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GROWING IMPORTANCE OF ENERGY EFFICIENCY IN BUILDING SECTOR

Keywords: construction processes, energy efficiency, neural networks, predictions

Abstract

The purpose of this article is to go deeply into the knowledge of energy consumption by the construction sector. The unproven tendency to optimize all energy processes in infrastructure construction is what is intended to be successfully demonstrated in the article. It describes concepts such as embodied energy, lifecycle-assessment and the possible results of using BIM software. A survey was developed to check the awareness of the construction market players about this topic. The results were analyzed with an artificial neural network that predicts the market trend for the future. Energy measurements of the entire life cycle of construction projects (buildings or infrastructure) and the use of recycled materials from demolition or other industries can be the future in a few years and all the policies in Europe are taking in account this idea. After talking with all survey respondents that work in the construction sector as service, machinery, materials or consulting companies, the conclusion reached in the article is that the energy consumed in the construction processes should be taken into account in a mandatory way.

Introduction

The growing urbanization contributes to extensive construction activities, accelerating global population migration to metropolitan areas, with a proportion expected to reach 60 per cent by 2030. Moreover, construction engineering stimulates almost 40 per cent of global energy consumption and 25 per cent of greenhouse gases [1]. These horrifying numbers are explaining how significant for environmental impact is the construction sector and where we should try to find an effective solution to get rid of the problem. Buildings and non-building structures are the world's largest energy consumers and will continue to be a source of rising demand for energy in the future. Globally, the final energy consumption of the sector doubled between 1971 and 2010 mainly driven by population growth and economic growth [2]. If no effective ways to reduce energy consumption are implemented in the building industry, this trend will be propagated for the future.

There are different sub-sectors in the industry. For instance, the residential sector is one of the most important consumers of energy and therefore makes a significant contribution to climate change [3]. According to the literature review, recent energy consumption and environmental analysis of buildings have been focused primarily on direct energy consumption and greenhouse gas emissions of operating processes. Indirect accounting has been rarely taken into account to investigate the environmental impacts during the entire service life of buildings.

On the other hand, transportation plays an important role in supporting social development as well as national economic development. According to published research, the most CO_2 emissions in road construction are coming from the production of raw materials [4]. Energy consumption in the whole life cycle of the projects turns out to be one of the key parameters in choosing road construction alternatives [5].

However, focusing mainly on the maintenance phase limits the opportunity to reduce other building-related energy consumption, and although the environmental impacts resulting from construction and logistics are small compared to the operating phases, its cumulative impact is significant. A building's or non-building structure’s energy consumption includes two parts of energy: embodied energy (required to extract, process and transport materials to the point of use or application) and operating energy (needed to be used during the maintenance phase).

To manage data connected with energy consumption and assess alternative solutions, a smart repository is required that can hold this data and perform relevant data extraction and calculations. According to some authors, BIM additional tools are sufficiently flexible to hold additional information (despite geometry and basic features of materials) and calculate the combination of additional and integrated knowledge [6]. As a final result, BIM implementation can help with achieving energy efficiency and lowering long-term operational costs, reduce energy consumption in buildings etc. [7]

The article is an attempt to answer the question, which is very important from the point of view of the construction project management: should energy consumption of construction processes be obligatory in choosing the best design alternatives at the very beginning of the projects?

The paper includes an explanation of the basic definitions connected with the topic of the research. Moreover, it describes and concludes the results of an investigated study on the perception of particular stakeholders of construction projects: building service providers (e.g. contractors), suppliers of building materials (e.g. manufacturers), and suppliers of construction machinery and other equipment (e.g. machinery sharing companies). The respondents were asked if they find a comparison of energy consumption in construction processes useful in planning the construction projects. The results were also used to forecast their future opinions and compare the trends. Moreover, the article is an attempt to evaluate the assumptions about the growing importance of energy efficiency in the building sector.

