them;
- terms of the grant support of energy efficiency projects by international donor organizations.

When selecting the variants of financial mechanisms, it is recommended to give preference to the ones that envisage the minimum financial burden on the co-owners and ensure the project’s payback within the minimum time period.

3.1. FORMATION OF MONEY FUNDS IN MULTI-FAMILY BUILDINGS

Depending on the legal status (OSBB, HCC or NAABC), multi-family buildings have different possibilities to form the funds/resources for implementation of energy efficiency measures.

The costs of implementation of energy efficiency measures in a multi-family building are divided among the co-owners pro rata their co-ownership shares, unless the decision of the meeting of co-owners or legislation provide for a different procedure of division of funds.

3.1.1. Associations of co-owners of apartment buildings

For the purposes of funding of energy efficiency projects in multi-family buildings where OSBBs are established, special funds may be established in accordance with the set procedure. The funding sources for the OSBB special funds may be:

- monthly contributions of co-owners;
- single-time targeted contributions of co-owners;
- voluntary money contributions of natural persons and legal entities;
- targeted funding out of local budgets;
- targeted contributions of other legal entities;
- funds received by the association from the lease of auxiliary premises;
- other sources of funding that are not prohibited by law.

Decisions on establishment of OSBB special funds with definition of the expected sources of funding of these funds and the procedure for the use of accumulated funds are made by the general meeting of the association. These decisions are effective if at least two thirds of the total number of co-owners voted in their favor.

The monies of the special funds are kept at OSBB’s accounts at banking institutions.

3.1.2. Housing construction cooperatives

In accordance with the Model Charter of the Housing Construction Cooperative, HCCs are entitled to establish special funds for implementation of energy efficiency projects at the cost of:

- share contributions;
- contributions for capital renovation of the residential building (buildings);
- contributions for operation of the residential building (buildings);
- proceeds from the lease of non-residential premises;

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3. Sources of funding of the measures for improvement of the building’s energy efficiency

Decisions on establishment of the special funds for implementation of energy efficiency projects are passed by the HCC general meeting with definition of the sources and conditions of their formation, as well as the procedure for spending of the accumulated funds.

The general meeting of the cooperative members (meeting of authorized representatives) is recognized quorate if at least 2/3 of the total number of cooperative members (authorized representatives) are present. Decisions of the general meeting of the cooperative members (meeting of authorized representatives) are passed by at least 3/4 of the votes of the cooperative members (authorized representatives) present at the meeting.

The monies of the special fund are kept at the HCC’s account at a banking institution.

3.1.3. Multi-family buildings with non-associated co-owners

Non-associated co-owners of apartment buildings (NAABC) are also obligated in accordance with effective legislation to ensure current repair and capital renovation of the apartment building’s joint property in the case of necessity. Funding of these works including improvement of the building’s energy efficiency should be a part of the costs of management of the multi-family building. The cost of services on management of a multi-family building are defined by the agreement of the parties and specified in the contract with the manager.

Decisions on definition of the costs for management of a multi-family building including those for implementation of energy efficiency measures are made by the meeting of co-owners provided it is voted for by the owners of apartments and non-residential premises whose total area exceeds 75 percent of the total area of all apartments and non-residential premises of the multi-family building.

As multi-family buildings with non-associated co-owners are not legal entities, the funds for financing the energy efficiency measures in such buildings are accumulated at the banking accounts of individual buildings opened by the manager (company/individual entrepreneur).

3.2. ATTRACTION OF CREDITS AND BORROWED FUNDS

OSBBs and HCCs, as legal entities, are entitled to receive credits and loans for implementation of energy efficiency measures on the conditions agreed with relevant banking institutions or creditors of other categories.

As non-associated co-owners of apartment buildings are not legal entities, they cannot directly act as subjects of credit relations with banking institutions. Therefore, attraction of credits or loans for implementation of energy efficiency measures may be realized through their managing companies.

In 2015, JSC “Oschadbank” and PJSC JSB “Ukrgasbank” started crediting OSBBs and HCCs, as well as individual citizens who live in multi-family buildings for the purposes of procurement of the energy efficient equipment and/or materials. Within the State Targeted Economic Program of Energy Efficiency and Development of the Sector of Production of Energy Resources out of Renewable Energy Sources and Alternative Fuels for 2010-2016, OSBBs/HCCs are provided with financial support in the form of compensation of 40 percent of the loans for implementation of the measures (the cost of works are not taken into account) but not more than

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36 Official website of JSC “Oschadbank”. Available at: http://www.oschadbank.ua/ru/energo/
37 Official website of PJSC JSB “Ukrgasbank”. Available at: http://www.ukrgasbank.com/ukr/sme/credit/osbb/
38 Resolution of the Cabinet of Ministers of Ukraine of 01.03.2010 N 243 “On Approval of the State Targeted Economic Program of Energy Efficiency and Development of the Sector of Production of Energy Resources out of Renewable Energy Sources and Alternative Fuels for 2010-2016”. Available at: http://zakon0.rada.gov.ua/laws/show/243-2010-%D0%BF
UAH 14,000 per one apartment in a multi-family building under one loan agreement. In case of procurement of equipment and/or materials by individual citizens who live in multi-family buildings, the compensation is provided in the amount of 30% of the credit for implementation of the measure but not more than UAH 14,000 under one loan agreement.

It should be noted that the state support does not apply to all materials and equipment but only to those included in the tentative list of energy efficient equipment and/or materials that are parts (components) of the equipment and materials set by the Procedure for Use of the Funds Earmarked in the State Budget for Implementation of the Measures for Efficient Use of Energy Resources and Energy Saving approved by the Resolution of the Cabinet of Ministers of Ukraine of 17.10.2011 № 1056.

In addition, banks may issue loans to cover the cost of works on implementation of energy efficient equipment and/or materials.

At the same time, crediting of energy efficiency measures at OSBBs is provided by PJSC JSCB “Lviv” that participates in the Program of Credit Guarantees of the United State Agency for International Development (DCA USAID), which allows the commercial bank to lower the collateral requirements and extend the term of crediting. The program of unsecured crediting for OSBBs and HCCs is also offered by JSC “MetaBank”. PJSC “OKCI BANK” offers leasing of equipment for energy saving (for example, heat meters, heating units, etc.).

Positive experience of crediting for OSBB and HCC motivates other commercial banks to develop relevant crediting products, which will contribute to the expansion of the access to crediting resources for the co-owners of apartment buildings.

3.3. SUPPORT FROM THE STATE BUDGET AND LOCAL BUDGETS

State support of OSBB and HCC is provided as part of the Program of Support of Implementation of the Energy Strategy of Ukraine in the Area of Energy Efficiency and Renewable Energy Sources in accordance with the Procedure for Spending of the Funds Earmarked in the State Budget for the Measures on Efficient Use of Energy Resources and Energy Saving.

The State Budget funds envisaged by the Program are spent to motivate OSBBs and HCCs to implement energy efficiency measures by providing a compensation of the part of the loan taken for procurement of energy efficient equipment and/or materials included:

- equipment and materials for installation of individual heating units;
- heat flow regulators by weather conditions and relevant additional equipment and materials;
- metering units for water (hot and cold) and thermal energy, in particular, metering equipment (meters)

Official website of PJSC JSCB “Lviv”. Available at: http://www.banklviv.com/uk/individuals/credits/?productid=34
Official website of JSC “MetaBank”. Available at: http://www.mbank.com.ua/content/view/121/136/lang,uk/
The list is not exhaustive and may be changed according to the Government’s decision.
3. Sources of funding of the measures for improvement of the building’s energy efficiency

and corresponding additional equipment and materials;

- multi-zone (multi-tariff) electricity meters (active electricity meters) and relevant additional equipment and materials;
- translucent structures with energy saving glass including windows and balcony doors for the areas in common use (entrances, cellars, technical premises, attics, etc.) (except single-chamber) and relevant additional equipment and materials;
- equipment and materials for heat insulation (thermal modernization) of outer walls, cellars, attics, roofs and basements;
- equipment and materials for thermal modernization of internal systems of heating and hot water supply;
- equipment and materials for modernization of the systems of lighting of the areas in common use (including replacement of electric wiring, lamps and sockets, installation of automatic switches);
- pumping system of heating and/or hot water supply and relevant additional equipment and materials;
- solar heating system and/or hot water supply system and relevant additional equipment and materials;
- doors for the areas in common use (including entrances, cellars, technical premises, attics) and relevant additional equipment and materials.

Compensation of a part of the loan is a single-time payment of 40% of the loan for implementation of said measures but not more than UAH 14,000 per one apartment of the multi-family building under one loan agreement.

Local governments implement within their budgeting capacity the programs of financial support of OSBBs and motivation of energy efficiency measures in multi-family buildings that allow reducing the financial burden on the co-owners provided their participation in relevant crediting programs. In such cases, local programs may envisage not only the compensation of the interest on the loans but also co-funding for the implementation of individual energy efficiency measures. For the receipt of detailed information on such programs and the conditions of participation, it is recommended to apply to the local government authorities at the place of residence.

3.4. RECEIPT OF GRANT SUPPORT

Grant is one of the forms of funding of energy efficiency projects by international donor organizations. Grants are provided for free on a gratuitous basis as part of the grant programs for the support of implementation of energy efficiency measures in Ukraine including those in multi-family buildings for the purposes and on the conditions set by the grantor. Participation of co-owners of the multi-family building in grant programs would contribute to the reduction of the financial burden in the course of implementation of energy efficiency projects.

Today, a number of foreign and international organizations implement grant programs in Ukraine for the support in the area of energy efficiency. To obtain detailed information on specific grant programs and participation conditions, it is recommended to visit the official websites of these organizations.

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4. SELECTION OF THE WORK CONTRACTORS FOR IMPLEMENTATION OF ENERGY EFFICIENCY PROJECTS

Development and implementation of the projects for energy efficiency improvement of the multi-family building envisages implementation of an aggregate of various activities that require involvement of specialists/contractors with relevant competencies. The selection of implementers/contractors with the necessary level of qualification at all stages of the project implementation is extremely important as this is a prerequisite of the achievement of the expected result from implementation of energy efficiency measures.

Selection of implementers/contractors bears certain risks connected with their possible insufficient qualification. Such risks, however, may be minimized on condition of the compliance by the building co-owners with certain practical recommendations developed after many years of practice including international experience of development and implementation of energy efficiency projects. First of all, it is recommended to select the implementers/contractors on a competitive basis, which envisages receipt of relevant applications from several potential implementers/contractors expressing their intention to participate in the project and further comparison of their qualification characteristics and price bids.

Co-owners of the multi-family building (OSBB/HCC, NAABC) have the right to appoint the work contractors independently for each phase of the project in accordance with the procedure they have set. Considering the fact that no procedures have been set by legislation as to the competitive selection of implementers/contractors in the OSBB/HCC and NAABC buildings such procedures shall be set and approved by the meetings of co-owners. At the same time, in the cases of the use of the funds from the State Budget and local budgets on a co-funding basis it should be borne in mind that the key spending unit may establish a procedure of spending and the procedures of funding of relevant volumes of services and works are subject to the legislative requirements with regard to public procurement. In addition, it should be noted that if crediting resources are used as part of co-funding of the projects there may be certain requirements to the procedures of procurement of services and works set by creditors (banking institutions), which should be clarified in each specific case.

Organization and implementation of the projects of energy efficiency improvement of apartment buildings requires the co-owners to possess certain special knowledge including understanding of the organizational and practical aspects of the technical and energy assessment of the building, determination of thermotechnical indicators and energy saving potential, selection of the optimal technical solutions and funding models, technical design and engineering, state expert examination of the design and budget documentation (if needed), repair, construction and mounting works including relevant technical supervision of the works quality, qualified evaluation of the project implementation results, etc.

