MULTICRITERIAL EVALUATION METHODS FOR THE SELECTION OF COMPETING ENERGY-EFFICIENT TECHNOLOGIES

DAUDZKRITERIĀLĀS VĒRTĒŠANAS METODES KONKURĒJOŠU ENERGOEFEKTĪVU TEHNOLOĢIJU ATLASEI

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Keywords: multicriterial methods, energy-efficient technologies, comfort, heat balance of buildings

ntroduction

Raising the energy efficiency of buildings as end consumers of energy is becoming the main constituent part of the energy policy in the countries of the world because: the building complex and the need to ensure human living standards require more than 40% of the useful energy; the saved energy is several times cheaper than the energy obtained anew and supplied o the consumers; raising the room temperature by 1 degree increases the heating costs; the payback time of the renovation of the heating system is usually shorter than the payback time of thermal insulation of buildings; the tariff of thermal energy set by the regulator has a direct mpact on the payback time of the project; it is advised to centralise heat supply as the basis in he nearest perspective in spite of the comparatively great losses in the heat networks; the existing improvements and reconstruction of buildings is connected with a possibility to take economically sound measures for raising their energy efficiency; it is necessary to take into consideration power intensity when building materials and products are made (when the energy efficiency of a building complex is determined, preference should be given to the materials the production energy efficiency of which is relatively small) as well as the circumstance that modern technologies, materials, structures and equipment are implemented successfully in order to raise energy economy in the market (therefore their wide application should be promoted).

Energy economy in the buildings is achieved in two ways: by improving the thermal protection properties of the envelopes and by updating the heat supply systems. There is a great number of energy saving measures which differ by the materials, labour costs and the efficiency of their application. Measures should be selected from them which satisfy the requirements of maximum effect with minimum costs.

The efficiency function of an energy-efficient building

The optimisation of an energy-efficient building has the following content: to determine such indices of the architectonic and engineering technical solutions of the building which ensure minimised energy consumption for the creation of the indoor climate in the building. In a general, mathematical way the efficiency function of an energy-efficient building is:

$$Q_{min} = F\,(ai), \tag{1}$$

where Q_{min} – the minimum energy consumption for the creation of the indoor climate in the buildings; a_i – the indices of the architectonic and engineering technical solutions which ensure minimisation of the energy consumption.

Estimation of the harmonisation of the form of the designed buildings, considering the particular weather conditions in the construction region, is carried out by comparing the consumption of thermal energy Q_{min}, *Wh*, for the case of heating and cooling of the building when the form considers in the best way the impact of the outdoor climate in the construction region, and the consumption of thermal energy Q, *Wh*, for heating and cooling of the building accepted when the building is designed. In actual designing it is not generally possible to implement energy-efficient buildings because of various restrictions which are the consequences of the requirements for a particular construction project or because of quantitative and qualitative considerations that were not taken into account in mathematical simulation. In such a case an index is introduced which characterises the realised and the optimal decision, and which is called the thermo energetic efficiency index of the solution of the project and determined by the formula:

$$\eta = \frac{Q_{\min}}{Q} \qquad (2)$$

where Q_{min} – the energy consumed to create the indoor climate in energy-efficient buildings; Q – the energy consumed to create the indoor climate in the buildings to be designed.

The efficiency index of solution of the project which characterises the difference between the designed building and the building in which the impact of the outdoor climate of the construction region is best taken into account should be within the limits: $0.7 \leq \eta \leq 1$.

Considering the accepted division for the mathematical model of the thermal mode of the building as a unified thermo energetic system, the thermo energetic efficiency index in 3 interconnected sub models of the project is determined by the formula:

$$\eta = \eta_1 \cdot \eta_2 \cdot \eta_3 \qquad (3)$$

where: η_1 – the thermo energetic efficiency index of the impact of the outdoor climate on the optimal registration of buildings; η_2 – the thermo energetic efficiency index for optimal selection of thermal protection of the envelopes; η_3 – the thermo energetic efficiency index for optimal selection of the systems ensuring the microclimate of buildings.