Theoretical background

Embodied energy

The embodied energy of an object (building, non-building structure) represents the “total amount of primary energy consumed in its manufacture and delivery to site, including extraction of the raw materials required” [8]. It is also described as the mass of CO, released to the atmosphere during manufacture and delivery phase. In the construction sector, the so-called zero-impact buildings are now more accessible than ever before. The embodied energy of buildings has recently become more popular due to the fact that low-operational-energy buildings often achieve their energy efficiency advantages during maintenance phase thanks to better insulation layers, more energy-saving windows, and modern environmental engineering (heating/cooling) systems that reduce the operating energy demand. These solutions are comparatively affordable nowadays. The energy used to extract raw resources, process materials, assembly of product components, transport between each step, construction, maintenance and repair, deconstruction and disposal are examples of embodied energy. It is therefore important to use a whole-life cycle carbon accounting framework to analyze such emissions in buildings [9].

Life Cycle Assessment

Life-cycle assessment (LCA), also known as life cycle analysis, has existed for years in various types of meaning. It was developed as a system method in the 1960s to assess resource and energy use, as well as the associated burdens generated in air, water, and land. In response to this vision, a methodology was created to list and quantify the use of resources and energy and emissions to the environment associated with the whole life cycle of a product, package, or process [10].

The most commonly used evaluation framework in LCA includes the following steps [11]:

1. Purpose of the study and scope definition,
2. Inventory - the final result is a list of all environmental interventions related to the function of the product,
3. Impact assessment – performed to summarize the information in the inventory.

Many challenges appear when it comes to applying this cradle-to-grave (entire project “life-cycle”) analysis. In the construction sector, it can be used, for example, to calculate embodied energy and associated environmental impacts of the buildings or non-building structures.

Society of Environmental Toxicology and Chemistry (SETAC) published a report entitled Life-Cycle Assessment in Building and Construction in 2003 [12]. This report adds two more issues as being particularly important for LCAs of buildings and constructions: use and application of results, and relation to other tools (Life-cycle costing – LCC, Environmental impact assessment EIA).

Apart from the evident advantages of this approach, there are some weaknesses consisting of the inability to investigate local impacts as it is generally calculated on a global scale for environmental damage. In reality, such assumptions are not always valid and when released in vulnerable areas, for example, emissions can have a greater impact.

Therefore, a better solution is to combine LCA with methods to assess local impacts, such as risk assessment [13].

However, the importance of LCA is still increasing in the construction sector. It is important to communicate analyses in a transparent manner with as much information as possible to avoid misinterpretation.

Energy efficiency and BIM solutions

The energy efficiency of buildings is one of today's most popular research areas. The retrofitting of energy efficiency in existing buildings is a major topic in this area. At the present stage, the focus of energy efficiency retrofitting research is the implementation of energy conservation technologies and retrofitting plans optimization [14]. Not only embodied energy is important from the point of view of the energy consumption optimization in construction projects. Post-construction energy consumption is a demanding issue which accounts for a large proportion of the total energy consumption of the building.

Building Information Modeling (BIM), as a leading technology, plays a vital role in facilitating project delivery success, especially during post-construction [15]. Unfortunately, the main reasons why BIM is now quite ignored as a reliable database used for such purposes are:

1. low BIM training,
2. very low owners' willingness to use BIM due to accurate calculation of construction costs.

Project owners believe the BIM will add to the cost of construction while the contrary is true - BIM reduces the cost of construction [16].

However, in literature, there is a vast discussion about sustainability dimension of the construction projects, e.g. whether CO_2 emissions saved from energy consumption do not outweigh the embodied CO_2 emissions etc. Undoubtedly, the analysis from the perspective of the entire life cycle of construction projects is inevitable. Therefore, further research on the integration of these indicators is therefore expected in the future, where BIM tools have already demonstrated their value in sustainable building assessments [17].

Methodology

In order to achieve the established research goal, and thus answer the question whether it is worth considering the energy efficiency of construction projects throughout their entire life cycle, the following research plan was carried out.

In the beginning, a questionnaire template was prepared. It was decided to conduct face-to-face interviews, which ideally fit in the study of problematic issues. The aim of the research was to examine the opinions of representatives of the construction industry on the need to analyze the energy consumption of construction processes. In addition, they were expected to learn about their preferences as to whether such considerations should be mandatory or not.