As the co-owners of apartment buildings are not always able independently to ensure organization of the all types of works at different stages of the project, it is recommended to involve qualified consultants (individuals or legal entities) at the initial phase of the project’s preparation. In this context, the most optimal is the option when this consultant undertakes the functions on management of the whole project, namely, the functions of the project manager. In this case, the project manager may be given the task to provide consulting, organizational, supervision and representative services on behalf of the co-owners in the relations with other participants of the project process. This approach allows ensuring the comprehensive approach and maximum efficiency.

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48 Law of Ukraine “On Public Procurement”. Available at: http://zakon4.rada.gov.ua/laws/show/1197-18. Detailed information on the regulatory acts in the area of public procurement can be found at the official national website “Public Procurement”. Available at: https://tender.me.gov.ua/EDZFrontOffice/menu/uk/cms_provisions_list_type1
of resolution of the project’s tasks. It is recommend to select the consultant (project manager) based on the general principles of competitive selection of the work implementers/contractors. At the same time, an extremely important factor for decision-making with regard to involvement of a particular consultant (manager) is the confidence in his/her independence upon other potential participants of the project process in order to ensure realization of the interests of the project’s customers.

4.1. PROCEDURE FOR ORGANIZATION AND CONDUCT OF THE COMPETITIVE SELECTION OF IMPLEMENTERS/CONTRACTORS FOR ALL STAGES OF THE PROJECT

At the moment, there is a sufficient number of companies and individual specialists working in Ukraine who can provide services and conduct works within the energy efficiency projects. For organization of the competitive selection of implementers/contractors, it is recommended for the people authorized by the co-owners of the multi-family building to organize the project development to:

- make a tentative list of potential implementers/contractors in accordance with the contents of the project phases. For the receipt of necessary information, it is possible to use any information opportunities including Internet resources, official directories, materials of public presentations, advertisements, recommendations of persons experienced in the implementation of energy efficiency projects, etc.;

- apply to potential implementers/contractors with the letters to invite them to participate in the competitive selection of the work contractors as part of the project of energy efficiency improvement of the multi-family building. In the invitation letters, the following should be indicated:
  - purpose of the project and general information on the multi-family building (address; year of construction; number of floors; number of entrances; number of apartments; total area, including residential, non-residential and heated area);
  - type of works, for which the implementer/contractor is searched for;
  - request to inform of the interest in participation in the project and (if answered positively) to provide information that characterizes the implementer’s/contractor’s professional experience and qualification level;
  - deadline for submission of the application for participation in the competition.

Upon receipt of the confirmation of interest to participate in the project from the invited entities, it is recommended to negotiate with potential implementers/contractors in order to determine the list of input data necessary for them to understand the tasks of the specific stages of the project and prepare relevant price bids. At the same time, it is also advisable to receive information from potential implementers/contractors that would allow assessing their qualification level, in particular:

- professional experience in the area of energy efficiency including business entity’s registration documents;

- specific examples of participation in similar projects (in writing with description of specific works or services) and provision of contact information on the customers (project site address, telephone numbers of people in charge, etc.) for the references;

- professional level of work contractors including availability of relevant qualification certificates and their roles in specific projects implemented;


If necessary or advisable, this may be done through an announcement.

For the request, it is advisable to include qualification requirements to the implementers/contractors based on the type of the planned works taking into consideration their specifics.
4. Selection of the work contractors for implementation of energy efficiency projects

- technical equipment, availability of necessary instruments, devices and equipment;
- vision as to possible optimal proposals in their opinion (drawings, methodology, estimations, etc.) with regard to the objectives of the project’s specific phase.

Additional information on the candidates’ qualification characteristics can also be obtained from media publications including Internet resources that cover market development, as well as interviews with previous customers or independent experts that have professional experience in the sector.

It is recommended to conduct the competitive selection (tender) of implementers/contractors on the basis of the comprehensive analysis and evaluation of price bids and data collected from the candidates as to their professional capabilities. It is also advisable to give preference to the candidates that provided the best professionally substantiated proposals for achievement of the project’s objectives.

In addition, it is also recommended when taking the decision to forecast possible risks connected with the activities of the potential implementer/contractor. Such risks may arise if the implementers/contractors use poor-quality materials, equipment with improper parameters or technical characteristics, violate technological processes, fail to comply with agreed terms of works, etc. The errors or mistakes in selection of implementers/contractors result in the failure to achieve expected savings, excess over the project budget, impossibility to payback the project within optimal time period, etc.

For minimization of said risks, it is recommended to include relevant provisions into the agreements with regard to the liability of implementers/contractors as a security in the event of their departure from the terms and conditions of the agreement, as well as to ensure proper control by the customer over their activities at all stages of the project implementation.

4.2. INVOLVEMENT OF ENERGY SERVICE COMPANIES INTO THE PROJECTS

During the last twenty years, there appeared specific business entities in Ukraine that specialize in the development and implementation of energy efficiency projects. They are commonly called “Energy Service Companies” (hereinafter also – ESCO). Some of such companies have already acquired certain positive experience in the course of implementation of the projects in the industry, municipal infrastructure, public sector and housing.

According to the commonly accepted definition ‘energy service company’ (ESCO): a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user’s facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria.

In case of involvement of ESCO in the development and implementation of the energy efficiency project, the list of said issues is not exhaustive and is not limited to the possibility to obtain other information from the candidates, which is necessary to involve the implementer/contractor. At the same time, one should understand that different requirements are set to the provider of each specific type of services or works. Ukrainian legislation defines the concept of “energy service” as a set of technical and organizational energy saving (energy efficiency) and other measures aimed to the reduction of energy consumption and/or costs for the fuel and energy resources and/or housing and utility services by the consumer of energy services in comparison with the consumption (costs) in the absence of such measures – Law of Ukraine “On Introduction of New Investment Opportunities, Guarantee of the Rights and Lawful Interests of Business Entities for the Purpose of the Large-Scale Energy Modernization”.

Available at: http://zakon5.rada.gov.ua/laws/show/327-19


Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0032
information on such companies may be received from publications including Internet resources, presentations, etc. In this case, selection of a specific ESCO as an implementer/contractor for the services (energy service) should be made in accordance with the above selection procedure.

As a rule, ESCOs offer energy services that may include development and implementation of energy saving projects including turnkey projects. A typical list of ESCO services provides for the following:

- energy assessment (energy audit) of the property;
- development and provision of recommendations for the set of optimal measures on energy efficiency improvement, as well as their technical and economic feasibility;
- providing or securing financial and investment management (in particular, optimization of the sources and conditions of funding, as well as efficient use of financial resources, etc.);
- management of financial and technical risks connected with implementation of energy saving measures;
- engineering (of implementation), mounting, integration of energy saving systems and supervision of implementation of energy saving measures;
- supply and assembly of equipment;
- technical maintenance of equipment or operation of the property as a whole, other activities.

According to the established practice ESCO services represent a unified set of measures paid by the customer out of the economy (saving) of energy resources and funds that were spent for their purchase. ESCO guarantees that such savings will be achieved and the costs for energy consumption upon implementation of energy saving measures will not exceed the preliminarily set figures. Therefore, the customers bear insignificant technical risks.

In the cases when the customer independently resolves the issues of funding of the project, ESCO may be involved based on the works contract for the provision of a set of services and works on the “turnkey” energy efficiency improvement of the multi-family building.

At the same time, the most common practice of ESCO involvement is that in the form of the energy service contract (ESC) where the models/options are determined depending on the project’s specifics and terms of funding. In particular, in some cases ESCO may participate in the project with its own financial resources or those involved by ESCO itself.

5. ENTRY INTO AGREEMENTS

In the course of development and implementation of the project of energy efficiency improvement of the multi-family building, a necessity arises to enter into commercial agreements. Depending upon the project implementation model selected by the customer, it is possible to apply the following types of civil and commercial agreements:

- services agreement;
- works contract;
- agreement of supply of goods/equipment;
- energy service contract.

Preparation and entry into agreements requires special expertise. Therefore, it is recommended to the

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The common term in the international legislation is “Energy Service Contract”. Available at: http://zakon0.rada.gov.ua/laws/show/435-15/page14

The “Warm House” website. Available at: http://tepdydim.com.ua/uk/energy_saving_technologies/companies_working_in_the_area_of_energy_conservation

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customers to invite qualified lawyers for that purpose in accordance with the proposed methodology for selection of implementers/contractors.

5.1. SERVICES AGREEMENT

Services agreements are entered into by the customer in case of necessity to receive information and professional consultations in legal, financial, marketing, technical and other issues, performance of energy audits, provision of engineering services, technical supervision of the construction and assembly works, etc. Such agreements are entered into in compliance with the requirements of the Civil Code of Ukraine.

A services agreement is executed in writing and should provide for the following terms and conditions:

- names and details of the parties;
- subject of the agreement - description of the services to be rendered;
- conditions of payment for services (amount, terms and procedures of payment);
- term of the agreement (in addition to the dates of the beginning and end of the service delivery, the agreement may provide for interim terms and if they are violated the contractor may be held liable);
- a possibility for the contractor to transfer the obligation under the agreement to a third party in case of necessity with the preservation of the customer’s full responsibility for the breach of the agreement;
- liabilities of the parties for non-fulfillment or improper fulfillment of the agreement;
- terms of early termination of the agreement (including that in case of the unilateral withdrawal of either party). It is important to remember that in case of the contractor’s unilateral withdrawal from the paid agreement the latter shall compensate all damages to the customer.

The price of the services agreement is set by the agreement of the parties. The customer is recommended to perform a preliminary study and analysis of price offers on the market of similar services.

5.2. WORKS CONTRACT

Works contracts are entered into by the customers with implementers/contractors for the design and survey and construction works. Since these types of works cover individual phases of the project and provide for a possibility to involve different contractors, it is recommended to enter such contracts separately – one contract for design and survey works and one contract for construction works. At the same time, it is probable that a potential contractor may offer a set of design and construction works. Therefore, the customer has to decide upon an optimal way to conduct the works. Considering that construction works may be diverse there may be one contractor (general contractor) appointed with the right to involve other entities on a subcontract basis or the customer may enter into separate contracts with each performer of relevant works.

It is recommended to perform execution (preparation) of works contracts for the design and survey works and construction works in accordance with the requirements set by the Civil Code of Ukraine, taking into account the specifics envisaged by the Economic Code of Ukraine, General Conditions for Conclusion and Execution of Works Contracts for Capital Construction and other legislative acts.

58 Articles 901-907 of the Civil Code of Ukraine. Available at: http://zakon0.rada.gov.ua/laws/show/435-15/page14
59 Articles 875-891 of the Civil Code of Ukraine. Available at: http://zakon0.rada.gov.ua/laws/show/435-15/page14
60 Articles 179-188 of the Economic Code of Ukraine. Available at: http://zakon5.rada.gov.ua/laws/show/436-15/page6
61 Resolution of the Cabinet of Ministers of Ukraine of 01.08.2005 N 668 “On Approval of the General Conditions for Conclusion and Execution of Works Contracts for Capital Construction”. Available at: http://zakon5.rada.gov.ua/laws/show/668-2005-%D0%BF
A works contract is entered into in writing and provides for the following material terms and conditions:

- names and details of the parties;
- place and date of execution of the works contract;
- subject matter of the works contract;
- contractual price;
- dates of the beginning and completion of the works (development of the design and budget documentation or construction);
- rights and obligation of the parties;
- procedure for securing the performance of obligations under the works contract;
- conditions for insurance of the risks of accidental destruction or damage of the construction object;
- procedure for provision of design documentation, resources and services;
- procedure for involvement of subcontractors;
- requirements to organization of the works;
- procedure for the customer’s control of the quality of resources;
- conditions for the design and technical supervision over the works;
- sources and procedure for funding of the works (design/construction);
- procedure of settlements for the works performed;
- procedure for transfer and acceptance of the completed works (construction object);
- warranty periods for the quality of finished works (operation of the construction object) and procedure for elimination of defects;
- liabilities of the parties for the breach of the terms of the works contract;
- procedure for regulation of disputes;
- procedure for amendment or termination of the works contract.

