Iwona **FORYŚ** • Ewa **PUTEK-SZELĄG** • Beata **ZIEMBICKA**

ENERGY INTENSITY OF A BUILDING IN THE PROCESS OF ESTIMATING THE MARKET VALUE OF A RESIDENTIAL UNIT

Iwona **Foryś,** Prof. (ORCID 0000-0002-2294-0672) – *University of Szczecin*
Ewa **Putek-Szeląg,** PhD (ORCID 0000-0002-2294-0672) – *University of Szczecin*
Beata **Ziembicka,** PhD (ORCID 0000-0001-8540-2866) – *Operat Beata Ziembicka*

Correspondence address:
Mickiewicza Street 64, 71-101, Szczecin, Poland
e-mail: iwona.forys@usz.edu.pl

ABSTRACT: Under current Polish legislation, the valuation of real estate should take into account the results of energy performance certificates and indications of for potential improvement of this performance which are economically viable and technically achievable. The Polish market of energy certificates is young. However, there are energy-intensive data that can be included in property valuation in the absence of energy performance certificates, especially in the case of residential units. The article proposes a way to assess the multi-family building's and its individual units' energy performance on the basis of information such as the location of the unit in the building, the consumption of heating units, the unit's (its living room's) sun exposure. Based on the analysis of the local real estate market (selected homogeneous housing estate in Szczecin), statistically significant relationships between the transaction price of a flat and its pricing features were sought, in particular those characterizing the energy intensity parameters of flats and buildings. The research is devoted to the current and important problem of including energy values in property valuation, but first of all it is important to improve the awareness of buyers and real estate professionals about the costs of heat energy and their impact on sustainable development.
KEY WORDS: property value, energy intensity of buildings, sustainable development

No. 4(71) 2019 • pages: 107-122 https://doi.org/10.34659/2019/4/52 JEL: Q56, R2, R15

Introduction

In the European Union buildings account for about 40% of the demand for non-renewable primary energy PE and are also responsible for more than a third of carbon dioxide emissions into the environment. Therefore, the main objective of the EU policy implemented in the construction sector is to become independent of non-renewable energy sources and improve the energy performance of buildings, while reducing carbon dioxide emissions to the environment. In 2008, EU countries introduced stricter regulations (climate and energy package) aimed at setting an indicative target value for energy efficiency, based on the national consumption of primary energy PE or final energy FE. Member States have been obliged to achieve a certain level of energy savings and environmental benefits by 31 December 2020. Objectives and tools to support the implementation of the above commitments have been included in subsequent communications and directives of the European Union, particularly Energy Performance of Buildings Directive, the so-called EPBD Directive and the Directive on the Energy Performance of Buildings (Directive of the Parliament..., 2010). Under the assumption of the above documents, to obtain reliable information about the building on the basis of energy performance certificates, Member States have to use harmonised calculation methods and energy classes (labels), based on consistent EU rules of assessment that take into consideration local climatic conditions, diversifying facilities by the national and regional level, available energy resources and legal regulations. The mandatory requirements of both directives have been incorporated in such legal acts as the Polish construction law (the Construction Law Act, 1994) and the Real Estate Law (the Act on the Real Estate Management..., 1997). The requirement to include energy performance certificates in the process of property valuation was also laid down in the European Valuation Standards (EEE, 2016). In Poland, a number of energy performance certificates issued for secondary market properties is still low. Therefore, in the absence of a market for energy performance certificates, it is not possible to make a comparative analysis of premises from the adopted database regarding the features describing energy efficiency.

Faced with an immature market of energy performance certificates for residential units, and in principle the lack of these documents in market trading, buyers are looking for alternative parameters of multi-family buildings and their individual units that are responsible for heat losses (Kazak et al., 2018, p. 1653-1661). These parameters are used for comparison with other offers on the market. They allow for informed decisions in the context of environmental care. Similarly, property appraisers need alternative tools to evaluate properties on sale. Their toolbox requires comparative attributes of properties from the transactional database, including those that relate to energy intensity.

The purpose of the study is to identify features and their variants that describe a multi-family building and its residential units in terms of energy intensity. In the article, an attempt is made to change the view on property valuation and to verify the existing approach to the valuation process which does not include the analysis of features related to energy intensity of buildings. The authors' aim is to answer the question whether the energy performance of a multi-family building (and individual flats) in the form of the previously ignored attributes responsible for heat consumption influences the value of residential units and whether it should be taken into account in the valuation of market rights to residential units.

