MODELS FOR ENERGY EFFICIENCY OF BUILDING THERMO INSULATION

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Abstract

The making of a model for management of buildings condition needs at first place to identify factors and their potential influence. As such has been recognizes the thickness of the thermoinsulation material, the energy savings provided by this material, the prices for the energy source used in the building and the size of investment in laying the thermoinsulation on the building. Measuring the impact of each factor requires specific analytical model. In addition, all these models can be combined in a system for evaluating the economic efficiency of an investment in overall building thermoinsulation. Expectations are that this system of models will allow to appraise in advance any investment when choosing among multitude thermoinsulation materials and having different energy sources within the building.

Keywords: economic efficiency, energy efficiency, investment models.

1. INTRODUCTION

For the last twenty years the concept ‘energy efficiency’ has gained a significant popularity worldwide and raised multiple debates on governmental and scientific stages. The concept is primarily referred to the manner of management and reduction of the energy consumption. The immense significance of the energy efficiency evolves from the presumption that due to the major usage of primary energy resources in production, such as coal, crude oil and petroleum products, nuclear energy, natural gas, biofuels and biomasses, huge quantity of greenhouse gases is emitted in the atmosphere, and that causes overall negative effects on environment and population.

For the climate conditions in Europe, the energy consumption is considerable. Huge part of the energy costs is formed by households and comprises the energy used for heating and hot water supply in winter and for air-conditioning in summer. The annual increase in consumption of primary energy sources prompted for even more pessimistic forecasts, which insisted in many countries to be undertaken actions for reducing the energy consumption through measures for improving energy efficiency. Some of these measures provided new methods for improving the buildings condition, which are focused mainly on energy saving – thermo insulation of the exterior components of buildings, such as floors, walls, and roofs, as well as replacement of the buildings technical installations with energy efficient ones. These methods may be applied irrespectively of each other, as well as cumulatively, since the latter opportunity proposes a higher level of energy saving.

2. MODELS FOR ENERGY EFFICIENCY OF BUILDING THERMO INSULATION

The necessity of managing the buildings condition in terms of improvement stems from the human need of comfort and functionality, but also from the following sizeable statistical data for the number of residential buildings in Bulgaria (table 1) and the share of energy consumption from households compared to the total energy consumption in national economy (table 2):

Table 1: Housing Statistics in Bulgaria to 31.12.2015

Residential buildings (number)	Distribution by exterior walls material type		
	reinforced concrete and panel	Brick-built	other
2 069 867	77 812	1 650 013	342 042

Source: Bulgarian National Statistical Institute

Table 2: Final energy consumption by sectors in thousand tons of oil equivalent

Sectors	2008	2009	2010	2011	2012	2013	2014
Industry	3451	2443	2549	2693	2576	2579	2701
Transport	2832	2772	2738	2722	2871	2604	3255
Housing	2125	2149	2262	2391	2377	2257	2213
Agriculture	186	183	184	204	198	193	188
Services	958	939	987	1040	1021	964	1010
TOTAL	9552	8486	8720	9050	9043	8597	9367
Share of housing	22%	25%	26%	26%	26%	26%	24%

Source: Bulgarian National Statistical Institute

The combination of the data shown provides a new overview on the methods for improving buildings condition, as a greater attention is given to those ones which guarantee lower energy consumption in buildings. Each action that leads to long-term reduction of energy consumption in buildings enhances their energy efficiency.

According to the UN Framework Convention on Climate Change, the essence of ‘energy efficiency’ is to reduce the atmosphere pollution through control over the greenhouse gas and other substances emissions by means of more efficient production, transfer, distribution and consumption of energy.

Among the measures recommended by the International Energy Agency in order to gain energy efficiency in the everyday life of individuals and organizations as economic subjects, is exactly the choice of effective thermo insulation and window systems in favour of saving energy and financial resources

Directive 2010/31/EU on the energy performance of buildings states that buildings account for 40% of total energy consumption in the EU. Meanwhile, tendencies for sector expanding indicate increase of its energy consumption, and therefore growth of greenhouse gases emissions. Hence, the improvement of buildings energy efficiency would allow the EU to comply with the Kyoto Protocol to the UN Framework Convention, and honour its commitment to reduce, by 2020, the overall greenhouse gas emissions by at least 20% below 1990 levels.

