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RESEARCH ARTICLE

The requirement system of the Hungarian directive on the energy performance of buildings

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Abstract

The Energy Performance Building Directive 2002/91/EC (EPBD), issued by the European Commission, gave a general framework for the calculation of the integrated energy performance of buildings. The Directive was adapted and implemented by the EU's Member States in 2006.

The Hungarian regulation was worked out in the Department of Building Energetics, Budapest University of Technology and Economics and the author was a member of the team. In the regulation, the requirements have three levels: requirements are set for the maximum allowable thermal transmittance of the building elements, the specific heat loss coefficient of the building and the integrated energy performance of the building service systems. This paper describes the background calculations and diagrams. When formulating the requirements, the aim was that compact buildings with good orientation and appropriate glazing ratio should fulfil the requirements on the specific heat loss coefficient once the requirement on the thermal transmittance of the elements was fulfilled. The requirements were verified on a large, randomly generated building sample for 2,600 technically feasible geometries. The role of glazing – the window ratio, orientation, thermal properties and solar energy transmittance – in the energy balance of the heating season was analysed in more detail. The calculations showed that South facing walls with a large window ratio and good insulation (U_{wall} < 0.45 W/m^{2}K ; U_{window} < 1.6 W/m^{2}K) resulted in a heat gain over the heating season in Hungary.

Keywords

thermal transmittance · heat loss coefficient · integrated energy performance

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1 Introduction

The well-known problems of environmental pollution and finite fossil energy resources have prompted decision-makers to implement legislative measures in order to establish the preconditions for sustainable development, including sustainable housing. The aim is, as it is usually formulated, to decrease the energy consumption of buildings, which represents about 40 percent of the gross energy consumption in Europe. Besides national standards, direct and indirect international initiatives can also be mentioned in this field. Among these, the latest is the Energy Performance Directive 2002/91/EC (EPBD), issued by the European Commission on 16 December 2002 [1]. The Directive, which had to be adapted and implemented by the EU's 25 Member States by 2006, gives a general framework for the calculation of the integrated energy performance of buildings and lays down requirements on the energy certification of buildings. The integrated energy performance includes, among others, the energy use for heating, cooling, ventilation, hot water supply and lighting, all expressed in primary energy. National regulations have to follow the concept of the EPBD and have to be harmoniZed as much as possible, but different climatic and social conditions are inevitably reflected in input data and in the numerical values of the requirements.

All legislative measures aiming at sustainable construction are appreciated by responsible professionals and decision-makers. At the same time, it is their duty to direct the attention to possible misinterpretations or inadequate drafting of requirements.

Two main problems must be enumerated concerning the EPBD. First of all, although in some sentences the rationality of energy saving investments is mentioned, the EPBD encompasses operational energy only and does not deal with life cycle energy balance. Secondly, the integrated energy performance, which is expressed in a complex way, includes many components which are not directly related to the building. As a result, the building itself might be "lost" in the regulation. Unless special requirements are formulated focusing exclusively on building-related components of the energy balance, the trade-off possibilities might make it easier to compensate for the poor quality of the building e.g. with a more efficient hot water supply or combined heat and power generation.

The Hungarian regulation was worked out in the Department of Building Energetics, Budapest University of Technology and Economics under the leadership of Professor András Zöld. The author was a member of the working team. This paper focuses on the requirement system of the Hungarian regulation. In order to avoid the above mentioned undesirable trade-off, the requirements have three levels.

2 The Hungarian requirement system

2.1 The third level: the level of the integrated energy performance

The highest level of the requirements is the integrated energy performance, E_P [2]. This is the amount of energy estimated to meet the needs associated with a standardized use of the building, which may include heating, hot water supply, ventilation, cooling and lighting. The energy use also includes the system losses and the self-consumption of the installations (e.g. fans, pumps). The generated own-energy provided by photovoltaics, solar collectors or co-generation can be subtracted.

The integrated energy performance is expressed in terms of primary energy use per floor area and year (kWh/m^{2}a). Since its value depends on the standardized use of the building, different requirements have to be laid down for the different uses. The buildings can be classified into categories such as:

- residential buildings;
- offices;
- educational buildings;
- wholesale and retail trade services buildings;
- hotels and restaurants;
- hospitals;
- social- communal buildings;
- sport facilities;
- assembly buildings;
- swimming pools and baths;
- production and logistic buildings.

The allowable integrated energy performance is a function of the building envelope surface to heated volume ratio. The requirements for residential buildings, offices and educational buildings are illustrated in Fig. 1.