An overview of the literature

Awareness of the importance of climate and natural phenomena creates the need to conduct analyses and make models of rational use of environmental goods, including in the issue of depletion of natural resources. Research on the implementation of sustainable development principles on the basis of real estate value theory (Burchard-Dziubińska, 2007, p. 220-221; Foryś, Putek-Szeląg, Ziembicka, 2019) has a special role to play. However, the principles of pro-ecological sustainable development on the property market should be considered broadly, taking into account such sectors of the economy as construction, being a part of the investment process of "physical" creation of buildings. Modern, efficiency-oriented ecological solutions that slow down the process of value loss as a result of technical wear and tear meet ecological standards, minimize the environmental impact of the building throughout its life cycle, but also affect the value of the property. They provide healthier conditions for users by improving the quality of air inside the building (Batóg et al., 2019) and the spatial layout of the property (Belniak, Głuszak, Zięba, 2013, p. 122-127).

The pro-environmental dimension of the property market reflects the desire to increase the value of real estate, taking into account: environmental protection including the need for clean air, better quality of life as well as improved economic growth (Czarnecki, Karpoń, 2012, p. 304). It is also a search for a compromise between "inviolability" of the natural environment, for present and future generations (sustainable development) and social and economic development (Jaworowicz-Rudolf, 2010, p. 46-53). According to Siemińska, each new investment project brings changes to the environment and interferes with the existing balance (Siemińska, 2013, p. 62), hence sustainable development involves, among other things, the design and construction of buildings to be harmoniously inscribed in the environment as environmentally friendly, maintaining their functionality and durability, using as little energy as possible and ensuring comfort of use. In turn, Kryk points out "the necessity of ecoconsumption conditioned by people's perception of ecological needs and the level of their ecological awareness" (Kryk, 2007, 116-117). The environment is treated by the users as a utility.

Environmentally friendly property market sets out mutually complementary directions and their harmonious interactions in the following dimensions: social, economic and environmental, while meeting the criterion of limiting the consumption of domestic energy within the limits of profitability. These are the objectives set by the European directives, which provide for the reduction of energy demand of buildings by minimising losses through building envelope and effective use of heat gains and of renewable energy resources. It is a pursuit of energy self-sufficiency of buildings achieved through the implementation of energy-optimal structural, material and installation solutions (Czarnecki, Karpoń, 2012, p. 309). Energy intensity can be attained with standardised tools for the assessment of buildings' environmental performance that set out detailed rules and requirements for the economic assessment of their characteristics (based on, inter alia, functionality and technical parameters) as well as for the detailed inspection of their results (PN-EN 15643-4, 2012).

Economic growth contributes to an increase in energy consumption and CO_2 emissions to the environment, therefore raising individual consumers' and entrepreneurs' awareness is of great importance for the externalisation of environmental costs (Burchard-Dziubińska, 2007). It is one of the objectives of ethical principles of sustainable development with regard to the natural environment (Rogall, 2010, p. 394-403). It is not the amount (in strict sense) of consumed energy that reflects the economic development and innovativeness, but the efficient use of resources, with particular stress on the use of renewable resources (Michalak, 2009). Therefore, when looking for solutions stimulating efficiency, one should remember that it stems from energy-saving solutions relating to technical activities, the aim of which is to achieve economic benefits (energy-saving). In a broader sense, the issue can also be extended to environmental protection measures.

The consumed energy can ensure the material well-being of an individual, at different levels. For example, Germany consumes 170 GJ of final energy per capita (EK), the USA 328 GJ, and Japan 171 GJ per capita (Rogall, 2010, p. 404). Differences may result from cultural and climatic conditions, but also from different efficiency of technical facilities. Domestic heating (about 74%) and hot water preparation (about 12%) have the highest share in final energy consumption of households. Therefore, it is important to increase energy efficiency of new and existing buildings (Kazak et al., 2018). Energy performance assessment applies to the design, construction and operation of buildings and applies to buildings and their technical systems (Broniewicz, 2018, p. 36-48). With regard to "old" buildings, thermal upgrading is of crucial importance, while in the case of newly built ones, higher standards of thermal protection is of crucial importance.