The key question was:

Do you think that considering the energy consumption of construction processes should be obligatory when choosing a design and technology variant of a given construction project?

Then the respondents were asked about the scale of activity they represent, working in a given company, as well as their experience resulting from the length of time involved in the construction market, as well as the type of activity in which they gained experience. The latter could refer to the building services supply, supply of building materials, construction machinery or equipment and other supplies. 47 people were examined in the period from January to February 2019.

Palisade software, in particular, the *NeuralTools* package, was used to develop the research results. It gives Microsoft Excel, the industry-standard data analysis and modelling tool, a new and powerful modelling toolset. Neural nets can learn complex data relationships. By imitating the brain's functions, patterns in data can be discerned and predictions extrapolated when new data are given.

In the dataset of collected records, three variables were defined as independent (business scale, experience, category of activity), and the categorical dependent variable was the opinion (“Yes”, “No”, “I don’t know”) about the above research question. The automated testing option was used on random 20% of cases. The network type was set to *PN/GRN Net*. These net types require no additional options to be selected for training which is the main advantage of the settings. A prediction for a case with an unknown dependent value is obtained by interpolation from training cases, with neighbouring cases given more weight. Optimal interpolation parameters are found during training. In addition, prediction accuracy is similar to other types of nets.

For making forecasts, 27 examples of cases represented by different scales (3) and types (3) of activity were determined in three selected years: 2030, 2050 and 2100. Such a choice was motivated by the desire to check the trend of opinion in the future.

At the same time, the assumption was made that the year when the respondent started work on the market means not the moment of starting the collection of experience (in this case the sooner does not mean the more experience), but the cultural anchor of perceiving certain problems. It is assumed that the experiences gained at the beginning of the career are propagated for life and result in contamination of opinion in the future.

Table 1 shows a fragment of the answers collected.

Table 1. Sample answer sheet

No.	Business scale	On the construction market since	Category of activity	Energy consumption of construction processes obligatory?
1	country	2006	Building services provider	Yes
2	country	2016	Building services provider	No
3	Europe	1998	Other (please specify)	Yes
…	…	…	…	…
46	world-wide	1975	Supplier of machinery and construction equipment	Yes
47	world-wide	1984	Building services provider	Yes

Source: own research

Research results

The scale of activity conditioning the type of experience collected by the respondent is shown in Figure 1.

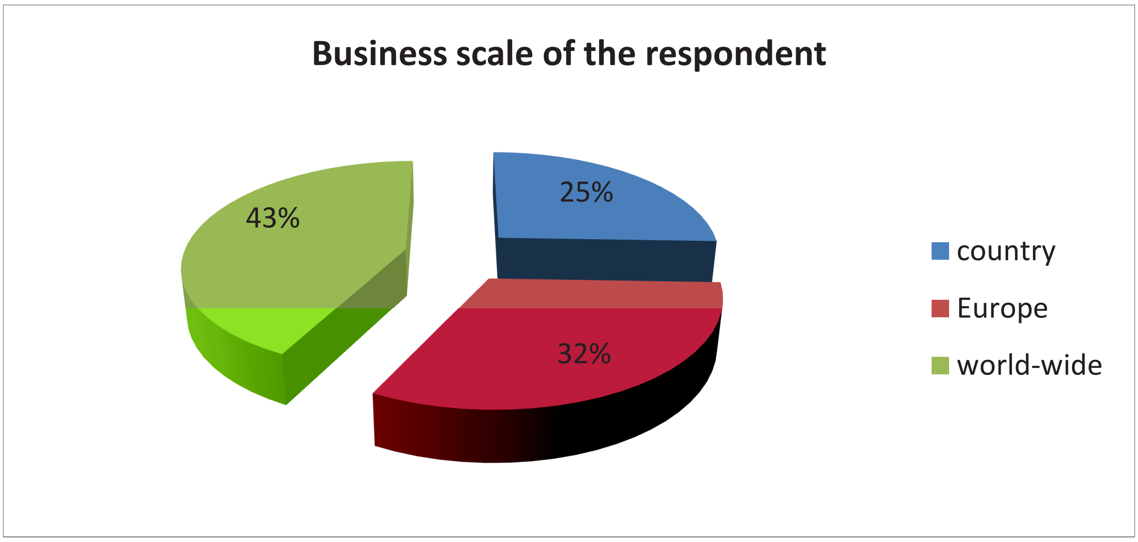


Fig. 1. Surveyed respondent's features: business scale

Source: Authors.