In the works contract, the parties may provide for other terms and conditions that are essential for regulation of their relations.

If necessary, the parties may use the Model Works Contract for capital construction\(^\text{62}\).

The contractual price is set in the works contract on the basis of the estimated budget\(^\text{63}\) as a tentative or fixed price. The contractual price is deemed fixed, unless otherwise stipulated by the contract.

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\(^{63}\) According to Sub-clause 3 of Clause 4 of Article 31 of the Law of Ukraine “On Regulation of Urban Development Activities” the estimated budget as a part of the design documentation is subject to expert examination on condition of implementation of the project with the estimated budget over UAH 300,000 using budget funds, monies of state-owned and municipal companies, institutions and organizations, as well as the loans issued against state guarantees. Available at: http://zakon2.rada.gov.ua/laws/show/3038-17/page2
5.3. AGREEMENT FOR SUPPLY OF GOODS/EQUIPMENT

Supply agreements are concluded by the customer if it is necessary to purchase goods or equipment provided the co-owners pass a decision at the general meeting to do this by themselves with the subsequent transfer thereof to the implementers of relevant works. Under the supply agreement, one part (the supplier) undertakes to transfer (supply) the goods to the other party (the buyer) within the agreed terms and the buyer undertakes to accept those goods and pay a certain amount of money for them.

The issues pertinent to the entry into the supply agreement are regulated by the Civil Code of Ukraine and the Economic Code of Ukraine.

Supply agreements are concluded in writing and provide for the following material terms and conditions:

- names and details of the parties;
- subject, quantity and mix of the supply;
- terms of payment for the goods/equipment supplied (amount, dates and procedure of payment);
- terms and procedure of delivery;
- quality of goods/equipment supplied;
- guarantee of the quality of goods/equipment; claims in connection with the defects of the goods/equipment supplied;
- completeness of goods/equipment supplied;
- liabilities of the parties for non-fulfillment or improper fulfillment of the agreement.

In the agreement, the price is set by the consent of the parties. At the same time, it is recommended to the customer to perform monitoring of price offers and terms of supply of similar goods/equipment from different suppliers when deciding on the procurement of goods/equipment in order to select the most favorable option.

5.4. SPECIFICS OF ENERGY SERVICE CONTRACTS

ESC is an agreement where the subject matter is the provision of energy service by the contractor, which is paid by the funds resulting from the reduction of consumption and/or costs for the fuel and energy resources and/or housing and utility services compared to the consumption (costs) in the absence of such measures.

A variant of ESC is “Energy Performance Contract” (EPC) – a contract between a beneficiary and an implementer of energy efficiency improvement, which is verified and observed throughout the entire term of the agreement, and investments (works, supplies or services) into such measures are compensated depending upon the level of improvement of energy efficiency specified in the contract or a different category of energy performance, such as, financial savings.

In the international practice, a number of EPC models have been developed with the most common being:

- Guaranteed Savings Contract – GSC;
- Shared Savings Contract – SSC;

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64 Articles 655-697 of the Civil Code of Ukraine. Available at: http://zakon2.rada.gov.ua/laws/show/435-15/page11
65 Articles 265-271 of the Economic Code of Ukraine. Available at: http://zakon0.rada.gov.ua/laws/show/436-15/page8
Energy performance contract with guaranteed return of investment - FOC (First Out Contract);

Energy performance contract for supply of energy resources and energy management (Chauffage Contract);

Full Management Contract.

Each of the above models has its specifics as to the organization and implementation of energy efficiency projects, as well as funding terms and settlements with energy service providers. Therefore, when the customer receives offers from ESCO to enter into EPC it is recommended to analyze the terms of the contract involving a lawyer of the proper qualification in order to exclude or minimize possible risks in the course of the project implementation.

Effective legislation of Ukraine defines the material terms and conditions of the energy service contracts for the public procurement of energy service. It is recommended, however, to take them into consideration also in the course of drafting the contracts under the projects of energy efficiency improvement of apartment buildings as they are of general nature and may be used in business relations that are not subject to the provisions of public procurement law.

5.4.1. Minimum components (requirements) to be contained in energy service contracts

In the course of drafting of energy service contracts, it is recommended to consider the experience of European countries in this area, which is enshrined in relevant regulatory acts pertinent to energy efficiency.

In particular, energy service contracts implemented in the public sector of European countries and other related documents should contain the following components (requirements):

- a clear and transparent (precise) list of measures for improvement of energy efficiency to be implemented and/or effect of their implementation;
- guaranteed savings to be achieved through the implementation of the contractual measures;
- duration and phases of the contract, terms and periods of reporting;
- a clear and transparent list of obligations of each party;
- references to specific terms for achievement of the savings;
- a clear and transparent (precise) list of step-by-step implementation (accomplishment) of the measure or sets of measures and related costs;
- obligations to fully implement the measures defined in the contract and other accompanying documents with the view of all changes entered in the course of the project;
- the rules that regulate inclusion of relevant requirements into any sub-contracts with third parties;
- clear and transparent reflection of financial implications of the project and shares of both parties in the achieved money savings (including the service provider’s fee);
- clear and transparent procedure for measuring and verification of the guaranteed savings under the contract.

Details of the content and specifics of the above EPC models can be found in the publication “Energy Service Contracts: Opportunities and Prospects in Ukraine”. Available at: http://eeau.org.ua/en/files/publications/

Article 5 Law of Ukraine “On Introduction of New Investment Opportunities, Guarantee of the Rights and Lawful Interests of Business Entities for the Purpose of the Large-Scale Energy Modernization”.

Available at: http://zakon5.rada.gov.ua/laws/show/327-19


contract, procedure of quality control and guarantee;

provisions that explain the procedures connected with the changes of market conditions that influence the contract’s content and results (that is, changes of energy prices, intensity of use of equipment);

detailed information on the obligations of each party and their liabilities for breach thereof.

5.4.2. Conditions that ensure achievement of economic effect from implementation of energy service contracts

A key issue of the energy service contract is **assessment of the saving of energy and funds**. For relevant calculations, the methodology is used based on the comparison with the baseline consumption of energy resources, which allows obtaining quantitative indicators of consumption of energy resources in physical terms (GCal, kWh*hour) before implementation of energy efficiency measures and then calculate the financial effect of their implementation.

As a rule, the baseline indicators are taken from the per-building heat and electricity meters. At the same time, in the absence of per-building heat metering equipment (as stated above) the heat consumption volume is determined by means of calculation.

Effective legislation defined the baseline consumption of the fuel and energy resources, as well as housing and utility services as the averaged volume of annual consumption of the fuel and energy resources and the housing and utility services (in physical terms) by the customer’s property, for which energy service is procured with the indication of the volumes of consumption of each type of the fuel and energy resources and the housing and utility services for the three years that precede the year, in which energy service is procured for public funds.71

At the same time, if during the period, for which the consumption of the fuel and energy resources, as well as housing and utility services is calculated at the site, for which energy service is procured the customer or the procurement procedure participant detects non-compliance with the air temperature requirements, level of lighting or other building maintenance requirements set in accordance with sanitary regulations in the area of workplace management, maintenance of buildings, structures, the baseline level is determined in accordance with the methodology approved central executive authority that ensures formation of the state policy in the area of use of the fuel and energy resources, energy saving, renewable energy sources and alternative fuels.72

The above circumstances become probable when a multi-family building was, for example, underheated, that is, when the standard projected indicators of microclimate in the premises was not complied with due to the supply (for various reasons) of less thermal energy. In this case, the customer has to understand that there are two tasks that are being simultaneously resolved in the course of implementation of the energy efficiency project at such a site: achievement of the projected standard indicators of microclimate in the premises and reduction of energy consumption. These indicators may have a significant impact on the estimated indicators of economic effect and the project’s payback.

At the same time, it is recommended when determining the baseline to use not only the readings of meters for three previous years but also other factors that influenced the volume of consumption of energy resources during that period (specifics of the building’s operation, natural and climatic fluctuations, etc.) In addition, as the parties calculate the economic effect of the project’s implementation they have to forecast and take into consideration possible changes of the energy consumption mode in the future. This would allow making the calculations more accurate, which is very important for estimation of financial and economic indicators for the whole project.

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72 Sub-clause 1 of Clause 1 of Article 3 of the above Law.
If the selected EPC model provides for the long-term cooperation with ESCO (for instance, the Shared Savings Contract or the Full Management Contract) it is recommended also to set in the energy service contract the level of reduction of the consumption and/or costs of payment for relevant fuel and energy resources and/or housing and utility services to be achieved as a result of implementation of energy service for each year when the energy service contract is in effect.

In order to achieve the expected result from implementation of energy efficiency measures, it is also recommended to set in the energy service contract the conditions for the parties' compliance with the agreed and/or statutory mode and conditions of the use of the fuel and energy resources and/or housing and utility services in the course of the contract execution (including the air temperature regime, artificial lighting and other characteristics that comply with regulatory requirements in the area of maintenance of apartment buildings).

In some cases, circumstances may arise that make it impossible for the grounds beyond the parties' control to ensure the agreed regime and conditions for the consumption of the fuel and energy resources and/or housing and utility services. Therefore, it is recommended in such situations to set the procedure for calculation of the energy service result in the contract.

An extremely important element of the energy service contract, which is recommended to be taken into account, is the definition of the procedure and methods for measuring (calculation) and verification of the actual level of reduction of the consumption and/or the customer’s costs for payment for the fuel and energy resources and/or housing and utility services as a result of implementation of energy efficiency measures in comparison with the consumption and/or costs during the periods before the project.

For the correct assessment of the project results and prevention of possible disputes in the future, it is extremely important for the parties to define in the contract and agree upon the specific indicators to be used as the basis for calculation of economic effect:

- actual energy consumption or estimated consumption of energy resources in accordance with design standards;
- saving of the fuel and energy resources in physical terms or financial economy in money terms.

5.4.3. Price of the energy service contract

The methodology for setting the price of the energy service contract may depend upon the terms of funding of the project and the EPC model selected by the customer in accordance therewith.

In particular, if the customer develops and implements the energy efficiency project for its own funds the model that is most commonly used in such cases is the Guaranteed Savings Contract.

This model provides for a possibility to involve ESCO as the general contractor to implement the agreed set of measures (services/works) that guarantee the reduction of the customer’s energy consumption (in physical terms) up to the optimal level\(^73\). In such a case, ESCO undertakes all technical risks with regard to the project’s development and implementation and the customer bears all financial risks including credit risks connected with the compensation of borrowed funds.

Under this model, the cost of the energy service contract is set on the basis of the project’s estimated budget consisting of the costs for implementation of its relevant phases and activities. The contract price may also include the customer’s costs approved in the course of the preparation of the contract with regard to ESCO’s premium in case of the excess over the guaranteed saving of energy resources. In addition, the cost of

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73 The optimal level of energy consumption is determined based on the results of the technical and economic feasibility study for the measures for improvement of energy efficiency of the building.
the project may include additional costs for proper verification of the efficiency of the measures implemented.

If the energy efficiency project is funded by ESCO or financial resources mobilized by ESCO the customer may be offered other EPC models that envisage long-term cooperation of the parties within the investment payback period (for instance, Shared Savings Contract, First Out Contract or Full Management Contract).

In this case, the price of the energy service contract may be equal to the sum of the reduction of the customer’s consumption of relevant fuel and energy resources and/or housing and utility services to be ensured by ESCO for the entire duration of the energy service contract, as well as relevant prices (tariffs) that were effective as of the date of announcement on the application of the energy service procurement procedure. Herewith, the contract price should include the fixed percentage of the reduction of the customer’s costs for payment of relevant fuel and energy resources and/or housing and utility services due to the energy service provider.

The reduction of the energy service customer’s costs is the difference between the baseline consumption of the fuel and energy resources and housing and utility services and the actual consumption of the fuel and energy resources and housing and utility services multiplied by the prices (tariffs) for the fuel and energy resources and housing and utility services effective during the period under calculation\(^74\).