Efficiency is the subject of many studies, analyses and discussions and is usually associated with productivity, as it is a result of the actions taken, representing the relation of the produced effects to the incurred outlays. As an economic category, efficiency is usually associated with economic and effective implementation of measures leading to growth (economic in the sense of optimising cost expenditures; effectiveness measured by the level of achievement of an desired objective). From an ex post point of view, efficiency is the result of activities performed, whereas from an ex ante point of view it is a forecast of anticipated effects, with the involvement of specific resources at a given time. When relating the effect to the outlay, the dynamics and level of growth depend on the adopted efficiency measure. In economic decision-making, the outlay is expenditure necessary for the implementation as well as for the maintenance of an investment. In a broader sense, a measure which produces the best results at the lowest cost may be considered effective (Solińska, Soliński, 2003, p. 95-109). The Ministry of Investment and Development (www.miir.gov.pl) indicates that "energy efficiency of a building, or energy performance, is the degree to which a building is prepared to ensure comfort of use in accordance with its intended use, with the lowest possible energy consumption by that building". The efficiency assessment includes an analysis of characteristics of the building and its fitting-out that have an effect on its energy consumption. The main principles in energy-efficient construction include the choice of the smallest possible area with an assumption that the building is compact in shape (rectangular or square plan), abandonment of cellars and attics, the choice of a simple one- and two-way roof, optimal location in relation to the directions of the world, optimal quantity of built-in installations and evaluation of thermal insulation of building envelope (walls, ceilings, roof, ground floor).

The Energy Efficiency Act (2016) defines it as the ratio of the utility effect of a facility, appliance or installation produced under typical conditions to the amount of energy absorbed by the facility. The measure of energy efficiency is the utility effect, which is e.g. lighting and the level of users' thermal comfort. According to the EU directives, the efficiency should be analysed together with the estimated economic life cycle of the building (if an energy performance certificate is required). Energy efficiency should therefore be analyzed in the context of energy intensity (consumption) in the "top-down" perspective, as an integrated system covering a number of issues including: use of energy from available renewable sources, implementation of the best possible technological and installation solutions (optimal in terms of energy and economically viable), the building's physics and its thermal diagnostics throughout its life cycle, the environmental effect including CO_2 emissions to the environment, promotion of energy efficiency, inspection of socio-economic effects of energy efficiency improvements, and creation of municipal policy instruments (Geryło, Mańkowski, Piasecki, 2012, p. 323-330).

Energy efficiency can be linked to economic and environmental efficiency so that the whole could form a "hybrid" of a technical solution balancing the economic cost, the environmental cost and the savings effect for the customer and the environment. According to the current regulations, it poses a challenge for residential property managers whose duty is to manage their resources in the right way by choosing an optimal method of distributing the total costs of heat purchase which is settled on a per unit basis. This method, after considering the compensating factors of energy consumption for heating purposes, should contribute to stimulating energy-saving behaviours for each flat depending on its position of the building, regarding the residents' thermal comfort and normative ventilation of flats. The measure of efficiency can also be the discounted rate of return on investment for renovation in the fixed period of time (net present value).

During the long-term operation of a building, its energy quality may change, depending on many factors (Koczyk et. al., 2009, p. 95-498):

- building's geometry, its geographical location and layout of the rooms,
- thermal quality of materials used for the building envelope and exterior joinery,
- effective protection in summer against heat losses and radiation,
- diffusion and airtightness of the building,
- architectural details eliminating the influence of thermal bridges,
- the ability of the structure to use natural ventilation and cooling solutions for the building,
- the good practice of continuous maintenance and repair of the building together with technical facilities.

An energy-efficient building is one that is equipped with highly efficient installations, emitting as little heat as possible to the environment. Energy consumption is considered to be low when it is 50% less than in traditional buildings according to the standards in force at the time of construction (Alsabry, Pigalski, Maciejewski, 2010). Meeting these standards depends on the climate zone for which the assessment is made, including the variability of external air temperature, wind speed and solar intensity. The value in use of a building is therefore determined by actions that aim to reduce the consumption of operating energy, without compromising the thermal comfort and well-being of users (Jaworowicz-Rudolf, 2010), while maintaining visual comfort and extending the service life (durability).

In the nearest future the Polish construction industryis expected to change its philosophy of designing and maintenance of low-energy houses (Ziembicka, 2016). However, potential buyers do not yet perceive the energy certificate as an attribute that adds value to the transaction. In their research, the authors indicate that in the central location of the city of Szczecin, the condition of the facade of the building in confrontation with an attractive location does not matter much (Putek-Szeląg, Ziembicka, 2016, p. 409-417), while in the case of buildings outside the city, the process of thermal upgrading of buildings may, however, contribute to a higher price of properties on the market (Foryś, 2006, p. 55; Bełej, Gulmontowicz, 2009). The property managers' experiences shows that the key factor influencing the effeciency is the shape of the building, location of the residential unit on offer, thermal quality of the building envelope, the type of ventilation, window and door woodwork, as well as the layout of rooms adapted to climatic conditions (Sujkowski, 2014). Settlements of heat energy costs take into account heat gains in the heating season, while in the case of residential units, the energy demand of rooms in the summer season is ignored.