These circumstances as shown above define the two radical methods for improving the buildings condition in terms of energy saving: (1) through thermo insulation of the exterior components of buildings, and (2) through replacement of the buildings installations with energy efficient ones, including systems built for renewable energy sources usage.

There are a great number of technically feasible models for thermo insulation of the exterior components of buildings. Their variety is prompted by:

• Wide range of thermo insulation materials applicable for enveloping a definite building component (walls, floor, roof, windows);

• Mode of insulation execution – on the external or internal sides of buildings, or both;

• Envelope of only one building component or in combination.

Decision on application of a particular model exclusively depends on its economic efficiency.

Mathematical models are widespread and most appropriate for economic processes expression. The elaboration of a mathematical model comprises determination of the variables and relations between them. Economic-mathematical models are a subset of the mathematical models and represent a combination of mathematical relations (equations or inequalities) which express particular aspects of real economic situation in various conditions for their appearance. A methodological base in economic models is the proportion between costs and benefits.

Improvement of the buildings condition in terms of energy saving is part of the national policy of energy efficiency, defined by strategic and legislative documents elaborated in compliance with the EU regulations.

The Bulgarian Strategy on Energy by 2020 is fundamental and defines the trends of priority in the energy policy. A main one is decrease of the energy intensity of the national economy and increase of its energy efficiency, including by zero-energy buildings. This is really indispensable having in mind the energy intensity data of the Bulgarian economy (table 3), which are the highest compared to those of the other EU member states.

In order to gain positive results in this direction, the Strategy sets ambitious goal to reduce, by 2020, the energy intensity of GDP by 50%, and takes the path toward energy saving affirmed by the EU directives. Two actions provisioned to be executed are:

• Timely improvement of energy characteristics of the existing buildings and introduction of more stringent energy standards for newly constructed buildings;support to private initiatives for enhancing the energy independency of public and residential buildings through thermo insulation and reduction of the energy costs through building solar installations for hot water, local heating systems using biomass or thermal or geothermal sources.

Table 3: Energy intensity, energy consumption and emissions in EU-28 (2014)

EU member country	Energy intensity (toe/$1000 GDP) PPP 2000	Primary energy (toe/ per capita)	Energy consumption (kWh/ per capita)	Emissions CO2 (kg CO_2/ USD) PPP 2000
United Kingdom	0.11	3.40	6067	0.28
Ireland	0.10	3.37	6277	0.28
Denmark	0.11	3.46	6462	0.28
Germany	0.14	4.08	7148	0.34
Netherlands	0.15	4.85	7229	0.33
Belgium	0.18	5.47	8523	0.34
Luxembourg	0.13	8.42	15883	0.33
France	0.15	4.16	7703	0.21
Spain	0.13	3.04	6310	0.29
Portugal	0.13	2.27	4822	0.28
Italy	0.11	2.94	5656	0.28
Austria	0.12	3.99	8218	0.25
EU-28	0.14	3.51	6384	0.31
CEE	0.27	2.45	3411	0.67
World	0.19	1.83	2782	0.46
Sweden	0.17	5.36	14811	0.15

EU member country	Energy intensity (toe/$1000 GDP) PPP 2000	Primary energy (toe/ per capita)	Energy consumption (kWh/ per capita)	Emissions CO2 (kg CO_2/ USD) PPP 2000
Finland	0.21	6.64	16351	0.34
Estonia	0.24	4.03	6346	0.78
Lithuania	0.17	2.73	3557	0.26
Latvia	0.14	1.98	3087	0.24
Poland	0.17	2.57	3733	0.53
Czech Republic	0.21	4.28	6461	0.54
Slovakia	0.19	3.39	5268	0.38
Hungary	0.16	2.64	3989	0.33
Slovenia	0.16	3.83	6918	0.34
Romania	0.18	1.83	2488	0.41
Bulgaria	0.26	2.59	4595	0.64
Greece	0.11	2.71	5723	0.34
Cyprus	0.14	3.24	6172	0.42
Malta	0.10	1.99	4818	0.33

