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BUILDING ENERGY EFFICIENCY IMPROVEMENT AFTER THERMOMODERNIZATION

The article examines the consumption of fuel in given facility, in relation to the existing climatic conditions. It has been analyzed the building energy efficiency improvement after thermomodernization. Summarizes the nature of the changes in the cost of energy/fuel for the facility, with the change of income and inflation in Poland. A comparison of the terms of use of the building by the residents on the basis of questionnaire surveys was conducted. It was shown the different effects of thermomodernization of multi-family building. Quoted as examples of various other projects implemented thermomodernization in that locality.

Key words: building energy efficiency, energy consumption, thermomodernization.

Розглядаються різні ефекти термомодернізації житлового будинку, які належать до концепції збалансованого розвитку. Проведено аналіз підвищення енергоефективності будівлі після термомодернізації, порівняно витрати палива, витрати на експлуатацію, умови ввикористання будівлі мешканцями і т.п. до і після термомодернізації. Наводяться як приклади інші проекти реалізації термомодернізації в даній місцевості.

Ключові слова: енергоефективність будівлі, споживання енергії, термомодернізація будівель.

Introduction

Rapid growth in energy consumption seen in recent years caused significant reduction of natural resources and deterioration of natural environment. Maintaining current production level and standards of living and remembering of environmental protection and health condition of societies at the same time will be possible only if the natural resources are reasonably administered, taking into account energy, economical and environmental efficiency of the implemented undertakings. This situation gave rise to the idea of sustainable development. Principal legal acts of many countries promote sustainable development and energy efficiency.

According to the Worldwatch Institute, in the USA erection and operation of buildings accounts for 65% of total electric power consumption and causes 30% of greenhouse gas emission. In the European Union it is 42% of electricity use and 35% of greenhouse gas emission, respectively. Waste and debris from deconstruction of buildings also poses threat to the environment.

Thus evolution of construction industry and adjustment of current resources to energy-efficient building standards by implementation of innovative technologies and solutions which combine beneficial economic effects with energy effects and which reduce negative environmental and climatic impact of buildings is an imperative part of ensuring of energy efficiency of construction industry and implementation of the sustainable development rules.

Over the last ten years in Poland has made huge progress in the field of energy efficiency. Energy intensity of the Gross Domestic Product has fallen for nearly a one third, primarily due thermomodernization projects performed in the framework of the Act regarding support of thermomodernization activities and modernization of street lighting, the optimization of industrial processes or reduces the heat losses in transmission.

Thermomodernization of buildings is the main component of reduction of energy use in the construction and greenhouse gas emission involves. In Poland thermomodernization activities have been increasingly intensified for over twenty years and at the beginning they were mostly focused on renewal and elimination of defects in the buildings built by industrial technologies. After implementation of the act regarding support of thermomodernization activities, new opportunities to execute such operations in a systematic way, basing on an algorithm of technical and economic analysis of an investment, have emerged. These regulations provided legal background for complex thermomodernization. Interest in thermomodernization based on the act has been gradually increasing, evidence of which is the number and amount of granted and paid bonuses for thermomodernization initiatives (Fig. 1).