The survey is dominated by the opinions of respondents working in global enterprises. Next, a type of activity is shown in Figure 2.

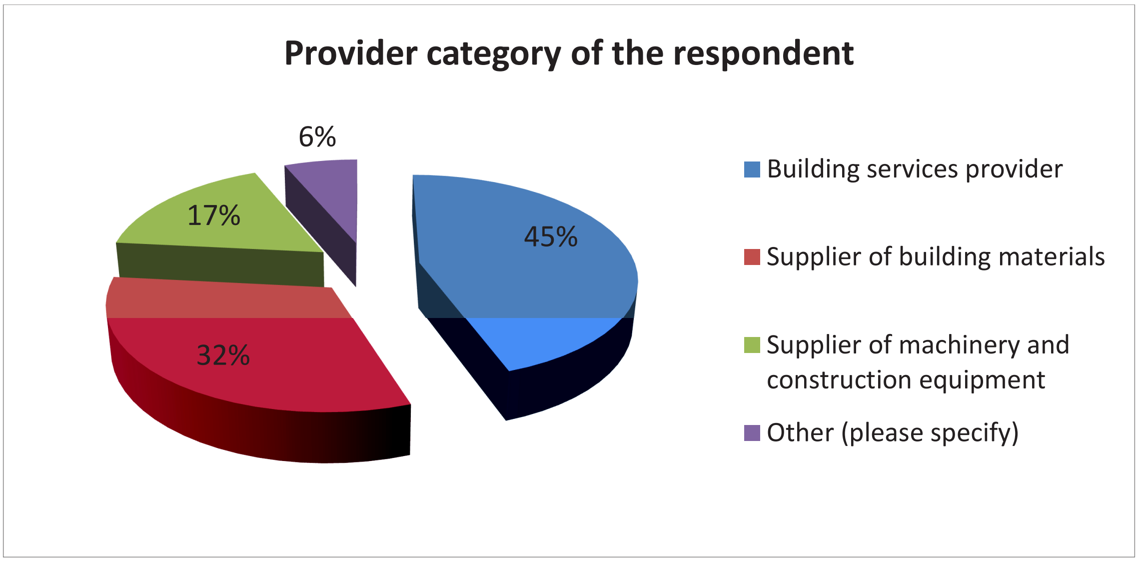


Fig. 2. Surveyed respondent's features: provider category

Source: Authors.

The analysis is dominated by opinions of respondents working for providers of building services. Figure 3 presents an opinion of the respondents about mandatory analysis of energy consumption of construction processes in choosing the best variants of the project.

