E(NERGY) P(ERFORMANCE) C(ERTIFICATE) OF BUILDINGS AND DWELLINGS
Influence of Disposition and Orientation

by

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Following the guidance set by the Directive on the energy performance of buildings (recast) (EPBD2), current regulations in Serbia which refer to the issue of energy efficiency and energy certification of buildings provides an opportunity of certification of selected unit of a building, such as a dwelling. This measure was set in order to make it possible for owners or tenants of the building or the building unit to assess and compare its energy performance. From the user's perspective this measure is very important since, apart from reviewing the quality or the deficiencies of space in which they live, it would be an important parameter of economic evaluation of the apartment in the future. As energy performance of the apartment is not a priori identical to that of the whole building, the paper will analyze and compare these values for different positions in a horizontal and vertical plan of the same apartment within the building. Comparison of the results obtained for individual dwellings and for a building as a whole, will provide insight into the extent to which the disposition and the orientation of the apartment affect its energy performance.

Key words: *energy performance certification, building, individual dwelling, disposition, orientation, energy demand*

Introduction

The European regulations from 2002 relating to the energy performance of buildings have recognized the need for energy certification of both buildings and individual apartments [1]. This approach has been maintained through the further development of European legislation in this area and in the Directive from 2010, the need that tenants or owners have access to the energy performance of their homes has been highlighted. *Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building and reference values such as minimum energy performance requirements in order to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance* [2].

According to the current national Rulebook on the conditions, contents and manner of issuing certificates of energy performance of buildings from year 2011 in article 13, it was emphasized that the energy passport is issued for the entire building or a part of a building

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when it is defined as a building with more energy zones. Energy passport can be issued for a part of the building that makes an independent usable whole, such as, for example, commercial property, apartment, *etc.*, for existing buildings that are sold, leased, reconstructed or energetically rehabilitated. Building or its independent usable unit can only have one energy passport [3].

In this way there is a possibility of energy certification of the apartment, as a separate entity within the building, but such practice is rarely implemented in local conditions. Considering the fact that each apartment has its own characteristics from the standpoint of geometric characteristics, disposition in the building, thermal envelope assembly and orientation, it is expected that there will also be difference in energy demand for heating. This study should provide insight into the extent to which these differences are expressed and whether they affect the change in the energy rating of the apartment compared to the other apartment or in relation to the entire building. The paper extracted typical position of the apartments in the building, which may have different energy needs [4]. In a horizontal plan, this refers to the apartment placed: at the end of the building and between two other apartments, while in a vertical plan variations include positions: above an unheated cellar, between the two apartments, or on the top floor to the flat roof. For all of these dispositions of flats different orientation were analyzed (south, north, and east/west) and being the most common method of energy rehabilitation carried out by individual users, different types of built-in windows were discussed. Analyzed model building is based on a reference model that is recognized within a housing fund of Belgrade as a representative of a mass housing construction in the sixties.

Reference type of residential buildings

Temporal and spatial features of the reference building type

The principal idea for the formation of the model for analyzing was based on a selection of the reference building type, which is significantly present, and thus representative of the existing Belgrade housing stock. Since the most intense housing construction in Belgrade occurred after World War II in the area of New Belgrade, these facts set the temporal and spatial features of the reference building type [5].

The postwar period was marked by a destroyed housing stock and the great migration of the population in the capital, which has created the need for simultaneous intervention in housing in several directions: restoration of building stock that was destroyed in the war, as well as construction of new buildings, to meet the growing housing needs. New Belgrade was in focus of housing construction, which was a planned urban complex that was supposed to respond to the demands of increased housing demand, but also to represent the model of the new socialist system. The fact that from 1946 to 1970, around 110000 dwellings were built in Belgrade, 30000 of which were built only in New Belgrade, shows the intensity of the residential production in the newly formed urban territory [6]. It is important to say that this was a period when there were no thermal regulations in domestic legislation, which creates the need to consider this housing stock in the context of energy rehabilitation in the next period. Therefore, this particular study could represent a guideline for future interventions.