Research methods and data

The article searches for the relationship between the transaction price of residential units and the factors determining the energy intensity of buildings and these units. To evaluate these relationships, elements of structure analysis are used to determine the basic descriptive statistics of the sample. Average values, standard deviation and quartiles are analysed. Due to the fact that the data are ordinal variables the Spearman rank correlation coefficient is used to verify the dependency. The Spearman's rank correlation coefficient is calculated as follows (Aczel, 2000):

$$\rho_{xy} = \rho_{yx} = 1 - \frac{6 \cdot \left(\sum_{i=1}^{n} d_i^2 + T_x + T_y\right)}{n \cdot (n^2 - 1)}, \quad (1)$$

$$d_i = \text{rank } x_i - \text{rank } y_i,$$

$$T_x = \frac{1}{12}\sum_j \left(t_j^3 - t_j\right),$$

$$T_y = \frac{1}{12}\sum_k \left(u_k^3 - u_k\right),$$

where:

t_j – number of observations in the sample having the same j-th value of the characteristic rank x,

u_k – number of observations in the sample having the same k-th value of the characteristic rank y,

n – number of observations.

The coefficient takes values from <-1;1> and informs about the strength and direction of the dependency. The closer the absolute value of the coefficient to unity, the stronger the relationship (positive or negative).

Using the indicated measures and basing on the analysis of the local property market (a selected homogeneous housing estate in Szczecin), statistically significant dependencies between the transaction price of a flat and its pricing characteristics are sought, in particular those concerning the parameters of energy efficiency of flats and buildings.

For this purpose, to the classical characteristics of units which are included in the valuation as a standard, we propose three characteristics to assess the buildings and units located in them, in terms of their energy intensity, i.e.: sun exposure of the unit (living room), consumption of heating units, position of the unit in the building. Data from the Housing Cooperative "Dąb", public statistics, databases and our own research were used for the analysis. The research covered selected buildings in the Housing Cooperative's stock – erected in the years 1979-1984, in a prefabricated concrete slab technology (mainly the Szczecin system). We analysed transactional data from the secondary market of flats in the above mentioned buildings for the years 2008, 2011, 2014, 2017 and data concerning readings of units of heating energy consumption in individual flats. The research area covered the following streets: Jasna, Kostki Napierskiego, Rydla, Łubinowa and Lniana. The choice of the "Słoneczne" housing estate for the study was conditioned by:

- homogeneous location,
- a homogeneous housing stock in terms of construction time and building technology,
- similar heat transfer coefficient U for all buildings,
- a homogeneous and most efficient source of heating,
- diversified position of the buildings in relation to the directions of the world,
- various types (shapes) of buildings,
- position of flats in the building (central or end wall position).

The above conditions and characteristics allowed for a detailed analysis of the impact of each of them on the transaction price of residential units, with regard to the energy efficiency of buildings and units located in them. The buildings were grouped into four types depending on their height and shape, i.e. high buildings: star-shaped (three arms form cubic blocks of tall buildings), ordinary-shaped (cube), cascade-shaped (sloping cubic blocks) and all low-shaped (up to five storeys) buildings. Seven low buildings and eighteen high-rise buildings were observed, including: nine buildings forming three stars, two cascade buildings and seven ordinary buildings.

The residential units were divided into two categories, i.e. the ones located centrally in the building and those at the end wall. The central position of the unit in a building was considered to be more advantageous in terms of energy savings, while the end wall position was considered to be less advantageous. The following number of units was observed in each year of the study, broken down into end wall and central units:
2017: 10 end wall, 74 central units,
2014: 8 end wall, 47 central units,
2011: 5 end wall, 57 central units,
2008: 11 end wall, 80 central units.

Due to right-skewed distributions, four variants based on positional measures were adopted for the heating energy consumption characteristic: first and third quartiles and the median, minimum and maximum (for subsequent intervals respectively 0, 1, 2, 3).