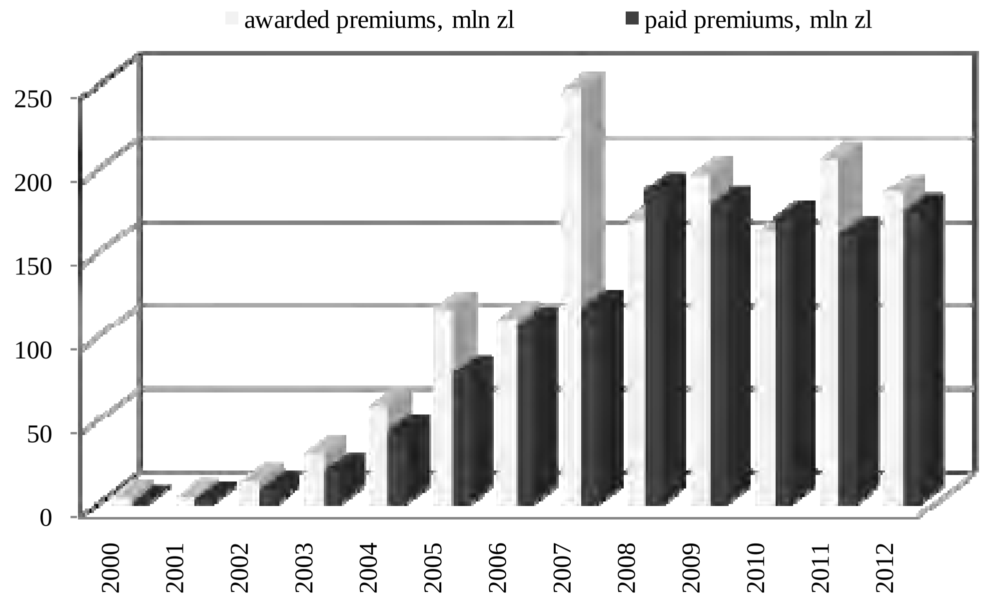

Fig. 1. The amount of awarded and paid thermal modernization bonuses [1]

Still, the energy efficiency of the Polish economy is about three times lower than in most developed European countries and about two times lower than the average in the European Union. Additionally, primary energy consumption in Poland, based on the number of population is almost 40% lower than in the in most developed European countries, which indicates the great potential in range of energy saving in Poland.

Improving energy efficiency and the rational use of existing energy resources, with a view to increasing energy demand, are areas in which Poland attaches great importance. The priority objective of the Government was to create a legal basis and a system for support of improves energy efficiency activities. Energy Efficiency Act defines the purpose of energy saving range, support mechanisms and a system to monitor and collect the necessary data. The Act also provides a full implementation of the European directives in the range of energy efficiency.

An integral part of the Energy Efficiency Act is a system of energy efficiency certificates so called "white certificates", as the market mechanism, which gives the possibility to obtain measurable energy savings in three areas: increase energy savings by final users, increase energy savings by the own needs of unites and losses of electricity heat and natural gas in transmission and distribution. Therefore "white certificates" are a mechanism which stimulates and enforces energy saving activities. "White certificates" can get only for projects with highest economic efficiency.

Problems concerning the decrease of energy resources and energy saving in building industry are addressed in numerous texts. In this article analyzed the building energy efficiency improvement after thermo modernization. The analysis was made on the basis of thermo modernization effects monitoring conducted over several years in a residential building.

Characteristics of the analyzed building

An example of thermomodernization is a multi-family residential building owned by a tenant association. Thirty people, usually retired, live in the condominium. Three-story building with a non-residential attic, with a full ground basement was erected in the years 1953-1955 using traditional technologies, with walls made of solid bricks and suspended reinforced-concrete beam and block floors. Basic data about the analyzed building are shown in Table I.

Table I

Basic data about the analyzed building

Parameter	Symbol	Unit	Value
Number of stories	-	-	3
Heated cubic capacity	V_e	[m^3]	2 158
Net area of the building	P_{net}	[m^2]	557
Heated area	P	[m^2]	536
Number of flats	-	-	12
Shape's coefficient	A/V_e	[m^{-1}]	0.61

Technical construction requirements including thermal standards have not been met in the building for a long time. In Table II shows the values of the heat transfer coefficient for partitions in the analyzed building and the requirements in this regard.

Table II

Heat transfer coefficient

Partitions	U	U_{max}
	[$W/(m^2K)$]	
External wall	1.50	0.30
Ceiling under the attic	1.90	0.25
Ceiling above the basement	1.30	0.45
Windows	2.6	1.8
Doors	4.0	2.6

This resulted in significant losses of energy. Percentage share of the heat losses through the individual partitions in the analyzed building are show in the Fig. 2.

