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Use of an interactive nZEB model in architectural education

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ABSTRACT: In the Faculty of Architecture at Slovak University of Technology in Bratislava (FA-STU), the author teaches students in both Bachelor and Master degree studies to design environment-friendly buildings to *passive house* or near zero-energy building (nZEB) standards. Realistic evaluation tools are used in the design studios and theoretical concepts are covered in the lectures. To connect these approaches, an interactive small house model (a cube 6 x 6 x 6 metres) has been developed, where different characteristics can be changed - location, orientation, urban situation, window distribution and size, shading elements and surroundings, thermal insulation of walls, roof and floor, window characteristics, ventilation type, heating and hot water (HW) preparation, and use of solar panels. This model has been used in lectures and seminars to show students the consequences of their abstract design decisions, and to help them understand the architectural principles of energy efficient buildings.

INTRODUCTION

The architect's role is creative; they form spaces for our life and design architectural forms, but to do that they have to understand other *professions*, such as building construction, stress analysis, the physics of buildings and heating ventilation and air conditioning (HVAC) design. The architect does not replace the specialist, but must communicate with them in the integrated design process, and they must lay down the basic outlines of the architectural design. This influences the performance of the building, including the *environmental performance* and energy efficiency. This relationship to specialists is reflected in architectural education, but in dealing with specific problems, usually there are no specialists at hand to simulate the real-life design process and the time for these *marginal* topics is limited, as is the expertise and experience of the students. On the other hand, for teaching students to understand these specific issues, exact results are not needed; understanding the design process is more important.

ENVIRONMENT-FRIENDLY DESIGN

In the Faculty of Architecture at Slovak University of Technology (FA-STU) students are taught in both Bachelor and Master degree studies to design sustainable buildings, to create architecture that is friendly to the environment and healthy. The Institute of Ecological and Experimental Architecture at STU has focused on these topics since the early 1990s. Factual feedback started with the use of the green building evaluation method based on the research done in co-operation with the University of Technology in Vienna [1].

Today, the author uses the common European tool for sustainable building assessment (CESBA) prepared in an international research project and modified for educational use by the University [2][3]. In the subject Architecture and Environment, the author asks students to evaluate one of their older designs and to suggest modifications to improve its *green-building* quality. This tool is used in selected studio designs, which helps students to comprehend which parameters of their design influence its *environmental performance* during its life-cycle. One of these parameters is the energy efficiency of the building. Its improvement is required by the European and Slovak legislation; only near zero-energy buildings (nZEB) should be built after 2020 [4].

UNDERSTANDING ENERGY EFFICIENCY

The author responded to the demand for nZEB, trying to help students to understand how their *architectural* decisions influence energy efficiency. They are taught the use of realistic (although simplified) calculation tools [5], as well as the basics of building physics and the theory of energy-efficient design [6]. Those two approaches are not really interconnected and that results in the lack of intuitive understanding of the consequences of the architectural decisions. That is why a simplified interactive building model was developed in the form of a small house (cube 6 x 6 x 6 metres), where different characteristics can be changed, e.g. location, orientation, urban situation, window distribution and size, shading elements and surroundings, thermal insulation of walls, roof and floor, window characteristics, ventilation type, heating, hot water preparation and the use of solar panels. This model is used in lectures and seminars to show students the consequences of their abstract design decisions and to help them understand the architectural principles of energy-efficient buildings.

Tools used for the Evaluation of Energy Efficiency

In the students' studio designs realistic tools are used to evaluate the results of their work from the point of view of energy efficiency and sustainability, while simulating an integrated design process. Programs such as PHVP (Passivhaus Vorprojektierungspaket), multi-comfort house designer (MCHD), the simplified CESBA tool, Ecotect and others are used according to the specific design situation. See Figure 2 for a CESBA title sheet example. These methods help to promote energy-efficient and environment-friendly principles in the young generation of architects.

In the late 1990s, a simple graphical energy-efficiency evaluation tool LT4 was used [7] that had been developed at University College Dublin [8]. This tool uses energy performance curves from a mathematical model, where only a few key design variables are left for the user to manipulate. This helps students to evaluate easily the influence of their decisions, using just a calculator and pencil. The LT4 does not produce an accurate estimate of the performance of an actual building, but enables comparisons and gives a picture of the relative importance of various architectural decisions. Today, LT4 is obsolete and cannot be used for an nZEB evaluation without major modifications, but it was one of the inspirations for the interactive nZEB model. See Figure 1 for an LT4 completed sheet example.

