

Tool for Evaluation of Energy Efficiency of Buildings in Early Design Stages

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Abstract

Due to the lack of knowledge and suitable tools, consideration of energy efficiency in architectural competitions is difficult in terms of objectivity, consistency and simplicity. The project “Integrating energy-relevant aspects in architectural competitions (IEAA)” addresses this problem. Developed measures and tools point out, how an easy implementation could be done. Main outcome of the project is an assessment-tool useable to quantify energy efficiency of buildings in early planning stages. Results of the tool provide the jury objective criteria to compare different projects in terms of energy efficiency.

1. Introduction

In the project development phase and the early design stages various decisions with considerable effect on energy efficiency of a building have to be made. In further planning process bad energy performance caused by a lack of compactness, unsuitable orientation or window size is very costly to correct. Especially in these early design stages hardly any instruments are available to give a quick evaluation of the energy efficiency of a building draft.

For such evaluation tools multidimensional conflicts need to be solved. On the one hand an increasing number of architectural competitions focus on energy efficiency due to developer’s request of low construction costs for energy-efficient buildings with low operational costs during their usage. For jury-members without detailed knowledge and experience about energy efficiency in buildings, objective criteria are missing to make a comprehensible evaluation of the submitted projects possible. On the other hand different requirements of architects and engineers often result in a conflict: Architects are anxious to optimize their designs regarding energy efficiency with as little effort as possible. As a result of a lack of knowledge to make such optimizations single-handed, experts are consulted. For a complete energetic evaluation of a building comprehensive data of construction materials, HVAC systems, etc are necessary. In this early design stage competition plans are limited to fundamental information concerning building design and urban integration of the design concept. Thus the necessary detailed data for engineers to evaluate and optimize the building’s energy performance are not available.

A project team consisting of the three partners Institute of Thermal Engineering (TU Graz), Inter-University Research Centre for Technology, Work and Culture (TU Graz) and Division of Sustainable Construction of the Institute of Structural Engineering (BOKU Vienna) applied itself to develop an assessment-tool for energy efficiency of buildings in early planning stages which fulfils the described requirements in the best possible way. The result of these efforts is the IEAA-assessment-tool.

2. IEAA-assessment-tool

As part of the project an on-line survey asked architects about their opinion on energy efficiency aspects in architectural competitions. A predominant part of the participating architects asked for objective measurements in architectural competitions with clear criteria to provide a comprehensive evaluation of the results within the preliminary evaluation. Especially a simple tool to estimate energy efficiency in early planning stages would be helpful for architects as well as developers. Requirements for such an assessment-tool are summarized in table 1:

Table 1. Requirements for an assessment-tool concerning energy efficiency aspects in architectural competitions [1].

task	structure	results
variety of architectural competitions	easy to understand	clear without ambiguity
different energy-standards	clear structure	comprehensible
different detail levels	little input effort	objective





The result of the efforts to fulfil the requirements presented in table 1 is the “IEAA-assessment-tool”. It is a practicable instrument to make an evaluation of the energy efficiency of a building draft in early planning stages. This article describes structure, basic calculation algorithms, possible application and experiences from competitions, supported within the IEAA-project.

3. Structure of the program

Important parameters that influence energy efficiency of buildings such as compactness and building orientation, HVAC-systems or active use of solar energy are covered by the IEAA-assessment-tool. Besides useful energy – which is used for regulatory requirements in Austria at present – the assessment also considers final and primary energy. These different assessment levels show possible improvements in the energy efficiency of the designs and based on these results immediate optimizations are possible.

A modular structure was established to fulfil the requirements of a variable application for different types of architectural competitions and at the same time reducing the necessary input parameters to a minimum. Three basic modules for the building envelope and the building’s HVAC-systems are supplemented with a module for active use of solar energy. Table 2 gives a short description and the resulting values of the four modules of the assessment-tool.

Table 2. Overview of the modular concept of the IEAA-assessment-tool.