Structural features of the reference building type

In the period after World War II, the global trend of industrialization of construction has been recognized in domestic housing construction, which contributed to a gradual abandonment of traditional construction techniques. The imperative of mass construction, imposed upon the needs of the newly established urban population, has caused drastic changes in construction industry that were necessary to realize the newly created housing needs. Advantages of the industrial mode of construction, achieved through a reduction of manual labor, faster and more efficient construction, better quality of the built elements manufactured in better conditions, requested a higher degree of mechanization, trained labor force, higher investments in a production programs and equipment. A prerequisite of the new system of construction was standardization of construction elements and modular co-ordination, which have been accepted in domestic practice and verified in the standards as an initial step towards the introduction of industrialized construction.

During the sixties and seventies, on the territory of Yugoslavia, several prefabricated or semi-prefabricated systems have been realized and more or less successfully implemented in housing construction. In a variety of systems of construction, stands out the IMS system that originated from scientific research and innovations of domestic constructors and which was massively applied in practice by all major construction companies and survived in the market of housing construction over a longer period of time. The system was named upon the Institute for Testing Materials of Serbia (IMS) where it was invented.

The IMS system is a prefabricated, skeleton, reinforced concrete, prestressed structure, consisting of up to three floors high columns, coffered reinforced concrete floor construction and cantilever slabs. The span of the floor structure, supported in two directions, was initially 4.20/4.20 m. In the course of time it changed, adapted to new needs and other functions of buildings. Connecting elements were prestressed cables, which were laid in the space between floor structures and the columns, in both orthogonal directions. The system also consists of the stiffening walls, stair plate and edge-beams [7].

Façades of multi-family residential buildings built in the analyzed period by using the mounting systems had a distinctive shape, with horizontal window bands and prefabricated parapet panels. Typical examples of these façade solutions are shown in fig. 1. Prefabricated parapet elements have had a multilayer structure containing a mandatory reinforced concrete layer, thermal insulation in the function of protection and a finishing layer, which is made either of reinforced concrete, or as a layer of mortar. It is worth noting that although the first thermal regulations in the country appeared only in 1967, reinforced concrete parts were always made as an isolated, albeit with minimal insulation [8].

Figure 1. Examples of typical façades of the buildings from the sixties

Multi-family residential construction during this period was marked by the use of flat roofs, which become an inevitable way of shaping roof level. Thermal insulation of the roof structure was carried out with various materials (polystyrene, heraklith, perlite mortar, glass wool), but what they had in common was the small thickness of these layers (2-5 cm), which talks about the lack of recognition of the significance of thermal insulation in the overall thermal balance.

The most frequently used floor construction of residential apartment buildings was the mosaique parquet placed on a cement screed, or some other base that is composed of wood chips. Sound insulation layer of hard-pressed mineral wool, sand or granulated cork was usually placed over the floor construction.

Typical windows of the sixties and alter was a wooden, single frame, connected double sash window with single glazing, which usually had an internal canvas roller blind or a wooden roller blind. Doors were usually wooden, having a plywood leaf structure.

According to the IMS, in the first decade of the application of the system (1957-1967) 36 buildings with 8676 apartments were built in the area of New Belgrade, while by 1983, more than 15000 apartments were built. This means that about every other resident of New Belgrade, lived in an apartment that was built according to this system [9]. In the sixties, New Belgrade apartment block 21 was built in the IMS system, in which a special attention attracts the building GF + 4, with very elongated dimensions in a form of a meander, (length of around 1000 m) and a total of 895 apartments [10]. Precisely in such a building it is possible to recognize all the dispositions of all dwellings that were analyzed in the work

Creation of a model building

Morphology and disposition of model building and dwelling

The formation of a model building initially was based on schematic drawings published by the IMS corresponding to constructed buildings from the beginning of the implementation of systems, fig. 2. Due to better comparability of the data obtained, a model building is treated as a residential lamella with four identical apartments per floor and a common unheated staircase placed in the central zone of the building. Such a disposition of the staircase and the entrance zone to the apartments is a standard principle of floor plan organization for many collective residential buildings [11].