Source: http://www.iea.org/stats/index.asp

The Energy efficiency Law in force from 2008 stipulates the elaboration of regulations related to heat preservation and energy saving in buildings, energy performance of buildings, process of energy investigation and certification of buildings upon energy efficiency categories, including the order of registration of experts who execute the processes of investigation and certification:

• Regulation No. RD-16-1058 of 10 December 2009 for energy consumption indicators and energy characteristics of buildings,

• Regulation No. RD-16-1594 of 13 November 2013 for energy efficiency investigation, certification and assessment of the energy savings in buildings,

• Regulation No. 7 of 2004 for energy efficiency, heat preservation and energy saving in buildings.

The last stipulates the major indicators for energy efficiency of buildings, the minimum requirements to the energy characteristics of buildings, technical requirements for energy saving and heat preservation, methods for calculating the annual energy consumption, and technical standards in thermo insulation design. The Regulation is applied when designing the thermo insulation of new and existing residential and non-residential buildings, which are classified into two groups: buildings with average-volume wanted temperature of the inner air over 15°C and relative air humidity up to 70%, and buildings with average-volume wanted temperature of the inner air 12÷15°C, which are heated at least three months annually. A new clarification in the Regulation is its relevance to manufacturing buildings where it is necessary a particular microclimate to be sustained, as well as to the design of thermo insulation of the exterior buildings elements that have specific characteristics of temperature - humidity conditions, such as public laundries, stationary refrigerators, premises with relative air humidity over 70%, agricultural and stock – breeding buildings, conservatories, etc.

Models for improvement of buildings condition based on architectural and structural details

The legislative documents concerning improvement of the buildings condition, through thermo insulation of the external structural elements, do not provide particular classification of buildings. There is not foreseen a classification of buildings according to the type of their construction or the type of their exterior structural elements – subject of thermo insulation. A classification is available for statistical purposes, according to which there are armoured-concrete, massive and other buildings . The classification of buildings, according to their function and the type of their exterior structural elements, has decisive role in choosing a model for thermo insulation and therefore in the economic efficiency evaluation of the investment for its implementation.

The exterior structural elements of buildings (walls, roof, floor and windows) have essential role to the formation and maintenance of a particular microclimate in buildings. Generally, there is difference between the temperatures on the two opposite sides of an exterior element, as well as between the humidity of the inner air and those of the atmospheric air. That difference causes physical processes of heat transferring through the exterior building elements. In this connection, the main functions of the thermo insulation of the exterior building elements are:

• To impede at the most the heat exchange between the air in the building and the atmospheric air;

• To contribute to the reduction of energy loss within the winter when buildings are heated, as well as to limit the energy consumption for cooling in summer.

A variety of architectural and constructional modes are elaborated for implementation of thermo insulation of exterior building elements (table 4).

Table 4: Models for thermo insulation implementation based on architectural and structural details

Exterior building element	Architectural and Construction details				
wall	Brick-wall 25 cm with thermo insulation from outside (new building)	Brick-wall 25 cm with thermo insulation on the inside (new building)	Brick-wall 25 cm with thermo insulation from outside (existing building)	Concrete wall with thermo insulation from outside	Wall of YTONG with thermo insulation from outside
roof	Single, with horizontal concrete slab	Single, with inclined concrete slab	Double, with horizontal concrete slab and Sloping wooden roof	Double, flat, with concrete slabs	Metallic
floor	Above unheated premises, with thermo insulation underneath	Above unheated premises, with thermo insulation on top			

In elaborating of architectural and constructional elements it is necessary to be used the so-called efficient thermo insulation materials, i.e. materials with coefficient of thermal conductivity $\lambda \leq 0{,}18$ W/m.K.

