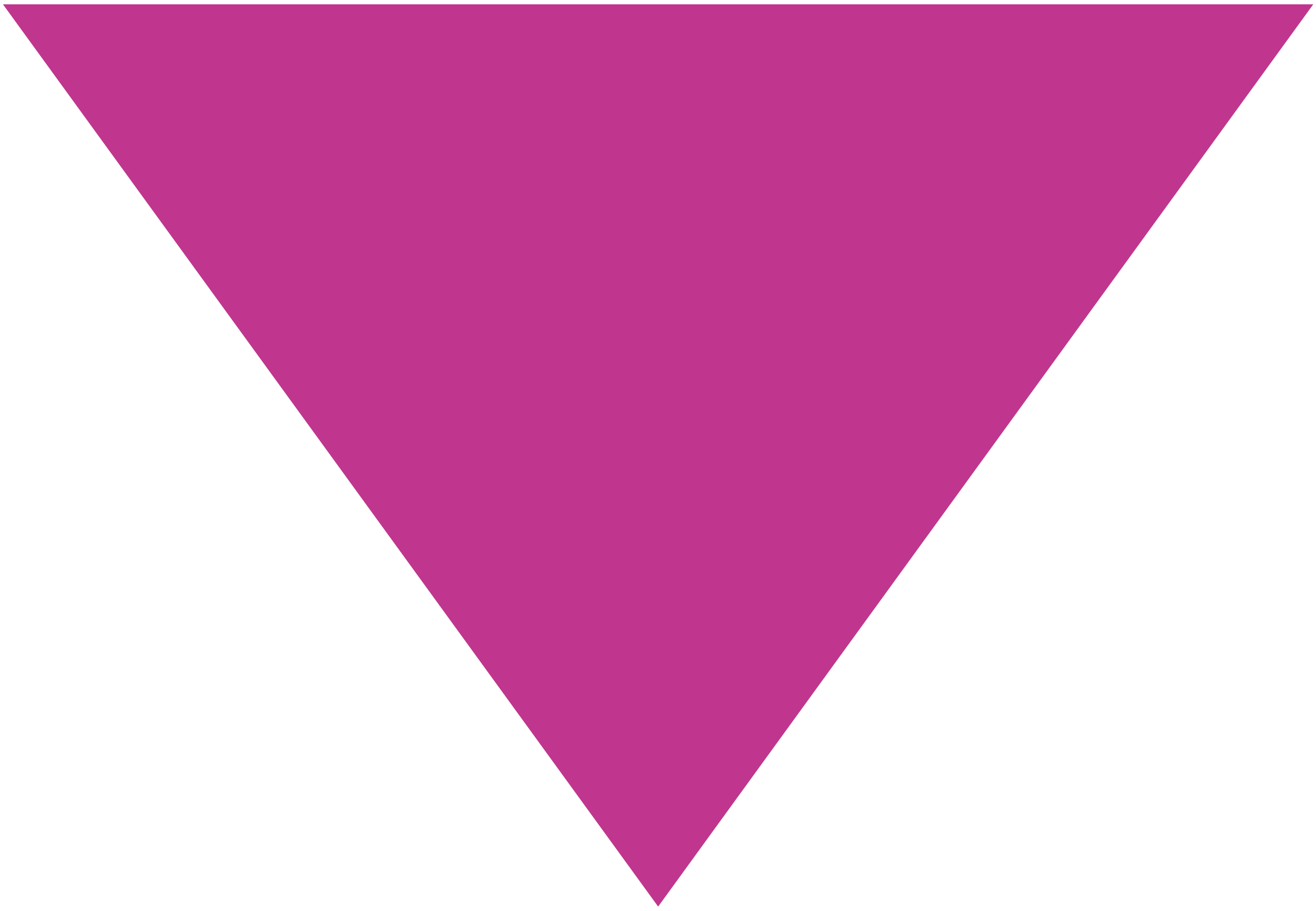
ARCHITECTURE IN PERSPECTIVE

VYSOKÁ ŠKOLA BÁŇSKÁ - TECHNICKÁ UNIVERZITA OSTRAVA FAKULTA STAVEBNÍ KATEDRA ARCHITEKTURY



13

edited by: MARTINA PEŘINKOVÁ, SANDRA JÜTTNEROVÁ, LUCIE VIDECKÁ 2021

13^{th} / 13.

