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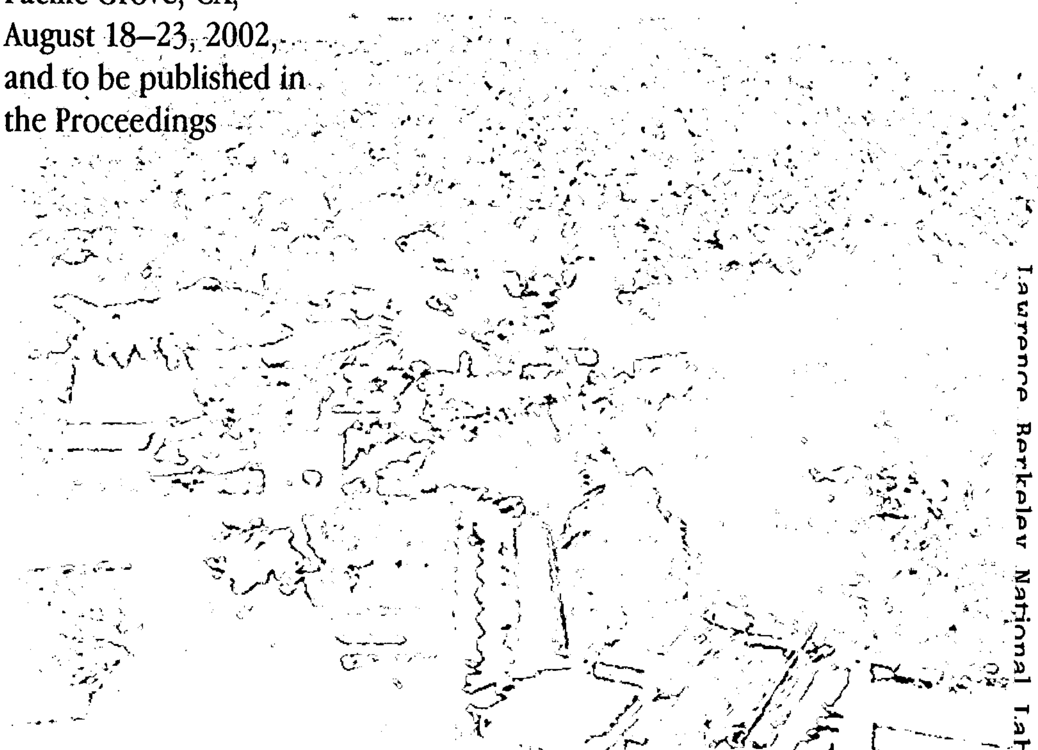

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Abstract

The need for proper consideration of energy-related performance aspects during building design has been identified since the energy crises of the 1970s. However, energy performance is still considered in a very small fraction of building projects, mainly because proper consideration is very expensive. It requires the use of computational software tools, which are not easy to learn and are time-consuming to use.

Several attempts have been made to facilitate the use of energy simulation tools, but none has brought a significant increase in the consideration of energy performance. Energy related performance criteria are still considered only in a small fraction of buildings and, in most cases, after most of the building design is complete.

This paper is focused on the main barriers in properly considering energy-related performance aspects in building decisions, which range from sociopolitical, to technical. The paper includes consideration of issues related to the general interest of the building industry in energy performance and environmental impact, current practice trends, modeling capabilities and performance of tools, compatibility of computational models and availability of data.

Finally, a strategy for government-industry collaboration towards removing the barriers is presented, along with the main issues that need to be resolved towards potential implementation.

Introduction and Background

The need for proper consideration of energy-related performance aspects during building design has been identified since the energy crises of the 1970s. Several efforts were initiated at that time by universities and research institutions for the development of building energy simulation tools that would allow prediction of building energy use. Building energy performance prediction requires use of algorithmic models that compute building energy and mass flows, based on building structure and materials, climatic conditions and building operational characteristics throughout the course of a year. Such research and development efforts have been supported mainly by public funds and are continuing since then. They have resulted in several simulation tools, with varying degrees of modeling capabilities, computational requirements and prediction accuracy. Some of these tools focus on whole building energy simulation (Klein et al., 1976; Birdsall et al., 1990; Winkelmann et al., 1993; http://www.bso.uiuc.edu/BLAST; Clarke, 1996), while others focus on specific areas, such as ventilation and air flow (Feustel, 1992; Pelletret and Keilholz, 1997), lighting and daylighting (Modest, 1982; Ward, 1992; Hitchcock, 1995; Baty, 1996; Ward and Shakespear 1998), or on specific building components and systems, e.g., luminaires, windows (http://windows.lbl.gov/software).

During the 1980s, such simulation tools were available only on workstation and mainframe computers and were used mostly by researchers and specialized consultants, for research purposes, development of codes and standards, and for the design of large, high-visibility building projects. In the meantime, computers were increasingly utilized by most building industry segments in everyday business practices, including drafting, construction management, cost estimating, facility management, etc. This trend has been continuing since then, resulting in better tools that are being adopted by a continuously growing segment of the industry.