The exterior building elements, primarily façade walls, generally have sections which are made of material with increased thermal conductivity (concrete, steel) and usually called “thermal ties”. Typical thermal ties in buildings are eaves, cornices, balconies and loggias, bay-windows and passages, slabs over unheated basement, windows and balcony doors, transverse concrete walls, columns, exterior walls, beams and corners. For each of them there are models for implementation of the thermo insulation.

Energy accumulation

Passive heating systems are also used in practice. They function on the base of solar radiation as different types of elements are built-in into the buildings: basilica openings, collective-accumulating walls/roofs, thermo-syphon systems, heat-phase changing collective-accumulating walls. The built-in of such elements into the buildings facades depends on constructive compatibility, economic reasoning and client agreement.

The energy transforming exterior construction also deserves a special attention. An integral techno-economic model of this construction is elaborated into two versions (with only one or with two constructional modules). Their optimization is estimated through the function of the minimum annual costs.

Methods for energy saving estimation after building thermo insulation

Heat preservation in consequence of thermo insulation is the difference between the values of heat consumption before and after the thermo insulation of the building. Multiple methods are developed on how to determine the necessary energy quantity for heating. Regarding assessment of projects for buildings thermo insulation, technical requirements for energy saving are stipulated in Regulation No. 7 of 2004, as well as technical rules and standards for thermo insulation design, which are applicable to buildings with wanted inner air temperature higher than 19°C and relative air humidity less than 75%.

Methodology for calculation of the energy consumption indicators and buildings energy characteristics are provided in appendix to the Regulation No. 7 of 2004. The methodology is developed in conformity with BSS EN 832, European good practices in the field of heat preservation, and the climate conditions in Bulgaria. It shows how to calculate the heat loss through the exterior building elements and internal heat transfer, through the building ventilation, as well as the heat quantity gained through sunshine and internal sources. Energy consumption is determined for major values of the following climate factors: average monthly temperatures of the atmospheric air, duration of the heating period, day-degrees and average-hour intensity of sunshine.

Models for determination of the investment size in improving the buildings condition

The investment in building envelope should be determined through cost calculation method due to that technical implementation of building thermo insulation consists of different construction and assembly works. The value of each construction work is to be calculated in accordance to pricing schemes endorsed and applied in construction which have some particularities.

One of them requires, when pricing for each construction site and each construction work provisioned in the technical documentation, to be used the so-called “Bill of quantities”. There are two approaches that might be applied – by prices of consolidated indicator (such as 1 m^2 built-up area) or by type of construction/assembly work. In both cases it is necessary to be compiled a general bill that emphasizes the completeness of the construction site and the ability for its exploitation. Regarding the essence and particular economic functions of the Bill of quantity it may be concluded that the second approach is more appropriated to construction sites with specific technical and economic characteristics, such as buildings to be enveloped.

The application of the second approach requires detailed bills per unit of each type construction/assembly work (m^2 for implementation of XPS on brick walls; m^2 stucco; m^2 mineral plaster, etc.) which to be compiled at the end into a general bill of the project for building envelope.

Setting the prices of the major resources needed – materials, labour and machine time, is of primary significance. The prices are determined on the basis of generally defined for each construction work norms of material consumption, labour and machine time, and depend on current market prices of materials, remunerations to construction workers, rent prices per unit machine time and transport costs. A general bill of quantity is composed in accordance to the quantities and the calculated prices of the construction works needed for overall implementation of the building thermo insulation. It also contains additional costs related to warehousing, provision of protective equipment during work and social security, maintenance of equipment and machines, organization and management of the construction process.

The general norms of consumption of materials, labour, and machine time, on the basis of which the prices of the construction works are determined, and hence the total Bill of quantity of the construction projects, are usually taken as tentative. The design and construction companies may change them in conformity with the specific features and conditions for implementation of the construction works. In Bulgaria, such norms for consumption are published into multiple practical guides, and also are integrated into software products for pricing in construction. Quite recently efforts are made by some scientific organizations in partnership with construction associations to develop norms of consumption through examination of modern materials application.