The geometric shape of the building essentially affects the consumption of energy. Therefore the geometric coefficient of the compactness of the building is introduced as the relation of the envelope area to its included volume.

Multicriterial approach

The criteria for the energy efficiency evaluation of the building comprise: the climatic parameters of the surrounding environment; the indoor climate parameters of the building; architectural and constructional solutions and the geometric coefficient of the compactness of the building; thermo technical parameters of the envelopes of buildings; the coefficient of the filling area of the openings for light; characteristics of the heating and hot water supply systems; characteristics of natural and mechanical ventilation; characteristics of the air conditioning system; as well as the parameters of the impact of the building on the surrounding environment; the lighting equipment, of internal heat and moisture release, the parameters of the use of solar radiation in passive systems.

The energy efficiency criteria should be economically grounded, i.e. application of the energy-saving measures should be economically profitable and give effect in the nearest perspective. Therefore all the technical parameters already mentioned should be supplemented by ecological and economical criteria that characterise various technical measures of raising energy efficiency.

It is always necessary to know the planned final result of the energy saving measures – what they ensure and which criteria will dominate in them. These may be the following measures: to gain considerable economic effect in saving energy resources, taking into account the trend for the prices to rise; to reduce the negative impact on the surrounding environment thus improving ecology and economics; to improve the indoor climate in houses which favourably affects the living and working conditions of the people; to take a complex decision in which one of the aforementioned criteria is optimal.

When designing energy efficient structures, methods should be chosen in which it is necessary to define clearly the main requirements in such aspects: the initial conditions in the calculation methodology of an energy-efficient building; the minimum requirements for the energy efficiency of new buildings; the classification and certification of the buildings to be reconstructed corresponding to their energy efficiency; the norms of specific energy consumption depending on the classification of buildings and premises, dividing them by the types of energy resources and energy consumption systems; drawing up of the energetic passport of buildings; minimum demands for modern heating systems with regulated heat consumption; minimum demands for modern ventilation systems with the use of heat recuperation; the energetic audit methods of a production enterprise meaning by "audit" not only the energy audit of the building but also the audit of production equipment and technological processes.

These main requirements are differentiated in the countries of the European Union for newly erected buildings, the buildings that are ready for occupation, as well as the structures of various categories, and they are imposed on the machinery due to functional and economic considerations.

The operative measures of the low costs of energy economy are such that the technological process is not interrupted in them, the technical solutions of which do not essentially differ from the original (not more than 10-15%), and whose payback period of the costs is less than a year. Such measures are: the energetic passport; the heat consumption and energy consumption management; the energetic audit.

The energetic passport is intended for the control of the heat protection thermo technical and energetic indices in an adequately designed, erected and maintained building. It includes normed and controlled parameters which envisage evaluation of the energy efficiency of the building. Information about energy consumptions should be entered into the data bases, it should be accessible to the owner, buyer, inhabitant and it should serve as an initiative for the development of investments. The energetic passportisation of the housing property should provide their management organisations with objective information.

The energetic passport of the building should contain reference values which ensure a possibility for the consumer to compare and evaluate the energy efficiency of the building. The passport should be supplemented with recommendations about the economically profitable measures of raising the energy efficiency of the building.

The main principle of rating the energy efficiency of a building is expressed by the formulae:

$$EP \leq EP_{max}, \qquad (4)$$

where **EP** – the calculated or measured primary value of energy consumption of the building, or the index of the carbon dioxide emissions; **EP_{max}** – the maximum value of energy consumption of the building, or the index of the maximum carbon dioxide emissions.

The value of expression **EP_{max}** must be standardised according to the country's technical and economic conditions. The value of expression **EP** is calculated or measured according to the procedures which take into consideration the thermo technical characteristic curves of the buildings. The value of the primary energy consumption of the building includes the calculated values of heat consumption for heating, the hot water supply, ventilation, air conditioning etc. for 1 m^2 of total area of the building.

The reasons why recurrent energetic passportisation of buildings is necessary are: deviations from the initial project during the construction of the house; the quality of the erection work and the maintenance quality of the equipment; reconstruction of the heating system with the installation of the regulating and balancing valves and room controllers; replacement of windows; reconstruction of the outer doors of the house and balcony glazing; specification of the calculation methods of the heat consumption of the building taking into account solar radiation, everyday heat release and infiltration.