During the 1990s, there have been two development fronts: one for the expansion of the simulation engines with respect to their modeling capabilities and prediction accuracy and the other with making them available to a broader range of users, including architects and engineers. The latter is focused on the limited commercial developments of "front" and "back" ends to existing simulation engines, which facilitate the development of the required input and the review of the resulting output. They also include efforts by research and academic institutions for the development of integrated software environments that support decision-making through integrated use of multiple simulation tools (Pohl et al., 1992; Mahdavi et al., 1996; Papamichael et al., 1997).

The work on both fronts continues until today, with new versions of old tools (http://www.doe2.com) as well as new tools (PSIC 1996; Crawley et al., 1999), still supported mainly by public funds. While most of the work on simulation engines is undertaken by academic and research institutions, some of the user interface work is being developed by private companies, in hopes of developing commercial software products. However, such efforts have had only marginal success because of several sociopolitical and technical barriers. Energy related performance criteria are still considered only in a very small fraction of building designs and retrofits and, in most cases, after most of the design is complete, at which point energy performance improvements can only be marginal in the form of "out of the box" technologies for specific building component and systems.

This paper is an attempt to identify the main barriers to developing and using simulation-based analysis and decision-support software as well as propose strategies for overcoming them. The paper is based on more than fifteen years of experience in developing simulation engines and simulation-based analysis, design and decision-making tools, and trying to push them to the market.

The Root Barriers

The root barriers in the development and use of building energy simulation tools are low market interest and high time-cost of energy performance prediction. The numbers of downloads for the most successful tools are in the low thousands (Crawley, 1997) while the number of regular users is usually much smaller. Although collectively state and national figures on building energy use and potential savings are high, they do not seem to be high enough at the level of individual buildings, where most building-related decisions are made. At this level, if at all present, energy has been traditionally towards the bottom of the performance criteria list in decision-making. Code compliance is as far as most building designers go with respect to considering building energy performance. Energy codes certainly prevent the design of energy-wasting buildings. However, they do not necessarily promote the development of energy efficient buildings that are friendly to the environment. Building designs that focus on energy efficiency and environmental impact from the early, schematic phases of building design can sometimes exceed code requirements by more than 50%, at the same, or even reduced initial cost (Larson, 1995).

The design of energy efficient buildings requires energy performance prediction capabilities at every step of the process. The current collective simulation capabilities available to the building industry are enough to allow for very accurate building performance prediction. The cost of using these simulation capabilities varies depending on the complexity of the building and the desired performance prediction accuracy. However, even for simple buildings, the cost is usually considered too high to be easily justified as a building design cost. Simulation tools are still very hard to use, and, in many cases, risky, because they require understanding of the modeling capabilities and the assumptions of the underlying models. Use of such tools requires significant involvement of specialized consultants, which raises the building design costs. Even experienced users of simulation tools require significant time in using them. Most of the time is spent in preparing the input information and processing the output, not leaving much time for exploring various design options (Majidi and Bauer, 1995). The information has to be duplicated in different formats for different tools, each of which addresses individual performance domains.

Most of the currently available efforts at state and national levels are targeted towards overcoming these two root barriers, i.e., increase the public interest in building energy and environmental performance and reduce the cost of considering it in building design and operational decisions. The efforts to increase public interest come in the form of educational material and incentives for the use of energy-efficient technologies and the design of energy efficient and environmentally friendly buildings. This paper is focused on efforts addressing the second root barrier, i.e. the reduction in the cost of considering building energy and environmental performance with improved simulation engines and software environments that make their use easier and faster.

Barriers in Developing Tools

Theoretically, it is possible to develop software tools that will make the consideration of building energy and environmental performance quick and easy. However, such tools require significant development efforts, equivalent to commercial software development. Unfortunately, the small market for energy and environmental impact tools does not attract commercial software development. Most of the current development efforts are mainly supported by public funds and are limited with respect to the allocated resources for development and support, resulting in slow progress. The goal of these efforts is to create a user base that provides a large enough market to justify business opportunities for commercial distribution and support.

Currently, the number of users of the currently available tools is too small to justify commercial distribution from a business point of view. In addition to the low market interest in energy efficiency, none of the currently available tools has reached a usability level that satisfies the desires and needs of the industry. As tools improve through continuous development, so does the number of interested parties and eventual users. A decade ago the collective number of interested parties was in the low hundreds, while today it has risen to a few thousands (http://www.eren.doe.gov/buildings/tools_directory). Growth is steady but very slow, mainly because of fragmented development. The number of tools under development is disproportional to the small size of the current market, resulting in further market fragmentation. Each individual software development effort is at the level of a few full-time persons per year, while the development and support of even simple commercial software applications requires financial support that is at least an order of magnitude higher.