	Modules	description	resulting values
	module 1 building basics	energetic assessment of “design-immanent” aspects such as compactness, orientation, window area as well as horizon- and self-shading	HWB*, KB* EEB PEB, CO ₂
	module 2 building advanced	energetic assessment of “non design-immanent” aspects with consideration of construction elements, flexible shading elements, building’s thermal capacity, etc.	HWB, KB EEB PEB, CO ₂
	module 3 building services	simplified energetic assessment of the HVAC-system (space heating, domestic hot water, cooling, ventilation, lighting) based on the chosen energy source	EEB PEB, CO ₂
	module 4 active solar energy use	consideration of the use of active solar energy by thermal and photovoltaic solar collectors	EEB PEB, CO ₂

HWB*...useful energy for heating (utilization profile residential building; regulatory requirements); KB*...useful energy for cooling (without internal gains; regulatory requirements); HWB...useful energy for heating; KB...useful energy for cooling; EEB...final energy; PEB...primary energy; CO₂...CO₂-emissions

The IEAA-assessment-tool is based on the calculation algorithms of the Austrian energy performance certificates for buildings. The tool's kernel is the official educational-tool of the energy performance certificates, provided by the Austrian Institute of Construction Engineering (OIB) [2]. The user interface was adapted to the requirements of project development and early design stage.

For the evaluation of the energy efficiency different resulting values are in use:

- Useful energy for heating (HWB) and for cooling (KB) can be used to evaluate the thermal performance of the building and the building envelope.
- On level of final energy the partial results of the HVAC-systems (heating, ventilation, air conditioning, cooling and lightening) can be summed up to the demand of final energy (EEB). This value shows – especially in the modules 3 and 4 – the energy efficiency of the combination of HVAC-systems and design concept.
- Primary energy level is presented in two characteristic values: primary energy demand and CO₂-emissions.

Those resulting values are used in the IEAA-assessment-tool to evaluate the energy efficiency of buildings. Defaults (U-values, reference equipment for HVAC-systems, shading system, etc.) were specified in order to evaluate different levels in all basic modules (module 1 – module 3). These defaults vary in the different modules and are incrementally replaced by user inputs. If module 4 is used, the yields of the active solar energy use lead to a reduction of final energy, primary energy and CO₂-emissions in the basic modules. In illustration 1 the interdependences of the modules are shown.