In design studios, the students use the free PHVP tool [5]. Solar access is evaluated using the *solar envelope* method [9] or physical models (in a heliodon or with a sundial) or virtual CAD software models. Typically, the multitask model approach is used [10]. In the design studios of the study module *Architecture and Ecology*, the students participate in architectural competitions, i.e. the Multi-Comfort House Contest or Active House Award, where specific energy-efficiency evaluation tools MCHD [11] (see Figure 4) and active house radar [12] (see Figure 5) are used. Sometimes, the author uses passive house planning package (PHPP) [13] (see Figure 5) and its graphical interface, designPH [14] for SketchUp modelling software.

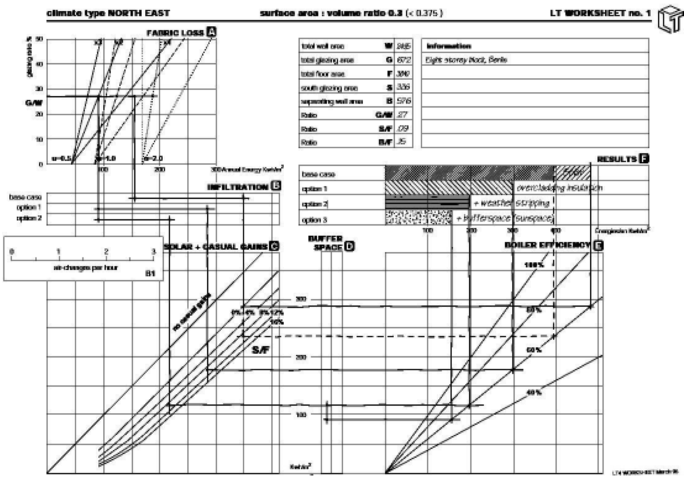


Figure 1: Completed LT4 sheet example [8].

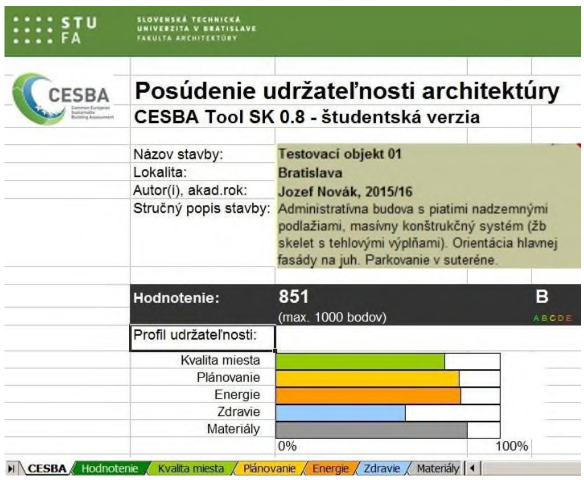
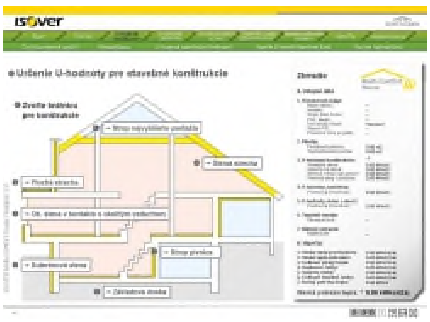
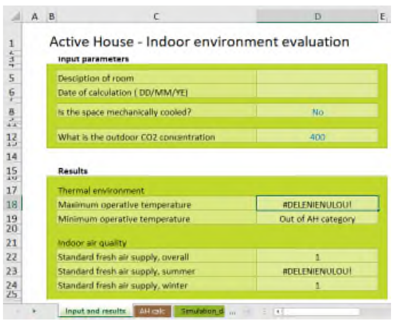


Figure 2: The title sheet of the student version of CESBA tool [2].





