Does the EPBD promote the solar architecture?

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ABSTRACT: The ***E**nergy **P**erformance of **B**uilding **D**irective*, issued by the EC on 16 December 2002 (referred to as **EPBD**) aims at the implementation of new building regulations in the Member States of the EU. At the first sight it may be supposed that according to the new regulations the defensive character of buildings: improved thermal insulation of the envelope and glazing of lower transmittance will dominate due to the typically prescriptive character of the requirements. Nevertheless the solar character of the buildings can be kept with adequate combination of defensive measures and passive solar concept. Designers can and should be motivated to follow this approach by carefully formulated building regulation. The new Hungarian Building Regulation allows optional calculation methods facilitating simplified and more precise calculation of passive solar gains. Thousands of model calculations illustrate that applying the last option either the investment cost can be decreased or the better thermal performance can be proven and a more favourable rating of the building can be achieved.

Keywords: energy, regulation

1. INTRODUCTION

Well-known problem of environmental pollution and limited fossil energy sources, on one hand, and the energy consumption, on the other hand, prompted the EC to issue the Energy Performance Directive 2002/91/EC. Each Member State of the EU25 is obliged to develop and implement national regulation by 4th of January 2006. The regulations should follow the concept of the EPD and they should be harmonised as well as possible, although different climatic and social conditions will inevitably be reflected in input data as well as in the form and numeral values of requirements.

According to the EPBD the thermal performance of buildings should be expressed in an integrated value which includes several components: besides of the "classic" services such as heating, ventilation, cooling it consists the energy consumption of hot water and lighting, too. The last ones can hardly be influenced by the architectural design; they depend mainly on the users' habits.

Each component of the energy consumption is to be expressed in primary energy. The solar energy is taken into account with zero primary energy content, thus in this sense the directive promotes the application of *active solar* and *PV* systems. Nevertheless, these systems make the *building* “solar” if they are not only added elements but integrated parts of the building envelope. Although there are many good examples of such high-tech solutions, they cannot recently be considered as typical.

No doubt, the intention to cover and regulate all kind of energy consumption in buildings is a considerable step forward. However, it raises several crucial questions, first of all in residential buildings where the relative weight of user related components seems to exceed that of the building related ones. Limiting the integrated energy consumption only the building itself may “disappear” in the regulation: pro forma efficient mechanical systems could compensate the bad thermal quality of the building.

In order to prevent such an unfavourable trade-off, the majority of the new building regulations involves prescriptive rules for the maximum of the *U* values of the separate building elements. These requirements do not depend on the use of the building.

Strict limitation of *U* values of separate building elements suggests that the new buildings must be of defensive character with a low average *U* value and modest glazed ratio and the solar features will be lost. With such regulation one can expect that many designers will not be motivated in creation of a solar building: it is simple to apply elements of $U = 0.2 – 0.3$ W/m^2K, to have good mechanical systems and the task will be over, as far as energy is concerned.

The new Hungarian Building Regulation aimed at the re-focussing of the building itself creating an interim requirement between the whole system and the building elements. It is proven by experience that motivating design options rather than prescriptive rules promise better results.

2. BUILDING REGULATION

2.1. The structure of the Hungarian Building Regulation

The new Hungarian Building Regulation aims at the promotion of passive solar architecture in the everyday practice. It offers different methods and rules of calculation with different level of accuracy (and certainly with different design tools and workload); nevertheless the energy requirements are the same in any option. It has to be confessed that several main stream designers do not pay great attention to energy conscious approach especially if it requires much more work in the early stage of the design procedure. The intention was to motivate these designers to use more accurate methods, which results either in some saving in the investment or a better rating of the building.

Self intended the simulation would be the most accurate method. Although well known tools are available, from formal point of view their application cannot be obligatory because they are not confirmed by CEN standards – and no related EN norms are expected before 2008. Therefore the designers are only advised to use one of the existing tools in sophisticated cases (double skin facades, high glazed ratio, mechanical cooling).