Each apartment occupies two fields of the structural grid lengthwise the lamella and one and a half in width, whereby there is a loggia within a single grid. In accordance with the characteristics of the reference building, openings are set in horizontal window strips occupying 50% of the corresponding surface of the façade while in the part where there is a loggia, this percentage is slightly higher (about 70%) due to the formation of doors.

It is assumed that lamella has a district heating system which is the predominant way of heating in apartment blocks of New Belgrade.

The paper analyzes the apartments which have different positions in the building and therefore different sizes of thermal envelope which results in a different demand for energy for heating and potentially different energy categories.

There are two typical positions of flats in a floor plan of a lamella which are shown in fig. 3:

– Type 1: apartment on the corner of the building (the beginning and the end of the building), there are two façade planes, one of which having openings, and

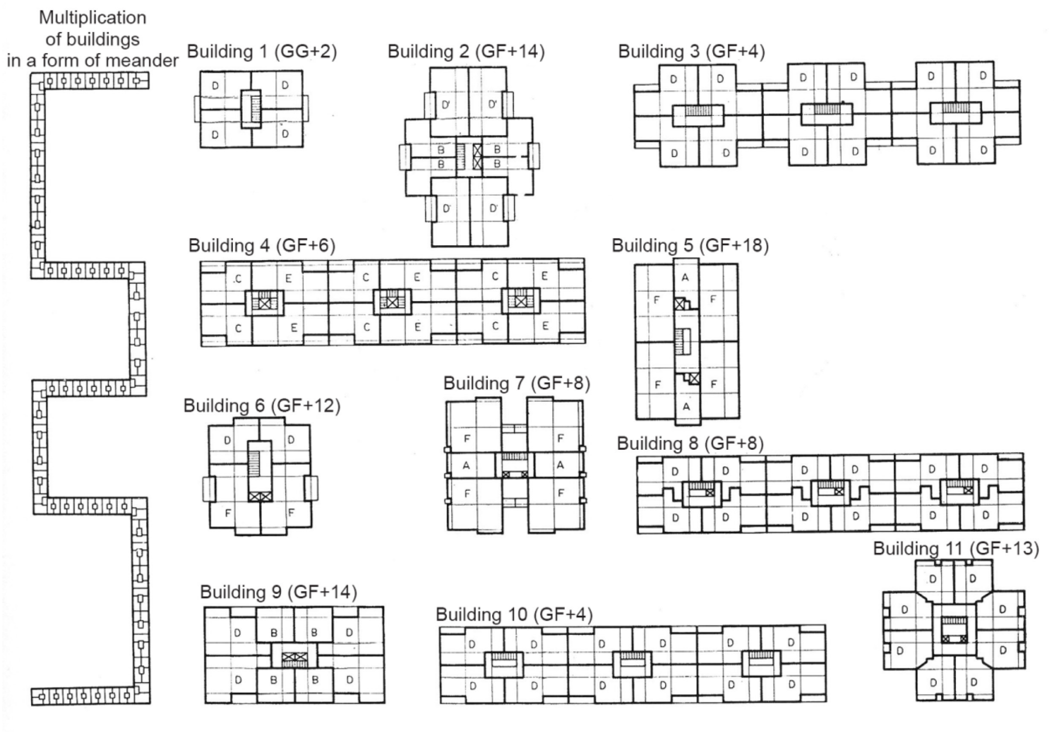


Figure 2. Schematic floor plans of various buildings constructed in the IMS prefabricated system

- Type 2: apartment in the central part of the building, built between the neighboring apartments, one façade plain with openings.