The common structure of a standard energetic passport includes: the climatic characteristics of the construction region, including information about the heating period and the intensity of solar radiation on variously oriented surfaces under the existing conditions of cloudiness; the calculated indoor temperature and moisture; general construction information about the geometry and orientation of the building, the number of storeys and their volumes, the area of the envelopes and the floors of the heated premises; information about the indoor climate maintaining systems and regulation methods related to the climatic conditions and other heat generating sources in the house; the values and energetic parameters of the heat protection projects of the building, including indices both for individual compartments and the entire building, the summarised energetic parameters of the building, such as the specific energy consumption for heating the house during the heating period and for one heating degree-day; cheek-up of the agreement of the thermo technical and energetic indices of the house with the rated values; changes in the erected building (of its planning, constructive, microclimate maintaining systems) in comparison with the project; the results of the energy audit – determination of the energy consumption and heat protection parameters of the house after its one-year operation and the summarised thermo technical and energetic parameters obtained on its basis; a comparison of the heat protection and energetic characteristics of the project and the operation of the building, assigning an energy efficiency degree with respective abatements or sanctions, certification of the building and economically profitable measures in order to raise energetic efficiency.

The energetic passport is drawn up by applying two methodologies: the heat protection designing methodology for the building and the experimental control methodology of the energetic and thermo technical parameters of the operated house. In evaluating the energy consumption of the building under natural conditions not only the consumption of heat supplied to the house by the heating system is taken into consideration but also the other sources of energy which release heat in the building: the hot water supply, electric lighting fixtures and household appliances, etc. For example, in conformity with the legislation of the Scandinavian countries – the energetic passportisation of all the existing buildings should be carried out once in one and a half years.

The next measure in the field of operative energy saving is the heat and energy consumption management in buildings. This direction is considered in the world practice as strategically the most efficient one. At present, application of the efficiency of this measure in Latvia is based mainly on changing the heat supply pattern – a transition from central heat supply points to individual ones. If the buildings are supplied with heat from central heat supply points, the temperature of the direct heat carrier in the heat pipeline is the same in the buildings with different technological functions (administrative buildings, schools, dwelling houses, theatres, cinemas, production premises, etc.) and heat protection.

The use of individual heat supply points with the blocks of management opens wider possibilities for saving energy due to lowering the prognosticated indoor temperature in most modern public and industrial buildings during the night, at the weekends and on the holidays. According to the international experience, lowering the prognosticated indoor temperature gives 15-20% economy of energy in the heating season.

In order to ensure energy efficiency of buildings, it is very important to carry out energy consumption and heat protection check-ups of the object. This is necessary to ensure a feedback between modern solutions envisaged in the project and their energetic efficiency in operation, i.e., to check the thermo technical characteristics of the envelopes envisaged in the project, and the conformity of the energetic indices of the technical systems with the characteristics and indices practically realised in the course of the construction and maintenance of buildings.

For this purpose natural heat check-ups are carried out for the buildings which are used for more than a year (to remove from the building structures moisture which had accumulated there when the wet water-related technological processes of building were carried out) with obligatory measuring the heat consumption by the heating system and simultaneous control of the changing heat and air modes of the building. Such check-ups are called energetic audit which is defined as a series of operations aimed at the determination of the energetic efficiency of a building and evaluation of measures with a purpose to raise its energetic efficiency and energy economy. The results of the energetic audit form the foundation for the classification and certification of buildings by their energy efficiency. The energetic audit may be conducted also with an aim to inspect closer some of the thermo technical and energetic characteristics of houses. The audit of buildings is conducted by independent accredited organisations. In accordance with the results of check-ups, an energetic efficiency degree is assigned to the house and recommendations are provided how to raise this parameter.