5.4.4. Terms of settlements (payments) under the energy service contract

In the course of the reconciliation by the parties of the terms and conditions of settlements (payments) under the energy service contracts, it is recommended for the customers to take into consideration the organizational specifics of implementation of the energy efficiency projects and selected EPC models.

If ESCO is involved to participate in the project as a general contractor (EPC model – Guaranteed Savings Contract) the payment for the works done may be made after the customer’s acceptance of the completed works (construction project) or phase-by-phase with interim payments as the works are being delivered and confirmed by relevant completion certificates. In addition, the parties may provide for the customer’s advance payment and set the procedure for its use in the contract. Final settlement may envisage additional reward to the ESCO based on the final assessment of the economic effect achieved by the project.

If the actual level of reduction of consumption and/or costs for relevant fuel and energy resources and/or housing and utility services as a result of the energy service does not comply with the terms and conditions of the energy service contract through the ESCO’s fault the energy service provider is obligated to:

- eliminate the defects and/or implement additional energy service measures to ensure the compliance with the conditions of the energy service contract;
- compensate the difference between the actual reduction of consumption and/or costs for relevant fuel and energy resources and/or housing and utility services and the level of reduction calculated on the basis of the provisions of the energy service contract.

If under the EPC model the funding of the project was provided by ESCO out of its own or borrowed resources the terms of settlement may provide for the division of payments within the project’s payback period. Herewith, the settlements under the energy service contract are made at the cost of the reduction of the customer’s costs compared with the costs that would be incurred in the absence of the energy service for the payment for the fuel and energy resources and/or housing and utility services for the relevant period based on the prices (tariffs) that were effective during the period under calculation.

It should be noted that in case of the use of the Shared Savings Contract model the contract may additionally...
5. Entry into agreements

envisage the division of the saved funds received as a result of implementation of energy efficiency measures between the customer and the contractor. Similarly, the payments may be made under the Full Management Contract model. At the same time, the First Out Contract model makes it possible for ESCO to retain 100% of the revenues received from implementation of the project until the full payback of the investment (including settlements on the credits, loans or other forms of funding) and achievement of the projected level of return: the larger the saving, the shorter the project’s payback period.

In case of the early termination of the energy service contract concluded under either of the last three models by the customer’s initiative the latter shall pay the unpaid part of the price of the energy service contract to the contractor provided the latter (ESCO) did not breach its obligations under the energy service contract.

5.4.5. Ownership right to the property created (installed) in the course of the project’s implementation

Upon expiration of the term of the energy service contract, the customer acquires the ownership right without any additional payment for all property created (installed) under the energy service contract.

At the same time, there may be situations in some cases when some property (equipment) could be created or purchased (installed) at the ESCO’s cost as part of the project, which was not envisaged by the design and budget documentation. In order to regulate the issues of the ownership right to such property (equipment), it is recommended to set the terms of its transfer to the customer in the contract. In particular, the contract may provide for the customer’s right to buy out the property (equipment) from the contractor at the residual value after a certain period of operation.

5.4.6. Term of the contract

The term of the contract is determined depending upon the model selected by the customer for implementation of energy efficiency measures. In particular, if the project is implemented under the Guaranteed Savings Contract model the term of the contract is limited to the period until the completion of a specific phase of works involving ESCO.

In the cases when the models of Shared Savings Contract, First Out Contract or Full Management Contract are selected, there may be an indication that the contract expires earlier than its completion date in case of the compensation of the project price (cost). That is, the energy service contract is terminated ahead of its term if the aggregate amount of payments made under the energy service contract to the contractor reaches the price of the energy service contract.

In the European practice, a typical distribution of the future money savings may be 85% for ESCO and 15% for the customer.
6. Annex 1. Table of measures as part of preparation and implementation of the project of energy efficiency improvement of the multi-family building

<table>
<thead>
<tr>
<th>#</th>
<th>Phase/Measure</th>
<th>Purpose</th>
<th>Implementer</th>
<th>Documentary formalization of the result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparatory</td>
<td></td>
<td></td>
<td>Presentation materials with the calculation of the possible reduction of consumption of energy resources and saving of funds, as well as the approximate cost and payback period of the project.</td>
</tr>
<tr>
<td>1.1</td>
<td>Preliminary assessment of the energy saving potential</td>
<td>Calculation of the approximate possible reduction of the consumption of energy resources and saving of funds</td>
<td>Co-owners</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Preliminary assessment of the cost of energy saving measures</td>
<td>Calculation of the approximate cost and payback period of the project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>Study of the options of possible funding of the project</td>
<td>Preliminary determination of the sources and conditions of funding of the project</td>
<td>Co-owners</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>Presentation of justification of feasibility of the project implementation at the general meeting</td>
<td>Informing co-owners of the project’s advantages</td>
<td>Co-owners</td>
<td>Minutes with the resolution of the general meeting on implementation of the project including: appointment and authorization of people in charge; preliminary definition of the sources and conditions of funding; procedure of selection of the service and work contractors; procedure of reporting on the status of implementation of the project.</td>
</tr>
<tr>
<td>2</td>
<td>Pre-project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Selection of the works/services contractors</td>
<td>Ensuring quality of services/works</td>
<td>Co-owners</td>
<td>Minutes with the resolution of the authorized body of co-owners/owner on appointment of contractors. Entry into agreements with works/services contractors.</td>
</tr>
<tr>
<td>2.2</td>
<td>Assessment of technical condition of the structures and engineering systems</td>
<td>Assessment of the building’s technical condition</td>
<td>Certified specialists</td>
<td>Report on the building’s technical condition.</td>
</tr>
<tr>
<td>2.3</td>
<td>Energy audit</td>
<td>Study of the building’s energy characteristics</td>
<td>Certified specialists</td>
<td>Report of energy audit.</td>
</tr>
<tr>
<td>2.4</td>
<td>Development of the TEF for measures (investment TEF)</td>
<td>Making an optimal list of measures and technical solutions, tentative cost of the project</td>
<td>Certified specialists</td>
<td>TEF of measures (investment TEF).</td>
</tr>
<tr>
<td>2.5</td>
<td>Preparation of the technical design assignment</td>
<td>Setting the framework conditions and requirements to the design solutions</td>
<td>Certified specialists</td>
<td>Technical design assignment.</td>
</tr>
<tr>
<td>3</td>
<td>Development of design documentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Selection of contractors for development of the design documentation</td>
<td>Ensuring quality of the works</td>
<td>Co-owners</td>
<td>Minutes with the resolution of the authorized body of co-owners/owner on appointment of the contractors for development of design documentation. Entry into agreements with developers of design documentation.</td>
</tr>
<tr>
<td>№</td>
<td>Phase/Measure</td>
<td>Purpose</td>
<td>Implementer</td>
<td>Documentary formalization of the result</td>
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<td>----</td>
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<td>-------------------------------------------------------------------------</td>
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<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3.2</td>
<td>Development of design documentation</td>
<td>Documentary formalization of technical decisions passed with the description of the volumes and estimated costs of works, sequence of works and terms of fulfillment, as well as graphical formalization of technical solutions</td>
<td>Certified specialists</td>
<td>Design documentation with the conclusions of the state expert examination.</td>
</tr>
<tr>
<td>4</td>
<td>Implementation of construction works</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Selection of contractors for construction works, suppliers of equipment and materials</td>
<td>Ensuring quality of the works</td>
<td>Co-owners</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Implementation of construction works</td>
<td>Implementation of design solutions</td>
<td>Certified specialists</td>
<td>Executive documentation, work completion certificates.</td>
</tr>
<tr>
<td>4.3</td>
<td>Technical and design supervision of the construction works</td>
<td>Control of implementation of design solutions and quality of work</td>
<td>Certified specialists</td>
<td>Marks in the executive documentation, reports (if violations are found).</td>
</tr>
<tr>
<td>4.4</td>
<td>Commissioning of the building</td>
<td>Certification of the compliance of the completed construction works with the design solutions and legislative requirements</td>
<td>Co-owners (authorized person)</td>
<td>Operational readiness certificate. Declaration on the operational readiness of the property of the 1st through 3rd categories of complexity. Certificate of the compliance of the completed construction project of the 4th and 5th categories of complexity to the design documentation and confirming its operational readiness.</td>
</tr>
<tr>
<td>5</td>
<td>Operation of the building during the post-project period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>Monitoring of consumption of energy resources</td>
<td>Setting the indicators of actual consumption of energy resources</td>
<td>Co-owners</td>
<td>Reports on the indicators of consumption of energy resources by relevant metering equipment.</td>
</tr>
<tr>
<td>5.2</td>
<td>Evaluation of the project results (achieved energy efficiency)</td>
<td>Comparison of the indicators of actual consumption of energy resources with the project targets</td>
<td>Co-owners</td>
<td>Report (if inconsistencies are found).</td>
</tr>
<tr>
<td>5.3</td>
<td>Current maintenance of the building</td>
<td>Ensuring proper operation of the building</td>
<td>Certified specialists</td>
<td>Work completion certificates.</td>
</tr>
</tbody>
</table>

Source: Authors

Table 4. Measures of energy efficiency improvement of apartment buildings
7. ANNEX 2. AN EXAMPLE OF SIMPLIFIED CALCULATION OF TENTATIVE HEAT CONSUMPTION BY A RESIDENTIAL BUILDING AFTER THERMAL MODERNIZATION

The below example of calculation for a residential building in the city of Chernivtsi may be used for estimation of specific input of thermal energy for heating at a preliminary stage of an energy efficiency improvement project in a building.

For the calculation, the following indicators are used: reduced heat transfer resistance of the building envelope characterizing the existing building before thermal modernization and similar indicators expected to be achieved after the thermal modernization.

The calculation methodology used in this example is based on the methodologies approved by effective regulatory acts of Ukraine. The main idea of the simplified methodology is to estimate the volume of thermal energy necessary to maintain the standard indicators of temperature in the premises taking into consideration the heat losses (through the building envelope, ventilation and heating systems including heating equipment, distribution systems, pipelines, risers, etc., as well as the heating unit equipment), as well as considering additional heat gains into the building from solar radiation and humans, equipment, household appliances and lighting in the building.

The purpose of the simplified calculation is to determine the estimated volume of saving of the thermal energy needed to heat the building in compliance with the sanitary and hygienic standards before the thermal modernization ($Q_{before}$) and afterwards ($Q_{after}$). Correlation of said indicators allows finding the coefficient of the conventional reduction of the heat consumption as a result of thermal modernization, which is calculated based on the formula $f = Q_{after} / Q_{before}$. The projected minimum consumption of thermal energy for heating of the building after the thermal modernization is a product of the volume of actual consumption of heat before the thermal modernization ($Q_{before}$) measured by the meter of based on the data of the heating service supplier and the conventional reduction coefficient ($f$) according to the formula: $Q_{after} = Q_{before} \cdot f$.

The actual volume of heat consumption after the thermal modernization is within the range of $Q_{after}$ and $Q_{after}^2$. That is, minimum consumption of heat will correspond to $Q_{after}^2$, and maximum - $Q_{after}$. In practice, it is recommended to use the arithmetic average of the two for the purposes of calculation of economic indicators.

At further stages, more specific calculations (as the error may reach 10%) requires involving specialist: energy auditors, certified experts in evaluation of technical conditions, designers. The complete example of the calculation is contained in DSTU B (National Standard of Ukraine) A.2.2-12: 2015

7.1. GENERAL INFORMATION

Project: a five-storied residential building in the city of Chernivtsi located in the 2nd Temperature Zone (Annex “B” to DBN (Building Standard) B.2.6-31:2006). The building is a rectangular in shape with the dimensions of 13,5x38,0 m, with a basement and an attic. Total height of the building: 20 m. The building has two entrances with stair wells.

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76 DSTU B A.2.2-12:2015 “Energy Efficiency of Buildings. The method for calculation of energy consumption for heating, cooling, ventilation, lighting and hot water supply”.