Methods for evaluation of the economic efficiency of investments in buildings thermo insulation

The main indicator for economic efficiency of investments in buildings thermo insulation should be the impact that energy consumption has on labour productivity. The increase in production output due to proportional augmentation of labour, material and energy resources has no economic impact. The retention of production output while reducing labour consumption leads only to limited speed-up of production. Increasing production output while cutting labour and energy costs is the most intense way to develop. On the conservative principle - less labour to achieve the same production output, the general principle must be opposed - less labour and energy to gain higher output. Every new research aims at achieving economic impact by: energy efficiency (driven by lower fuel and energy consumption, energy savings, environmental energy use, etc.); structural effect (it reveals by simplification of constructions, reduction of production areas, increased concentration of production equipment, reduction of engineering communications, etc.); technological effect (it is achieved if the scheme of energy provision improves production technology, for example, improving the micro-environment features); ecologic effect (it is observed when there are savings of conventional energy sources, as well as using alternative sources).

Due to its comprehensive nature, the aggregate cost method is very widely applied in the field of energetics and engineering. Specifically, when designing projects for improving the energy performance of existing and newly-constructed buildings, it is assumed that investment costs are made once (within one year) and the energy-saving effect is durable. Then the function of the aggregate annual specific costs will be as follows:

$з = W+(p+E_H). I_0$, as

W (*kWh/ m^2.year*) is the value of energy loss through 1 m^2 area of exterior building elements (walls, doors, windows, ceilings, roof),

p, (*%*) is amortization rate for maintaining the exterior building elements,

E_H (*year^{-1}*) is the wanted coefficient of economic efficiency of the investment in measures for energy efficiency improvement;

I_0 (*amount per m^2*) is the investment size for thermo insulation implementation.

Payments for investment/credit return are to be determined through the wanted value of the coefficient for economic efficiency $E_H = \frac{1}{T_{pb}}$. In cases where energy saving projects are being implemented, in order to determine their economic efficiency, it is also necessary to use the following indicators: value of the energy saved; investments made, so to achieve energy savings; additional operating costs on provision of facilities in order to achieve energy saving; decreased extraction/production and transport costs on provision of conventional energy sources; diminished investments in the extractive industry due to the energy savings, etc.

The technical life of buildings thermo insulation projects (*in number of years*) is determined by the physical durability of the materials used which is approximately 10 years as certified by manufacturers or distributors. But it is also supposed that it could be extended up to 50 years. The economic life is the period which for the project is profitable (i.e. there are energy savings). Obviously, it has to be the economically rational (expedient) period for payback of the investment.

Techno – economic evaluation of measures for energy efficiency is performed on the basis of: I_0 – investments costs for the project execution; *S* (*kWh/year*) – net annual energy savings; *E* (*price/ kWh*) – price of the energy source used during the project duration; *n* (*number of years*) – technical lifecycle of the project; n_r (*%*) – rate of discount to be used for calculating the present values of cash flows (energy savings).

The investment costs I_0 comprise all costs that need to be made for the project overall implementation: costs on technical design; costs on purchasing and supply of thermo insulation materials and construction works execution; costs on energy consumption; costs on exploitation and maintenance.

When evaluating the economic efficiency of projects for building thermo insulation it is appropriate the annual net savings to be calculated as follows:

$\boldsymbol{B = \sum_{i=1}^{k} S_i E_i - \Delta O\&M}$, as

B (*amount per year*) e annual net savings,

S (*kWh/ year*) – energy quantity saved for one year in result of thermo insulation,

E (*price per kWh*) – price per unit energy source used in the building,

Δ O&M (*amount per year*) – variation in costs on exploitation and maintenance.

Regarding investment costs in buildings thermo insulation, it is not expected costs to be made on exploitation or maintenance of the thermo insulation system within the technical life of the materials used (according to the technical features indicated in declarations of specification and/or quality certificates issued for each material). So, the variable *Δ O&M* in the equation may be eliminated. The equation does not envisage opportunity for greater savings due to discount in result of shortening the payback period in cases of credit usage.