For the everyday practice manual methods (and their software supported versions) are given, focussing on simplicity and taking into account that no detailed input data are available in the early stage of the design when building permit is applied for and the fulfilment of the energy requirements must be proven.

The requirement system has three levels. On the top the integrated energy performance is expressed as kWh/m^{2}a primary energy, which includes all building and user related components of the energy consumption. It depends on the surface to volume (*A/V*) ratio and the use of the building.

"On the bottom" the *U* values of the building elements are limited. Some characteristic figures: wall 0.45, flat roof 0.2, window with wooden or plastic frame 1.6, with metal frame 2.0.

In between a specific heat demand value is limited as a function of the surface to volume ratio. It includes all but only building related characteristics:

$$q = \frac{1}{V}\left[\sum AU + \sum l\Psi - \varepsilon\frac{\sum A_{tr} g I_{CUM}}{DH}\right] \quad (1)$$

where
q – the specific heat demand value, W/m^{3}K
V – heated volume, m^3
A - the area of the exposed building elements, m^2
U – the heat transfer coefficient of the elements, W/m^{2}K
l – the length of the constructional joints, thermal bridges, m
Ψ- linear heat transfer coefficient, W/mK
ε – utilisation factor,
A_{tr} –the area of the transparent building elements, m^2
g – global transmittance of transparent elements,
I_{CUM} – cumulative irradiance, kWh/ m^{2}season
DH – degree-hours, Kh

Specific heat loss and passive solar gains are inherent characteristics of the building (the only possible user intervention is to modify *g* if movable shading devices are provided). All other ones depend more or less on the users' habits, the efficiency of the mechanical systems, the energy carrier, thus the building, the mechanical systems and the user are "mixed".

The regulation offers three options for the calculation of the *q* value

a) to miss the solar gain (taking into account the losses only the result will be on the safe side);
b) to take into account the solar gain with the cumulative value of diffuse radiation (without checking the solar access);
c) to calculate the solar gain for each orientation, based on the analysis of solar access.

The maximum of the *q* value is shown in Fig. 1.

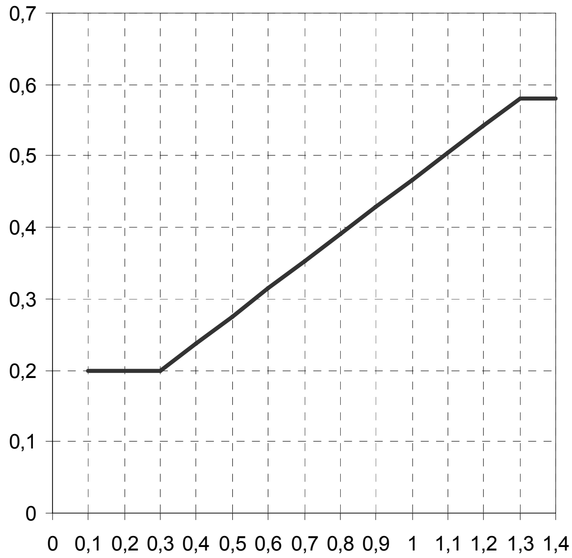

Figure 1: The maximum of the *q* value (W/m^{3}K) in the function of the surface to volume ratio.

The surface to volume ratio is a widely used parameter of the building. Certainly the transmission losses are proportionate to the area of the building envelope and the specific value relates to the unit of the volume. Attention should be paid to compact forms, however the depth of the plan and the sufficient well insolated façade area must not be forgotten.

The surface to volume ratio cannot be substituted by other geometric data, such as perimeter to built-in area because in the last case the compactness of the section is neglected. Similarly the effect of ceiling height should be taken into account.