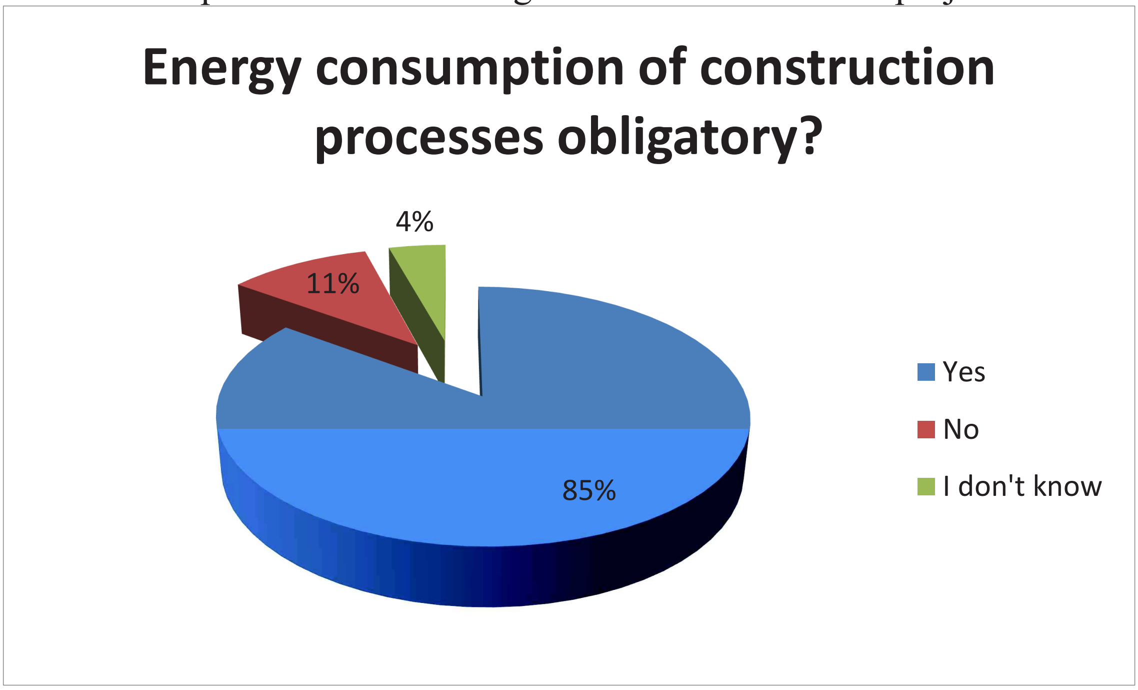
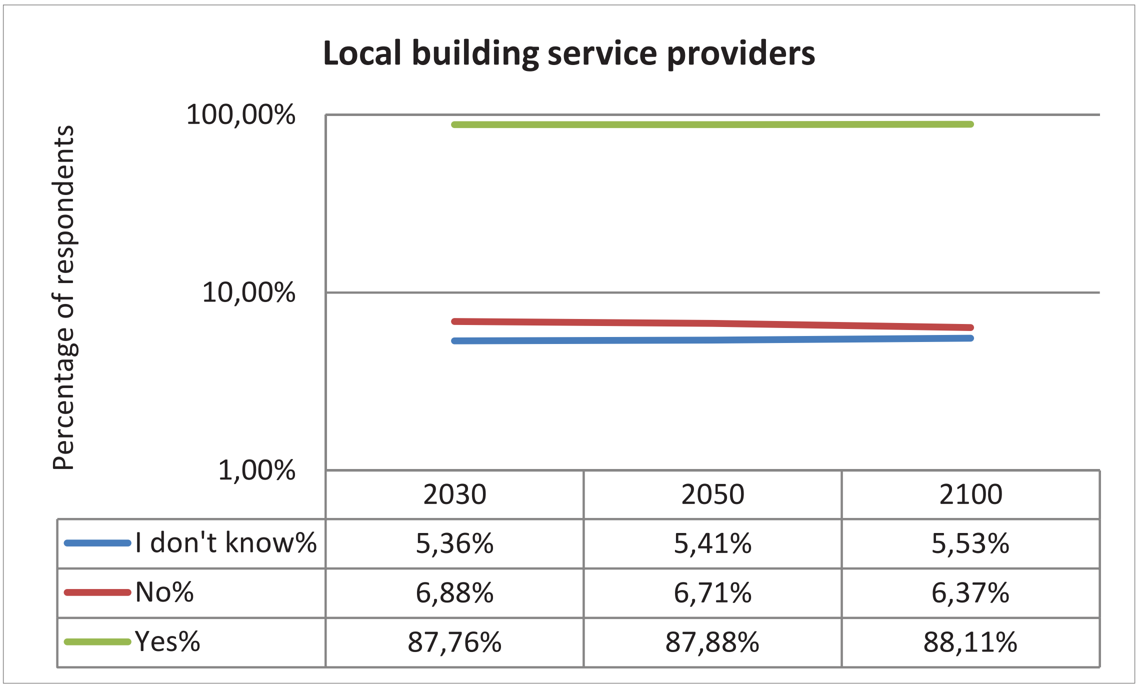


Fig. 3. Opinion on mandatory analysis of energy consumption of construction processes in choosing alternative design variants

Source: Authors.