Architecture in Perspective 2021
/ Architektura v perspektivě 2021

VŠB - Technical University of Ostrava
Faculty of Civil Engineering, Department of Architecture

Vysoká škola báňská Technická univerzita Ostrava
Fakulta stavební, katedra architektury

Proceedings of the International Conference / Sborník příspěvků z mezinárodní konference

Editors / Editoři:
prof. Ing. Martina Peřinková, Ph.D.
Ing. arch. Sandra Jüttnerová
Ing. arch. Lucie Videcká

Graphic / Grafická úprava:
Ing. arch. Sandra Jüttnerová, Ing. arch. Lucie Videcká

Print / Tisk:
VŠB - TU Ostrava

Publisher / Vydavatel:
VŠB - TU Ostrava, Faculty of Civil Engineering, Department of Architecture /
VŠB - TU Ostrava, Fakulta stavební, Katedra architektury

ISBN 978-80-248-4552-4

THE IMPACT OF THE ORIENTATION OF INDIVIDUAL FAMILY HOUSES ON THE ENVIRONMENT

Roman Ruhig - Ema Ruhigová

ROMAN RUHIG, ING. ARCH. ET. ING., PHD.

Department of Architecture
Faculty of Civil Engineering
Slovak University of Technology in Bratislava
Radlinského 11, blok C, 19. floor, 810 05 Bratislava, Slovakia

ruhigroman@gmail.com

The author graduated from the Faculty of Architecture and the Faculty of Civil Engineering of the Slovak University of Technology in Bratislava, Department of Architecture. He currently works as an assistant professor at the Department of Architecture at the Faculty of Civil Engineering. In the research he focuses on sustainable concepts for renovated buildings and urban planning. It pays special attention to interspaces and their influence on the energy efficiency of buildings. He and his wife Ema Ruhigová founded the architectural office ER Atelier, Ltd. in 2018.

EMA RUHIGOVÁ, ING. ARCH. ET. ING., PHD.

Department of Architecture
Faculty of Civil Engineering
Slovak University of Technology in Bratislava
Radlinského 11, blok C, 19. floor, 810 05 Bratislava, Slovakia

ruhigova.ema@gmail.com

She graduated from the Department of Civil Engineering and Architecture at the Faculty of Civil Engineering of the Slovak University of Technology in Bratislava and is currently an assistant professor at the Department of Architecture. At the same time, she studied at the Faculty of Architecture, Department of Architecture, and in addition to the school, she interned in the urban studio AŽ Project. Today he is an authorized architect of the ER Atelier studio. Her research focuses on cultural sustainability, non-invasive interventions in listed buildings and urban concepts with a positive impact on the environment.

ABSTRACT: From 1 January 2021, all new buildings in Slovakia must be built with almost zero energy demand, classified in energy class A0. This results in an increase in the thickness of the thermal insulation layers and the integration of technologies into buildings - such as heat recovery units, heat pumps, etc. However, a favorable calculation of the building's energy performance (EHB) depends not only on the quantitative calculations of the heat exchange envelope of the building and the technology used, but also on the orientation of the building to the world and the chosen shape of the building. Some developers currently offer for sale the same type of real estate, which is without changing the facade and layout built on land with different orientation to the world. Buildings built in this way do not always meet the necessary requirements for project evaluation and, due to less illumination of rooms, also reduce the internal comfort of the house. For the mentioned reasons, this article deals with the research of the impact of the new EHB requirements (valid from 1. 1. 2021) on the possible regulation of individual housing construction in spatial planning with emphasis on the influence of the orientation of family houses and their production of CO2 emissions. Environmental research compares ten identical single-storey and double-storey detached houses oriented to all sides of the world in four basic types of streets.