The last of the adopted characteristics concerned the sun exposure, but it was assumed that the comparisons would focus on the living room in which residents spend the longest time during the day. The three additional characteristics mentioned above that describe the building and premises in terms of energy intensity and that can be added to the analysis of the local market are proposed intuitively, basing on professional experience and technical knowledge (Ziembicka, 2019; Foryś, Putek-Szeląg, Ziembicka, 2019).

Results of the research

In the first step of the analysis, descriptive statistics of variables describing the transactions of residential units in the analysed years were determined. The results for the unit transaction price, unit floor area and the consumption of heat units in a given heating season are presented in the table below (table 1).

In individual years under analysis, the highest minimum unit price was recorded in 2017 (PLN 2591.84 per sqm) and the lowest in 2011 (PLN 1677.85 per sqm). The highest maximum unit price for residential units was paid in 2008 (PLN 5709.68 per sqm), while the lowest – in 2014 (PLN 4528.30 per sqm). The highest dominant was recorded in 2008 (PLN 4268.04 per sqm) and the lowest in 2014 (PLN 3427.67 per sqm). Regarding floor area, the highest dominant was 53 sqm (in 2011, 2014 and 2017), and in 25% of observations the flat size was not higher than 48.50 sqm. 75% of flats were at least 63.60 sqm (2011, 2014), and in 2008 and 2017 – at least 59.40 sqm.

Table 1. Structural parameters of the transaction prices of dwellings, floor areas and the quantities of consumed heating units in the years under study

	Average price [PLN/sqm]							
Year	Mean	Quantity	Standard deviation	Min	Max	Quartile 1	Median	Quartile 2
2008	4238.48	91	666.99	1951.22	5709.68	3958.76	4268.04	4639.18
2011	3901.66	62	578.64	1677.85	4867.92	3603.77	4020.62	4207.12
2014	3430.27	55	505.16	2230.97	4528.30	3114.48	3427.67	3670.10
2017	3859.28	84	519.29	2591.84	5257.73	3543.06	3811.19	4320.12
2008-2017	3813.99	685	602.19	1443.30	5709.68	3404.67	3820.75	4226.80
	floor area [sqm]							
2008	51.06	91	13.41	30.90	85.40	48.50	48.50	59.40
2011	53.53	62	14.23	30.90	82.00	48.50	53.00	63.60
2014	55.32	55	11.41	30.90	77.00	48.50	53.00	63.60
2017	52.70	84	13.54	30.20	85.40	48.50	53.00	59.40
2008-2017	52.68	685	13.31	30.20	85.40	48.50	49.00	59.40
	consumption of heating units in given heating period [unit/sqm]							
2008	8.00	91	8.61	0.00	39.30	1.35	5.23	11.63
2011	6.49	62	7.50	0.00	29.96	0.66	3.03	10.65
2014	4.43	55	4.47	0.00	21.54	0.86	3.10	6.66
2017	7.51	84	9.18	0.00	38.63	0.55	3.21	13.70
2008-2017	6.43	685	7.31	0.00	39.30	0.84	3.70	9.84

Source: author's own work.

Unit heat consumption varied and averaged from 4.43 unit/sqm in 2014 to 8.0 unit/sqm in 2008, with the highest dominant recorded at 5.23 unit/sqm in 2008, and the lowest at 3.03 unit/sqm in 2011. In 25% observations, the consumption of heating units was not higher than 0.55-0.86 unit/sqm, and in 75% observations it reached the value of at least 6.66-13.7 unit/sqm of floor area of a residential unit.

Table 2. Mean transaction prices of residential units [PLN thousands/m^2]

Item	Building type	2008	2011	2014	2017	2008-2017
1.	B1 (ordinary high-rise)	4 125.6	3 673.9	3 469.6	3 685.2	3 640.6
2.	B2 (star high-rise)	4 184.8	3 845.3	3 362.8	3 663.2	3 774.9
3.	B3 (cascade high-rise)	4 290.1	3 985.6	3 176.1	4 213.7	3 950.7
4.	B4 (all low)	4 339.9	4 190.3	3 597.2	3 972.7	3 927.8

Source: author's own work.

In 2008, in the housing stock under study the highest unit transaction prices were recorded for flats in low buildings and the lowest prices – in block-shaped high-rises. In 2011, prices were significantly lower than in 2008. The same situation was observed in 2014, when unit prices of flats in all types of buildings were low in comparison to 2008 and 2011. The prices rebounded only in 2017, while in cascade type high-rises the unit transaction price was comparable to 2008, while in other types of buildings (B1, B2, B4) the price was marginally lower than in 2008. On average, in the analysed period of 2008-2017, in the B3 and B4 type buildings the prices of 1 sqm of residential units were higher than in other types of buildings.