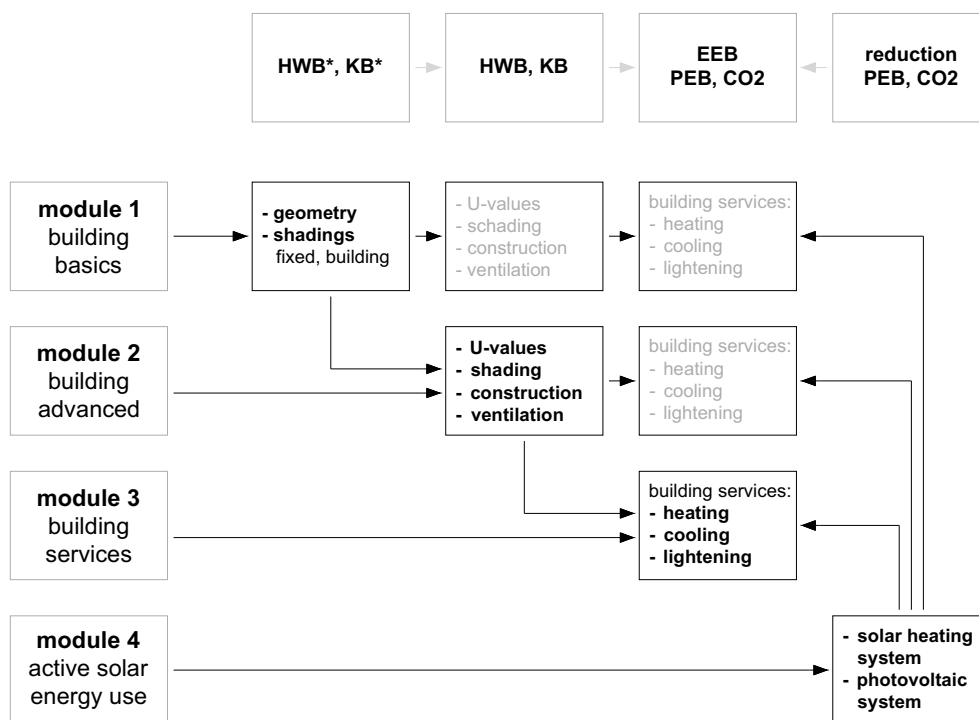


Fig. 1. Required input-parameters (black) and default-assumptions (grey) of the individual modules plus their result-values [1].

4. Application in architectural competitions

The IEAA-assessment-tool was developed for the evaluation of energy efficiency of buildings in architectural competitions. Furthermore it is possible and useful to implement the tool into the whole design process. The modular structure provides the flexibility needed to react to a variety of processes and projects and adapt individual energy-relevant objectives to each competition. After adjusting the tool to the specific requirements of the competition, it will be handed out to the participating architects to use it independently. The completed tools are sent back together with all necessary presentation plans and documents and are implemented in preliminary evaluation and report. They are part of the required documents in a competition. Finally the preliminary examiner composes an explanatory report for the jury meeting. Based on the submitted quantitative results the jury can discuss further qualitative aspects of energy efficiency like special shading forms or ventilation concepts to carry out a comprehensive evaluation of the building's energy efficiency (see figure 2).

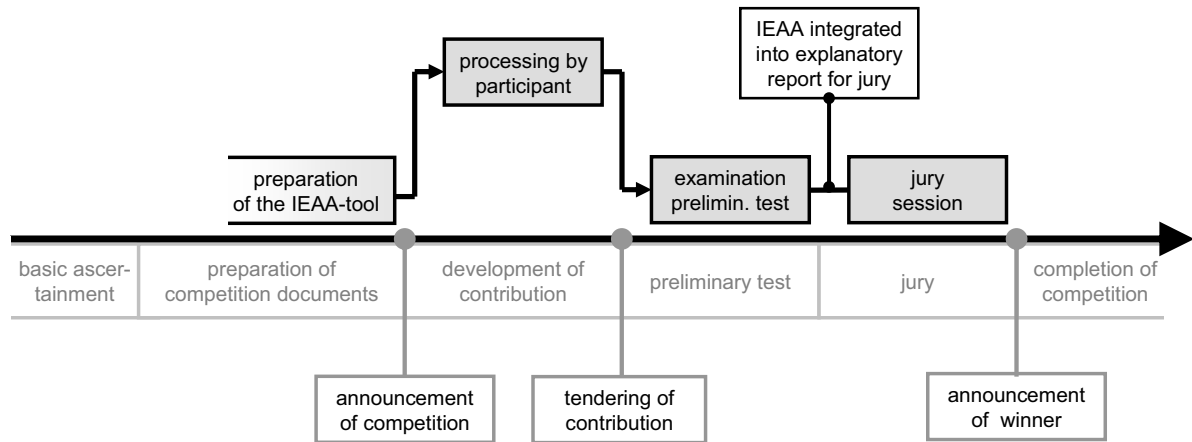


Fig. 2. Integration of the IEAA-assessment-tool in architectural competitions.