It is self intended that the ventilation losses are directly proportionate to the heated volume, even if the air change rate depends on the use of the buildings. In a normal case the air change rate does not depends on the building (if the air tightness is satisfactory and no extra ventilation is necessary to prevent condensation or to control the harmful emission of the building materials). 10 – 30 cm difference in ceiling height may lead to 3 – 10% difference in ventilation losses.

Formulating the "defensive" requirement in W/m^{3}K (as it was in the previous national standard, too) provides a freedom of the design: several realistic combinations of building elements of different *U* values can be found which fulfil the requirement.

The "volumetric" data can easily be translated to an average U value of the whole envelope just on the base of the surface to volume ratio (Fig. 2.)

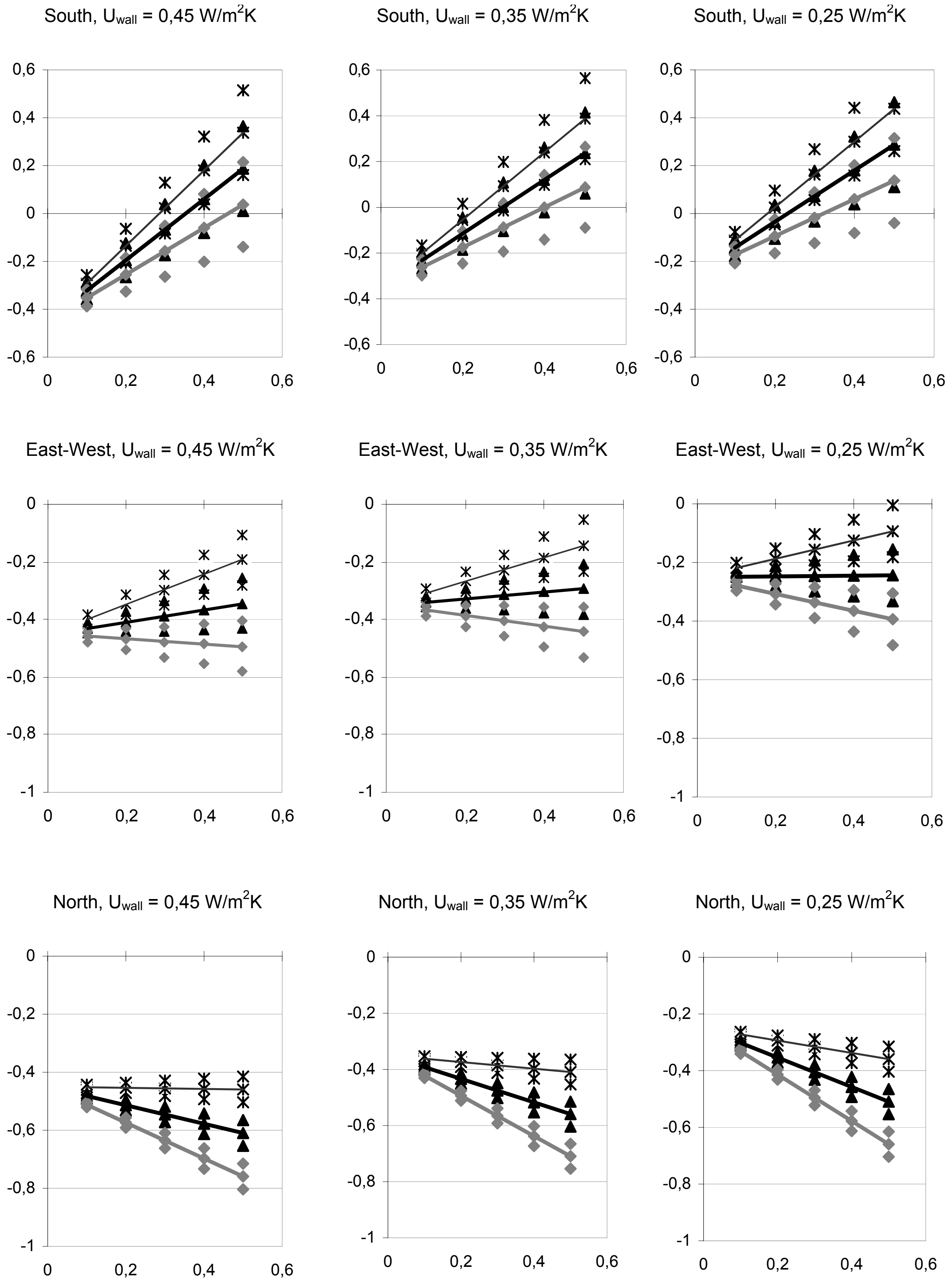

Figure 3: Average energy balance of 1 m². elevation in function of the glazed ratio
Curves: U_{window} =1,0 W/m²K U_{window} = 1.3 W/m²K U_{window} = 1.6 W/m²K

In case of option a) the above *q* values are equivalent with the average *U* value of the envelope, shown in Fig. 2. (The average *U* value includes the thermal bridge effect which is some 10% - 30% of the one dimensional losses).

Encompassing the defensive quality the designer is on the safe side at the cost of good thermal insulation. Thus if the designer does not intend to spend time on the calculation of solar gains, he/she should pay for the laziness with extra thermal insulation or limited glazing ratio. Certainly the real *q* value will be better than the requirement, but this fact cannot be proven by this simplified approach.