Regarding reliability in evaluating the economic efficiency of real investments, methods based on discounted cash flows are proven into practice: discounted payback period (*DPBP*), net present value (*NPV*), internal rate of return (*IRR*), and profitability index (*PI*).

Cash flow modelling consists of determination of all revenues and expenses associated with project implementation for the period of its technical and economic lifecycle. Models are built on the basis of indicators and criteria analysed above. The energy consumption and the expected energy savings depend on climatic seasons - a feature that affects the cash flow. Pre-design preparation and research, design and project management, and project financing are also contingent on these prerequisites.

Regulations related to measures for energy efficiency enhancement do not provide particular requirements or criteria for quality of thermo insulating, and do not define their relevance to the design standards and rules. Among all applicable indicators, fundamental to the characteristics of the exterior building elements are suggested to be:

- *Protection from condensation*, which depends on the minimum required value of the thermal transmittance resistance R_T ($K.m^2/W$):

$$R_T = \frac{\theta_T - \theta_0}{\Delta\theta_H . \alpha_i}$$, as

θ_T is the air temperature wanted in premises (ºC);

θ_0 is the temperature of the atmospheric air (ºC);

α_i is the coefficient for heat transfer from the inner air to the inner surface of the wall ($W/m^2.K$);

$\Delta\theta_H$ is the temperature drop between the inner air temperature and the temperature at the inner surface of the wall (ºC).

The temperature drop $\Delta\theta_H$ is function of the inner air and atmospheric air temperatures and humidity of the inner air, as for each building their values are changing in wide range. In some cases, it is determined according to the relation $\Delta\theta_H \leq (\theta_T - \theta_P)$, as θ_P is the dew temperature. It is determined by the so-called I-D of humid air. It is founded that $\Delta\theta_H$, depending on the air humidity in the premises, has direct impact on the necessary thickness of the insulation, when internal air temperature is constant. The atmospheric air temperature θ_0 is diverse for each climate region of the country, among -10 до -20 ^{0}C. The coefficient of heat transfer α is defined in many resources and takes the value $\alpha = 8.7$ W/ m^2.K.

- *Provision of physiological comfort* – it depends on the $\Delta\theta_K$ which is significantly less sensitive than $\Delta\theta_H$. For example, to people it must be $\Delta\theta_K \leq (\theta_T - \theta_C)/2$. This indicator for quality of thermo insulation implementation has not been taken into account yet in buildings design. Compliance with this requirement means people/animals to feel comfortably in buildings, without sense of cold, and sickness restraint. Admittedly, it will raise the price of estates.

Both requirements are introduced and analysed in Regulation No. 7 of 2004. The requirement “prevention from condensation” means to be determined the minimum needed investment for implementation of the thermo insulation in order to avoid condensation in the building which causes appearance of fungi and other health injuring microorganisms. The second requirement – provision of physiological comfort, sets the maximum expedient amount of investment. It is expected the optimal investment size to be among the two values described. The integration of the two major requirements into analytical model provides opportunity to estimate building thermo insulation projects taking into account both quality and techno – economic efficiency characteristics. Making this opportunity a reality calls for optimization of each exterior building element (walls, roof, floor, etc.) in terms of their energy efficiency enhancement.