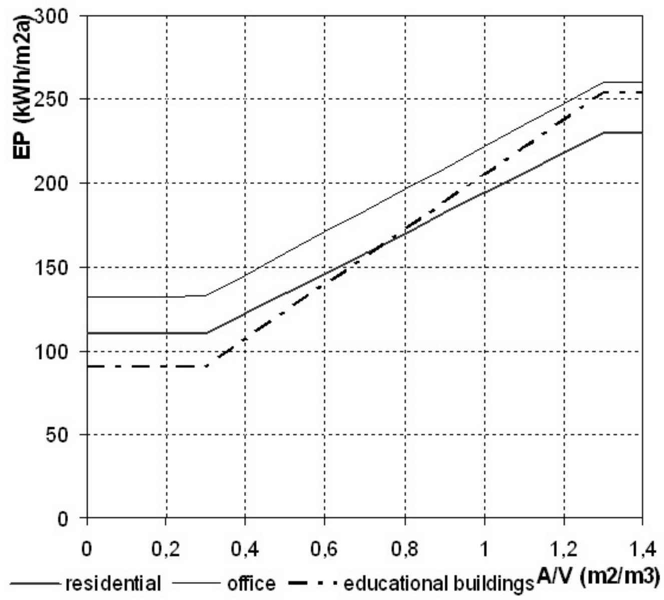

Fig. 1. Integrated energy performance

2.2 The second level: the level of the specific heat loss coefficient

The integrated energy performance describes the building and the building services in a complex way. The problem with this indicator is that the energy use directly related to the building represents only a small fraction of the total use. Theoretically it would be possible to compensate the poor insulation of a building with more efficient hot water supply or lighting system. Even if these systems are actually installed in the building, there is no guarantee that the standard user uses the system in a standard way, that the function of the building does not change or that the building services are replaced at the end of their useful lifetime for services of at least similar quality [3].

In order to prevent these undesirable trade-offs, another requirement level has to be introduced which includes all building-related parameters, and only those. This level is the specific heat loss coefficient, q, which is the sum of the transmission losses and the utilized solar gain for the heating season, for 1 K temperature difference , divided by the heated volume of the building (W/m^{3}K).

The specific heat loss coefficient is the sum of:

- the product of the area of the building envelope elements and their average thermal transmittance;
- the heat loss due to the thermal bridges at connections and junctions;
- the utilized fraction of the solar radiation entering the building through the glazing;
- the passive solar gains (sunspaces, energy collecting surfaces etc).

The allowable specific heat loss coefficient depends only on the surface-volume ratio of the building, it is independent from the function of the building. The requirement is depicted in Fig. 2.

If the effect of the solar gains is neglected – which is to err on the side of safety – the allowable average thermal transmittance of the building envelope can be derived from the specific heat loss coefficient. The requirement on the average thermal transmittance is a hyperbola shown on Fig. 3.