Table 3. Mean consumption of heating energy units by building types [unit/m^2]

Item	Building type	2008	2011	2014	2017	2008-2017
1.	B1 (ordinary high-rise)	8.27455	10.30033	4.87786	10.40431	8.408831
2.	B2 (star high-rise)	7.96346	2.91844	3.39900	5.93681	5.394915
3.	B3 (cascade high-rise)	6.226179	3.968422	1.239359	4.770988	4.805913
4.	B4 (all low)	9.95980	6.89071	6.79422	6.72087	7.010627

Source: author's own work.

The data summary in table 3 shows that in the analysed years the highest average consumption of heating energy units, i.e. 8.41 units per square meter, was recorded in ordinary block-shaped buildings (B1), while the lowest, i.e. 4.81 units per square meter, in the cascade type buildings (B3). The difference was significant (75%). When analysing the data, the coexisting weather conditions should be taken into account. In 2017, the lowest recorded temperature of the external environment was -7°C and was observed as temporary in four autumn-winter months of the heating season. In 2014, temperatures recorded were lower than in 2017, but they prevailed over a shorter period. Most often, in autumn and winter months the temperature oscillated around 0°C. In 2011, the situation was similar, i.e. the lowest temperature of -15°C was recorded at the end of December, but for the rest of the season it oscillated between 0°C to -5°C. The winter of 2008 was the warmest of all the years under study. The lowest temperature of -10°C was recorded in February, but from November to December the temperature usually ranged between 0°C and -5°C. In 2008 high heating energy consumption readings in all the buildings could be blamed for the use of older heat substations which were successively modernised in all the buildings in the following years. The most similar results in each year, and at the same time the highest values, were recorded in low buildings. The highest differences in results were found in B3 type buildings. In 2014 in the buildings of B1 and B3 types extreme values were recorded which significantly differed from the others. The same applies to data from 2011 collected for star-shaped high-rise buildings (B2).

The analysis of transaction prices in the years under study shows significant differences both in reference to the most frequently occurring price (empirical dominant) as well as the strong left-skewed distributions in 2008 and 2011 and symmetrical price distributions in subsequent years. In 2008 and 2011 prices were mostly in the range of PLN 4-4.5 thousand per sqm. In 2014, prices dropped to PLN 3-3.5 thousand per sqm, while in 2017 they rose to PLN 3.5-4 thousand per sqm.

The research into correlation between unit prices and price formation characteristics was carried out in two stages: for all the characteristics in total and in selected years, as well as for selected years by the type of building. The study of total correlation for all the buildings in subsequent years showed the effect of the building type on the unit price of a flat. Equally important turned out to be the variable of the floor space and of the position of the residential unit in the building. In 2017, a negative relation was found between the property environment ad the price. Over the whole period under study the public transport access in the remained in a weak negative relation with the variable (table 4).

Since the unit price and building type correlation turned out to be statistically significant (table 4), the next step was to look for the correlation between the transaction price and price shaping characteristics in particular building types. A positive correlation between the unit price and the usable floor area was found here. It was statistically significant in the case of the B1 and B2 type buildings. In the B1, B2 and B3 buildings, unit prices were positively correlated with the position of a residential unit in a building. In the B3 type buildings prices were positively correlated with the neighbourhood while negatively with the sun exposure of the living room (table 5).

Table 4. Pearson's rank correlation coefficients of transaction price and variables characterizing residential units sold in years 2008-2017

Variable	2008	2011	2014	2017	2008-2017
Building type	0.172	0.358	-0.025	0.281	0.199
Neighbourhood	0.188	-0.003	0.180	-0.220	-0.013
Access to public transport	0.064	-0.040	0.259	-0.204	-0.081
Position on storey	0.055	-0.028	-0.237	-0.030	-0.022
Floor size	0.492	0.549	0.514	0.241	0.384
Energy consumption per 1 m^2	-0.027	-0.051	0.086	-0.140	-0.029
Position in building	0.367	0.088	0.361	0.123	0.219
Living room sun exposure	-0.091	-0.234	0.099	0.016	-0.046

Source: author's own work.