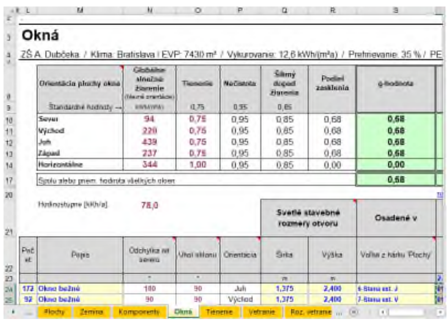


Figure 3: Screenshot from MCHD [11]. Figure 4: Screenshot from AH-Radar [12]. Figure 5: Screenshot from PHPP [13].

All these tools are relatively simple to use, and can be applied in the early stages of the design process, where the architectural decisions largely influence the final energy performance. They reflect the design choices, but if these are not based on deep knowledge or an intuitive understanding of the principles of energy-efficient buildings, the resultant solutions can be somewhat random. These can be optimised by testing multiple alternatives of a solution. This is time-consuming and a deeper understanding of the design principles obviating or minimising this is more efficient. This is the reason to look for a tool enabling more effective expression of the theory and the basic design principles of energy-efficient architecture.

INTERACTIVE nZEB MODEL

The first inspiration to create an interactive nZEB model was the use of the LT4 tool. It was easy to explain on a single sheet of paper the main factors influencing energy performance of the building and their relative importance. But LT4 was developed 20 years ago; today it is unusable given changed standards and *pencil and paper* techniques these days seem a bit strange. Another inspiration was an assessment of a PhD thesis, which had some wrong assumptions. The author explained the problem using a simple building model and a number of PHPP calculations. This method proved to be effective and it was decided to use it for architectural education.

Parameters of the Model

The goal was to identify the most relevant parameters influencing energy performance of a building and to study their impact using an easy-to-understand model. To simplify the model, the exact location of the building was not included and neither was its form factor (surface to volume ratio, A/V). The influence of climate, depending on location, can be easily explained in a few slides and charts [15] and usually, it is not subject to the architect’s decision. The same applies to the size of the building (this is the main factor for A/V).

Two examples were chosen of the typical local climate (Bratislava and Žilina) and the model is a small house, where various factors can have a more pronounced impact. Small houses had been studied in the past [16]; a six-metre cube is the smallest compact family house model with a standard typology. During seminars or interactive lectures, students test the influence of the modified parameters on the energy-performance of the building and on summer comfort, which starts to be more important in Slovakia’s changing climate. The students see the effects of their decisions and they can try to optimise the model using different approaches.

This practical exercise, which can be done during a one-hour lesson, helps students to understand the impact of the individual parameters, as well as their synergy. It is hoped that students will start to *feel* intuitively likely good design decisions in a similar way that they understand building structures.

The parameters the author included were the area and orientation of the glazing, the type of shading (including surroundings), quality of the thermal insulation of the building envelope (walls, roof, floor, windows, doors), airtightness and heat recovery efficiency. To simplify decision making, additional parameters are only two-value switches: self-standing or terraced house, southern or northern location, lightweight construction or heavy thermal mass, compact cube or modified form with worse A/V ratio, standard or thermal-bridge-free details, south or southwest orientation of the main façade and high or low sunlight permeability (g-value) of the glazing. These parameters affect the heating energy demand and the summer thermal comfort expressed as the share of the days with the interior temperature over 25°C. They represent the first optimisation step. The second step, efficiency of the HVAC system and of the warm water heating, and the third optimisation step, use of renewable energies, can be later added to this model.

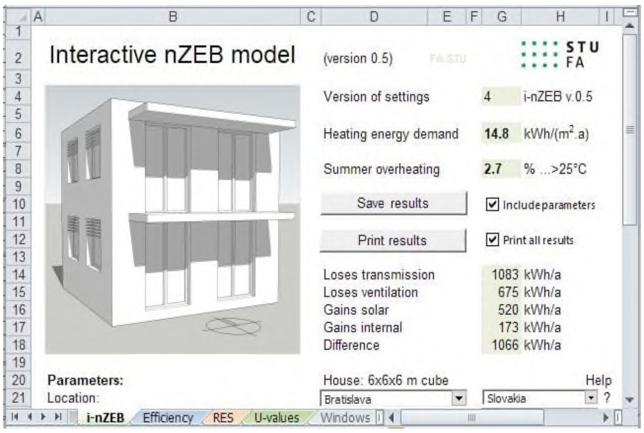


Figure 6: Screenshot of the output portions of the i-nZEB program sheet.