The form and way of the energetic audit depends on the defined task: to conduct the classification of the house by its energetic efficiency indicating the buildings which need urgent reconstruction from the energetic point of view; to perform energetic certification of the building testifying that the particular house meets the requirements of the normative documents; energetic audit is carried out in order to find out individual component parts of the energetic balance of the building with an aim to draw up a plan of measures for the reduction of energy consumption. Such an energy audit is labour-consuming because contact methods are to be used when inspecting individual structural elements of the envelopes to determine their thermo technical and energetic characteristics.

Indoor microclimate and comfort

Since people stay mainly in the dwelling or working houses or rooms, the efficiency of their work depends, to a great degree, on the quality of the indoor climate. The concept 'microclimate' should be understood as maintaining constant definite condition of air in the room which can be characterised by air temperature, moisture and purity.

The condition of air defined by such parameters as constant temperature, moisture and velocity of the masses of air in which humans feel especially well is called a comfort zone.

However, the range of all the parameters cannot be determined in a detailed way because one has to take into consideration also many other factors, such as the characteristics of the envelopes of the buildings – their surface temperature, etc.

The human sensation of warmth depends on four factors: air temperature; air moisture; velocity of the masses of air (mobility); the surface temperature of the envelopes.

The human sensation of warmth may be the same at different combinations of these parameters. However not every combination of these parameters ensure comfort conditions.

Man feels comfort in case such amount of heat is released from him which is equal to that produced by his organism. Consequently, the human sensation of comfort is determined by the equilibrium between the heat generation and the heat release in the surrounding environment. Depending on the kind of activity the released heat is uniformly returned to the environment. The values of the heat release of one man, according to DIN 1946/2, are indicated in the following table:

Kind of activity	Degree of activity	Heat release [W]
Sedentary work, usual office work	I	100
Light standing load, the work in the laboratory	II	150
Work of medium load	III	200
Hard physical work	IV	>250

Due to the natural thermoregulation man can easily adapt himself to the variations of the parameters of the surrounding environment. Great importance is attached to the way of physical regulation of the body temperature, or the external heat release. As a result of heat generation and heat release, the internal temperature of the human body is maintained within a range of 36.6÷36.8°C. The temperature of the human skin is dependent on the parameters of the surrounding environment, and usually it is 33°C. The interaction of the human warmth with the surrounding environment is called the equilibrium of the body warmth, or temperature. For man to feel comfort, the main condition of the heat comfort should be:

Heat release = released heat.

The main task of the room climatisation is to maintain such parameters of the air medium in which every person, due to his or her individual natural thermoregulation, would feel comfort, i.e. they would not feel the impact of the surrounding environment. If an excessive amount of heat is released from the human body, for instance, because of lowered surface temperature of the envelopes, it is felt as discomfort.

The heat comfort means pleasant human sensations in the heated room. The temperature and moisture adequacy may be the chief calculation values for the indoor conditions; these indices are also taken as the basis for load calculations. In any possible working place most workers should feel comfort but, approaching the centre of the comfort zone, greater comfort is felt. The human comfort depends also on such factors as: air purity; noises; lighting; the kind of activity, etc.

The main task of heating, ventilation, conditioning systems is to ensure that the factors mentioned were in agreement with the metabolic action of the human organism and the norms of breathing. The indoor temperature is generally considered as the primary criterion in the evaluation of the heat condition of the heated rooms which, like the air velocity, determines the convection transfer of the flow of heat from the human body into the surrounding environment. The indoor air temperature is considered comfortable if it is: 20÷22 ° C in winter and 22÷24 ° C in summer.

The human sensation of comfort is affected by the internal surface temperature of the envelope, which is as important as the indoor air temperature. The mean arithmetic value of the internal surfaces of the envelopes t_w and the indoor air temperature t_{in} can be defined as the efficient indoor temperature t_e:

$$t_e = \frac{t_{in} + t_w}{2}. \tag{5}$$

Usually this value is a normative value in designing the heating systems of the rooms. If the surface temperature of the envelope is lower, then the indoor air temperature must be higher. This condition should be observed in order to obtain joint heat comfort. In a general case, the room is considered thermally uncomfortable if the temperature difference of the wall surface and air is greater than 4.5°C. Figure 1 shows a comfort zone in connection with temperatures of the envelope and the indoor air.