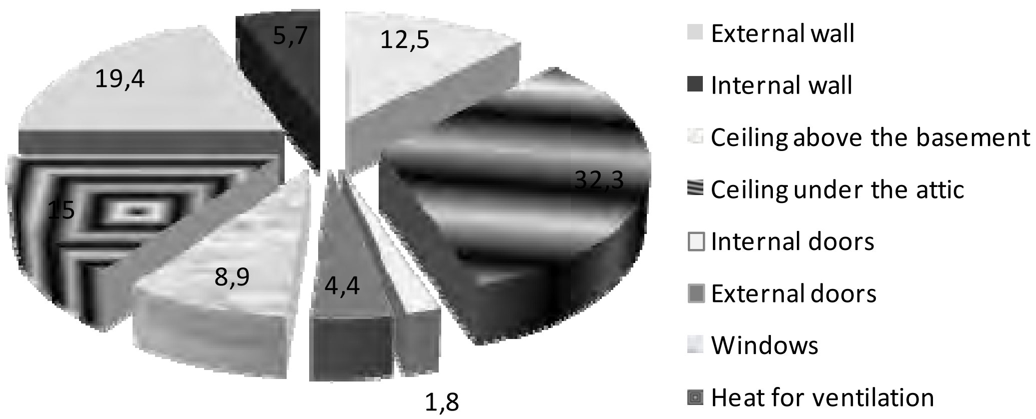

Fig. 2. Percentage share of the heat losses by the individual partitions

High values of heat transfer coefficient for partitions in the analyzed building and substantial heat losses resulted in a significant demand for heat. It demonstrates Table III.

Table III

Selected energy indicators of the analyzed building before thermomodernization

Parameters	Unit	Before
Design heat load of the heating system	[kW]	77.28
Design heat load of the hot water	[kW]	10.5
Heat demand for heating without the efficiency of the system	[GJ/year]	957
Heat demand for heating with the efficiency of the system	[GJ/year]	2 289.5
Heat demand for hot water	[GJ/year]	248.4
Indicator of the heat demand for heating without the efficiency of the system	[kWh/(m^{3}year)]	123.2
Indicator of the heat demand for heating with the efficiency of the system	[kWh/(m^{3}year)]	294.7
Indicator of the heat demand for heating with the efficiency of the system	[kWh/(m^{2}year)]	1187.5
Energy consumption in 2003	[GJ/year]	1351.5

The apartments and water were heated individually in each flat. Performance of old heating equipment was very poor. Also was observed high use of heating fuel, energy and water. Bad technical conditions of the building, in particular of chimneys, were reported too.

Description of the thermomodernization project

High use of heating fuel and energy was a basic reason for the decision of a complex thermal modernization to be made according to the dispositions included in the energy audit report [3]. The most optimal option provided first of all for insulation of exterior walls, floor with the attic and the floor over basement. Detailed list of improvements and methods of their implementation is shown in Table IV.

Table IV

List of improvements and methods of their implementation

Kind of improvements	The method of realization
Reducing losses by heat transfer through the exterior walls	Insulation of the walls, styrofoam
Reducing losses by heat transfer through the internal walls of the staircase to the attic	Insulation of the walls, styrofoam
Reducing losses by heat transfer through the floor with the attic	Insulation of the attic floor on a top, styrofoam, concrete screed
Reducing losses by heat transfer through the floor over basement	Insulation of the floor over basement from the bottom, styrofoam and rock wool in a a boiler room
Reducing losses by heat transfer through the windows and heating ventilation air	Sealing or exchange old windows for new ones
Reducing heat demand for hot water	Creation in building collective water heating systems with a water use meter
Reducing heat demand for heating and increasing the efficiency of heating	Creation in building an independent eco-pea coal fired boiler house and central heating system, installation of thermostatic radiator valves

Suggested exchange old windows for new ones individually by residents. The insulation thickness and heat transfer coefficients in partition walls are shown in Table V. The audit and thermal modernization of the building were made in 2003.

The building was furnished with an independent eco-pea coal fired boiler house with a 50 kW boiler, central heating and collective water heating systems with a water use meter and a chimney. The type of use of several rooms, which were transferred free of charge by the owners to the tenant association as a jointly-owned space, was amended for the purpose of the boiler house.

Table V

Summary of the insulation thickness and heat transfer coefficients

Partitions	U [W/(m^{2}K)]		U_{max}	Insulation
	Before	After	[W/(m^{2}K)]	[cm]
External wall	1.50	0.23	0.30	14
The ceiling under the attic	1.90	0.20	0.25	18
The ceiling above the basement	1.30	0.44	0.45	6
Windows	2.6	1.1	1.8	exchange for a new
Doors	4.0	2.6	2.6	exchange for a new

Thanks to these initiatives which were a consequence of conscious participation in making decisions regarding common welfare of all members of the association, one central source of heat for the purpose of central heating and water heating was made in the building. This in turn reduced the costs of the investment completion which were supposed to be incurred individually by each owner. Moreover, old water supply, sewage and electrical systems were replaced during the modernization of the building and ventilation ducts were cleaned. These additional services were beyond the scope of works and funds awarded to the thermal modernization of the building.