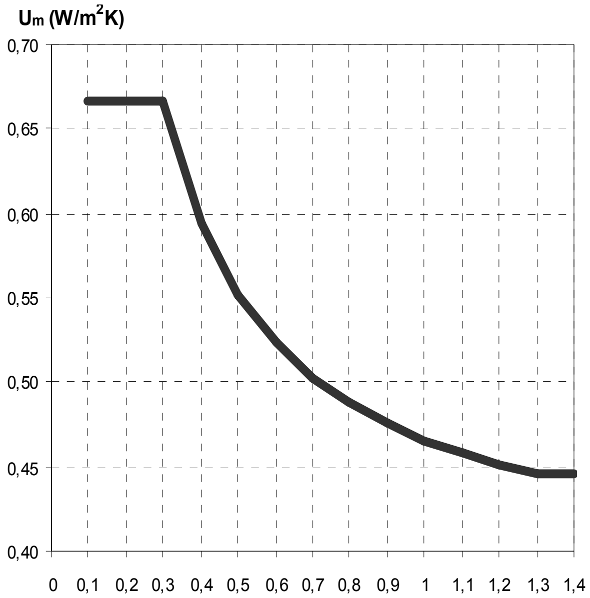

Figure 2: The maximum of the average *U* value in the function of the surface to volume ratio if no passive solar gains are taken into account.

In case of option b) the solar gain is calculated without the analysis of the solar access. To be on the safe side the cumulative value of diffuse (or as an approximation the global for North) radiation can be taken into account. Self intended this solar gain will be modest, nevertheless it facilitates either to save some thermal insulation if the required *q* value is met or to get a better rating.

In case of option c) the solar access must be analysed. Although it is an elementary method one cannot say that it is typical in the everyday practice and no doubt, it is time consuming. Nevertheless if the insolation of the glazed parts of the façade is proven one can calculate the solar gains taking into account the cumulative value of global radiation according to the orientation. The difference is considerable as it can be seen in Table 1.

Table 1. Design cumulative values of the global radiation for the traditional heating season (15 October – 15 April in Hungary)

Orientation	North	East-West	South
Cumulative irradiance, kWh/ m^{2}season	100	200	400

2.2. How the options may motivate the designers?

In Fig. 3. the energy balance of a unit façade area is shown in W/m^{2}K at the average conditions of the heating season in the function of the glazed ratio. Three orientations, three different walls, three different windows with three different *g* values (0.5, 0.6, and 0.7) have been considered. The curves belong to *g* = 0.6. The transparent part of the windows is 85% of the total window area.