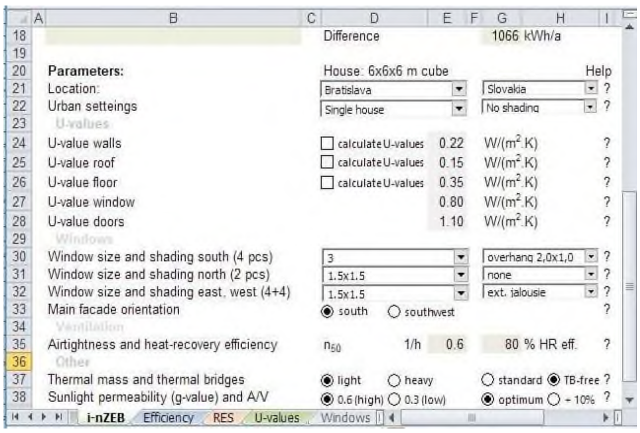


Figure 7: Screenshot of the input portions of the i-nZEB program sheet.

The interactive nZEB model is not intended to be used for exact calculations; approximate outputs are sufficient for achieving the goals set for students (see Figures 6 and 7 for sample output and input screens). Also, it is desirable to keep the back-end of the system simple and easy to modify. Some values are calculated exactly, e.g. heat losses through the building envelope. Other, more complicated ones are pre-calculated for typical values using the very precise PHPP software and eventually interpolated according to the exact input values and/or to the results of other partial calculations. Heat losses and solar and internal gains are put together for winter and summer situations and results can be saved for later comparison and analysis.

An interactive nZEB model, or i-nZEB, was developed as an Excel application, usable both in Microsoft Excel and its freeware alternatives. The first prototype version had a single input/output tab; an auxiliary tab for U-value calculation of non-transparent constructions can be added. The next version is planned to have an improved user interface with added tabs for the second and third optimisation steps. Eventually, calculations for buildings other than the single six-metre cube can be supported. Tabs can be added for the building envelope area summary and for the input of windows. Functionality of this final version of the i-nZEB tool will be like the PHVP tool, but many more parameters can be modified. The results will be not exact, but for educational use they will be precise enough.

Testing of the Model

The first test of this interactive nZEB model was done before finishing the prototype version. Its aim was to verify the pedagogical principles of the tool and to get feedback from students. The procedure was explained, students used a sheet of paper for writing up their inputs and the teacher quickly calculated the exact heating energy demand and overheating probability for these inputs using PHPP software. Then, the students evaluated results, changed some input values and compared the new results with the previous ones. This was repeated approximately 20 times during the lesson. The use of a fully functional program can increase the number of possible iterations or leave more time to discuss the process and the results.

Students participating in the test proclaimed that this exercise helped them to better understand the nZEB design process, and the final setup of the model parameters, suggested by the students in this test, was deemed the best possible. Questions were raised as to the weight given to winter savings and summer comfort. It was not defined in advance and students hesitated as to how to prioritise. The *form factor worsening* parameter was not used and it may be omitted. Positive feedback mainly concerned the better understanding of the influence of the size, orientation and shading of windows, as well as awareness of the importance of airtightness and ventilation with heat-recovery in nZEB.

The final version of the interactive nZEB model is under construction [17]. The first draft includes the user interface and the basic calculations for the most important parameters. The first complete version will be tested in the winter term 2018/2019, when it can be used with a larger and more representative group of students.

CONCLUSIONS

Testing the interactive nZEB model has confirmed its pedagogical usefulness. The author suggests use of the finished model in both Bachelor and Master studies to teach students what influences an nZEB design.

For the future, it is planned to add second and third steps of nZEB optimisation (technology efficiency and renewable energies) to the model and possibly replacing the PHVP tool (or other simple calculation tools) for CESBA calculations in design studios with the modified version of this nZEB model. The model would have more options for building location and no limitation of the size and form of the building envelope. Some of the approximate calculations can then be replaced by more precise ones.

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