In the vertical section of the building three characteristic positions have been recognized and shown in fig. 3:

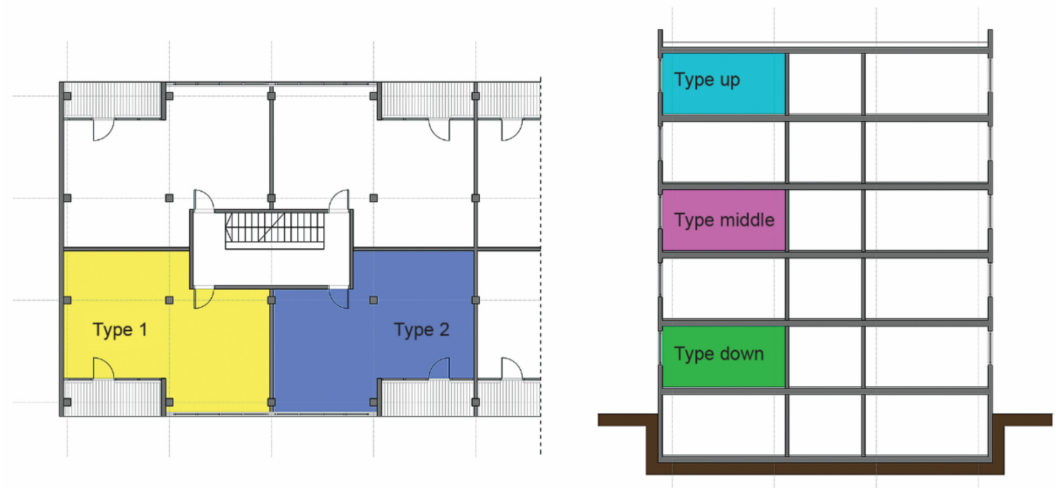


Figure 3. Floor plan and section of the model building

– Type-down: apartment on the ground floor below which there is an unheated basement.
– Type-middle: apartment on the middle floors having a dwelling above and below.
– Type-up: apartment on the top floor, above which is a flat roof.

The following criteria discussed in the paper refer to the orientation of the façade. Considering that the model building is formed from unilaterally oriented apartments, three typical cases of orientation of the façade with openings are analyzed:

– northern orientation,
– southern orientation, and
– eastern/western orientation (which exhibit the same results in the energy performance of the building – flat).

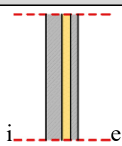
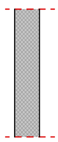
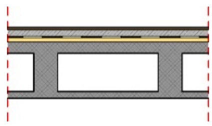
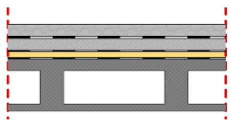
In the calculation of energy performance, an open position of the building is considered, when more than one of its façades is exposed to the wind, which corresponds to the disposition of buildings in the urban matrix of New Belgrade.

On the basis of defined criteria, energy needs for all positions established dwellings (horizontally and vertically) and possible orientations were calculated.

Structural elements of a model dwelling

A model apartment materialized in accordance with the characteristics of the reference buildings built in the IMS system during the sixties, and selected assemblies of elements of its thermal envelope are shown in tab. 1. Original state of walls and floor constructions was assumed, since usually there was not any intervention in these elements of the thermal envelope.

Table 1. Elements of thermal envelope

Façade wall	Wall to the staircase	Floor construction above the basement	Floor construction bellow the flat roof
			
– Concrete 8 cm – Cement bonded wood wool 5 cm – Concrete 4 cm – Mosaic tile finishing 0.5 cm	– Reinforced concrete 14 cm	– Mosaique parquet 1 cm – Cement screed 3 cm – Kraft paper – Mineral wool 2 cm – The IMS floor construction 25 cm	– Gravel 5 cm – Hydro insulation 1 cm – Lean concrete laid to fall 5 cm – Bituminous layer – The EPS 2.5 cm – Hot bitumen coating 0.5 cm – The IMS floor construction 25 cm
$U = 1.2$ W/m^{2}K	$U = 3.2$ W/m^{2}K	$U = 0.75$ W/m^{2}K	$U = 0.81$ W/m^{2}K

Precast façade panels have a multilayer structure with reinforced concrete layers on the outside and the inside, insulation in the central part, and outer finalizing layer of mosaic tiles. The walls towards an unheated staircase have been adopted as 14 cm thick reinforced concrete walls.