The function of the aggregate specific annual costs is formulated, as well as the functions for the optimal thickness of the thermo insulation and the minimum specific annual adjusted costs. The model consists of thermo physical, constructional and economic variables and coefficients which determine the economic efficiency, namely: wanted air temperature within the building (*ºC*); atmospheric air temperature (*ºC*); required value and actual value of the temperature drop between air temperature in the building and the temperature on the inside surface of walls (*ºC*); coefficient of heat transfer from the air inside the building to the inside surface of walls (*W/m.K*); temperature measured on the inside surface of the walls (*ºC*) at which condense appears; the wall temperature (*ºC*); thickness of the external coatings of the wall (*m*); thickness of the thermo insulation material (*m*); thickness of the vapour barrier folio (*m*); coefficient of heat transfer from the external surface of the wall to the atmosphere (*W/m.K*); coefficient of heat transfer of the materials used for walls external coating (*W/m.K*); coefficient of heat transfer of the thermo insulation material (*W/m.K*); coefficient of heat transfer of the vapour barrier folio (*W/m.K*); energy loss through the walls (*kWh/m*^{2}); payback period of the credit (*in years*); wanted index of profitability in case bank credit is used; aggregate specific annual adjusted costs (*лв./ m*^{2}*.год.*); investment costs needed for implementation of the thermo insulation (*amount per m*^{2}); values of atmospheric temperatures at intervals of 2 ºC; the duration (*h*) of atmospheric temperatures hold at intervals of 2 ºC; price per unit (*kWh*) energy according to the energy source; prices of the materials used for the wall external coats (price per *m*^{2}); price per unit (m^2, m^3, etc.) thermo insulation material to be used for building enveloping; economically optimal thickness of the thermo insulation material (*m*); minimum required thickness of the thermo insulation material (*m*) in order to avoid condensation and to ensure physiological comfort; minimum aggregate annual adjusted costs (*amount per m*^{2}*.year*).

The main function of the techno – economic model for energy efficient thermo insulation of buildings is elaborated in such a manner that allows at each stage of implementation process to be evaluated. It is achieved through formulating the function of the total annual costs (costs/ *m*^{2}*.years*), total annual energy losses, and investment amount which includes also additional costs related to labour, materials supply and storing, and profit for the construction works contractor. A model is elaborated for calculating the minimum needed thickness of the thermo insulation, and conditions are set for minimum investment costs on thermo insulation (Terziev., Filipov, , Enimaneva, 2017a, str.460-491; Terziev, Filipov, Enimaneva, 2017b, str.56-91; Terziev, Filipov, Enimaneva, 2017c, , str.92-121; Terziev, Enimanev, Enimaneva, 2017d, pp. 601-624; Terziev, Enimanev, Enimaneva, 2017e, pp. 625-651; Terziev, Enimanev, Enimaneva, 2017f, pp.653-676; Terziev, Enimanev, Enimaneva, 2017g, pp.533-573; Terziev, Enimanev, Enimaneva, 2017h, pp.574-609; Terziev, Enimaneva, Filipov, 2017i, pp. 9-27).

3. CONCLUSION

The analysis of methods for modelling the economic efficiency and estimation of projects for buildings thermo insulation comes to the following conclusions:

- Development of methods, theoretic and applied methods and standards for evaluation of the techno – economic efficiency of projects for buildings thermo insulation will predetermine their future implementation;

- The concept of economic efficiency in projects evaluation, including projects for energy efficiency enhancement, is not thoroughly examined and developed;

- When making a decision on particular project for building envelope in terms of energy consumption reduction, the decisive indicator has to be the total annual costs because they reflect the optimization of technical features (such as minimum required thickness of the thermo insulation, maximum energy saving for particular thickness of the insulation, etc.) and minimization of the investment costs;

- Models for evaluating the economic efficiency of projects in buildings thermo insulation should take into considerations the requirements for condensation avoidance and physiological comfort which determine respectively the minimum and maximum values of the investment;

- Optimization of the cash flows in result of energy savings will be in place only if projects for thermo insulation of buildings are managed in conformity with the seasonal character of the energy consumption and the expected value of the energy savings used for paying back the investment in due time;

- Discounted methods for evaluation of investments in buildings thermo insulation projects may be applied if the following conditions for their modification are in place:

1) The net cash flow to be the value of the energy quantity saved, calculated by current price of the energy source used in the building;

2) Appropriate determination of the discount rate having in mind that investment in building thermo insulation is one-time process and its payback starts in consequence through the energy savings;

3) The investment payback period should not exceed the time limit of technical exploitation of the thermo insulation system, as otherwise the investment would be economic inefficient.

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