Methodological Recommendations for Co-Owners of Apartment Buildings: Development of Energy Efficiency Projects
7.2. TYPE AND STRUCTURAL SOLUTIONS OF THE BUILDING

A stand-alone residential building.
Basement floor: prefabricated reinforced concrete structures.
Wall panel of red bricks: 380 mm.
Roof: false hip.
Attic floor: prefabricated reinforced concrete structures with the slag layer.
The attic and the technical cellar are not heated.
The translucent structures (windows, balcony doors) are double-glazed in wooden double frames.

Heating system:
- hot water heating with the connection to the district heating system;
- one-pipe vertical system with the bottom distribution and without automatic balancing at the risers;
- pipes in the cellar are not insulated;
- weather regulation in the heating unit is missing;
- heating equipment (radiators) is not equipped with heat regulators.

7.3. GEOMETRIC PARAMETERS OF THE BUILDING

Data on the areas of building envelope, heated area, area of residential premises and kitchens, heated volume, as well as geometric shape of the building and its orientation with respect to the cardinal directions that are necessary for the calculations are determined on the basis of the design documentation, which should be kept at the housing maintenance office or local architecture authority, or (if the design documentation is unavailable) the building’s technical data sheet, which should be kept at a local technical inventory bureau, or measured by the project’s initiators and entered into Table 5 of Annex 4.

Key spatial planning indicators:
- **Air-conditioned (heated) area of the building** – \( F_h = 2,370 \text{ m}^2 \). The air-conditioned area is determined based on the internal overall dimensions of the building envelope including the area of internal walls and partitions that divide the premises within the air-conditioned (heated) volume;
- **Air-conditioned (heated) volume of the building** – \( V_h = 7,110 \text{ m}^3 \) is calculated as a product of the floor’s heated area and the internal height measured from the floor surface to the ceiling of the last floor;
- **Total area of the building envelope** – \( F_{\Sigma} = 2,211 \text{ m}^2 \) is determined by the building’s internal dimensions including the attic and cellar areas;
- **Total area of external non-transparent walls** – \( F_{nt} = 627 \text{ m}^2 \) (without window and door openings) is the product of the perimeter of outer walls inside and the internal height of the building measured from the floor surface to the ceiling of the last floor including the areas of window and door jambs from the inner wall surface to the inner surface of the window or door casement. The aggregate area of windows is calculated based on the dimensions of window openings. The area of outer walls (non-transparent part) is estimated as the difference between the total area of outer walls and the area of windows and outer doors;
- **Total area of windows** – \( F_{tw} = 864 \text{ m}^2 \) including each of the façades (South, North, West, East): area of windows at the North façade – \( F_n = 432 \text{ m}^2 \), area of windows at the South façade – \( F_s = 432 \text{ m}^2 \). At the two other facades, there are no windows;
7. Annex 2. An example of simplified calculation of tentative heat consumption by a residential building after thermal modernization

- Total area of entrance (outer) doors – F_d = 9 m²;
- Total area of the unheated attic floor – F_ow = 474 m². The area of horizontal elements of the envelope (roofing, attic and basement floor) is estimated as the area of the building surface (within the internal surfaces of outer walls). For the inclined surface of the ceiling at the top floor, the area of the attic floor is estimated as the area of internal surface of the ceiling;
- Total area of the floor over the technical crawl space – F_c1 = 237 m² (the cellar is under a part of the building).

7.4. INPUT DATA FOR CALCULATIONS

Heat insulation of the building is achieved due to increase of the heat transfer resistance of the building envelope. Its indicators R_{refor} and R_{after} are shown in Table 5 of the Annex.

The heat transfer resistance indicators of the outer walls, attic and basement floors of the building before the thermal modernization (R_{before}) are calculated (as show below) and similar indicators for windows, balcony doors and entrance doors are based on the results of experimental research of the Institute of Technical Thermal Physics of the National Academy of Sciences of Ukraine (said indicators are applied to the windows and balcony doors of all types of residential buildings of the past years).

Thus, the heat transfer resistance of outer walls (R_{ow}) is – 0,65 m²K/W (R_{ow} = \frac{d}{\lambda_p} = \frac{0,38}{0,22} = 0,65 m²K/W, where d= 0,38 m wall thickness, and \lambda_p = 0,58 W/(m·K) - heat conductivity of the bricks is determined according to the Table Л1 DBN B.2.6-31: 200677.

The heat transfer resistance of the attic (R_{af}) and basement floors (R_{bf}) is calculated using the same formula but taking into account the multiple layers of these floors that have different thickness and heat transfer coefficients.

In particular, for the attic floor (R_{af}) – 0,8 m²K/W; It is calculated based on the fact that the thickness of the reinforced concrete slab is 0,22 м, the concrete heat conductivity \lambda_p = 2,04 W/(m·K), and 130 mm of the slag layer \lambda_p = 0,19 W/(m·K) (DBN B.2.6-31:2006 Table Л11).

Heat transfer resistance R_{af} = \sum \frac{d}{\lambda_p} = \frac{0,22}{2,04}+0,130/0,19 = 0,8 m²K/W

For the floor over basement (R_{bf}) – 1,46 m²K/W; It is calculated on the basis of the fact that the thickness of the reinforced concrete slab is 0,22 м, the concrete heat conductivity \lambda_p = 2,04 W/(m·K), 50 mm foam polystyrene \lambda_p = 0,045 W/(m·K), 50 mm of concrete and sand \lambda_p = 0,81 W/(m·K) over the sand layer of 110 mm \lambda_p = 0,58 W/(m·K) (DBN B.2.6-31:2006 Table Л11).

Heat transfer resistance R_{bf} = \sum \frac{d}{\lambda_p} = \frac{0,22}{2,04}+0,05/0,045+0,05/0,81+0,11/0,58 = 1,46 m²K/W

Statutory values of heat transfer resistance for residential building envelopes to be achieved after the thermal modernization (R_{after}) are set in Table 1 DBN B.2.6-31:200678.

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78 Table 1 DBN B 2.6-31:2006. Available at: http://polimin.ua/wp-content/uploads/2014/04/DBN-V.2.6-31-2006.pdf
7. Annex 2. An example of simplified calculation of tentative heat consumption by a residential building after thermal modernization

<table>
<thead>
<tr>
<th>Building Envelope Element</th>
<th>R_before (m²K/W)</th>
<th>R_after (m²K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer walls, ((R_{ow}))</td>
<td>0,65</td>
<td>3,3</td>
</tr>
<tr>
<td>Attic floor, ((R_{af}))</td>
<td>0,8</td>
<td>4,95</td>
</tr>
<tr>
<td>Floor over the basement, ((R_{of}))</td>
<td>1,46</td>
<td>3,75</td>
</tr>
<tr>
<td>Window glazing and balcony doors, ((R_w))</td>
<td>0,34</td>
<td>0,75</td>
</tr>
<tr>
<td>Outer entrance doors, ((R_{wd}))</td>
<td>0,4</td>
<td>0,65</td>
</tr>
</tbody>
</table>

Table 5. Heat transfer resistance indicators of the building envelope

In addition to the heat insulation of the building envelope, the project envisages modernization of the engineering systems:

- Installation of an individual heating unit with weather regulation;
- Automatic balancing at risers.

7.5. CALCULATION OF THE THERMAL TECHNICAL INDICATORS OF THE BUILDING «AFTER THE THERMAL MODERNIZATION»

The building’s total need of thermal energy during the heating period \(Q_{\text{year}}\) \((Q_{\text{after}})\) is calculated according to the formula:

\[
Q_{\text{year}} = Q_k - (Q_{\text{dhg}} + Q_s) + Q_{\text{H,em,ls}} + Q_{\text{H,dis,ls}} + Q_{\text{H,gen,ls}},
\]

where

- \(Q_{\text{year}}\) – estimated consumption of thermal energy for heating during the heating period, kW∙hour;
- \(Q_k\) – heat losses through the building envelope and infiltration losses (through ventilation) during the heating period, kW∙hour;
- \(Q_{\text{dhg}}\) – domestic heat gain (from humans, equipment, appliances, etc.) during the heating period, kW∙hour;
- \(Q_s\) – heat gain through windows from solar radiation during the heating period, kW∙hour;
- \(Q_{\text{H,em,ls}}\) – heat losses due to heat extraction/emission in the heating system (heat losses at heating devices and hydraulic misbalance of the system), kW·hour;
- \(Q_{\text{H,dis,ls}}\) – heat losses from transportation of heat via pipelines located in the cellar and/or attic (outside the building’s heating envelope);
- \(Q_{\text{H,gen,ls}}\) – losses for production/generation and accumulation of heat in the building’s heating unit depending upon its type, kW·hour.

The calculation of the formula elements is contained in further sections of the Methodology.

7.5.1. Calculation of total heat losses through the building envelope

The building’s total heat loss through the envelope \(Q_k\), kW·hour, is calculated according to the formula:

\[
Q_k = X_1 \cdot K_{\text{bld}} \cdot D_s \cdot F_x = 0,024 \cdot 1,48 \cdot 3587,5 \cdot 2211 = 302070\text{kW}\cdot\text{hour},
\]

where

\[X_1 = 0,024\] - dimension factor;

79 Thermotechnical indicators before the thermal modernization are calculated in a similar way.
7. Annex 2. An example of simplified calculation of tentative heat consumption by a residential building after thermal modernization

$k_{bld}$ – general heat conductivity factor of the building’s heat insulation cover, $W/(m^2\cdot K)$ – defined in Section 7.5.2. For this calculation, $k_{bld} = 1.48$ $W/(m^2\cdot K)$; the calculation is provided;

$D_d$ – number of degree-days;

$D_d = (t_a + t_{hp,s}) \cdot Z_{hp} = (20+0,5) \cdot 175 = 3587,5 \circ C \cdot days$, where

$t_a$ – estimated temperature of the air $t_a = 20 \circ C$ (according to DBN B.2.6-3:2006 for residential buildings Table Г.2.);

$t_{hp,s}$ – average temperature of outside air during the heating period $= +0,5 \circ C$ (Table 2, Column 22);

$Z_{hp}$ – duration, number of days of the heating period is 175 days (according to DSTU-Н Б.1.1-27:2010 (Table 3), duration of the heating period for Chernivtsi (from 19 October to 12 April).

$F_\Sigma (m^2)$ – inner total area of the heated part of the building envelope including the top floor roofing (floor) and the floor of the lowest heated premises. It is calculated on the basis of the data specified in Section 7.3 of this Methodology.

7.5.2. Calculation of the building’s general heat conductivity factor

The building’s general heat conductivity factor $K_{bld}$, $W/(m^2\cdot K)$, is calculated according to the formula:

$$K_{bld} = k_{red} + k_{inf} = 0,88 + 0,46 = 1,34 W/(m^2 \cdot K)$$

$k_{red}$ – reduced heat conductivity factor of the building’s heat insulation cover, $W/(m^2\cdot K)$. It is calculated below. $k_{red} = 0.88$.

$k_{inf}$ – heat losses due to infiltration and ventilation, $W/(m^2\cdot K)$. It is calculated below. $k_{inf} = 0.46$.