Energy and economical efficiency of thermomodernization

In the years 2004-2012 the effects of the thermal modernization were monitored. Basic effect of thermmomodernization is reduced consumption of fuel resulting from reduced heat consumption. Between the years 2004 and 2012 an average consumption was at the level of 431 GJ/year. Average energetic effect was about 70%. Selected energy indicators after thermomodernization are shown in Table VI.

Table VI

Selected energy indicators of the analyzed building after thermomodernization

Parameters	Unit	After
Heat demand for heating without the efficiency of the system	[GJ/year]	273.2
Heat demand for heating with the efficiency of the system	[GJ/year]	402.4
Heat demand for hot water	[GJ/year]	198.7
Indicator of the heat demand for heating with the efficiency of the system	[kWh/(m^{2}year)]	208,7
Average energy consumption in in the period 2004-2012	[GJ/year]	431

Average fuel consumption calculated in accordance with the conditions of a standard heating period in this period was 17.1 tons/year (Fig. 3). This value for 2003 amounted 48.4 tons/year.

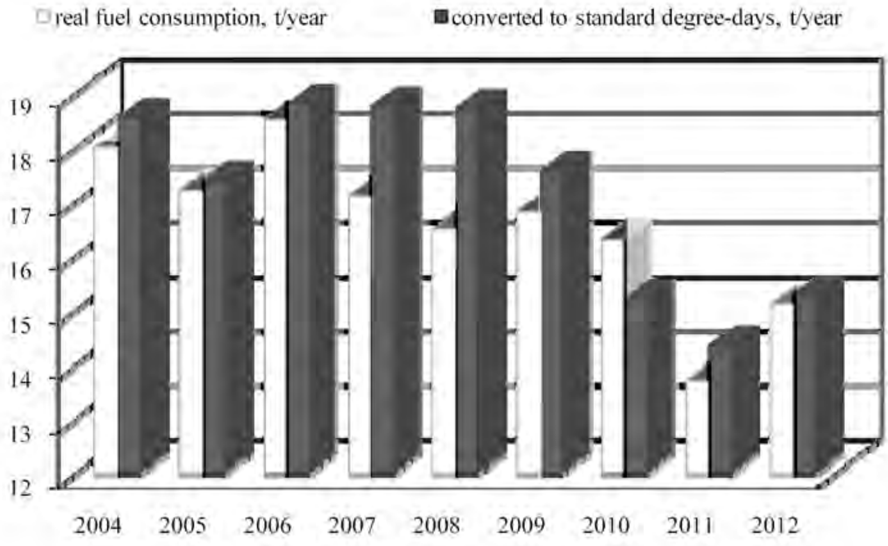

Fig. 3. Real fuel consumption and converted to a standard degree-days

A distinct downward trend in fuel use is associated with improvement of the heating system performance and using fuel of higher calorific value. Use of electric power and water decreased in the building, as well. The bills of electricity for the purpose of central and water heating were approximately three-fold lower. We can observe an interesting result if we compare annual cost of energy with costs to be incurred by the inhabitants if the thermal modernization of the building had not been made (Fig. 4).

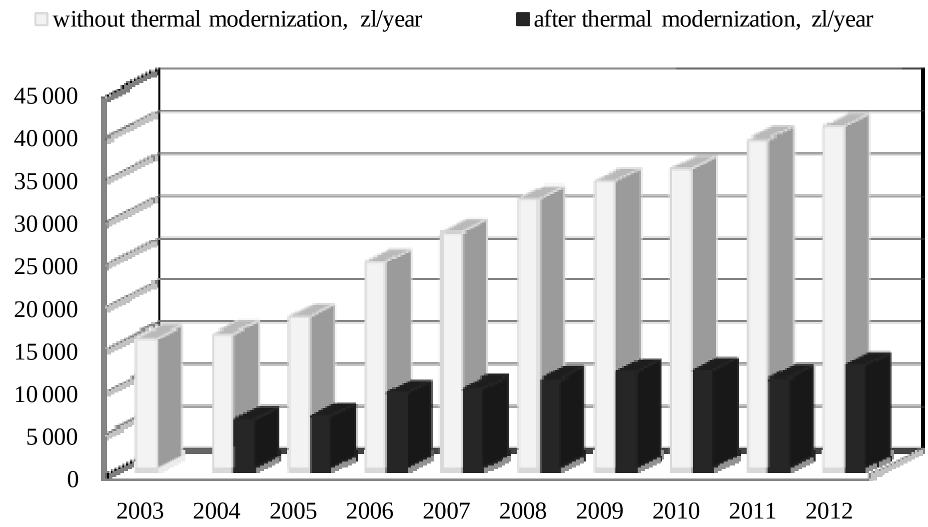

Fig. 4. Annual energy costs in comparison to the cost without doing thermal modernization

Average savings related to reduction of heat costs per each inhabitant for the entire period under the assessment was about PLN 810.00/year and about PLN 50/year for each resident although a 2.5-time rise of the coal price was observed in that period.