5. Practical use of IEAA

As part of the project the IEAA-assessment-tool was used in selected architectural competitions to evaluate energy efficiency of the submitted projects. Feedback was consistently positive from all parties – developers, participating architects, preliminary examiners and jury members. Positive aspects such as clear and simple structure and little input effort were mentioned. For practical use in architectural competitions mainly module 1 “building basics” is employed, sometimes supplemented by module 4 “active solar energy use” if active energy use is considered. The following examples explain individual processes in more detail [4]:

5.1. Invited competition for the Frauenfeld Kindergarten-Annex

Ambitious energetic standards and low operating cost were important criteria for the municipality Schwechat (Lower Austria) in the architectural competition for the new kindergarten annex in November 2008. The annex to the kindergarten should achieve passive house standard and the energy efficiency of the drafts was an important evaluation criterion. An expert on energy efficiency, architecture and passive houses was invited as a jury member and could therefore cover this expertise in the jury. The project team accompanied the municipality during the competition and was available for questions on passive houses and energy efficiency. A first test version of the IEAA-assessment-tool was used for preliminary evaluation. Since the assessment-tool was still under development the project team filled out the IEAA-assessment tool. Participants had to complete a prepared form to hand over necessary data to the experts to fill out the assessment-tool.

The decision of the jury took place unanimously and the winning project had a very good evaluation in terms of energy efficiency. The groundbreaking ceremony was held in August 2009 and the kindergarten annex is being built within budget.

5.2. Invited competition for Hausmannstätten Primary School

In this architectural competition for a new primary school in Hausmannstätten (Styria) the IEAA-assessment-tool was filled out for the first time by the participants themselves. The project team advised the developer and the preliminary examiner in preparing the tool before it was dispatched with the tender documents to the participants. After tendering of the contributions a plausibility check of the

inputs was done by experts. With the specially developed IEAA-analysis-tool it was possible to present an evaluation of the results in the examination report. (see fig. 2).

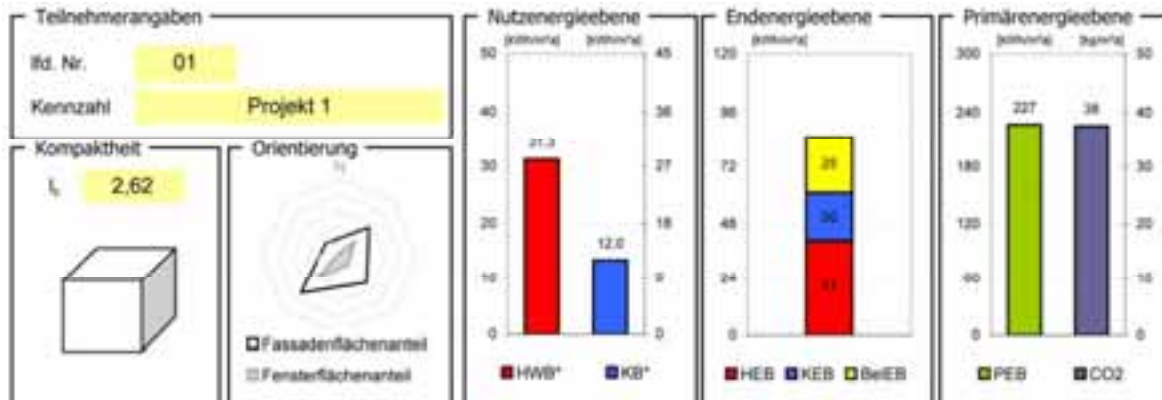


Fig. 3. Illustration of the results provided by the IEAA-analysis-tool.

In the jury meeting, in June 2009, a comparative analysis of the energy-relevant aspects was presented by the project team. The examined competition projects exhibited serious differences in the obtained values. The examination report of the project team for the jury-members contained a neutral, project-related description of the energy-relevant aspects of the submitted projects. The described results of the analysis of the energy efficiency were partly questioned by the jury members. Due to systematic method and the clearly presented application limits of the IEAA-assessment-tool the results were included into the evaluation of the jury.