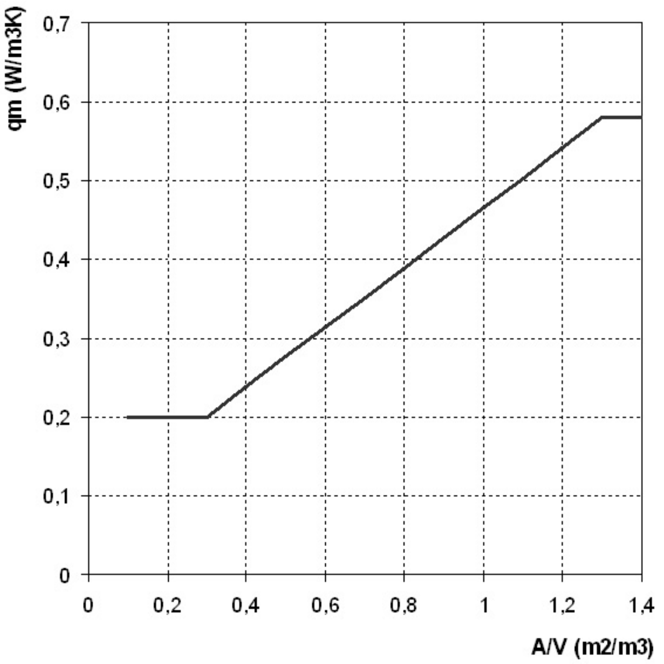

Fig. 2. Maximum specific heat loss coefficient

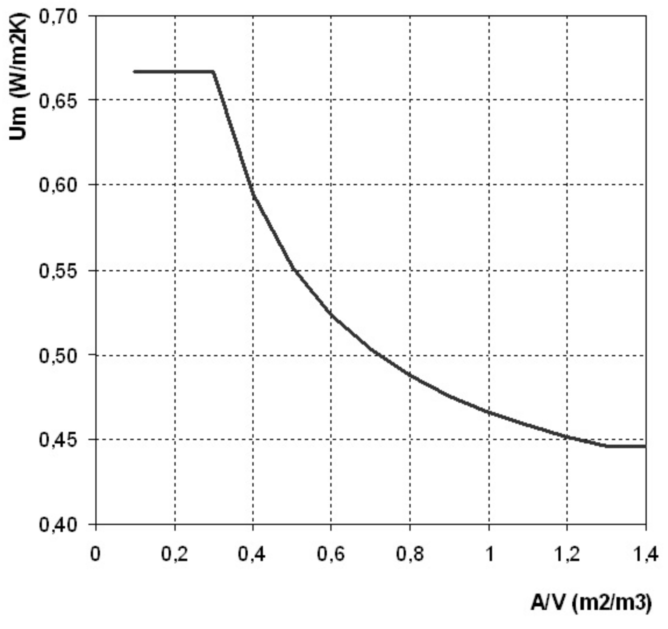

Fig. 3. Maximum average thermal transmittance

2.3 The first level: the level of the building element

Although the thermal transmittance of the building elements is determined directly by the specific heat loss coefficient of the building and indirectly by the integrated energy performance, it is also necessary to restrict the heat loss of each element. Without specifying the maximum thermal transmittance of the elements, the following cases could occur even if the specific heat loss coefficient of the building fulfils the requirements:

– the insulation of some elements might not fulfil the fabric protection and/or thermal comfort requirements;

– a significant difference in the thermal resistance of the building envelope elements could adversely affect the thermal performance or thermal comfort of certain rooms or zones (e.g. rooms on the top or bottom floor of a multi-storey house);

– a significant difference in the thermal resistance of the connecting elements/junctions would increase the effect of thermal bridges.

The thermal transmittance of an element (U-value) is defined in this case as the average thermal transmittance, which means that if the construction or some parts of the construction are composed of more than one material (e.g. a timber frame wall consists of studs and insulation or a window consists of frame and glazing), the calculation of the thermal transmittance value has to take this into account.

The thermal transmittance of the building envelope elements cannot exceed the values shown in *Table 1*. The values do not include the effect of thermal bridges, except for thermal bridges interrupting/breaking through the insulation layer. The heat capacity of a building element is a function of the mass. Low heat capacity corresponds to a lower time constant (thermal inertia) and a lower utilization factor, which means that a lower fraction of the heat gain is actually utilized. The lower heat gain has to be compensated with higher thermal resistance, which is reflected in the more rigorous thermal transmittance values recommended for lightweight constructions in the table.

2.4 The relationship between the requirement levels

The building fulfils the requirements if all three levels are fulfilled. If the specific heat loss coefficient of the building fulfils the requirements, the integrated energy performance calculated from the standardized use will generally also fulfil the requirements provided a usual, modern, well-planned building service system is applied and the energy carrier is gas. This is shown on Fig. 4.

However, if due to certain reasons the building service system is unfavourable (e.g. the main energy carrier is electricity), the integrated energy performance still has to be lower than the allowable maximum value. This can be achieved through lower heating energy use and consequently with a specific heat loss coefficient below the limit (better insulation, better openings or higher solar gain utilisation), as depicted in Fig. 5.

Conversely, if due to favourable building service systems the integrated energy performance is lower than the requirements, the specific heat loss coefficient still cannot be lower than the given value.