It can be seen that for the North facing facades the increasing glazed ratio results in increasing heat loss, thus either the glazed ratio should be lower or the elements should be better insulated.

Although it is not true for other orientation, the result of the simplified calculation will be the same if the solar access is not analysed. (Without proving the solar access it must be supposed that the windows are in shadow.) Thus the fulfilment of the requirements can be proven only if either the glazed ratio is limited or the *U* value of the elements is low, thus more expensive thermal insulation and/or more expensive windows should be used. The rating of the building corresponds again to the formal result even if the real energy balance is better.

This situation is supposed to motivate the designers: if he/she does not spend time for the analysis of solar access, the building will be more expensive. Self intended, in the reality the energy performance may or will be better but this better performance will not be acknowledged in the rating.

Providing the solar access is proven the situation may be much better. In Figure 3. it can be seen that on Equator facing facades the glazed ratio is not limited, moreover the bigger the glazed ratio the better is the energy balance. Thus an important feature of the solar architecture can be kept. Even on the East and West facing facades the glazed ratio is not limited with windows of *U* = 1.3 W/m^{2}K or less.

Having in mind that considerable solar gain is formally proven by calculation this fact facilitates

- either cheaper thermal insulation if the aim is just to met the required *q* value
- or to get a better rating of the building according to its real and proven thermal performance.

2.3. The chance of formal approval of meeting the requirements

In order to illustrate the importance of the solar gain a series of calculation has been carried out. A considerable number of buildings (1000 in each version) have been investigated varying the parameters in a randomised way. The calculation has been carried out according to the options a), b) and c), thus without taking into account the solar gain, with simplified method (diffuse radiation only) and with detailed method supposing that the facades are insolated.

In each case it was supposed that the *U* value of the building elements correspond to the prescribed allowable maximum – it is expected that in the practice the designers would start in the same way.

It has been supposed that 5, 65 and 30% of the transparent elements are oriented towards North, East-West and South, respectively. Two categories:

heavy and light weight buildings have been investigated in order to illustrate the effect of the utilisation factor.

The randomised parameters varied in the following intervals:

- surface to volume ratio: 0.3 - 1.3;
- form factor: 1 – 12;
- floor number: 1 – 9;
- ceiling height: 2.7 – 3.2 m;
- glazed ratio: 10 – 50%;
- frame ratio of windows: 10 – 30%.

The number of buildings in each category (1000) facilitates to use statistical methods. In Figures 4 – 6 the maximum allowable *q* value is put. The average *q* value of the investigated buildings in the middle of the “cloud” of the calculated ones is shown, too. The dotted lines border the interval in which 90% of the calculated 1000 *q* values can be found, thus 5% of the values are below the lower dotted lines and 5% exceed the upper one.

The Figures 4 – 6 show the results for heavy weight buildings. In the first case it can be seen that without taking into account any solar gain the fulfilment of the requirement can be proven only in about 6 – 7 % of the buildings. In all other cases the *U* values must be lower than the maximally allowable figures of the separate building elements.

In other terms the exaggerated simplification must be compensated by better thermal insulation. As a consequence the real thermal performance of the building will be better, but this fact will not be acknowledged in the rating, because it is not proven by calculation.