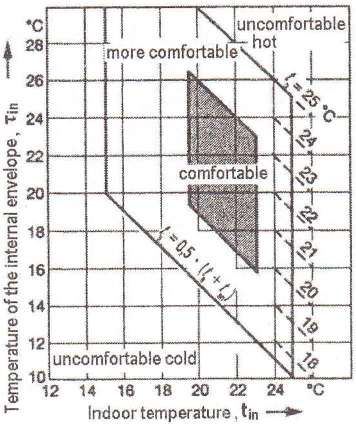

Figure 1: Dependence of the comfort zone on the temperature of the internal envelope and the indoor temperature, according to G.Reicher and V.Frank

The higher limit of the moisture in the room depends on the structural peculiarities of the room and the calculated winter temperature. No appearance of the condensate is allowed on the internal surfaces of the windows and the doors, as well as between the layers of a multi-layer wall, ceiling and floor structures. If the condensate still appears, the moisture can damage the house. The condensate may be the cause of rot, unpleasant odours, the growth and reproduction of various micro-organisms which do harm to the building and human health.

During the warm period of the year high level of moisture in the room is not beneficial to the people. The allowed relative moisture is 60% because at higher relative moisture the people feel discomfort. Under the conditions of low outdoor temperatures and great indoor moisture a possibility increases for the inner surfaces of the envelope to get covered with the condensate. In order to avoid moisture condensation problems, the level of relative indoor moisture during the winter season must not exceed 30%.

In the heating season the variations in the level of relative moisture from 20 to 60% occur without practically affecting the human (then he is more sensitive to the variations in the air and surface temperatures, less to the moisture variations). If the relative moisture in the room is within the range of 35÷70%, it has little impact on the human sensation of the heat comfort because it is the presence of the water vapour that determines the evaporation intensity of water from the human body. Figure 2 shows the comfort zone in connection with relative moisture of the indoor air.

The velocity of the flowing air in closed rooms affects very much how man feels. In connection with the ventilation systems and the conditioning equipment, the draughts caused by the air which is too cold and blown into the room too quickly are the main reasons for the dissatisfaction with the work of this equipment.

Therefore, at normal temperatures (18÷20°C) the allowed air velocity in the room is not more than 0.1m/s, at temperatures 20÷22°C the allowed air velocity is 0.1 to 0.2m/s.

Most people have unpleasant sensations when the air velocity is 0.25m/s, and more. The choice of the indoor air velocity in the zone where people stay (the living part of the room) depends also on the way how the room is used. In the part of the room where there are people who are working actively, greater intensity of the moving air is allowed. Figure 3 shows a comfort zone in connection with the air velocity.

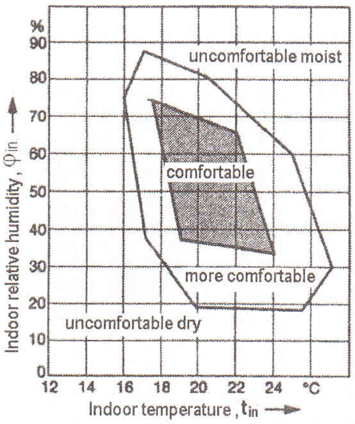

Figure 2: The comfort zone in connection with the relative moisture and the indoor temperature, according to F.P.Loizden and N.Fraimark

In conformity with the principles of system analysis, the designing of an energy-efficient house as a joint energy system includes optimisation of three interconnected energetic models which are easier subject to research: a mathematical model for the thermo energetic impact of the outdoor climate on the envelope of the building; a mathematical model for the thermo energetic balance of the rooms, i.e. energy which is inside the building; a mathematical model for the heat accumulating characteristics of the envelopes.

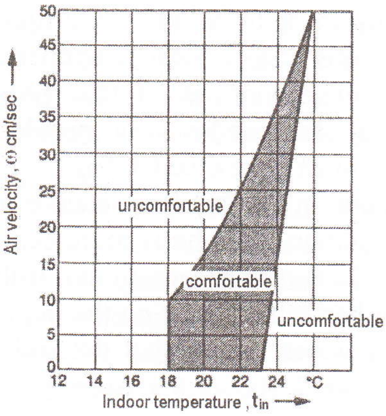

Figure 3: The comfort zone depending on the air velocity, according to Rirshel-Rais

If necessary, each of the aforementioned subsystems can be shown by means of the decomposition method as much smaller energetically connected elements.