Similarly, if the thermal transmittance of the building elements fulfils the requirements, the specific heat loss coefficient will generally also fulfil the requirements provided the building has a compact form and the solar gains are well utiliz ed

Tab. 1. Maximum thermal transmittance of the building envelope elements (Extract of the requirements [2])

Building element	Thermal transmittance U [W/m^{2}K]	
	Maximum allowable	Recommended for lightweight constructions
External wall	0.45	0.35
Flat roof	0.25	0.20
Loft floor	0.30	0.25
Floor above unheated cellar	0.50	0.50
Window (wood and PVC)	1.60	1.60
Entrance door	1.80	1.80
Wall between heated and unheated spaces	0.50	0.40
Wall in connection with the ground between 0 and –1 m	0.45	0.45
Slab on ground (in a 1,5 m wide zone along the perimeter or insulation on the footing)	0.50	0.50

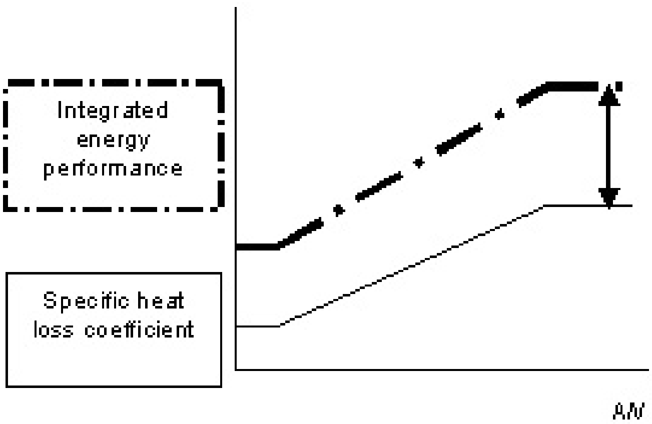

Fig. 4. The integrated energy performance and the specific heat loss coefficient

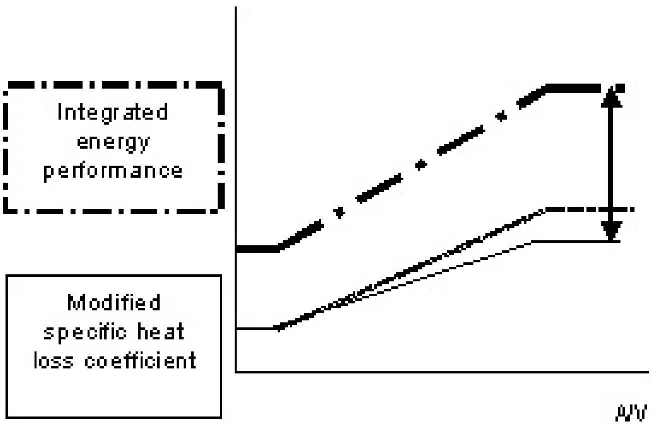

Fig. 5. The specific heat loss coefficient in case of unfavourable building services

(favourable orientation and glazing ratio). However, if the building is highly articulated or there are no solar gains, the building elements have to be better insulated than the minimum.

The gap between the building – the specific heat loss coefficient - and the building services – the integrated energy performance – can be determined statistically by assuming different combinations of modern systems typical for the given function. Below we shall focus on the determination of the first gap: that between the heat loss coefficient and the building element. This gap mostly depends on factors for which the architectural design of the building is responsible.

3 Verification of the requirements on the specific heat loss coefficient

Our goal was to verify the requirements on the specific heat loss coefficient on a large building sample.

3.1 Calculation of the specific heat loss coefficient

The allowable specific heat loss coefficient is the function of A/V, i.e. the ratio of the total envelope surface and the heated volume:

$$q = f(A/V)$$

The actual specific heat loss of the building cannot exceed the maximum value. At first sight it seems to be a contradiction that the requirement is strict for small A/V ratios and higher for large ratios (Fig. 2). This contradiction can be dissolved if we examine which buildings are characteristic on the left and right side of the diagram.

The same A/V ratio can be obtained with various combinations: a small but compact building might have the same A/V ratio as a large but highly articulated building. However, large buildings tend to have a more favourable A/V ratio, because the heated volume increases cubically with the increasing floor area.

Even if a small building (e.g. a compact single-family house) is well-insulated (but simply and at a rational cost), the heat loss per volume will be higher. Thus the apparently strict value on the left side of the diagram often corresponds to higher thermal transmittances, and vice versa.

The actual heat loss coefficient of the building depends on the properties of the envelope (area and thermal transmittance of each building element), the glazing ratio, the orientation etc., besides the A/V ratio. The Hungarian regulation offers two methods for its calculation: a simple and a detailed calculation. The most important difference is in the consideration of the solar gains. The two methods are actually three: in the simple method it is allowed to neglect the solar gains, this method is called "without solar gain" below. The "simple method" assumes that the building faces North on all sides, i.e. it receives only diffused and reflected radiation. This is the minimum solar radiation which enters the glazing even if it is constantly in the shade. The "detailed method" requires the verification that the given window is not shaded. One method is to draw the shadow mask of a given point and compare it with a cylindrical sun path diagram, for instance. If the window is sunlit for more than four hours a day on average in the heating season (preferably between 9 A.M. and 3 P.M.), the solar radiation corresponding to the orientation of the window can be taken into account.