The floor construction of a model dwelling has a closed cavity structure of a coffered IMS structure, modeled after the floor construction from the beginning of the application of this system. A layer of mineral wool as sound insulation and the subfloor is set over the construction with a final layer of mosaic parquet.

Flat roof is formed above the standard IMS floor construction and isolated by layers of bituminous waterproofing and a thin layer of thermal insulation, which was typical for structures built during the period. Typically for inaccessible flat roofs, the final layer is formed by a layer of gravel.

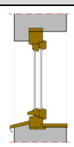
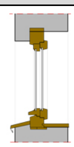
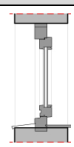
Three types of windows were varied on the investigated model, in order to perceive the current situation regarding the most commonly applied energy rehabilitation measures that refer to this particular element of the thermal envelope [12]. The assumption is that users who are interested in obtaining energy certificates perform certain investments in their apartments, which are almost always manifested through the change of the original wooden windows with more modern systems with a significantly better heat transfer coefficients and improved air tightness. It is assumed that more than one façade is exposed to the wind.

The following variants of windows were considered:

– Variant 1, originally built solution: wooden, single frame, connected double sash window with single glazing (U_w = 3.1 W/m^{2}K; g = 0.75), not being maintained and having poor air tightness (the number of air changes 1.2),
– Variant 2, originally built solution: wooden, single frame, connected double sash window with single glazing (U_w = 3.1 W/m^{2}K; g = 0.75), well maintained and having a medium air tightness (the number of air changes 0.7), and
– Variant 3, new windows with PVC or aluminum frames and double glazed glass unit (U_w = 1.5 W/m^{2}K; g = 0.4), air tightness is good (the number of air changes 0.5).

The relevant thermal characteristics of the applied windows are shown in tab. 2.

Table 2. Characteristics of applied windows

Variant	Variant 1 original window	Variant 2 original window	Variant 3 replaced window
Window type			
	Wooden, single frame, connected double sash window with single glazing	Wooden, single frame, connected double sash window with single glazing	The PVC or aluminum frames and double glazed glass unit
Air tightness	Poor	Medium	Good
Number of air changes, n, [h^{-1}]	1.2	0.7	0.5
Thermal transmittance, U, [Wm^{-2}K^{-1}]	3.1	3.1	1.5
Solar factor, g	0.75	0.75	0.40

The doors between the apartments and the unheated stairway made as a wooden, having a plywood leaf structure, with a thermal transmittance U = 3.0 W/m^{2}K.

By combining adopted window types with previously defined variations of position and orientation of model dwellings resulted in 54 alternative solutions of energy performance of the initially same apartment.

Results

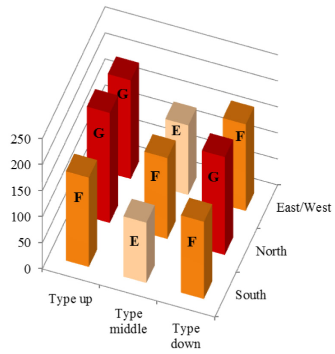
Results of the analysis are expressed through the values of the energy needed for heating per unit area, $Q_{\text{h,an}}$, for each of the analyzed apartments, as well as the corresponding energy class. Thermal properties of applied structures, as well as energy performance of the analyzed buildings were calculated by using non-commercial software KnaufTERM 2 Pro [13], which is based on requirements and settings of the relevant thermal regulations [3, 14]. Table 3 presents obtained results for the Type 1 apartment (at the corner of the building), for three variations of applied windows, for all orientations and all vertical dispositions of flats (down, middle, and up), while in tab. 4 diagrams of energy consumption and energy classes of the apartment are presented, in order to differentiate the obtained results according to the adopted individual parameters.

