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Simulation-based decision support tool for early stages of zero-energy building design

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ABSTRACT

There is a need for decision support tools that integrate energy simulation into early design of zero energy buildings in the architectural practice. Despite the proliferation of simulation programs in the last decade, there are no ready-to-use applications that cater specifically for the hot climates and their comfort conditions. Furthermore, the majority of existing tools focus on evaluating the design alternatives after the decision making, and largely overlook the issue of informing the design before the decision making. This paper presents energy-oriented software tool that both accommodates the Egyptian context and provides informative support that aims to facilitate decision making of zero energy buildings. A residential benchmark was established coupling sensitivity analysis modelling and energy simulation software (EnergyPlus) as a means of developing a decision support tool to allow designers to rapidly and flexibly assess the thermal comfort and energy performance of early design alternatives. Validation of the results generated by the tool and ability to support the decision making are presented in the context of a case study and usability testing.

Contents

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Introduction

The modelling of net zero-energy buildings (NZEBs) is a challenging problem of increasing importance. The NZEBs objective has raised the bar of building performance, and will change the way buildings are designed and constructed. During the coming years, the building design community at large will be galvanised by mandatory codes and standards that aim to reach neutral or zero-energy built environments [1–3]. At the same time, lessons from practice show that designing a robust NZEB is a complex, costly and tedious task. The uncertainty of decision making for NZEBs is high. Combining passive and active systems early on is a challenge, as is, more importantly, guiding designers towards the objective of energy and indoor comfort of NZEB. Table 1 shows the six main building design aspects that designers should address early on during the conceptual stage. The integration of such design aspects during the early design phases is extremely complex, time consuming and requires a high level of expertise, and software packages that are not available. At this stage, the architects are in a constant search for a design direction to make an informed decision. Decisions taken during this stage can determine the success or failure of the design. In order to design and construct such buildings it is important to assure informed decision making during the early design phases for NZEBs. This includes the integration of building performance simulation (BPS) tools early on in the design process [4,5].

BPS is ideal to lower such barriers. BPS techniques can be supportive when integrated early on in the architectural design process. Simulation in theory handles dynamic and iterative design investigations, which makes it effective for enabling new knowledge, analytical processes, materials and component data, standards, design details, etc., to be incorporated and made accessible to practicing professionals. In the last ten years, the BPS discipline has reached a high level of maturation, offering a range of tools for building performance evaluation [6]. Most importantly, they open the door to other mainstream specialism, including architects and smaller practices, during earlier design phases.

However, despite the proliferation of BPS tools, the barriers are still high. Despite the proliferation of simulation programs in the last decade, there are no ready-to-use applications that cater specifically for the hot climates and their comfort conditions. Current design and decision support tools are inadequate to support and inform the design of NZEBs, specifically during early design phases. Most simulation tools are not able to adequately provide feedback regarding the potential of passive and active design and technologies, nor the comfort used to accommodate these environmental conditions [7]. Several studies show that current tools are inadequate, user hostile and too incomplete to be used by architects during the early phases to design NZEBs [8–10]. Architects suffer from BPS tool barriers during this decisive phase that is more focused on addressing the building geometry and envelope. In fact, architects are not on board concerning the use of BPS tools for NZEB design. Out of the 392 BPS tool listed on the DOE website in 2011, less than 40 tools are targeting architects during the early design phases, as shown in Figs. 1 and 2 [11].

On the other hand, the integration of BPS in the design of NZEB is challenging, and requires making informed design decisions and strategic analysis of many design solutions and parameter ranges and simulating their performance. A recent study by the author [12], aiming at ranking BPS tools' most important selection criteria, showed that architects ranked intelligence above usability, interoperability and accuracy, as shown in Fig. 3. Architects identified intelligence as the BPS tools' ability to inform the decision making and allow decision making on building performance and cost. Also architects indicated a lack of intelligence within the tools compared. The study revealed that architects and non-specialist users who want to design NZEBs frequently therefore find it difficult to integrate BPS tools into the design process.

Therefore, in order to deliver NZEBs we must lower the barrier between building design and performance, ensuring the best guidance is available during the critical decision making stages of NZEB design. Architects' decisions to design NZEBs should be informed. Research investigations in the literature describe the reasons for these barriers, but little effort has been done to develop the required methods and tools that can predict the building performance in

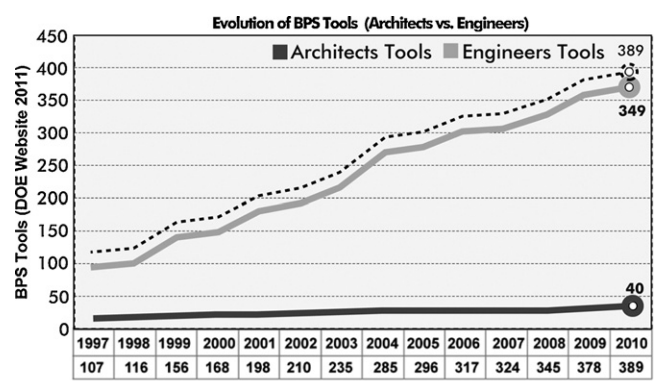

Fig. 1. Evolution of BPS Tools in the last 10 years.

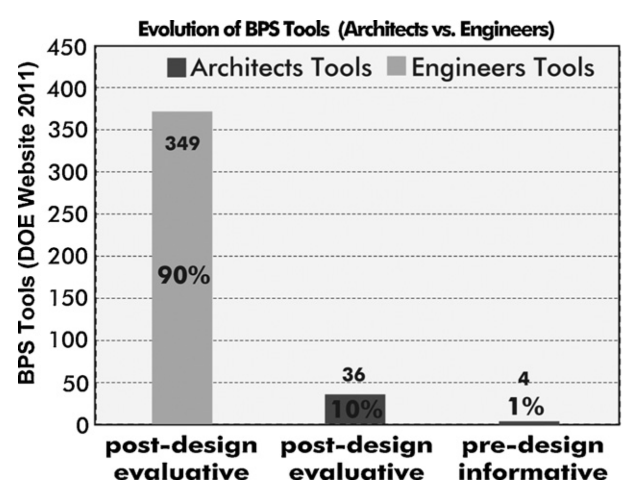

Fig. 2. Classification of BPS Tools pre- and post-design decisions.