The optimisation task of the thermal load to ensure warm conditions belongs to the tasks of the so-called optimal management the essence of which is setting such management modes of energy consumption ***Q(t)*** for heating the rooms which satisfy the equation of the thermal balance and the corresponding initial and final thermal conditions, and for which the consumption of energy:

$$Q(t)\cdot dt = \min \tag{6}$$

The management mode ***Q(t)***, which can solve this task is called optimal management but the path of the temperature variations of the corresponding indoor air is the optimal path. The essence of the solution: the heating time of the room must be minimal.

The energetic balance of the building

When calculating the thermal balance of a building, the losses of heat are taken into account that occur through the envelope (the transmission losses) and the loss of heat for heating the inflowing air, the release of heat generated by the local sources, the inflowing heat from solar radiation at normal cloudiness, as well as the ability of the heating system to respond to these variations of heat. The annual heat consumption (*J*) of the building is determined according to the formulae:

$$Q_{hs} = Q_t - Q_g = (Q_c + Q_v) - (Q_{in} + Q_s) \tag{7}$$

where Q_t – the total losses of heat, *J*; Q_g – the total inflowing heat, *J*; Q_c – the losses of heat due to heat transmission through the envelopes, *J*; Q_v – the losses of heat from ventilation, *J*; Q_{in} – the heat inflowing from the local sources, *J*; Q_s – the heat inflowing from solar radiation, *J*.

The losses of heat due to the heat transmission through the envelopes of buildings are determined according to the formulae:

$$Q = U\cdot A\cdot(t_{in} - t_{out})\cdot T\text{, [J],} \tag{8}$$

where U – the total heat transmission coefficient depending on the thermo technical properties of the envelope, $[W/m^2K]$; A – the surface area of a structural element, $[m^2]$; t_{in} – the mean indoor temperature, $[K]$; t_{out} – the mean outdoor temperature, $[K]$; T – the heating period, $[sec]$.

The total area of the heat transmission surfaces is defined as the sum of the areas bordering on the outdoor air (the walls, doors, windows, roofs), calculated along the outer perimeter, without the area of the foundation because it does not border on the outdoor air. The losses caused by ventilation of the rooms are determined according to the formula:

$$Q_v = c\cdot\rho\cdot V\cdot\frac{n}{3600}\cdot(t_{in} - t_{out})\cdot T = c\cdot V\cdot\frac{n}{3600}\cdot(t_{in} - t_{out})\cdot T\text{, [J],} \tag{9}$$

where c – the specific heat capacity of air, [$c = 0.36\ Wh/(m^3K)$ or $c = 1.0\ kJ/(kgK)$]; ρ – the specific air density,$[kg/m^3]$; V – the volume of the room,$[m^3]$; n – the air exchange coefficient,$[h^{-1}]$.

The index of the energetic efficiency of the building is characterised by the value of the specific consumption of thermal energy for heating and ventilation of the building per $1m^2$

[kWh/(m^2·year)] of the usable area or per *$1m^3$* [*kWh/(m^3·year*] of the heated volume and one degree-day of the heating period, considering the necessary parameters of the heat comfort. The correctness of these indices should be understood wider, taking into account the rated capacity of the heating system, the consumption of energy for indoor air conditioning in the summer period, the rated capacity of the cooling system and the consumption of energy for the acclimatisation of rooms during the year.

The value of the consumption of thermal energy for heating and ventilation of the building is determined dividing the annual consumption of heat by the heated usable area or the heated usable volume of this building:

$$q_{hs} = Q_{hs} / S_b \text{, [kWh/(m}^2\text{·year)] or } q_{hs} = Q_{hs} / V_b \text{, [kWh/(m2·year)],} \quad (10)$$

where S_b – the heated usable area of the house, m^2; V_b – the heated usable volume of the house, m^3.