It is obvious that the overwhelming majority of respondents point to the inevitability and necessity to analyze the energy consumption of building processes at the stage of selecting design solutions.

In the end, an analysis was carried out using artificial neural networks. Its results can be seen in Figure 4 and Figure 5.



	2030	2050	2100
I don't know%	5,36%	5,41%	5,53%
No%	6,88%	6,71%	6,37%
Yes%	87,76%	87,88%	88,11%

Fig. 4. The obligation of taking into consideration the energy consumption of construction processes in choosing between alternative variants of construction – according to respondents: building service providers operating on the ‘country’ level

Source: Authors.

Assuming that the respondent's presence in the construction market would be dated to 2030, 2050 and 2100, there is a clear upward trend regarding the positive assertion of a research question.

At the same time, there is a drop in negative opinions on this subject.

An interesting fact may be the distributions of the "I do not know" answer. The uncertainty of the respondent increases as the moment of starting the activity in the construction market increases. This is probably related to growing environmental risks.

It may also be conditioned by other factors (drop in the level of education, lower awareness), as well as those determinants previously unrecognized.

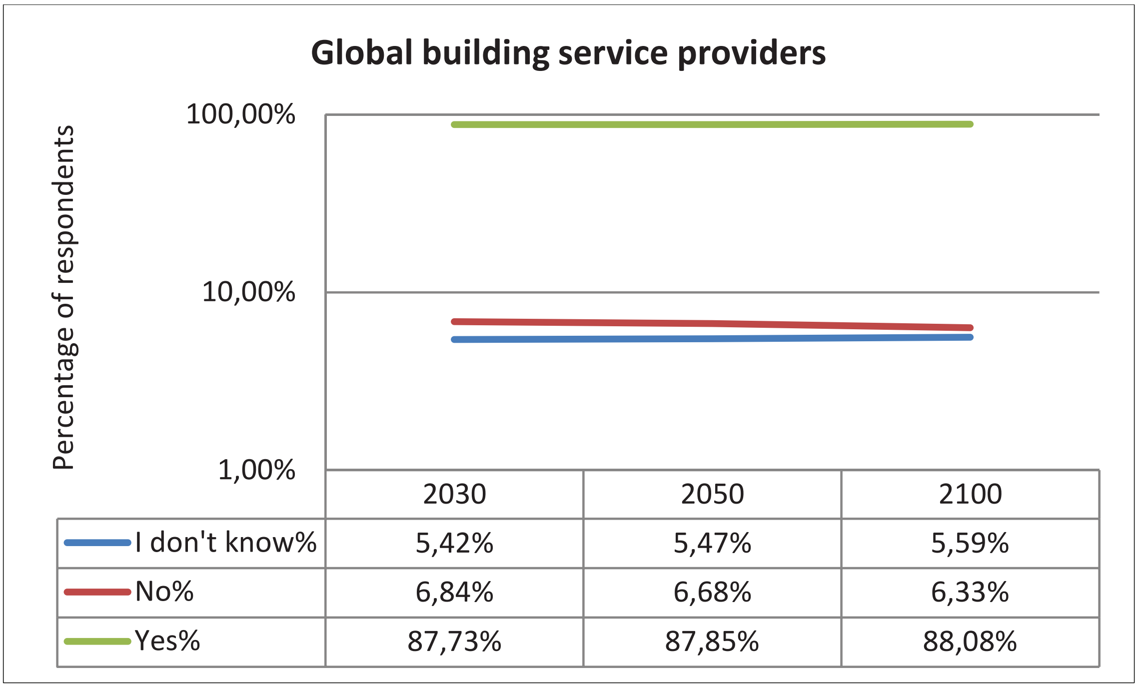


Fig. 5. The obligation of taking into consideration the energy consumption of construction processes in choosing between alternative variants of construction – according to respondents: building service providers operating on the 'world-wide' level

Source: Authors.

Comparing Figures 4 and 5, there is no significant change in the trend or distribution of responses depending on whether the respondent works in an enterprise operating on a local or global market. This may prove the universality of ecological problems. Also, the awareness of issues related to the energy consumption of construction processes probably does not depend on the scale of operations. This may be related to the widespread discussion about the need for energy efficiency in construction.