Reduced heat conductivity factor of the building’s heat insulation cover $k_{red}$. $W/(m^2\cdot K)$, is calculated according to the formula:

$$k_{red} = \xi \cdot \left( \frac{F_{nt}}{R_{nt}} + \frac{F_{il}}{R_{il}} + \frac{F_{d}}{R_{d}} + \frac{F_{d} \cdot n_{d}}{R_{d}} + \frac{F_{b} \cdot n_{b}}{R_{b}} + \sum L_k \right)$$

$$= \frac{627}{33} + \frac{864}{0,75} + \frac{9}{0,65} + \frac{474}{4,95} + \frac{237}{3,75} + \frac{2020}{2211} = 0,88 W/(m^2\cdot K)$$

where $\xi$ – coefficient that takes into account additional heat losses connected with the building envelope’s orientation with respect to the cardinal directions, angular premises, inflow of cold air through entrances into the building, for residential buildings $\xi = 1,13$;

$F_{nt}$, $F_{il}$, $F_{d}$, $F_{b}$ (m$^2$) – area of walls (non-transparent parts), translucent constructions (windows, roof lanterns), entrance doors and gates, roofing (attic floor, basement floor), m$^2$. Relevant values were listed in Section 3 of the Methodology;

$R_{nt}$, $R_{il}$, $R_{d}$, $R_{b}$ (m$^2\cdot K/\circ C$) – reduced heat transfer resistance of walls, translucent constructions (windows, roof lanterns), entrance doors and gates, roofing (attic floor, basement floor); floor on the soil – taking into consideration their division into zones indicating the heat transfer resistance values. Relevant values are presented in Section 4 of this Methodology;

$F_\Sigma (m^2)$ – inner total area of the heated part of the building envelope including the top floor roofing (floor) and basement floor. Relevant values are calculated in Section 7.3 of the Methodology;
7. Annex 2. An example of simplified calculation of tentative heat consumption by a residential building after thermal modernization

\[ \sum L_k = 202.0 \] - indicator that takes into account the overall heat exchange through linear heat conductive inclusions in the building’s heat insulation cover and is calculated in accordance with the recommendations of DBN B.2.6-31:2006. It is the product (illustrated by the example below in Table 6) of the linear value of the heat conductive inclusion (L) and the linear heat conductivity factor \( K_j \) determined for each type of inclusion in accordance with Table №3 DBN B.2.6-31:2006.

<table>
<thead>
<tr>
<th>Linear inclusions</th>
<th>L - linear value of the heat conductivity inclusion by internal surface, m</th>
<th>( K_j )</th>
<th>((L_k)_j = L_x K_j)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point of connection of the floor slab with the outer brick wall (Point 8, Table №3)</td>
<td>100</td>
<td>0,44</td>
<td>44</td>
</tr>
<tr>
<td>Point of angular connection (Point 9, Table №3)</td>
<td>150</td>
<td>0,31</td>
<td>46,5</td>
</tr>
<tr>
<td>Point of connection of the outer and inner brick walls (Point 10, Table №3)</td>
<td>50</td>
<td>0,49</td>
<td>24,5</td>
</tr>
<tr>
<td>Point of connection of the window top with the brick wall (Point 12, Table №3)</td>
<td>50</td>
<td>1,19</td>
<td>59,5</td>
</tr>
<tr>
<td>Point of connection of the window bottom with the brick wall (Point 13, Table №3)</td>
<td>50</td>
<td>0,55</td>
<td>27,5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>202</strong></td>
</tr>
</tbody>
</table>

Table 6. Calculation of the general indicator of heat exchange through linear heat conductive inclusions in the building’s heat insulation cover

7.5.3. Determination of the infiltration coefficient of the building’s heat conductivity

The conditional infiltration coefficient of the building’s heat conductivity that includes heat losses due to infiltration and ventilation \( k_{\text{inf}} \) \( \text{W/(m}^2\cdot\text{K}) \) is calculated according to the formula:

\[
k_{\text{inf}} = \frac{X_2 \cdot c \cdot n_x \cdot v_x \cdot V_x \cdot Y_3 \cdot \eta}{F_3},\]

where

- \( X_2 = 0.278 \) – dimension factor;
- \( c \) – specific heat capacity of the air \( c = 1 \text{ kJ/(kg} \cdot \text{K}) \);
n_{ex} – air exchange rate in the building during the heating period after the thermal modernization \( n_{ex} = 0.6 \text{ hour}^{-1} \) due to the installation of airtight metal and plastic windows (for the calculation "before the thermal modernization", it is accepted as 1)

\( v_v \) – rate of reduction of the air volume in the building that takes into account internal elements of the building envelope; \( v_v = 0.85 \).

F\( \Sigma \) – total area of the building envelope

\( \gamma_z \) – average density of infiltrating air, kg/m\(^3\), calculated according to the formula:

\[
\gamma_z = \frac{353}{273+0.5(t_i+t_{hp})} = 1.25 \text{ kg/m}^3
\]

\( t_i \) – estimated temperature of internal air \( t_i = 20^\circ C \) (according to DBN B.2.6-31:2006 for residential buildings (Table Г.2.));

\( t_{hp} \) – average outside temperature during the heating period = +0.5\(^\circ C \) (DSTU-Н Б В.1.1-27:2010 Table 2, Column 22).

\( \eta \) – coefficient of influence of the heat counter current in the building envelope (0.7 - for panel joints and multiple casement windows; 0.8 - for double casement windows and balcony doors; 1 - for single casement windows and balcony doors; in this case, the coefficient \( \eta \) is set with its highest value - the same for the whole building). It is set with its highest value for the whole building \( \eta = 0.8 \).

As a result, the heat losses due to infiltration and ventilation \( k_{inf} \) are

\[
k_{inf} = \frac{0.278 \cdot 1.0 \cdot 0.85 \cdot 7110 \cdot 1.25 \cdot 0.8}{2211} = 0.46 \text{ W/(m}^2\cdot\text{K})
\]

### 7.5.4. Calculation of heat gains

Domestic heat gains during the heating period \( Q_{dchg} \), kW·hour are calculated according to the formula:

\[
Q_{dchg} = 0.01 \cdot F_h \cdot 24 \cdot Z_{hp} = 0.01 \cdot 2370 \cdot 24 \cdot 175 = 99540 \text{ kW·hour, where}
\]

\( F_h \) – heated area of the building - 2,370 m\(^2\)

\( Z_{hp} \) – duration, number of days, of the heating period is 175 days (according to DSTU-Н Б В.1.1-27:2010 (Table 3) for the city of Chernivtsi (from 19 October to 12 April).

### 7.5.5. Calculation of heat gain from solar radiation through the windows

Heat gains from solar radiation through the windows during the heating period, \( Q_{s\_windows} \) kW·hour, for the four facades of the buildings oriented by the four cardinal directions - North (N), East (E), South (S) and West (W) or interim directions (North-West (NW), North-East (NE), South-East (SE) and South-West (SW)) are calculated according to the formula:

\[
Q_S = \zeta_a \cdot \epsilon_s (F_{n\_ln} + F_{s\_ls}) = 0.8 \cdot 0.54 \cdot (432-133+432-317) = 83981 \text{ kW·hour, where}
\]

\( \zeta_a \) – coefficient taking into account the shading of the window opening with non-transparent elements, accepted according to Table №1 DBN B.2.6-31 (single-chamber units in single sashes);
7. Annex 2. An example of simplified calculation of tentative heat consumption by a residential building after thermal modernization

\( \varepsilon_s \) – coefficient of relative solar radiation for translucent traceries, set according to Table №1 DBN В.2.6-31:2006 (single-chamber units in single sashes);

\( F_r, F_s \) – area of window openings of the building facades oriented accordingly by the cardinal directions, m². It is defined in Section 3 of this calculation;

\( I_n, I_s \) – average value of solar radiation during the heating period directed to the vertical East, West and South surface, kW·hour/m². It is set according to Table 2 DSTU Н Б А.2.2-5:2007.

For the city of Chernivtsi \( I_n = 133 \) kW·hour/m², \( I_s = 432 \) kW·hour/m².

**7.5.6. Calculation of heat losses in the heating systems**

**Total** heat losses at heat extraction/emission in the heating system (heat losses at the heating equipment and due to hydraulic misbalance of the system) – \( Q_{H,em,ls} \), kW·hour, in accordance with Section 15.4 DSTU Б.2.2-12:2015. For simplification purposes, the formula is presented, under which an approximate variant could be achieved

\[ Q_{H,em,ls} = K_1 \cdot Q_{em,out} \]

where

\[ Q_{em,out} \] – output energy from heating systems, kW·hour, energy demand for heating is calculated according to the formula:

\[ Q_{em,out} = Q_k - (Q_{dnr} + Q_s) \]

\[ Q_{em,out} = [302070-(99540=83981)] = 118549 \text{ kW·hour} \]

\( K_1 \) – simplified coefficient calculated using the methodology of DSTU Б.2.2-12:2015 for three different automation modes within the heating system at heat extraction/emission (heat losses at heating equipment and due to hydraulic misbalance of the system).

\( K_1 = 0,401 \) – heating equipment without temperature control and without automated hydraulic setup.

\( K_1 = 0,277 \) – heating equipment with temperature control without monitoring, adapted control, automatic hydraulic setting at risers.

\( K_1 = 0,115 \) – heating equipment with temperature control with monitoring, adapted control, automatic hydraulic setup at risers and heating equipment.

\[ Q_{H,em,ls} = 0,277 \cdot 118549 = 32838 \text{ kW·hour} \]

\( Q_{H,dis,ls} \) – heat losses at heat transportation via pipelines located in the cellar and/or attic (outside the building’s heat cover) calculated in accordance with Section 15.5 DSTU Б.2.2-12:2015 or in a simplified mode according to the formula:

\[ Q_{H,dis,ls} = K_2 \cdot Q_{dis,out} \]

where

\[ Q_{dis,out} = Q_{em,out} + Q_{H,em,ls} = 118549+32838=151387 \text{ kW·hour} \]

\( K_2 = 0,03 \) (for all transportation systems in residential buildings built before 2015)

\[ Q_{H,dis,ls} = 0,03 \cdot 151387 = 4541 \text{ kW·hour} \]
\( Q_{\text{H,gen,ls}} \) – losses for production/generation and accumulation of heat in the building’s heating unit depending upon its type, kW-hour, calculated in accordance with Section 15.6 DSTU Б А.2.2-12:2015 or the simplified formula:

\[
Q_{\text{H,gen,ls}} = K_3 \cdot Q_{\text{gen,out}},
\]

where

\[
Q_{\text{gen,out}} = Q_{\text{dis,out}} + Q_{\text{H,dis,ls}} = 151387 + 4541 = 155928 \text{ kW-hour}
\]

\( K_3 = 0.3 \) (for all transportation systems in residential buildings with centralized heating supply with central ratio governing according to the temperature schedule below 110 °C with the cutoff and without adjustment in the individual heating unit).

\( K_3 = 0.22 \) (for all transportation systems in residential buildings with centralized heating and central ratio governing in accordance with the temperature schedule below 110 °C without the cutoff and adjustment in the individual heating unit. Centralized heating with central ratio governing and a central heating unit without weather adjustment).

\( K_3 = 0.05 \) (for all transportation systems in residential buildings – centralized heating with ratio governing with the cutoff of the temperature schedule and weather adjustment in the individual heating unit).

\[
Q_{\text{H,gen,ls}} = 0.05 \cdot 155928 = 7796 \text{ kW-hour}
\]

Considering the defined elements of heat losses and heat gains in the building, as well as the losses in the heating system, the estimated heat losses are found for heating \( Q_{\text{year}} \) (\( Q_{\text{after}} \)):

\[
Q_{\text{year}} = Q_{\text{k}} - (Q_{\text{dng}} + Q_{\text{s}}) + Q_{\text{H,em,ls}} + Q_{\text{H,dis,ls}} + Q_{\text{H,gen,ls}} = 118549 + 32838 + 4541 + 7796 = 163724 \text{ kW-hour}
\]

In GCal: \( q_{\text{bst}} = \frac{163724 \cdot 3600}{1000000 \cdot 4,186} = 140.8 \text{ GCal}\)

where 3600, 1000000, 4,186 – coefficient for conversion of heat from kW/hour into GCal.

Under the same methodology, we determine \( Q_{\text{year}} \) (\( Q_{\text{before}} \)) before the thermal modernization (see the input data at the beginning of the example).

\( Q_{\text{year}} = 354.2 \text{ GCal} \)

The averaged indicator of the heat losses for heating for the last three years according to heat meters in the building \( Q_{\text{year}} \) (\( Q_{\text{before}} \)) is 301 GCal.