The fraction of the solar radiation that is actually utilized can be described with the utilisation factor. This factor is lower for lightweight buildings due to their low thermal mass and time constant. This is a simplified approach in order to keep the calculation method as simple as possible.

3.2 The relationship between the first and second requirement levels

The first level, the requirement on the thermal transmittance of the building elements mirrors the current situation and the potential of the building industry and the available building products in the near-future. The following guidelines were taken into account at the determination of the second level requirements:

- All buildings have to meet the requirements at a rational cost. If the geometry is unfavourable, glazing limitations, etc. might be necessary;
- The "laziness" of the designer, i.e. the total or partial neglect of the solar gains, is punished with stricter U-values (the use of the "simple" or "without solar gain" methods).
- A compact building with good orientation and appropriate glazing ratio should meet the requirements with the allowable maximum U-values.

All the calculations were carried out for a statistical sample representative for the technically feasible buildings of rational shape and spans. For simplicity, all buildings had a cellar and an unheated loft. The orientation was also fixed: it was assumed that 5 % of windows face north, 65 % east-west and 30 % south, the windows are 50 % sunlit.

The buildings were generated using as few variables as possible. The main variables were the useful floor area of the building, the number and height of the storeys, the window ratio, the frame factor of the window and the "form factor". The form factor is the ratio of the sides of a rectangle having the same perimeter and area as the building, this describes the shape and complexity of the plan. Based on these parameters, the area of the building envelope elements could be calculated. The thermal transmittance of each element was assumed to be the allowable maximum.

The variables varied in the following ranges:

- Useful floor area: 50 - 8500 m^2;
- Ceiling height: 2.7 – 3.5 m, depending also on the floor area;
- Number of storeys: 1 – 10, depending also on the floor area;
- Form factor: 1 – 18, depending also on the floor area;
- Window ratio: 10 – 50 % of the façade area;
- Frame factor: 10 – 30 % of the window area;

Based on these parameters, 2,600 different geometries were studied. For all buildings we have used the three calculation methods, separately for heavyweight buildings with maximum allowable U-values and lightweight buildings with the recommended lower U-values. The following diagrams show the specific heat loss coefficients in the function of the A/V ratio (Figs. 6-11). The dashed line is the linear trendline fit on the sample, the thick line is the requirement line.

The buildings under the requirement line meet the requirement on the specific heat loss coefficient with the allowable maximum (or recommended) U-values. According to the figures:

- most buildings do not fulfil the requirements "without solar gain";
- about 50 % of the buildings fulfil the requirements with the simple method;
- most buildings fulfil the requirements with the detailed method.

It can hence be stated that the requirement line meets the above mentioned guidelines because:

- The "without solar gain" method overestimates the heat loss coefficient of the buildings, thus most of the buildings do not fulfil the requirements with minimum insulation;
- The simple method is more realistic but the orientation of the building is still neglected. Compact buildings with appropriate glazing ratio meet the requirements;
- With the detailed calculation method, most buildings meet the requirements if the windows have good orientation and are partly sunlit. Only highly articulated buildings need to be better insulated.

The diagrams also indicate the difference between lightweight and heavyweight buildings. The recommended U-values are stricter for lightweight buildings, consequently, if solar gains are neglected, more lightweight buildings fall under the requirement line than heavyweight ones. This difference vanishes when applying the detailed method: lightweight buildings are better insulated but less solar gain is utilized. Here the fraction of the sample that meets the requirement is similar for heavy and lightweight buildings.