Ecological efficiency of thermomodernization

Decreased use of fuel influenced directly reduced emission of hazardous substances from the burning process to the air (Fig. 5.). Average air pollution emissions were reduced by about 51%, where the biggest decrease was observed for nitrogen oxides – 63%. Thus the environmental pollution bills, if were applied, would be lowered by 51%.

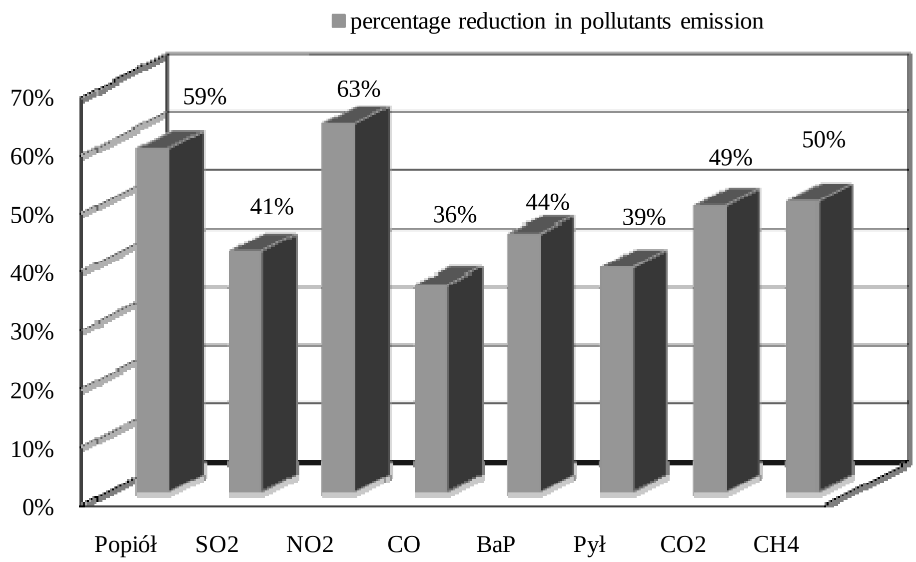

Fig. 5. Percentage reduction in pollutants emission

As can be seen replacement of furnaces with individual central heating systems for the purpose of providing heating to each apartment in analyzed building significantly reduces gas emission. In recent years a downward trend in number of flats and houses using furnaces to the benefit of central heating systems has been observed (Fig. 6.).

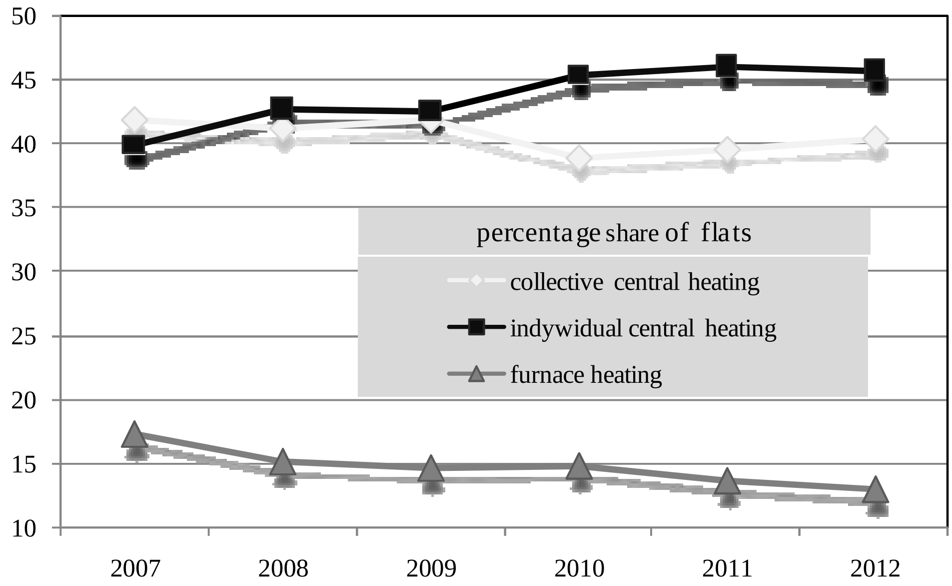

Fig. 6. Percentage share of flats with individual heating systems [4]