Thus, we calculate the coefficient \( f \), which is:

\( f = 140.8/354.2 = 0.398 \)

Calculation of \( Q_{\text{after}}^{e_2} \):

\( Q_{\text{after}}^{e_2} = 301 \times 0.398 = 119.8 \text{ GCal} \).

Thus, the actual heating need after the thermal modernization of the building is between the values of \( Q_{\text{after}}^{e_0} \) and \( Q_{\text{after}}^{e_2} \), that is, between 140.8 and 119.8 GCal. The average value is 130.3 GCal.
We calculate the forecast saving as a result of the thermal modernization:
\[
\Delta Q = Q_{\text{before}} - Q_{\text{after}} = \left[ Q_{\text{year before}} \right] - \left[ \text{average of } Q_{\text{after^1}} \text{ and } Q_{\text{after^2}} \right] = 301 - 130,3 = 170,7 \text{ GCal}
\]

\[\Delta Q = 170,7 \text{ GCal}\]

This indicator of reduction of the heat consumption is accepted for further economic analysis.

The tentative cost of the project of energy efficiency improvement is calculated according to the formula:

\[ PC = C_{\text{tech.assessment}} + C_{\text{audit}} + C_{\text{design}} + \sum_{j=1}^{k} C_{ij}, \]

where:
- \( C_{\text{tech.assessment}} \) – cost of the works of assessment of the building’s technical condition;
- \( C_{\text{audit}} \) – cost of the works of energy audit of the building;
- \( C_{\text{design}} \) – cost of development of the design documentation;
- \( C_{ij} \) – cost of implementation of the \( j \) measure on improvement of energy efficiency, UAH;
- \( k \) – number of measures.

For example, we will review the cost of preparation and implementation of the project of energy efficiency improvement of a 16-storied residential building.

For the project of improvement of the building’s energy efficiency, the following measures were selected:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measuring unit</th>
<th>Quantity</th>
<th>Unit cost, UAH</th>
<th>Total cost, UAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat insulation and waterproofing of the roof ISOFRAM UTGI</td>
<td>total area of the roof, m²</td>
<td>648</td>
<td>661.5</td>
<td>428 652</td>
</tr>
<tr>
<td>Heat insulation of the façade - Capatect A with the mineral wool insulation, façade plaster and paint</td>
<td>total area of façade, m²</td>
<td>2699</td>
<td>390</td>
<td>1 052 610</td>
</tr>
<tr>
<td>Heat insulation of the basement floor ISOFRAM UTGI</td>
<td>area of the basement floor, m²</td>
<td>648</td>
<td>243.5</td>
<td>157 788</td>
</tr>
<tr>
<td>Replacement of windows with metal and plastic windows</td>
<td>number of windows, pcs.</td>
<td>444</td>
<td>1 818.2</td>
<td>807 280.8</td>
</tr>
<tr>
<td>Replacement of doors</td>
<td>number of doors, pcs.</td>
<td>102</td>
<td>1 774.4</td>
<td>180 988.8</td>
</tr>
<tr>
<td>Installation of the per-building heat meter</td>
<td>pcs.</td>
<td>1</td>
<td>39 814</td>
<td>39 814</td>
</tr>
<tr>
<td>Installation of the per-building water meters</td>
<td>pcs.</td>
<td>2</td>
<td>10 598.5</td>
<td>21 197</td>
</tr>
<tr>
<td>Installation of the individual heating unit (IHU)</td>
<td>pcs.</td>
<td>1</td>
<td>198 877</td>
<td>198 877</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>2 887 208</td>
</tr>
</tbody>
</table>

Table 7. Calculation of the tentative cost of the project of energy efficiency improvement of the multi-family building

The cost of assessment of technical condition and energy audit depends on the building’s volume (total area), list of works conducted, research methods, structure and amounts of indirect costs and average wages in the organization that performs the assessment/energy audit.
It is recommended to calculate the works on assessment of technical condition according to the set standards\textsuperscript{80}. Taking into account the size of the building we assume that the cost of assessment of technical condition is UAH 20 000 and the cost of the energy audit is UAH 30 000.

The cost of design works is expressed as a percentage ($\approx 5.5\%$) of the cost of construction (using the data of Table A.2 DSTU Б Д 1.1.-7\textsuperscript{81}). As a result, the cost of design is about UAH 160 000.

The total tentative cost of the project is:
\[
PC = 2\,887\,208 + 20\,000 + 30\,000 + 160\,000 = \text{UAH 3 097 308}. 
\]
### Annex 4. Input data for estimation of the energy consumption by a multi-family building for heating after the thermal modernization

#### Address of the building or structure:

<table>
<thead>
<tr>
<th>Name</th>
<th>Measure unit</th>
<th>Response</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of construction</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General technical condition</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of floors</td>
<td>pcs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sections</td>
<td>pcs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sizes in the plan</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total height and floor height</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional use of the ground (basement) floor</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of the cellar, its height and functional use</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of the attic, its height and use</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of roofing</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material and type of construction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walls</td>
<td>cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floors</td>
<td>cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roofing</td>
<td>cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System of heating, heat supply, type of system</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems of individual heating in the building (number of units and apartments)</td>
<td>pcs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of the individual heating unit (IHU) in the building</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area of windows</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area of entrance doors</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of windows of the North façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of windows of the South façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Actual orientation by cardinal directions, for instance, North-East or South-West, etc.
<table>
<thead>
<tr>
<th>Name</th>
<th>Measure unit</th>
<th>Response</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of windows of the West façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of windows of the East façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heated area</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heated volume</td>
<td>m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area of internal building envelope</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of the attic (roof)</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of the cellar</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of outer walls of the North façade&lt;sup&gt;83&lt;/sup&gt;</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of outer walls of the South façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of outer walls of the West façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of outer walls of the East façade</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area of walls</td>
<td>m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perimeter</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total volume of thermal energy consumed by the building</td>
<td>GCal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(according to the meter of heating services provider)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for the heating period</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors

Table 8. Input data for estimation of energy consumption by a multi-family building for example, North-West or South-East, etc.

<sup>83</sup> Total area of walls with windows and actual orientation by cardinal direction, for example, North-West or South-East, etc.
### Structural element

**Outer walls (non-transparent building envelope)**

<table>
<thead>
<tr>
<th>Structural element</th>
<th>Saving of energy resources due to:</th>
<th>Reference to the regulatory act</th>
<th>Standard indicators</th>
<th>Possible technical solutions (what to do)</th>
<th>Problem aspects and risks</th>
<th>Practical advice for minimization of risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increase of the heat transfer resistance due to façade heat insulation.</td>
<td>DBN Б B.2.2-15 DBN Б B.2.6-31 DBN Б B.2.6-33 DBN Б B.2.6-34 DSTU Б B.2.6-35 DSTU Б B.2.6-36 DSTU-Н Б B.3.2-3</td>
<td>Standard heat transfer resistance Temperature zone I – 3,3 m²·K/W Temperature zone II – 2,8 m²·K/W.</td>
<td>1. Construction of outer insulation in compliance with Table 1 DBN Б B.2.6-33 (heat insulation of the building facades). 2. Construction of the &quot;active&quot; façade. 3. Reflecting cover, etc.</td>
<td>1. Poor quality of materials. 2. Construction of facades with significant thermal bridges. 3. Poor quality of works.</td>
<td>1. Selection of materials and devices with relevant quality confirming documents (certificates, quality passports, etc.). 2. Selection of contacting organizations that have qualified builders (qualification certificate, etc.).</td>
</tr>
</tbody>
</table>

### Structural element

**Windows and doors (window and door openings in outer building envelope)**

<table>
<thead>
<tr>
<th>Structural element</th>
<th>Saving of energy resources due to:</th>
<th>Reference to the regulatory act</th>
<th>Standard indicators</th>
<th>Possible technical solutions (what to do)</th>
<th>Problem aspects and risks</th>
<th>Practical advice for minimization of risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Increase of the heat transfer resistance due to new constructions of filling the window and door openings. 2. Increase of the heat transfer resistance due to modernization of filling the window and door openings.</td>
<td>DBN Б B.2.2-15 DSTU Б B.2.6-164 DSTU-Н Б B.3.2-3 DSTU Б B.2.6-79</td>
<td>Standard reduced heat transfer resistance Temperature zone I – 0,75 m²·K/W Temperature zone II – 0,6 m²·K/W.</td>
<td>1. Replacement of the filling of window and door openings with energy efficient filling (increase of the heat transfer resistance), with installation of air ducts, inflow valves, individual (local) heat recovery units. 2. Installation of the system of automatic shades. 3. Waterproofing of connections of window frames with window openings. 4. Replacement of window casements with increase of heat transfer resistance. 5. Application of additional absorbing films.</td>
<td>1. Poor quality of materials during construction. 2. Incompliance of the actual formula of the window system with the declared design indicators.</td>
<td>1. Selection of materials and devices with relevant quality confirming documents (certificates, quality passports, etc.). 2. Selection of contacting organizations that have qualified builders (qualification certificate, etc.).</td>
</tr>
</tbody>
</table>
### Structural Element

<table>
<thead>
<tr>
<th>Structural Element</th>
<th>Saving of Energy Resources due to:</th>
<th>Reference to the Regulatory Act</th>
<th>Standard Indicators</th>
<th>Possible Technical Solutions (What to Do)</th>
<th>Problem Aspects and Risks</th>
<th>Practical Advice for Minimization of Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>Renovation or complete replacement of the roof layers with the increase of the heat transfer resistance. Application of the additional heat insulation layer on the attic floor (roof).</td>
<td>DBN B.2.6-14, DSTU-H B.3.2-3</td>
<td>Standard heat transfer resistance: Temperature zone I – 5.35 m²·K/W (built-up roofing), 4.95 m²·K/W (attic technical floor); Temperature zone II – 4.9 m²·K/W (built-up roofing), 4.5 m²·K/W (technical floor, attic).</td>
<td>1. For built-up roofs - restoration of the old bituminous materials using infrared regeneration with application of the polyurethane waterproofing layer and protective materials. 2. Heat insulation of the unheated attic floor (roof) with mechanic protection, for instance, with a dry mountable screed.</td>
<td>1. Poor quality of materials. 2. Heat insulation constructions with significant thermal bridges. 3. Poor quality of works.</td>
<td>1. Selection of materials and devices with relevant quality confirming documents (certificates, quality passports, etc.). 2. Selection of contacting organizations that have qualified builders (qualification certificate, etc.).</td>
</tr>
<tr>
<td>Basement Floor</td>
<td>Increase of the heat transfer resistance of the floor over unheated cellar. Arrangement of constructions of the ground floor with the heat insulation layer.</td>
<td>DBN B.2.2-15, DBN B.2.6-31, DSTU-H B.3.2-3</td>
<td>Standard heat transfer resistance of the floor over unheated cellar: Temperature zone I – 3.75 m²·K/W; Temperature zone II – 3.3 m²·K/W. Heat transfer resistance of the floor over ground is not standardized.</td>
<td>1. Application of the additional heat insulation layer from the side of the basement floor. 2. Arrangement of the ground floor with the heat insulation layer. 3. Heat insulation of the basement and cellar wall in the soil outside (or inside) at least 1.2 m deep.</td>
<td>1. Poor quality of materials. 2. Heat insulation constructions with significant thermal bridges. 3. Poor quality of works.</td>
<td>1. Selection of materials and devices with relevant quality confirming documents (certificates, quality passports, etc.). 2. Selection of contacting organizations that have qualified builders (qualification certificate, etc.).</td>
</tr>
<tr>
<td>Structural element</td>
<td>Saving of energy resources due to:</td>
<td>Reference to the regulatory act</td>
<td>Standard indicators</td>
<td>Possible technical solutions (what to do)</td>
<td>Problem aspects and risks</td>
<td>Practical advice for minimization of risks</td>
</tr>
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</tr>
<tr>
<td>System of heating</td>
<td>Application of individual heating units in buildings; reduction of heat losses during heat distribution by decreasing the temperature of the heat agent; use of heat regulators at radiators and increase of their efficiency; reduction of the operation time of the heating system taking into account actual needs.</td>
<td>DBN B.2.2-9, DBN B.2.2-15, DBN B.2.5-39, DSTU-H Б B.3.2-3</td>
<td>1. Range of the resulting temperature in the premises to be maintained 22.0±2.0°C. 2. Temperature in the direct and reverse pipeline is set depending on the type of heating system but not higher than 150°C/70°C.</td>
<td>Manual regulation of the heat agent temperature at the heating unit or boiler room and regulators on radiators.</td>
<td>1. During the day it is necessary to monitor the readings of the meter in the premises and regulate the temperature and volume of the heat agent with heat regulators and the regulators at IHU and boiler room. 2. Possible waste of heat during the day when the position of the regulator was set improperly.</td>
<td>Applied in small heating systems only if the users regularly use heat regulators.</td>
</tr>
</tbody>
</table>