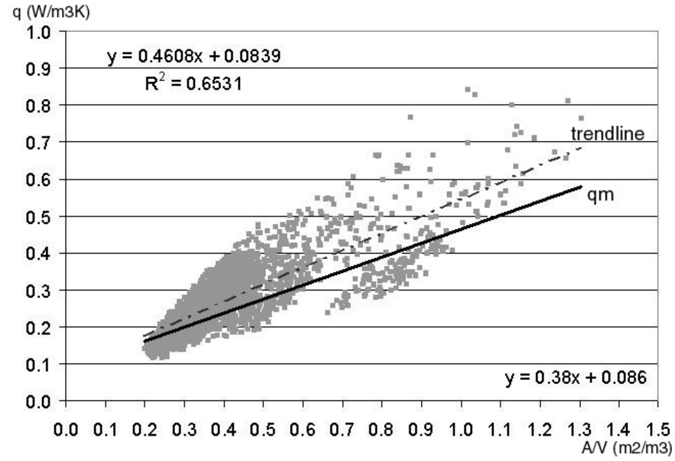

Fig. 6. Specific heat loss coefficient – without solar gain

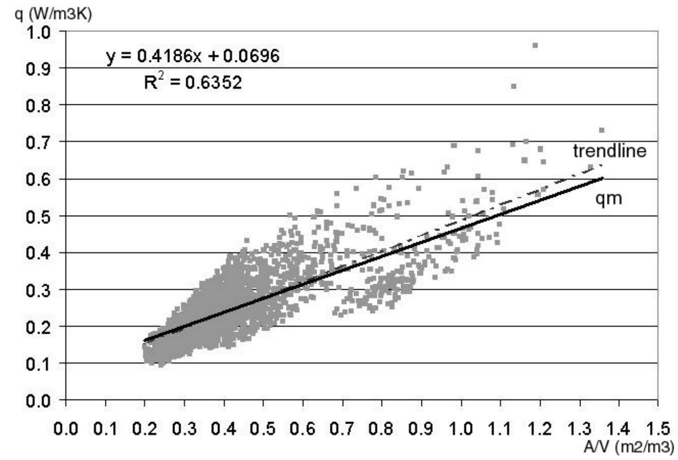

Fig. 7. Specific heat loss coefficient – without solar gain, lightweight buildings with the recommended U-values

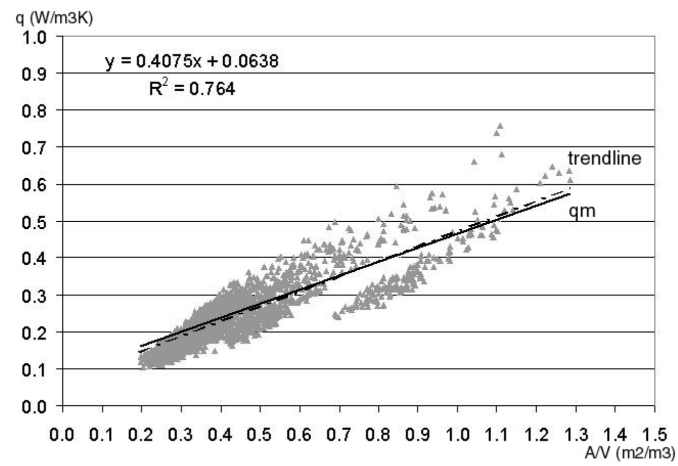

Fig. 8. Specific heat loss coefficient – simple method

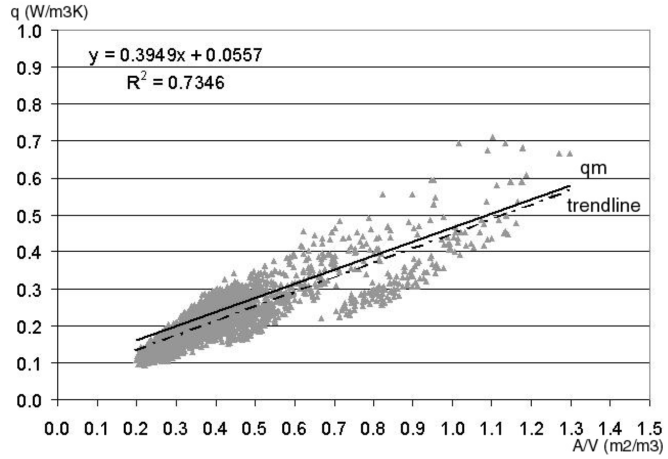

Fig. 9. Specific heat loss coefficient – simple method,lightweight buildings with the recommended U-values