Investigations witness that in the case of a standard multi-storey dwelling house it loses up to 40% of heat through the walls, 18% through the windows, 10% through the cellar, 18% through the roof, 14% through the ventilation system. The reduction of the losses of heat to the minimum is possible only by taking complex energy-saving measures. Figure 4 shows a scheme how the losses of heat are distributed through the envelope of the building.

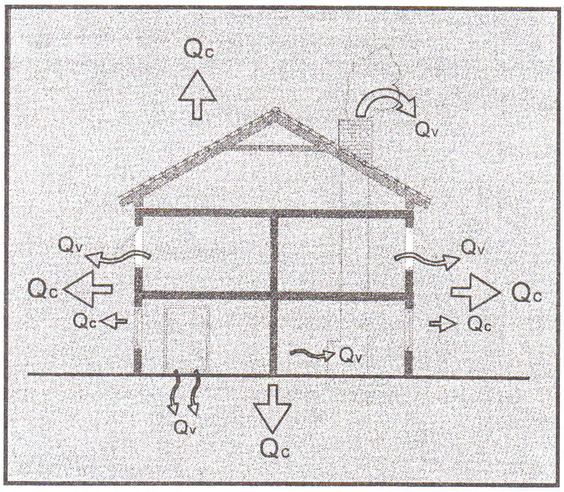

Figure 4: A distribution scheme of the losses of heat through the envelope of the building

The conventional view is that the heat protection optimisation of the envelope is a calculation method of the thickness of the thermal insulation layer "by the reduced minimum costs". In a general case the mathematical model of the reduced costs includes two indices: the production costs of the structural elements (single costs) and their maintenance costs. The calculation of the thickness of the thermal insulation layer "by the reduced minimum costs" is an objective, worldwide recognised method. This model reflects the reality of the economic situation existing in the country which may appear as an insuperable barrier to the practical implementation of the method. It is connected with the amount of energy and materials applied in the method.

The envelopes of most buildings are flat walls, i.e. parallel squares which mark off the building from all sides. The amount of heat transmitted through the envelope is determined according to the formula:

$$Q = U \cdot A \cdot \Delta t \cdot T = U \cdot A \cdot (t_{in} - t_{out}) \cdot T \text{, [J].} \quad (11)$$

Uneven heat release from the heating equipment causes temperature fluctuations of the indoor air and the internal surfaces of the envelope. The amplitude of the temperature fluctuations of the indoor air and the internal surfaces of the envelope depends not only on the thermo technical peculiarities of the heating system and the outer and inner envelopes but also on the arrangement of rooms.

The equation of variable heat supply can be presented as Fourier series from the transfer function. After integration in time we obtain:

$$\int_0^T Q(t)\cdot dt = Q_0 \cdot T\,. \tag{12}$$

The relation of the fluctuation amplitude A_Q of the heat flow to the fluctuation amplitude A_τ of the inner surface temperature of the envelope is called the heat acquisition coefficient Y_{in} of the inner surface of the envelope:

$$Y_{in} = \frac{A_Q}{A_\tau},\ [W/(m^2\cdot K)]. \tag{13}$$

Heat endurance of the envelope

The heat endurance of the outer envelope is the ability to preserve its temperature when the outdoor air temperature changes. The less are the temperature fluctuations of the inner surface of the envelope at a constant fluctuation amplitude of the air temperature, the higher is its heat endurance, and vice versa.

In this process the heat endurance of the envelope is characterised by the heat acquisition coefficient Y_{in} of the envelope surface. The higher is the heat acquisition coefficient, the less are the temperature fluctuations on the inner surface. The heat endurance of the outer envelope is characterised by the heat endurance coefficient φ, which is a calculated value – the relation of the difference between the indoor and the outdoor air temperatures $t_{in} - t_{out}$ to maximal difference $t_{in} - \tau_{min}$ between the indoor air temperature and the temperature of the inner surface of the envelope.