KEYWORDS: orientation to the world; family house; energy efficiency; project evaluation; passive solar gains; CO2 emissions; environment; urbanism

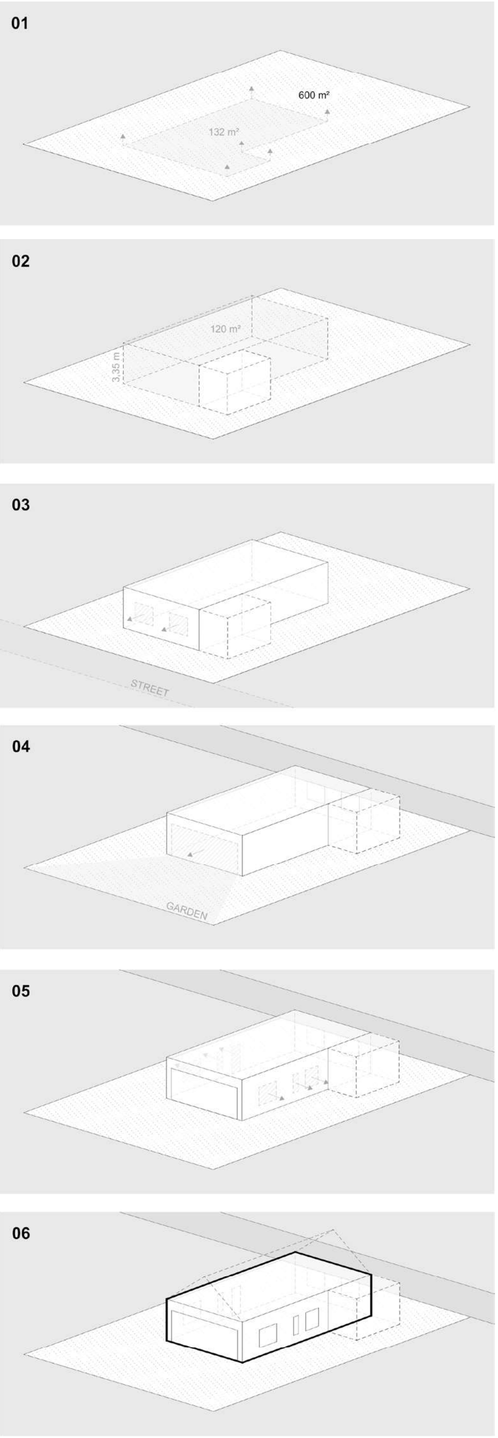
INTRODUCTION

At present, in the outskirts of Bratislava (as well as in other Slovak cities), large-scale construction of family houses is being designed and subsequently implemented, which has a significant impact on the environment not only through its construction, but also through the operation of buildings. From 1 January 2021, all new buildings in Slovakia must be built with almost zero energy demand, classified in energy class A0 [1]. This is associated with reducing emissions during the operation of the building, which results in increasing the thickness of thermal insulation layers and the integration of technologies into buildings (such as recuperation units, heat pumps and the like). However, the energy efficiency of a building may not only depend on the quantitative calculations of the heat exchange envelope of the building and the technology used, but also on the orientation of the building to the sides of the world and the selected volume, which also affects the building shape factor. Few articles considered the effect of orientation, size and glazing properties [2,3,4]. However, the research on the influence of window size, position and orientation on energy load is still missing. As the building designs are getting more dynamic and complicated, more detailed and thorough analysis on various window design factors should be conducted [5]. Building costs are a result of a range of factors, and further research is required to investigate broader cost implications of volume built designs with improved passive design performance. A frequent argument against increasing energy efficiency standards is that they lead to a requirement for more bespoke designs at increasing costs to builders, thus impacting upon affordability for consumers. On the contrary, this study indicates that house size is a critical factor in performance, and furthermore, that better performing designs require less adjustment across different orientations. This indicates that building standards regulation could be used to further drive energy efficiency standards without undermining affordability. It also indicates an opportunity for builders to provide more compact designs with passive solar features which are adaptable and therefore can be provided at relatively lower cost than bespoke alternatives [6]. Some developers currently provide for sale the same type of real estate, which is built on land with different orientation to the sides of the world without changes to the facade and layout. Buildings built in this way do not always meet the necessary requirements for project evaluation and, due to less illumination of rooms, also reduce the internal comfort of the house. The literature on passive solar design emphasises the importance of orienting glazing for optimal solar gain, while balancing glazing area, so that heat loss does not become too much of a factor on internal thermal performance [7]. A new generation of sustainable housing architecture is going to fuse the rules of sustainable development with aesthetic and technological principles. The orientation, form and size of objects, technological systems (including solar power solutions) as well as the specification of ecological effectiveness are now of equal status with other elements of the creative process [8]. For the mentioned reasons, this article deals with the research of the impact of the new EHB requirements (valid from 1. 1. 2021) on the possible regulation of individual housing construction in spatial planning with emphasis on the influence of family house orientation and their production of CO2 emissions.