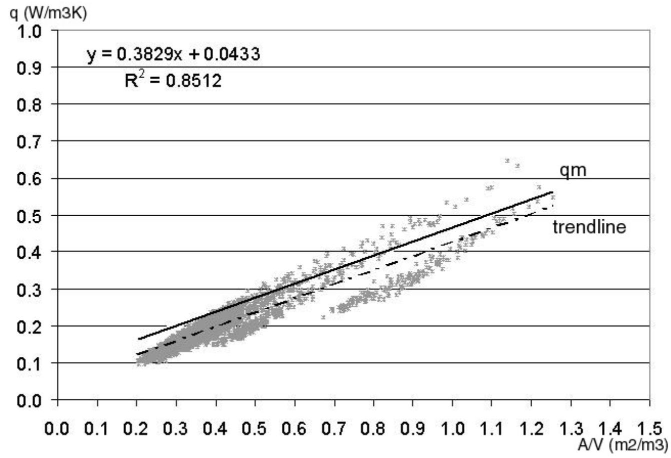

Fig. 10. Specific heat loss coefficient – detailed method

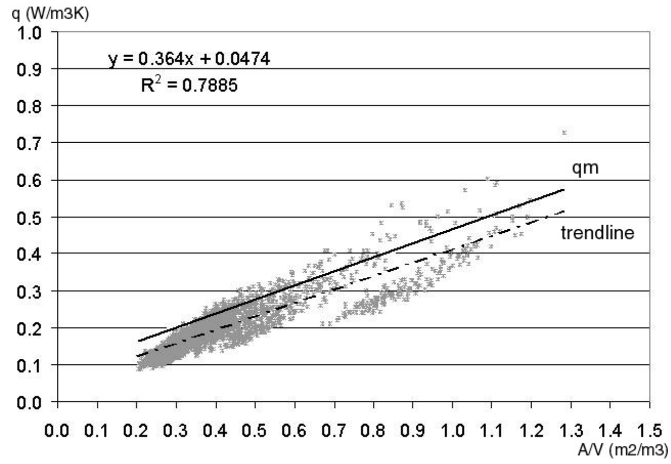

Fig. 11. Specific heat loss coefficient – detailed method, lightweight buildings with the recommended U-values

4 Glazing: losses and gains

One of the most interesting variables is the glazing ratio of the building. The evaluation of the glazing is two-sided: with the increase of the glazed area, both the transmission losses and the solar gains increase. Is there an optimum? In addition, the role of glazing also has to be judged during the summer months.

It is simple to calculate the losses and gains for 1 m^2 glass. More useful results can be obtained through a more complex analysis. Let us consider a 1 m^2 facade with a window. The following parameters can be varied:

– the orientation of the facade: South, East-West and North;