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Petrovs B., Zeltins N., Kreslins V, Actina G. Multicriterial evaluation methods for the selection of competing energy-efficient technologies

The aim of the research is to work out a methodological foundation for the evaluation of an energy efficient technology by designing the thermonergetic parameters of buildings. A multicriterial method is offered for the choice of thermal characteristics and calculation of the envelope of an energy-efficient building using the target function. As the main target function a possibility should be mentioned to employ the requirements of ensuring comfort conditions and microclimate in the rooms of the building. Following the comfort requirements, initial parameters are determined for the rooms in order to calculate thermal characteristics of the envelopes of an energy-efficient building. The energy balance of the building has been determined, as well as the directions of the heat flows and losses through the envelopes. There are given formulae for the calculation of the losses of heat through the envelopes arising as a result of infiltration and ventilation of the building. Fluctuations of the flow are discussed through the envelopes arising due to the variations in the indoor air temperature, as well as the temperature of the internal surfaces of the envelope. Formulae are indicated for the calculation of the heat endurance of the rooms, their envelopes when the indoor temperature and the temperature of the internal surfaces of the envelope are changing.

Petrovs B., Zeltiņš N., Krēsliņš V., Actiņa G., Daudzkriteriālās vērtēšanas metodes konkurējošu energoefektīvu tehnoloģiju atlasei

Pētījuma mērķis – izstrādāt metodiskos pamatus energoefektīvas tehnoloģijas vērtējumam, projektējot ēku siltuma parametrus. Tiek piedāvāta daudz kritēriju metode energoefektīvas ēkas norobežojošo konstrukciju siltuma raksturojuma izvēlei un aprēķiniem, izmantojot mērķa funkciju. Kā galvenā mērķa funkcija jāmin iespēja izmantot prasības komforta apstākļu un mikroklimata nodrošināšanai ēku telpās. Vadoties no komforta apstākļu nosacījumiem telpās tiek noteikti izejas parametri energoefektīvas ēkas norobežojošo konstrukciju siltuma raksturojuma aprēķiniem. Noteikta ēkas enerģētiskā bilance, kā arī norādīti siltuma plūsmu un zudumu virzieni caur ēku norobežojošām konstrukcijām. Norādītas formulas siltuma zudumu aprēķinam caur ēku norobežojošām konstrukcijām, kas rodas ēkas infiltrācijas un ventilācijas rezultātā. Apskatītas siltuma plūsmas svārstības caur ēku norobežojošām konstrukcijām, kas rodas ēkas telpu gaisa temperatūras, kā arī norobežojošo konstrukciju iekšējo virsmu temperatūras izmaiņu rezultātā. Norādītas formulas telpu, to norobežojošo konstrukciju siltumnoturības aprēķinam mainoties gaisa temperatūrai telpā un ēkas norobežojošo konstrukciju iekšējo virsmu temperatūrai.

Петров Б., Креслиньш В., Зелтиньш Н., Ацтиня Г. Многокритериальный метод оценки и выбора конкурентоспособной энергоэффективной технологии

Целью исследования является разработка методических основ оценки энергоэффективной технологии при проектировании тепловых параметров зданий. Для этого предложен многокритериальный подход для выбора и расчета тепловых характеристик ограждающих конструкций энергоэффективного здания. Для реализации многокритериального подхода выбора и расчета тепловых характеристик ограждающих конструкций здания предложено использовать целевую функцию. В качестве главной целевой функции отмечена возможность использования требований по обеспечению комфортных условий и требований по обеспечению микроклимата в помещениях здания. На базе требуемых комфортных условий в помещениях определены начальные параметры для расчета тепловых характеристик ограждающих конструкций энергоэффективного здания. Определен энергетический баланс здания и показаны пути тепловых потоков и потерь через ограждающие конструкции здания. Приведены также формулы для расчета тепловых потерь через ограждающие конструкции здания, за счет инфильтрации и вентиляции зданий. Рассмотрены колебания теплового потока через ограждающие конструкции здания за счет изменения температуры воздуха в помещении и температуры внутренней поверхности ограждающих конструкций здания. Приведены формулы для расчета теплоустойчивости помещений и их ограждающих конструкций при изменения температуры воздуха в помещении и температуры внутренней поверхности ограждающих конструкций здания.