SELECTION OF A FAMILY HOUSE REPRESENTATIVE

Due to the objective evaluation, it was necessary to find a representative (family house) who would represent the largest possible range of family houses. In picture no. 1 shows the development of a family house, which is based on individual analogies so as to meet all the criteria in the current construction.
In the first step, the size of the plot and its possible built-up area were chosen. These data were taken from the binding part of the zoning plan of the capital of the Slovak Republic, Bratislava, where there are detached houses from 600 - 1,000 m^2 (function code: 102) is considered on average with a built-up area index of 0.22 [9]. Due to the current parcelling and the need for investment to sell the most optimal land, a land with a minimum area of 600 m^2 was chosen. The built-up area then represented an area of 132 m^2.

In the second step, the heated volume was determined at a construction height of 3.35 m. Construction height consists of a clear height of 2.6 m [10] taken from the standard STN 734301 (which deals with residential buildings), the thickness of the fragment above the waterproofing (100 mm thermal insulation + 80 mm



Pic. 1.: Development of the mass of a representative family house (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

base concrete with underfloor heating + 20 mm floor) and thickness fragmentary ceiling structure (200 mm load-bearing structure + 350 thermal insulation). In this step, the volume that will not be heated was separated at the same time. This represents the volume of garages, conservatories or gazebos, which we do not have to consider within the heated volume. For this reason, only the built-up part of 120 m^2 is considered, above which only the heated volume is located.

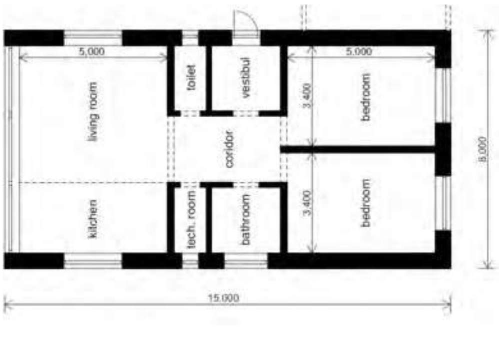
In the third step, windows to the street were installed, the dimensions of which were designed according to the standard STN 73 0580-2 (dealing with daylighting of residential buildings) [11]. The window constructions were designed for minimal dimensions of vertical windows in living rooms with one-sided side lighting. The size of the windows was affected by the clear height of the room (2.6 m), the width of the room (3.4 m) (Fig. 2) and the shading angle (0 °). The height of the window was set at 1.5 m, from which the width of the window developed according to the standard in question. The width of the windows facing the street was set at 1.87 m due to interpolations.

In the fourth step, the most exposed glazing leading to the garden was created. It was based on the hypothesis that house users prefer the optical connection of the daily zone and the garden. For this reason, this facade was opened as much as possible.