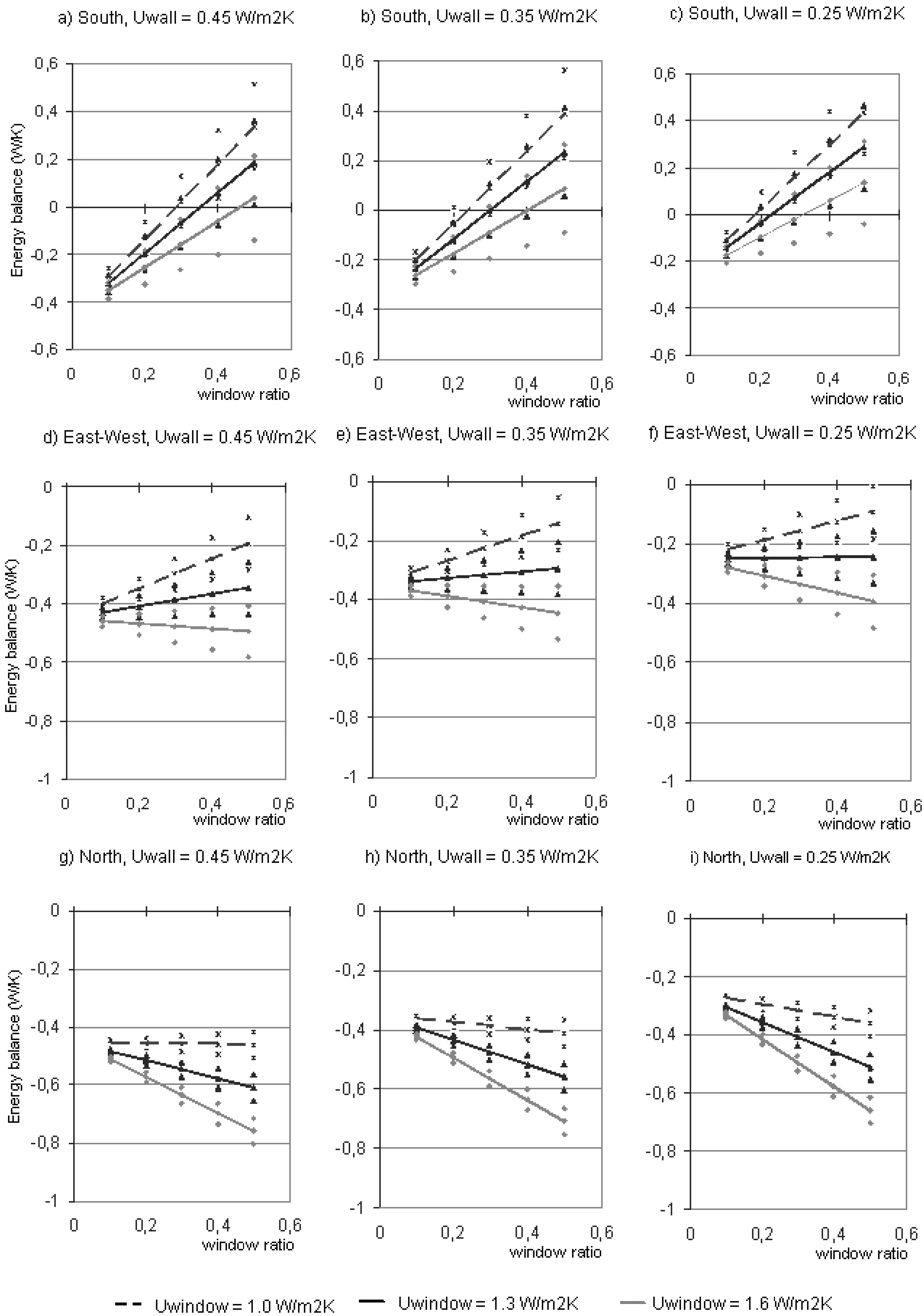

Fig. 12. Energy balance (W/K) of 1 m^2 facade in the function of the window ratio

- the ratio of the window and the facade: 10 – 50 %;
- the thermal transmittance of the wall: U_{wall}= 0.25 – 0.45 W/m^{2}K;
- the average thermal transmittance of the window: U_{window} = 1.0 – 1.6 W/m^{2}K;
- the total solar energy transmittance of the glazing: $g = 0.5 - 0.7$;
- the frame factor is constant: 0.85.

The calculations were done according to the detailed method for a heavyweight building. The results can be seen in Fig. 12, where the energy balance of the facade is depicted as a function of the window ratio. The diagrams correspond to walls with different orientations and U-values.

The first remarkable result is that the slope of the functions is positive for all south-facing windows, for some east-west and for special north windows. In these cases, the increase of the solar gain exceeds that of the losses if the window ratio increases. Conversely, if the slope is negative, the smaller windows become more favourable.

It is evident that the lower U-values of the wall and the window result in lower transmission losses and in a better energy balance. The energy balance of some south facing windows is even positive if the losses are minimised. However, the total solar energy transmittance of better insulating windows (more panes, selective coatings etc.) is typically lower, thus the solar gains passing through are reduced.

The thermal transmittance of a facade exactly fulfilling the first level requirements is U_{wall}= 0.45 W/m^{2}K and U_{window} = 1.6 W/m^{2}K, typically g = 0.6. These variations are displayed with the lowest line in Figs. 12 a, d, g. Moving to the upper line in Figs. 12 c, f, i the thermal transmittance improves to U_{wall}= 0.25 W/m^{2}K and U_{window} = 1.0 W/m^{2}K. Consequently, the losses decrease but the solar gain remains the same. In other words, the solar gains cover a bigger fraction of the losses. This is exactly the idea of passive solar architecture: a building is solar not because it receives a lot of solar radiation but because its non-renewable heating energy demand is low and the utilized solar gains cover a significant fraction of this low demand. This can be reached if both elements are well insulated and the available solar radiation is maximized.

These statements are valid for the winter. A complex evaluation of the glazing has to consider the summer conditions as well.

5 Conclusions

Regulations based on the Energy Performance Building Directive lay down requirements on the total energy consumption of the building expressed in primary energy. The Hungarian requirements system has three levels: the thermal transmittance of the building element, the specific heat loss coefficient of the building and the integrated energy performance of the building services. The second requirement level was based on the calculations and diagrams described in this paper. When formulating the requirements, the aim was that compact buildings with good orientation and appropriate glazing ratio should fulfil the second level requirement once they have fulfilled the first level.

With the developed calculation method, various future scenarios can be tested on a large building sample: e.g. what percentage of the buildings built recently would meet the requirements or to what extent the requirement can realistically be tightened in the future.

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