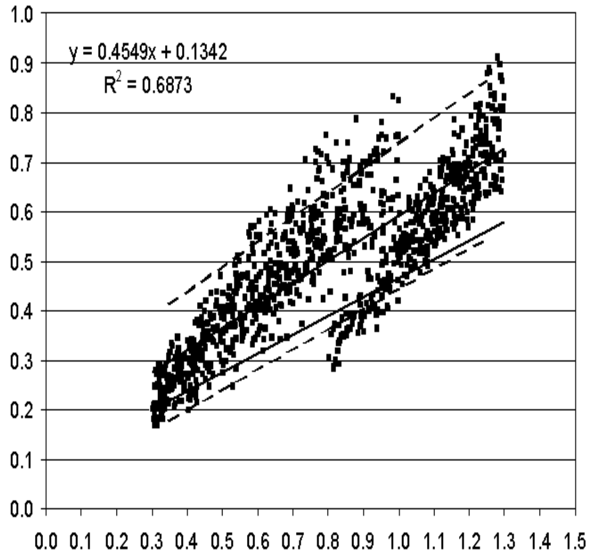

Figure 4: Calculated *q* values in the function of the surface to volume ratio. Heavy-weight buildings, without solar gain.

If solar gains are calculated with simplified method in about 25% of the buildings can be proven that the requirement of *q* can be fulfilled using elements with the maximum allowable *U* value.

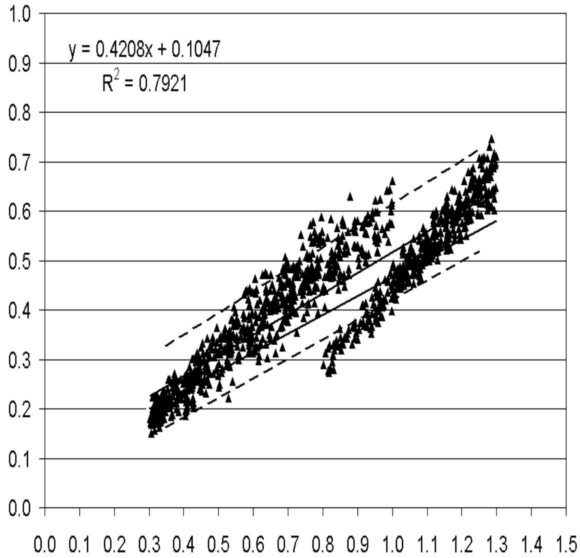

Figure 5: Calculated *q* values in the function of the surface to volume ratio. Heavy weight buildings, simplified calculation of solar gain.

In the case of detailed calculation and undisturbed solar access the dotted upper line coincides with the requirement which means that 95% of the 1000 building met the requirement if all building elements are of the maximum allowable *U* value. The line, marking the average *q* of buildings is below the requirement – the mean difference is 15%.

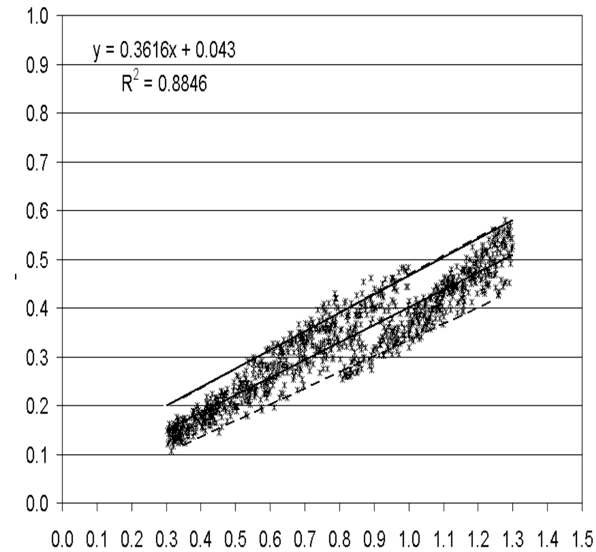

Figure 6: Calculated *q* values in the function of the surface to volume ratio. Heavy weight buildings, detailed calculation of solar gain, undisturbed solar access.

Self intended the *U* values of the building elements must not exceed the allowable maxima, thus the *q* value of the buildings will be better than the requirement. This fact - being proven by detailed calculation - will be acknowledged in the rating.

2.4. How long the heating season is?

The integrated energy performance of the building is to be expressed as a specific primary energy demand in W/m^{2}a. Self intended the length of the heating season and the degree-hours value is of fundamental importance.