Table 3. The corner apartment (Type 1)

Type 1.1	1. Original airtightness (poor airtightness)					
	South		North		East/West	
	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class
Type-up	171.57	F	211.14	G	189.37	G
Type-middle	115.79	E	155.35	F	133.58	E
Type-down	148.39	F	187.95	G	166.18	F
Type 1.2	2. Original state of windows (medium airtightness)					
	South		North		East/West	
	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class
Type-up	145.62	F	185.19	G	162.42	F
Type-middle	88.94	D	129.40	E	107.63	E
Type-down	122.44	E	162.00	F	140.23	F
Type 1.3	3. Replaced windows (good airtightness)					
	South		North		East/West	
	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class	$Q_{\text{h.an}}$ [kWhm^{-2}]	Class
Type-up	130.78	E	152.51	F	139.81	E
Type-middle	74.99	D	96.72	D	84.03	D
Type-down	107.59	E	129.32	E	116.63	E

Based on all of the analyzed parameters, it is clearly perceived that the energy required for heating depends on all the mentioned parameters, and that most of the energy was needed for dwellings whose surface thermal envelope was the largest and solar gains the smallest. This means that the angular flats below the flat roofs were the biggest consumers of energy, then the corner apartment above an unheated cellar, while those angular flats that were on a typical floor consumed the least energy. In this type of the apartment and the same type of windows considered, differences arise for two energy classes and in one case even for three.

Table 4. The corner apartment (Type 1), diagrams of energy consumption and energy class

<table>
<tr><th>Type 1.1</th><th>Type 1.2</th><th>Type 1.3</th></tr>
<tr>
<td>
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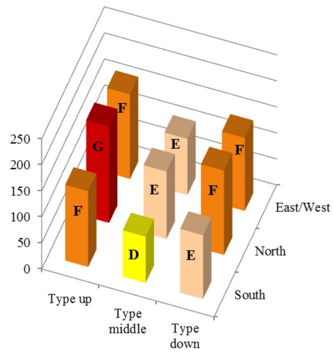
<td>
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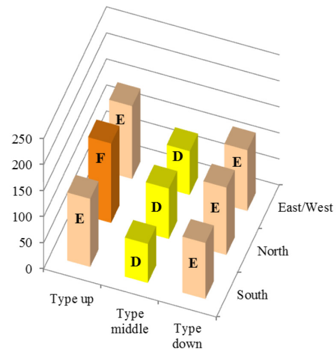
<td>
</td>
</tr>
<tr>
<td>– Corner apartment
– Original windows
– Poor airtightness</td>
<td>– Corner apartment
– Original windows
– Medium airtightness</td>
<td>– Corner apartment
– New windows
– Good airtightness</td>
</tr>
</table>

The amount of energy for heating varies in apartments of different orientations, so that the north-oriented apartments have the greatest need for energy, followed by apartments with the eastern or western orientation and the south oriented apartments. Differences in energy consumption were up to two energy classes.

Quality and airtightness of windows significantly affect the required amount of energy, and it is clear that the better sealing, the heat losses are smaller. Bearing in mind that the age of reference buildings is about 50 years, cases of bad airtightness of windows were considered, which in many cases corresponds to the real situation on the field, while medium sealing corresponds to well-maintained windows.

However, it is assumed that users who are interested in obtaining energy certificates carried out certain investments in their apartments that is almost always manifested through the replacement of original wooden windows with contemporary systems (PVC or aluminum) that have significantly better heat transfer coefficients, and improved airtightness.

In this type of dwellings, the largest differences occur between the north oriented angular apartment, placed on the top floor, having the windows of the lowest quality, and the apartment on the corner, in the central floor, facing south and having replaced windows. The first mentioned apartment was of the energy class G, whereas another apartment belonged to the energy class D, having a difference of three energy classes. Differences in energy demand for heating between these two residential units are about 136 kWh/m^2 per year. This case shows the possible real situation within a single building, where one apartment, less favorably positioned and oriented, but at the same time the owner has not changed nor maintained doors and windows, while the other is conveniently placed within the building and the owner has replaced the windows and thus further improved energy characteristics of the apartment. In this case, the differences in energy classes are highly expressed, showing to what extent certain flats are or are not better than others, and how the certification of individual housing units important for assessing the quality of the apartment from the standpoint of energy efficiency.