In the fifth step, windows are added to other rooms, the daily zone, the hygienic and technical background of the house. Their area depended on the selected maximum area of transparent structures on the house. The area of the glazing varies is in the range between 30 - 50% of the area of the perimeter wall [12]. In one of the forums where this information was presented, the topic is developed by Ing. arch. Irena Dorotjaková. According to architect, this size must depend even on its shading. Due to the need for profit from accommodation, investors buy smaller window constructions. For this reason, the glazing, which had only a 30 percent share on the front of the building, is also being considered. Due to the area of the perimeter walls (139 m^2 - area of the facade above the terrain) and the already defined window sizes from the previous steps (29.42 m^2), up to 30% remained 16.78 m^2. It was this area that was distributed to the remaining windows.

In the last sixth step, the exact heated volume was defined, which was used in the project evaluation calculations. From the point of view of material design, the object can be solved with a pitched roof, a flat roof, a countertop roof, etc. . In the research, a flat roof was considered, thanks to which the object has the most unfavorable shape factor of all variations (0.98), which should have an impact on the objectively better evaluation.

However, the resulting building should also have a rational layout with a separate night and day zone and technical background. The rooms were designed with minimal dimensions, so that the building is profitable and the usable area of the house was used as much as possible for the living area (Fig. 2).



Pic. 2.: Floor plan of a representative family house (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

INPUT DATA FOR CALCULATION OF BUILDING ENERGY PERFORMANCE

After selecting a representative family house and setting its parameters, it was possible to obtain enough data for calculations, based on which it was possible to compare the energy efficiency of the same family house with different orientation to the world. Boundary conditions were taken from the thermal technical standard STN 73 0540-3 [13]. The case study was solved in the city of Bratislava, which according to the standard is located in temperature area 1 with an altitude of 140 and wind area 2. External calculation temperature was considered for the city of Bratislava with a value of -11° C (calculation area -10° C) with a design relative humidity of the outside air 83.2%.

The proposed indoor temperature used in apartment buildings (dwellings) was 20° C with a design relative humidity of 50%. The latest data to be determined for the calculation of primary energy demand and CO2 emissions:

- the heat-exchange envelope of the building was designed for precise target recommended values according to the standard STN 73 0540-2 with thermal insulation,
- an air exchange of 0,5 l / h was considered in the rooms (hygiene criterion),
- window shading was considered with a coefficient of 0,5,
- recuperation with an efficiency of 80% has been proposed in the family house,
- domestic hot water is considered to be the same in all calculations as is the energy for its heating,
- the heating source was selected according to the most frequently installed heating system in Slovakia, which is natural gas [14].

The result of the calculations was the need for the building's primary energy and CO2 emissions in kg, which will be produced during the operation of the family house per year. The calculations of the project evaluation worked with standardized input data taken from the standard STN 73 0540-2 [15] dealing with the thermal protection of the building and its functional requirements. These should generalize the results and could be applied directly. The input parameters of the calculation are the same in all variants, except for the orientation to the sides of the world and the size of the heated volume, which affected the shape factor, which varied depending on whether the building is single-storey or double-storey. The calculation of the project's energy performance assessment of the building was carried out using the ISOVER Project Evaluation 1.0 (PEHA) program [16].

The family house was assessed with an orientation to all sides of the world and was considered as one-storey (pic. 3) and as two-storey (pic. 4), while the ratio of glazing to the non-transparent part of the facade remained the same. In this stage, 8 single-storey and 8 double-storey buildings were compared. As expected, the largest difference in energy efficiency was between the southern and northern buildings, which depended on the largest differences in solar gains. For comparison, the specific primary energy demand was on the southern orientation of the exposed glazing 45.337 [kWh / (m^2.a)] for the single-storey building and 49.247 [kWh / (m^2.a)] for the northern orientation, which makes a difference of 9.2%. The specific primary energy demand of a two-storey building (in the southern orientation) was 26.249 [kWh / (m^2.a)] and in the northern orientation 29.099 [kWh / (m^2.a)], which makes a difference of 9.0%. According to the scale of energy classes of the global indicator, all variant solutions reached the required class A0.