Another reason why hazardous gas emission is reduced is the fact that central boiler house prevents individual users from burning different types of waste including plastic.

Considerable decrease of demand for non-renewable primary energy was also reported. Demand for non-renewable primary energy in years 2003-2012 shown in Fig. 7.

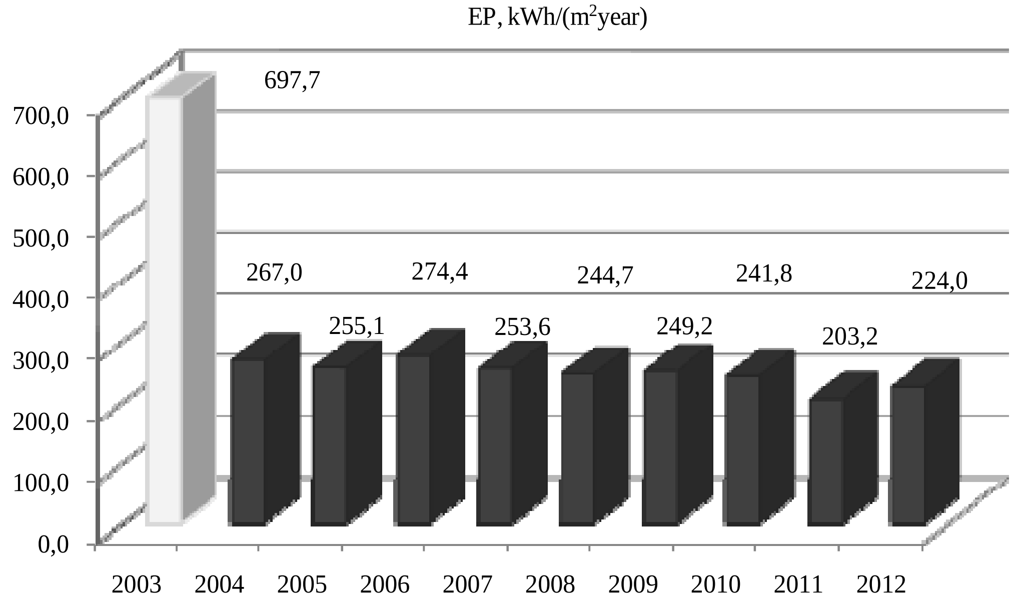

Fig.7. Reduction of demand for non-renewable primary energy

In the analyzed building aren't used renewable energy sources. By using e.g. solar collectors for preparing warm water can yet reduce the value of demand for non-renewable primary energy.

Summary and conclusions

Realization of thermomodernization works in a comprehensive way allows not only energy consumption but also decrease of building operation costs and reduction of environmental damages resulting from overusing natural resources and harmful gas emissions. Implementation of new technologies and solutions in the construction engineering is so important as it highly influence areas of greatest importance for sustainable development and energy efficiency of construction industry. In this article a case of comprehensive thermo modernization of a residential building was described. Such thermo modernization initiatives are ideal examples and can inspire and stimulate sustainable development in local communities, in particular in small towns and villages.

The study showed that:

1. Thermomodernization initiatives contribute to energy, economic and environmental effects related to sustainable development and energy efficiency of construction industry;
2. Comprehensive thermomodernization of a buildings brings the greatest effects and the shortest time of return on invested capital;
3. Thermal modernization can be carried out on especially beneficial conditions in ten ant associations since the members take responsibility not only for their apartments but also for the entire building (jointly owned spaces);
4. A large-scale thermal modernization investment can be completed even by a small, not particularly wealthy community which can reach various measurable benefits out of it;
5. In order to use the funds allocated to thermal modernization more effectively and initiate the Reed of thermal renewal it is necessary to intensify education and promotion of the advantages of such initiatives among the members and management of the tenant associations.

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