Table 5. Pearson's rank correlation coefficients of transaction price and variables characterizing residential units sold in years 2008-2017 by building type

Variable	Type of building			
	B1	B2	B3	B4
Neighbourhood	0.000	0.000	0.205	0.087
Access to public transport	0.000	0.090	0.000	0.000
Position on storey	-0.048	-0.008	-0.017	0.080
Floor size	0.494	0.460	0.291	0.294
Energy consumption per 1 m^2	-0.013	-0.061	0.020	-0.002
Position in building	0.197	0.252	0.172	0.006
Living room sun exposure	-0.090	0.047	-0.334	0.010

Source: author's own work.

Conclusions

The paper attempts to determine the impact of energy performance of buildings on the estimated market value of residential units in one of the housing estates in Szczecin in a situation when the property valuer does not have the energy performance certificate of the unit under valuation as well as the units adopted for comparison. For this purpose, the authors proposed three features enabling the valuation of buildings and their residential units, which are included in the valuation as standard in terms of energy intensity, i.e.: sun exposure of the unit (its living room), consumption of heating units, position of the unit in the building. First of all, the analysis of the correlation between the price of a residential unit and the price shaping characteristics showed a significant importance of the property size, while the position of the flat in the building turned out to be positively correlated with the characteristics related to energy efficiency. Only in B3 type buildings the sun exposure of the living room was negatively correlated. The analysis of correlations showed the significance of the building types classified according to their shape and height.

The most beneficial in terms of heat exchange with the environment turned out to be the star-shaped high-rises buildings and cascading buildings. It is also important to notice that the wind exposure of the gable walls of all the studied objects (north-west wind) significantly reduces the heat loss of the whole building due to the smaller surface area of these walls. The bigger the building external walls, the greater the heat loss. Such a regularity can be observed on the example of energy consumption by units in low buildings. Moreover, attention should be paid to the different levels of thermal comfort experienced by users and vacant flats in each of the buildings – therefore, the maintained indoor temperature in residential units differs from the design temperature, which is 20°C in rooms and 24°C in bathrooms.

The results obtained are a contribution to further research on the impact of the energy performance-relate characteristics of buildings and residential units on the market price. Significant correlations should then be taken into account in the process of estimating the value of the property.

Acknowledgements

The project is financed within the framework of the program of the Minister of Science and Higher Education under the name “Regional Excellence Initiative” in the years 2019-2022. project number 001/RID/2018/19. the amount of financing PLN 10.684.000.00.

The contribution of the authors

Iwona Foryś – 33.33%

Ewa Putek-Szeląg – 33.33%

Beata Ziembicka – 33.33%

Literature

Aczel A.D. (2000), *Statystyka w zarządzaniu*, Wydawnictwo Naukowe PWN, Warszawa

Alsabry A., Pigalski W., Maciejewski T. (2010), *Teoretyczne a rzeczywiste zapotrzebowanie energetyczne na centralne ogrzewanie i wentylację mieszkań w budownictwie wielorodzinnym*, "Przegląd Budowlany" Vol. 11, Warszawa, p. 39-45

Batóg J. et al. (2019). *Investigating the Impact of Airport Noise and Land Use Restrictions on House Prices: Evidence from Selected Regional Airports in Poland*, "Sustainability" No. 11(2):412, DOI: 10.3390/su11020412

Belniak S., Głuszak M., Zięba M. (2013), *Budownictwo ekologiczne. Aspekty ekonomiczne*, Wydawnictwo Naukowe PWN, Warszawa, 122-127

Bełej M., Gulmontowicz P. (2009), *Analiza wpływu prac termomodernizacyjnych na wartość rynkową lokali mieszkalnych w zasobach wielorodzinnych*, "Acta Scientiarum Polonorum. Administratio Locorum" Vol. 8(3), p. 16

Broniewicz M. (2018), *Refurbishment, strengthening and durability of existing building structures,* "Ekonomia i Środowsko" Vol. 4(67), p. 36-48

Burchard-Dziubińska M. (2007), *Ekologiczne determinanty rozwoju gospodarczego*, in: R. Piasecki (ed.) *Ekonomia rozwoju*, Polskie Wydawnictwo Ekonomiczne, Warszawa, p. 220-221

Czarnecki L., Karpoń M. (2012), *Ocena środowiskowa budynków a zrównoważone budownictwo*, "Budownictwo i inżynieria środowiska Zeszyty Naukowe Politechniki Rzeszowskiej" Vol. 59(3), p. 304

Dyrektywa Parlamentu Europejskiego i Rady 2010/31/UE z dnia 19 maja 2010 r. w sprawie charakterystyki energetycznej budynków

European Valuation Standards- ESW (2016), The Europem Group of Valuere's TEGoVA, Printed in Belgium by Gillis nv/sa