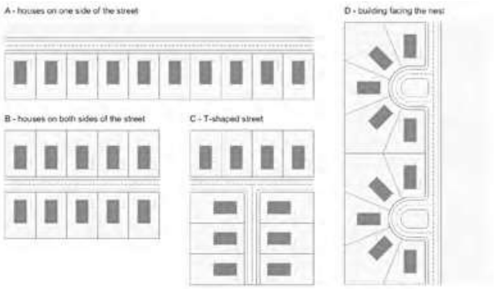
Pic. 3.: Detached house - one-storey building (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

Pic. 4.: Detached house - two-storey building (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

IMPACT OF FAMILY HOUSES ORIENTATIONS ON THE ENVIRONMENT

From their research, it is clear that the orientation of the house has a significant impact on the energy efficiency of buildings even with a smaller heated volume and that a certain building with different window sizes on facades facing other parts of the world parties may have different energy efficiency. In our research, we declared this influence on the calculations of a selected representative, who should represent a large number of buildings currently implemented (so-called Catalog Houses), where one type of family house is located on land with different orientation to the world. From the above, two research questions have been formulated: how big is the difference of the same houses to the building's energy performance with different orientation and how can more of the same houses in a street fragment have an impact on the environment?

For an objective comparison, four types of used street sections with ten houses were selected. The subject parts of the streets (pic. 5) were assessed on all 8 world parties with the same layout of family houses. In variant A, the houses were located only on one side along the road - in opposite to these houses, there was not family houses. This variant counted on the orientation of houses to only one side of the world. In variant B, the houses were evenly distributed opposite each other and thus half of the houses were oriented to one side of the world and the other half across the road to the opposite side of the world. Variant C considered a T-junction, where the houses were oriented on three sides of the world. In variant D, the development leading to the nest was considered, thanks to which the houses were oriented in this variant up to 5 sides of the world.



Pic. 5.: Variants of the assessed streets (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

A total of 32 situations were comparable, but some orientations from the same solar gains had the same results. After separating situations with the same final results remain 22 final situations with different results - 11 situations with single-storey construction (Table 1) and 11 situations with double-storey construction (Table 2).

The tables show the results with the total emissions produced by 10 family houses per year. The smallest difference was in the street in variant B with single-storey construction, where the difference between the north-south and east-west buildings was only 1%.

ONE - storey house

A - houses on one side of the street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north	**11818,8**
south	**10880,4**
west / east	**11462,4**

B - houses on both sides of the street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north south	**11349,6**
east west	**11462,4**

C - T-shaped street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north east west	**11604,96**
south east west	**11229,6**
west / east north south	**11394,72**

D - building facing the nest

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north northeast northwest west east	**11674,32**
south southeast southwest west east	**11257,68**
west / east north south SE / SW NE / NW	**11443,44**

Tab. 1.: Emission production results for single - storey buildings in variant situations (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

TWO - storey house

A - houses on one side of the street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north	**13968**
south	**12600**
west / east	**13480,8**

B - houses on both sides of the street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north south	**13284**
east west	**13480,8**

C - T-shaped street

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north east west	**13675,68**
south east west	**13128,48**
west / east north south	**13362,72**

D - building facing the nest

Orientation (garden direction)	Emissions CO2 in kg/(a) - overall
north northeast northwest west east	**13775,04**
south southeast southwest west east	**13158,72**
west / east north south SE / SW NE / NW	**13427,52**

Tab. 2.: Emission production results for two - storey buildings in variant situations (Source: R. Ruhig, E. Ruhigová: submitted to conference Architecture in Perspective 2021)

The biggest difference was observed in the location of the family construction only on one side - variant A. Specifically, between the location of the development to the north and to the south. This difference is almost 1.4 tons of CO2 waste per year per 10 homes. When designing a similar zone with, for example, 100 houses, such construction would create a difference of about 14 tons of CO2 waste per year, which could already affect the environment to a certain (albeit limited) extent. Of course, other aspects must also be taken into account when designing the zone, such as the rational position of buildings on both sides of the road and the like, but in some cases the location of family houses is only natural on one side of the road. For example family houses built in the urban area and on the opposite side of street is agricultural land (the side of extravillain). Variants C and D had the largest difference in CO2 emissions per year, depending on the world side, at around 3.2%.