5.3. Invited competition for residential housing Hausmannstätten (Graz)

The IEAA-assessment tool was also used to enhance and evaluate the energy efficiency of the winning project of the competition for a new residential zone in Hausmannstätten. The Styrian non-profit housing cooperatives asked the project team for an examination of energy-relevant aspects based on an architectural competition already completed. This competition was held in spring 2008 as an architectural competition by invitation only with five preselected participants. The task was planning of approximately 60 housing units with about 6,000 m² gross floor area basing on the conditions of subsidized housing in Styria. For the evaluation three competition projects (including the winning project) were selected, which suggested a larger dispersion concerning their energy efficiency values due to completely different conception of the projects.

To ensure comparability for all projects corresponding U-values for the building envelope were defined for module 1 to achieve the energetic standard of the developer. An objective comparison of all projects was possible and differences in the projects regarding their „design-relevant” aspects were shown. Furthermore it proofed roughly that the project achieved the necessary requirements of subsidized housing concerning energy-efficiency with the predefined U-values.

5.4. Invited competition Nursery Prochaskagasse (Graz) and Nursery Schönbrunnngasse (Graz)

For the two invited competitions for nursery schools in Graz-Prochaskagasse and in Graz-Schönbrunnngasse the developer (building department, city of Graz) specifically demanded the use of the IEAA-assessment-tool for all participants. Additionally an energy expert was entrusted to examine

energy efficiency standards. Thus, the project team prepared the assessment tool and advised the developer.

For the two nursery schools the developer defined “passive house”-standard as minimum energetic requirements. Additionally a generous employment of active solar use was demanded. Therefore module 1 „building basics” with U-values for lowest-energy standard (corresponds approximately passive house standard) and a mechanical ventilation system including heat recovery was specified in the IEAA-assessment-tool. Besides module 1 also module 4 “active solar energy use” for photovoltaic and thermal solar collectors had to be filled out by the participants.

Feedback from developer, preliminary examiner and participants was predominantly positive.

5.5. Experiences from supported competitions

Experiences from conducting these architectural competitions showed that limiting the process to module 1 “building basics” not only offers benefits in terms of a simpler competition process for participants and preliminary examiners but also provides important help for figuring out a building design’s energy assessment. Input parameters can be reduced to a minimum by focusing only on compactness, orientation and share of window surface. Advantage of this process is a reduced input effort for participants, hence reducing effort for the preliminary examiner and providing good energy evaluation for this early design stage. Furthermore using module 2 “building advanced” and module 3 “building services” offers the planner quick-assessment on energy efficiency during the draft process. During the design process effects of technical measures (other heating system, other energy source, other kind of construction etc.) on useful, final and primary energy level can be pointed out easily.

To achieve ambitious goals it is necessary to take energy-aspects into consideration from the very beginning of project development and to precisely formulate the requirements in the tender documents of the architectural competition. Defined conditions by developers are important for the results validity and interpretation. Consultation of energy experts is recommended if developers are not experts in the area.

The IEAA-assessment-tool is used to calculate quantitative energy figures; it does not judge or rank competition submissions. It should give the jury a representation of the energy efficiency that is as objective as possible to comprehensively assess the quality of a project according to the assessment criteria determined. The IEAA-assessment-tool provides a way of designing a more transparent selection process. The quantitative results must be viewed in the context of the competition submissions’ overall design. A voting technical juror with experience in energy-efficient construction can provide the necessary technical knowledge.

6. Conclusion

Energy-relevant aspects are not yet firmly anchored in architectural competitions. Developers, jury-members, preliminary examiners and participants have been uncertain due to a lack of quantifiable and objective criteria. Additional efforts for both participants and developers often inhibit implementation of energy aspects in the process. Although consideration of energy efficiency during project development and architectural competition is increasing, necessary specifications and strategies are often missing.

The project „Integrating energy-relevant aspects in architectural competitions (IEAA)” addresses this problem. Based on an on-line survey on this topic and a comprehensive analysis of selected architectural competitions a guideline and the IEAA-assessment-tool have been developed. Estimation of the draft’s energy efficiency in early design stages is possible. In architectural competitions it is possible to make a comparison of the submitted project’s energy performance and give jury members an objective and quantitative basis for their judgement.

Acknowledgment

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