The built-in apartments (Type 2), have a slightly smaller area of façade walls, compared with a corner (Type 1). Therefore, it is clear that the energy needed for heating lower. All other conclusions that were derived for the angular dwellings are still valid. Unlike the previously described apartment type, energy classes vary from C to G, while in the previous example, the best energy class was D. Table 5 presents results of the Type 2 apartment (in the middle of the building) for three variations of applied windows, for all orientations and all vertical dispositions of flats (down, middle, and up). Table 6 presents diagrams of energy consumption and energy classes of variations of the Type 2 apartments.

Table 5. The central apartment (Type 2)

Type 2.1	1. Original airtightness (poor airtightness)					
	South		North		East/West	
	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class
Type-up	147.62	F	187.18	G	166.54	F
Type-middle	91.83	D	131.99	E	110.76	E
Type-down	124.43	E	163.99	F	143.36	F
Type 2.2	2. Original state of windows (medium airtightness)					
	South		North		East/West	
	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class
Type-up	121.67	E	161.23	F	140.59	F
Type-middle	65.88	C	105.44	E	84.81	D
Type-down	94.48	D	134.04	E	117.41	E
Type 2.3	3. Replaced windows (good airtightness)					
	South		North		East/West	
	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class	$Q_{h.an}$ [kWhm^{-2}]	Class
Type-up	106.82	E	128.55	E	116.99	E
Type-middle	51.03	C	72.76	D	61.20	C
Type-down	83.64	D	105.36	E	93.80	D

Summing up the results of the corner apartments (Type 1) and those in the middle of the lamella (Type 2) it can be noticed that the biggest difference in energy demand for heating exists between a northern oriented corner apartment placed under the flat roof (Type 1-up) which manifests G energy class, and a built-in apartment in the middle of the building (Type 2 middle) facing south which manifests C energy class. The difference in the energy needed for heating is about 130 kWh/m^2 (which equals four energy class), and such situation occurs within the same building. In the next step, energy required for heating, as well as energy class were calculated for the entire building, in order to compare these values with those of the individual housing units.

In addition, an analysis of the lamella positioned to an east-west direction so that half of the apartments have southern, and other half north exposure. The different number of storeys of the buildings (GF+4, GF+5, and GF+6) was discussed, in order to determine the differences in energy demand for heating. The following variations were related to the type of windows that was discussed in three cases: when all the windows of the building were old and

Table 6. The central apartment (Type 2), diagrams of energy consumption and energy class

<table>
<tr><th>Type 2.1</th><th>Type 2.2</th><th>Type 2.3</th></tr>
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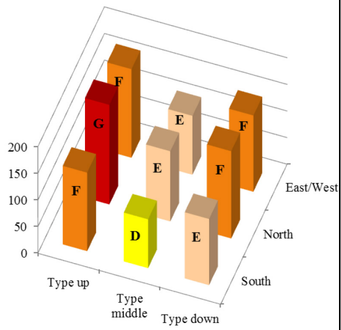
<td>
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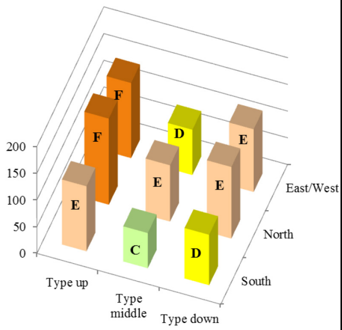
<td>
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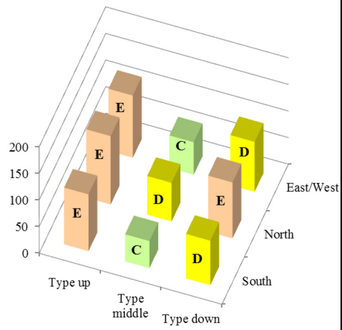
<td>
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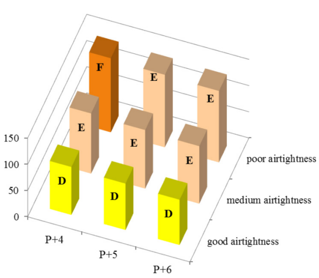
</tr>
<tr>
<td>– Central apartment
– Original windows
– Poor airtightness</td>
<td>– Central apartment
– Original windows
– Medium airtightness</td>
<td>– Central apartment
– New windows
– Good airtightness</td>
</tr>
</table>

poorly sealed, when all the windows on the building were of good airtightness (maintained the original windows) and the third variant of the building where all the windows were replaced. These situations are not real in the field, since the rare examples of buildings from that time where all the windows are original (or all are new), but such results provide the ability to compare the results at the level of the building as a whole and those of individual apartments that have the same type built-in windows. Results are shown in tab. 7.