CONCLUSIONS

The research points to the impact of the orientation of family construction on the environment. From the presented research it is clear that the orientation of the exposed glazing has a significant impact on the overall energy efficiency of the family house and also on the CO2 emissions produced during the year. Research has confirmed that energy efficiency also depends on the size of the object and its shape factor.

Research on this topic could continue and determine other representatives with a larger heated volume, or a different shape. However, it will be important to correctly determine the next representative as shown in this paper, i. based on analogies influenced by legislation, standards and common practice. The same or similar methodology could be used for other variants of family houses. From the presented results it is clear that the difference in the production of emissions, which is given by the buildings in one of the street built-up area, is not so significant in different orientations. However, with the current demand for new construction, these results may multiply, which could lead to a radical impact on the environment. Research should continue in other variations, where other types of buildings would be simulated - such as terraced houses, houses with common walls (semi-detached houses), atrium houses and the like. At the same time, alternatives with differential land sizes, different volumes and other street developments would be tested, which would further generalize the results and could result in a new basis for spatial planning. It can also be helpful in the process of designing urban studies.

SOURCES

[1] Decree no. 364/2012 Coll. Decree of the Ministry of Transport, Construction and Regional Development of the Slovak Republic, which implements Act no. 555/2005 Coll. on the energy performance of buildings and on the amendment of certain laws as amended

[2] K. Hassouneh, A. Alshboul, A. Al-Salaymeh, Influence of windows on the energy balance of apartment buildings in Amman, Energy Conversion And Management. 51, 2010, pp.1583–1591.

[3] L. Vanhoutteghem, G.C.J. Skarning, C.A. Hviid, S. Svendsen, Impact of façade window design on energy, daylighting and thermal comfort in nearly zero-energy houses, Energy And Buildings 102, 2015, pp. 149–156.

[4] S. Jaber, S. Ajib, Thermal and economic windows design for different climate zones, Energy And Buildings 43, 2011, pp. 3208–3215.

[5] Soojung Kima, Puyan A. Zadehb, Sheryl Staub-Frenchc, Thomas Froesed, Belgin Terim Cavkae, Assessment of the Impact of Window Size, Position and Orientation on Building Energy Load Using BIM, International Conference on Sustainable Design, Engineering and Construction, 2016, pp.1424-1431

[6] J. Morrissey, T. Moore, R.E. Horne. Affordable passive solar design in a temperate climate: An experiment in residential building orientation, Renewable energy, Melbourne, 2010

[7] Spanos I, Simons M, Holmes KL. Cost savings by

application of passive solar heating, Structural Survey 2005, Vol. 23 No. 2. pp. 111-130

[8] B. Majerska-Palubicka, Ecological aspects in current housing, Architecture in perspective, Ostrava, 2017

[9] Slovak technical standard, STN 734301, Dweling buildings, 2021 Spatial plan of the capital of the Slovak Republic, Bratislava, Part C.: Binding part of the territorial plan of the capital city of the Slovak Republic, Amendments 02, 2012, pp. 17

[10] Slovak technical standard, STN 730580-2, Daylighting of residential buildings, 2000

[11] Information on https://www.sme.sk/c/29159/okna-a-dvere-domu-otvorene-dokoran.html

[12] Slovak technical standard, STN 73 0540-3, Thermal protection of buildings.Thermal performance of buildings and components, Part 3: Properties of environments and building products, 2012

[13] Information on https://vykurovanie24.sk/druhy-vykurovania/vykurovanie-plynom/

[14] Slovak technical standard, STN 73 0540-2+Z1+Z2, Thermal protection of buildings. Thermal performance of buildings and components, Part 2: Functional requirements, 2019

[15] Computer program. ISOVER Project Evaluation 1.0 [online]. https://fragment.isover.sk/apps/v5_202104141331/html/projektove hodnotenie.xhtml, (accessed at 05/05/2021)

[16] F.H. Abanda, L. Byers, An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling), Energy, 2016