**Possible technical solutions (what to do)**

- **Manual regulation of the heat agent temperature at the heating unit or boiler room and regulators on radiators.**

**Problem aspects and risks**

- **1. During the day it is necessary to monitor the readings of the meter in the premises and regulate the temperature and volume of the heat agent with heat regulators and the regulators at IHU and boiler room.**
- **2. Possible waste of heat during the day when the position of the regulator was set improperly.**
### 10. Annex 5. Framework conditions and requirements for implementation of energy efficiency measures in multi-family buildings

<table>
<thead>
<tr>
<th>Structural element</th>
<th>Saving of energy resources due to:</th>
<th>Reference to the regulatory act</th>
<th>Standard indicators</th>
<th>Possible technical solutions (what to do)</th>
<th>Problem aspects and risks</th>
<th>Practical advice for minimization of risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBN B.2.2-9, DBN B.2.2-15, DBN B.2.5-39, DSTU-H Б B.3.2-3</td>
<td>1. Range of the resulting temperature in the premises to be maintained 22.0±2.0°C. 2. Temperature in the direct and reverse pipeline is set depending on the type of heating system but not higher than 150°C/70°C.</td>
<td>Automatic regulation of the heat agent temperature at the heating unit or boiler room depending on weather conditions with the adjustment of the inside temperature.</td>
<td>1. During the day it is necessary to monitor the readings of the meter in the premises and regulate the temperature and volume of the heat agent with heat regulators. 2. Possible short-term heat wastes during the day, when the position of the regulator was set improperly.</td>
<td>Recommended for small heating systems with insignificant heat load deviations in different premises.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DBN B.2.2-9, DBN B.2.2-15, DBN B.2.5-39, DSTU-H Б B.3.2-3</td>
<td>1. Range of the resulting temperature in the premises to be maintained 22.0±2.0°C. 2. Temperature in the direct and reverse pipeline is set depending on the type of heating system but not higher than 150°C/70°C.</td>
<td>Manual regulation with radiator valves (on condition that consumers use them regularly).</td>
<td>It is necessary to check the readings of the temperature sensor periodically in the premises and outside to avoid incorrect automatic signals at regulators.</td>
<td>Recommended as a standard system for residential buildings.</td>
<td></td>
</tr>
<tr>
<td>Structural element</td>
<td>Saving of energy resources due to:</td>
<td>Reference to the regulatory act</td>
<td>Standard indicators</td>
<td>Possible technical solutions (what to do)</td>
<td>Problem aspects and risks</td>
<td>Practical advice for minimization of risks</td>
</tr>
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</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.2-9, DBN В.2.2-15, DBN B.2.5-39, DSTU-Н Б B.3.2-3</td>
<td>1. Range of the resulting temperature in the premises to be maintained 22,0±2,0°С. 2. Temperature in the direct and reverse pipeline is set depending on the type of heating system but not higher than 150°C/70°C.</td>
<td>Automatic regulation of the heat agent temperature depending on weather conditions with the adjustment of the inside temperature. Regulation with heat regulators at radiators.</td>
<td>It is necessary to check the readings of the temperature sensor periodically in the premises and outside to avoid incorrect automatic signals at regulators.</td>
<td>High-quality regulation system recommended for all types of residential buildings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.2-9, DBN B.2.2-15, DBN B.2.5-39, DSTU-Н Б B.3.2-3</td>
<td>Range of the resulting temperature in the heating system to be maintained 22,0±2,0°С but not higher than 150°C/70°C.</td>
<td>Centralized regulation of temperature inside the premises. Regulation with heat regulators at radiators.</td>
<td>It is necessary to check the readings of the temperature sensor periodically in the premises and outside to avoid incorrect automatic signals at regulators.</td>
<td>Recommended only for per-apartment heating systems and single-family houses.</td>
</tr>
<tr>
<td>Structural element</td>
<td>Saving of energy resources due to:</td>
<td>Reference to the regulatory act</td>
<td>Standard indicators</td>
<td>Possible technical solutions (what to do)</td>
<td>Problem aspects and risks</td>
<td>Practical advice for minimization of risks</td>
</tr>
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<td>--------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Hot water supply systems</td>
<td>Reduction of excessive and wasteful consumption.</td>
<td>DBN B.2.5-39, DBN B.2.5-64, DSTU-H B.3.2-3</td>
<td>To avoid reduction of the heat agent pressure more than 20 kPa.</td>
<td>Reduction of circulation at night.</td>
<td>Reduction of hot water temperature and, consequently, hot water overconsumption.</td>
<td>Installation of meters taking into account reduction of the temperature below the standard.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.2-15, DBN B.2.5-64, DSTU-H B.2.5-73:2013, DSTU EN 1434-1:2006</td>
<td>Maximum dropping of the heat agent temperature at the heat meter – 25 kPa.</td>
<td>Installation of per-building and per-apartment metering equipment.</td>
<td>Per-apartment metering units should be designed with the fixtures that allow dismantling of the metering section without emptying of the system.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.5-39</td>
<td>1. The volume of the accumulation tank should be selected according to the peak load. 2. Possible installation of accumulation tanks under the working pressure or atmospheric pressure.</td>
<td>Installation of the heat accumulator.</td>
<td>1. Requires additional area for installation. 2. Need to apply anti-corrosion protection and insulation.</td>
<td>Need to estimate the volume of the hot water accumulation tank taking into account the peak load of the hot water system in the building, group of buildings, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.5-74, DSTU-H B.3.2-3</td>
<td>Characteristics are defined locally.</td>
<td>Installation of water regulators.</td>
<td>Possible regulator breakage as a result of crust or foreign substance.</td>
<td>Need to monitor the pressure difference at regulators and install a bypass line with manual regulation.</td>
</tr>
<tr>
<td>Structural element</td>
<td>Saving of energy resources due to:</td>
<td>Reference to regulatory act</td>
<td>Standard indicators</td>
<td>Possible technical solutions (what to do)</td>
<td>Problem aspects and risks</td>
<td>Practical advice for minimization of risks</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>DBN B.2.2-15, DBN B.2.5-67, DSTU-H B.3.2-3</td>
<td>1. Maximum dropping of the heat agent temperature at the heat meter – 25 kPa. 2. Water temperature of 30°C to 90°C, with relative water pressure range of 0,03 MPa to 1 MPa (0,3 bar to 10 bar) with nominal consumption provided preservation of their metrological characteristics.</td>
<td>Installation of per-building and per-apartment meters of the water supply system.</td>
<td>Existing buildings require either reconstruction or installation of several meters.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
</tr>
<tr>
<td>Cold water supply systems</td>
<td>Detection and reduction of excessive and wasteful losses cold water.</td>
<td>DBN B.2.2-15, DBN B.2.5-64, DSTU-H B.3.2-3</td>
<td>Water temperature of 0.1°C to 30°C, with relative water pressure range of 0,03 MPa to 1 MPa (0,3 bar to 10 bar) with nominal consumption provided preservation of their metrological characteristics.</td>
<td>Installation of per-building and per-apartment meters of the cold water supply system.</td>
<td>Existing buildings require either reconstruction or installation of several meters.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
</tr>
<tr>
<td>Structural element</td>
<td>Saving of energy resources due to:</td>
<td>Reference to the regulatory act</td>
<td>Standard indicators</td>
<td>Possible technical solutions (what to do)</td>
<td>Problem aspects and risks</td>
<td>Practical advice for minimization of risks</td>
</tr>
<tr>
<td>--------------------</td>
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<td>---------------------------------------------</td>
</tr>
<tr>
<td>Ventilation system</td>
<td>Ensuring the standard ventilation rate. Utilization of heat of the exhaust ventilation system.</td>
<td>DBN B.2.2-3, DBN B.2.2-4, DBN B.2.2-10, DBN B.2.5-67, DSTU-H Б B.3.2-3</td>
<td>Ventilation rate in the premises during warming not higher than 0,5 hours⁻¹. Ventilation rate should be set as 0,1 hours⁻¹ when the premises are not used and on condition of the closed windows and doors.</td>
<td>Extension or narrowing of ventilation channels, installation of grates.</td>
<td>Possible increase of heat losses with increase of ventilation rate.</td>
<td>Need to do separate calculations for each type of premises.</td>
</tr>
</tbody>
</table>

DBN B.2.5-67, DSTU - Н Б B.3.2-3 Characteristics are defined locally.

Installation or regenerating heat exchangers.

Cannot be implemented with the natural ventilation system.

1. Need to avoid fat or oil particles on the heat exchanger by installing the catchers.
2. Need to install control and automatic regulation devices to allow the working modes with periodic prevention of frost formation.
<table>
<thead>
<tr>
<th>Structural element</th>
<th>Saving of energy resources due to</th>
<th>Reference to the regulatory act</th>
<th>Standard indicators</th>
<th>Possible technical solutions (what to do)</th>
<th>Problem aspects and risks</th>
<th>Practical advice for minimization of risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment for metering of energy resources</td>
<td>Detection and reduction of excessive and wasteful heat losses in the heating system.</td>
<td>DBN В.2.2-9, DBN В.2.2-15, DBN В.2.5-67, DBN -Н Б В.3.2-3</td>
<td>Maximum dropping of the heat agent temperature at the heat meter – 25 kPa.</td>
<td>Installation of per-building and per-apartment meters of the heating system.</td>
<td>Existing buildings require either reconstruction or installation of several meters.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
</tr>
<tr>
<td>Detection and reduction of excessive and wasteful heat losses in the hot water supply system.</td>
<td>DBN В.2.2-15, DBN В.2.5-67, DSTU -Н Б В.3.2-3</td>
<td>1. Maximum dropping of the heat agent temperature at the heat meter – 25 kPa. 2. Water temperature of 30°C to 90°C, with relative water pressure range of 0.03 MPa to 1 MPa (0.3 bar to 10 bar) with nominal consumption provided preservation of their metrological characteristics.</td>
<td>Installation of per-building and per-apartment meters of the hot water supply system.</td>
<td>Existing buildings require either reconstruction or installation of several meters.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
<td></td>
</tr>
<tr>
<td>Detection and reduction of excessive and wasteful heat losses in the cold water supply system.</td>
<td>DBN В.2.2-15, DBN В.2.5-67, DSTU -Н Б В.3.2-3</td>
<td>Water temperature of 0,1°C to 30°C, with relative water pressure range of 0,03 MPa to 1 MPa (0,3 bar to 10 bar) with nominal consumption provided preservation of their metrological characteristics.</td>
<td>Installation of per-building and per-apartment meters of the cold water supply system.</td>
<td>Existing buildings require either reconstruction or installation of several meters.</td>
<td>1. It is necessary to install verified meters according to the installation project. 2. To organize centralized service and maintenance as well as prompt repair, replacement, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors

Table 9. Framework conditions and requirements for implementation of energy efficiency measures in multi-family buildings
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