To be sure about the above-indicated assumptions, an analysis of relative impacts on the dependent variable was done. The results are shown in Figure 6.

According to the results of the analysis, the greatest impact (92,06%) on the perception of the obligatory analysis of energy consumption in the selection of the variants in a construction project has the moment of the respondent's initiation in the construction market.

Other issues are much less important, namely: the type of activity (5,40%) and its scale (2,54%).

At the same time, it is worth emphasizing that to maintain the trend, attention should be paid to the need to continue environmental education, to maintain discussions about the validity of LCA analysis, and to promote energy-saving behaviours regardless of the industry.

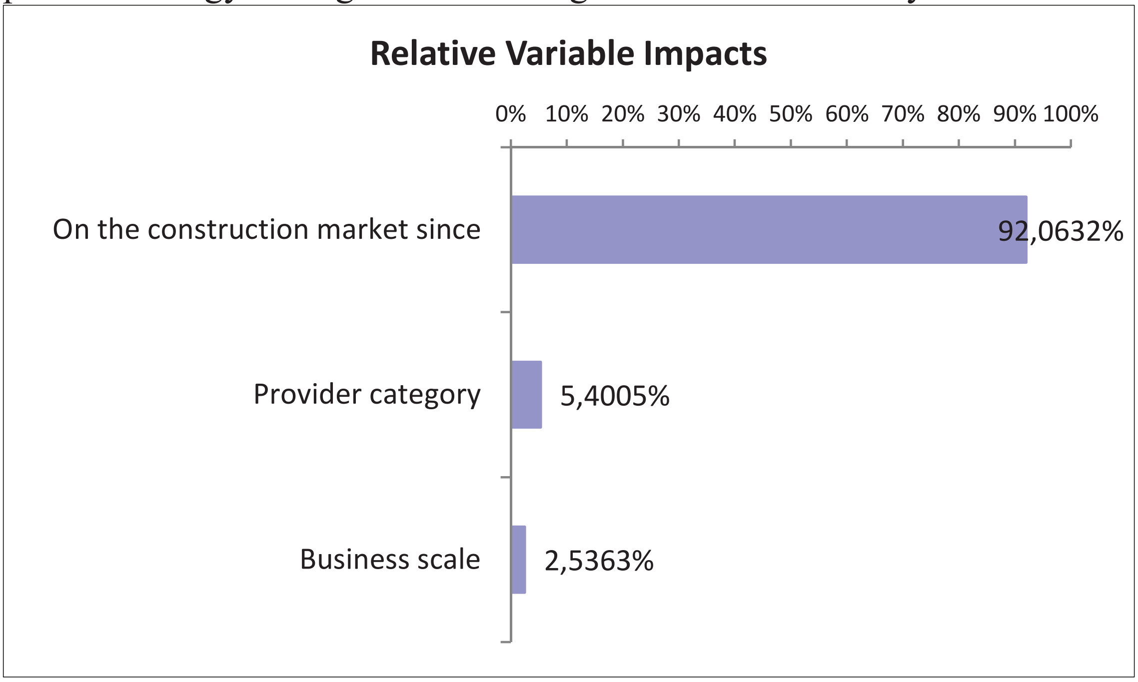


Fig. 6. Analysis of relative impacts on the dependent variable

Source: Authors.

Summary

The article refers to the issue of energy consumption in construction processes. Basic definitions related to the research problem were included in the text. The problem has been addressed in an innovative way. The need to examine representatives of the construction industry with diverse experience was noticed.

As a result of the conducted research, the outcomes of which are presented in the article, one should state the validity of the preliminary assumptions. Most of the respondents positively address the need for obligatory testing of energy consumption in construction processes. This can affect the selection of alternative design solutions.

In addition, it was noticed that the moment of initiation in the construction market may determine whether someone is more or less willing to pay attention to energy efficiency and energy consumption problems. One should get the impression that not the experience, but the course and conditions of career resulting from cultural changes have the greatest impact on the perception of problems that have become the reason for writing this article.

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