Foryś I. (2006), *Opłacalność procesów termomodernizacyjnych na przykładzie spółdzielczych zasobów mieszkaniowych*, "Studia i Materiały Towarzystwa Naukowego Nieruchomości" Vol. 14(1), p. 55

Foryś I., Putek-Szeląg E., Ziembicka B. (2019), *An attempt to determine the impact of energy intensity on the market value of residential premises on the example of selected multi-family buildings*, "Real Estate Management and Valuation", in print

Geryło R., Mańkowski S., Piasecki M. (2012), *Efektywność energetyczna rozwiązań konstrukcyjno- materiałowych- strategiczny projekt badawczy*, "Budownictwo i inżynieria środowiska Zeszyty Naukowe Politechniki Rzeszowskiej" Vol. 59(3), p. 323-330

Jaworowicz-Rudolf A. (2010), *Prawo do środowiska należytej jakości jako urzeczywistnienie koncepcji zrównoważonego rozwoju*, in: M. Burchard-Dziubińska, A. Rzeńca (eds.), *Zrównoważony rozwój na poziomie lokalnym i regionalnym*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź, p. 46-53

Kazak J. et al. (2018), *Indicator-based analysis of socially sensitive and territorially sustainable development in relation to household energy consumption*, "Engergy Rural Development" Vol. 17, p. 1653-1661, doi:10.22616/ERDev2018.17. N045

Koczyk H. et al. (2009). *Ogrzewnictwo praktyczne. Projektowanie. montaż. certyfikacja energetyczna. Eksploatacja*, Wydawnictwo Systherm, Poznań, p. 495-498

Kryk B. (2007), *Potrzeby a wiedza ekologiczna konsumentów,* "Zeszyty Naukowe Uniwersytetu Szczecińskiego. Prace Katedry Mikroekonomii" No. 11, p. 116-117

Michalak P. (2009), *Badania efektywności energetycznej budynku użyteczności publicznej wykorzystującego odnawialne źródła energii*, doctoral thesis, Akademia Górniczo- Hutnicza Wydział Inżynierii Mechanicznej i Robotyki, Kraków

PN-EN 15643-4 (2012), *Sustainability of construction works – Assessment of buildings* – Part 4: Framework for the assessment of economic performance

Putek-Szeląg E., Ziembicka B. (2016), *Analiza wpływu przeprowadzenia termomodernizacji na cenę lokali mieszkalnych na przykładzie budynku z wielkiej płyty na szczecińskim rynku nieruchomości*, "Studia i Prace WNEiZ Uniwersytet Szczeciński" Vol. 45(1), p. 409-418

Rogall H. (2010), *Ekonomia zrównoważonego rozwoju*, Wydawnictwo Zysk i s-ka, Poznań, p. 394-404

Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz.U. 2015, item 376 as amended)

Rozporządzenie Rady Ministrów z dnia 29 czerwca 2005 r. w sprawie powszechnej taksacji nieruchomości (Dz.U. of 2005 Nr 131 item 1092)

Siemińska E. (2013), *Ryzyka inwestowania i finansowania na rynku nieruchomości w kontekście etyki i społecznej odpowiedzialności*, Wyd. Naukowe Uniwersytetu Mikołaja Kopernika, Toruń, p. 62

Solińska M., Soliński I. (2003), *Efektywność ekonomiczna proekologicznych inwestycji*, Uczelniane Wyd. Naukowo- Dydaktyczne AGH, Kraków, p. 95-109

Sujkowski Z. (2014), *Ocena efektywności energetycznej budynków na przykładzie spółdzielni mieszkaniowej*, "Rzeczoznawca Majątkowy" Vol. 4(109), p. 22-32

Ustawa 1997 z dnia 21 sierpnia 1997 r. o gospodarce nieruchomościami (Dz.U. 2018 item 121 as amended)

Ustawa z dnia 15 kwietnia 2011r. o efektywności energetycznej (Dz.U. 2016, item 831 as amended)

Ustawa z dnia 7 lipca 1994 r. prawo budowlane (Dz.U. 1994 no 89. item 414 as amended)

Ziembicka B. (2016), *The influence of the technical condition of a building on the property's market value*. "Folia Oeconomica Stetinensia" Vol. 16(1), p. 197-207

Ziembicka B. (2019), *Szacowanie wartości nieruchomości z uwzględnieniem efektywności energetycznej budynku*, PhD dissertation, University of Szczecin, Szczecin