Table 7. Energy performance of the whole building

<table>
<tr><th>Lamela</th><th colspan="2">New windows (good airtightness)</th><th colspan="2">Original windows (medium airtight-ness)</th><th colspan="2">Original windows (poor airtightness)</th><td rowspan="5">
</td></tr>
<tr><td>No. of storeys</td><td>$Q_{h.an}$ [kWhm^{-2}]</td><td>Energy class</td><td>$Q_{h.an}$ [kWhm^{-2}]</td><td>Energy class</td><td>$Q_{h.an}$ [kWhm^{-2}]</td><td>Energy Class</td></tr>
<tr><td>GF+4</td><td>91.55</td><td>D</td><td>114.78</td><td>E</td><td>141.36</td><td>F</td></tr>
<tr><td>GF+5</td><td>88.61</td><td>D</td><td>111.89</td><td>E</td><td>138.42</td><td>E</td></tr>
<tr><td>GF+6</td><td>86.50</td><td>D</td><td>109.82</td><td>E</td><td>136.32</td><td>E</td></tr>
</table>

Based on these results it can be concluded that an increase in the number of floors reduces energy use for heating per square meter, because it increases the share of apartments situated in the central part of the building (as seen by the height of the building), which have better energy performance of dwellings on the ground and the last floor. These differences are not great if you look at per unit area (about 2.5 kWh/m^2 per year, within the same parameters), but if we consider the entire surface of the object, they are important and may be of interest for some further investigation.

Energy classes differ in three levels (D to F) and to the greatest extent they are conditioned by certain type of embedded windows (their quality and airtightness). Energy needed to heating varies around 20-25 kWh/m^2 by lowering (or increasing) the quality of the window, which led to a shift in the overall energy class.

Conclusions

By comparing the achieved energy classes on the level of the objects as a whole, and those of individual apartments it can be concluded that, in the case of dwellings, they vary from class C (as the best) to G (as the worst), while changes in energy class of the building as a whole vary in terms of levels F and D. These results show that by performing the energy certification of buildings, energy class of constituent dwellings may differ for two ranks from that of a building. Such situation represents a real problem from the perspective of the user of the premises in understanding a real energy performance of their living space. A special kind of problem occurs in buildings that are not connected to the district heating system and where each user heats its own space according to its own needs and capabilities.

Research has shown the extent to which the geometrical characteristics of the apartment, its position within the building (horizontal and vertical) orientation and the materialization determine the final energy needed for heating, *i. e.* define the energy class. Therefore, the need for energy certification of individual dwellings is shown as a necessity in defining the quality of living space that will certainly be valorized and recognized in present economic and market processes (lease, sale, *etc.*). Prospective tenants or buyers, need to have accurate information about the characteristics of the property which is the subject of their interest, including energy consumption for heating (and cooling), and the expected building's operational use costs.

Having in mind the expressed variations of energy classes between individual apartments and a building as a whole, and the fact that regulations basically determine the need for calculation of energy performance of the whole building, we may wonder if it would be necessary for the regulation to define an additional condition that would require that individual apartments, regardless of their position, fulfill the minimum energy class requirement which exists for the building as a whole. From the engineering point of view the answer would be positive.

Nomenclature

g – solar factor [–]
n – number of air changes per hour [h^{-1}]
Q – quantity of energy [kWhm^{-2}]
U – thermal transmittance [Wm^{-2} K^{-1}]

Subscripts

an – anually
h – heating
w – window

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