The length of the heating season depends on the balance point temperature. The daily average indoor temperature in a free–running building can be approximated with the following equation:

$$\bar{t}_i = \bar{t}_e + \frac{A_F q_{cas} + \varepsilon A_{tr} g I_d}{\sum AU + \sum l\Psi + 0.35 nV} \qquad (2)$$

where

t_i – the indoor temperature, ^{O}C
t_e – the external temperature, ^{O}C
A_F – the floor area, m^2
q_{cas} - casual (internal) gains, W/m^2
A_{tr} – the area of the transparent building elements, m^2
g – global transmittance of transparent elements,
I_d – cumulative daily irradiance, kWh/ m^{2}d
A - the area of the exposed building elements, m^2
U – the heat transfer coefficient of the elements, W/m^{2}K
l – the length of the constructional joints, thermal bridges, m
Ψ- linear heat transfer coefficient, W/mK
V – heated volume, m^3
n – air change rate, 1/h
ε – utilisation factor

In this equation the casual gains and the air change rate are design input values, prefixed according to the use of the building (residential, office, school, etc.). The average indoor temperature is the normal set value. The equation facilitates to calculate the daily mean external temperature at which the gains cover the losses. Based on statistical data the length of the heating season and the degree-hours value can be determined (simply using a diagram or a table),

In the recent practice the heating season starts and ends if the daily mean external temperature is +12 ^{O}C, the average length of the heating season is 195 days with DD = 72 000 Kh. The better the thermal insulation and/or the higher the solar gain the lower will be the balance point temperature. If undisturbed solar access is proven for the critical period (mid-November), the shorter heating season can formally be proven. The difference may be as considerable as 30 - 40 days.

The use of this calculation is optional, nevertheless if the designer takes the time to carry out it, lower energy demand can be proven and a better rating will be achieved.

2.5. The risk: the summer overheating

The glazed ratio is to be pondered from the point of view of the risk of summer overheating. This risk should be checked in a simplified way using an equation similar to (2) with the following modifications:

- the daily irradiation is taken for June,
- the utilisation factor ε = 1,
- the air change rate in the case of mechanical ventilation is the design value, in the case of natural ventilation depends on the position of windows and the possibility of night ventilation, according to simple rules of thumb,
- the *g* value can be modified if movable shading devices are provided.

The difference between the daily means of indoor and external temperature is limited; the allowable difference depends on the thermal mass of the building. Here the options of the calculation are the followings:

- to miss the analysis of the solar access – in this case the global radiation is to be taken into account for each orientation,
- to prove by the analysis of the solar access that the windows are in shadow.

The missing of the detailed analysis may force the designer to decrease the glazed ratio, due to the unacceptable risk of overheating.

3. CONCLUSIONS

According to the EPBD the MS should implement new building regulations. The "integrated approach" of the EPBD means that the energy balance involves several user related components.

In order to prevent unfavourable trade-off between the user related and building related components of the energy consumption many new regulations include prescriptive requirements limiting the *U* value of the building elements.

Such structure of requirements may lead to a situation that *the building itself will be lost* in the regulation. It is indispensable to develop or to keep a minimum requirement system focussing on and only on building related data which can be used at the very first stage of the design and guarantees a good thermal performance of the building itself as well as an acceptable "integrated performance" whatever will be the users' habit.

With this aim in mind in the new Hungarian Building Regulation a specific heat demand value is limited which depends on and only on the inherent characteristics of the building, including the passive solar gains.

According to the experience the motivation of the builders and designers is more efficient than a strict prescriptive regulation. Both parties are interested either in the investment or in the rating of the building. Therefore the Regulation offers different calculation options with different workload. Simplified options lead to higher investment and the real energy performance of the building will not be reflected in the rating because it is not proven. More detailed calculation results either in lower investment cost or in better rating. It is expected that in this way the designers will be motivated and more and more of them will apply the classic approach of the solar architecture.