While competition is healthy, most energy tools currently under development share the same goals and objectives and follow variations of mainly the same development principles and methods. With limited funding, most efforts focus on a few specific aspects and can deliver at best working prototypes, rather than usable tools. A more successful development strategy might be to allocate the combined public funds for development of building software tools towards a collaborative effort, where different teams could work at different levels of software development, from software engineering and schema development, to plug-and-play modules based on existing or new simulation engines for an overall simulation environment, to user interface elements, databases of building components and systems, case studies etc. This may be possible, since most of the funding for the development of tools comes from state and national government entities. Collaboration on strategic management of public funding could procure the necessary tasks for the development of an integrated and modular software environment and move forward in a way that is much closer to the successful operation of large software development companies. The key word here is "collaboration," which needs to occur at the funding and at the development levels.

Several roadmap development activities during the past few years (http://www.eren.doe.gov/buildings/technology_roadmaps), as well as workshops on the use of energy tools by tool developers and users (Crawley et al., 1997) have resulted in a relatively clear and commonly accepted understanding on what needs to be done. In a parallelism to the development of the car, we, as a society, have reached the point of knowing all of the required components, e.g., from the main part of the car, the engine (simulations), to the rest of the main car components and operational needs, like wheels, steering, gas, etc. (data structures, processes, actual data) to the accessories that will make it easy and safe to operate, like seats, lights, rear view mirrors, etc. (user interface elements for the preparation of input and the review of output). In the same way that it takes a factory to make a car, it will take a commercial level software development effort to make the type of integrated design tools that we know we need and want.

The current situation in developing energy and environmental assessment software is equivalent to producing either full working car components which do not work with each other to form a car, or prototypical cars with major limitations, ranging from lack of seats to lack of steering! In the same way that it takes a well-coordinated and funded design and development effort to make a usable car, it takes the same type of effort to produce usable software for proper consideration of energy and environmental performance issues during the building design process and life cycle. Such an effort needs to be handled at a high government level, which would be responsible for all building energy and environmental impact assessment and decision making software.

Barriers in Using Tools

The main barriers in using the currently available tools are related to combinations of limitations in time requirements and ease of use (preparation of input, execution, review of results), modeling capabilities (simulation engine), and availability and compatibility of input data (weather and building component and operational characteristics).

The development of simulation engines is a never-ending process, mainly because there are always new technologies to be modeled, e.g., distributed generation systems, or real-time simulation of control operations. Moreover, the continuous decrease of computing cost, continuously offers new opportunities for improved modeling capabilities and prediction accuracy. Time requirements for using these tools has the potential to be very low through the selection of appropriate simulation engines at different levels of performance assessment requirements, as well as through the development of appropriate user interface elements, e.g., links to Commercial CAD for geometry input and user interface improvements for non-geometric input and review of output. The modeling capabilities and time requirements issues can be properly addressed by coordinated development efforts, as described in the previous section. The availability of data, however, extends beyond government agencies and requires collaboration with manufacturers of building components and systems.

Following up on the car parallelism, just like cars need all kinds of additives for their different components and systems, e.g., gas, oil, brake fluids, antifreeze, etc., energy and environmental impact assessment software needs input data that accurately describe building components and systems, as well as local environmental conditions, to the extent required by the simulation algorithms. The currently available tools can handle only certain types of environmental data formats and each has its own limited library of a few generic alternatives for building components and systems that try to map the available options. One of the main needs identified in the workshops on the usability of software tools was the availability of input data for actual manufacturers' products, rather than for generic alternatives that represent classes of products. In certain fragments of the building industry, like the glass and window industries, we, as a society, have succeeded in developing standards for the content and format of electronic descriptions of products (http://www.nfrc.org; IES, 2000). This has greatly facilitated the use of software tools that need to compute lighting and thermal distributions and power requirements for assessment of comfort and energy needs. It needs to be extended to all segments of the building industry and needs to be coordinated with the development of the software tools.

Standardization of formats for the electronic representation of building components and systems is complicated by several factors. Building components and their semantic properties can be aggregated to form other building components in multiple ways, and they can be viewed from multiple perspectives depending upon the performance domain under consideration. Sometimes, required information such as the specifications and performance of particular components is considered proprietary and confidential. Some component properties require considerable infrastructure to measure, and the information may not be provided by all manufacturers of that component. However, efforts are already under way to address these limitations through an industry-wide collaboration on standardization and inter-operability of building simulation software (Bazjanac, 1999).

Conclusions

Software tools are essential for proper assessment of building energy requirements and environmental impact. The need and interest in such tools has been growing since the 1970s, however at a slow pace, following a slow development process. Current efforts for the development of such software tools are mainly supported with public funds, which are distributed in a fragmented way to many small, independent, uncoordinated development efforts, none of which can result in a tool that can attract large enough numbers of users to create business opportunities for a self-sustained market.

The development of a successful software environment requires a well-coordinated effort that is equivalent and similar to that for a commercial software product, addressing both, development and support needs. Leadership at a high government level could coordinate the allocation of the currently available funds towards a commercial-strength software environment that will attract enough users to create business opportunities.

The government efforts should be focused on several fronts, such as the main software engineering that will produce an appropriate software infrastructure; the development of standards for descriptive and performance characteristics of building components and systems; the simulation modules for the modeling of building technologies and processes; the development and maintenance of databases of required input data, ranging from weather to manufacturers' data for building components and systems; the development of links to CAD and other user interface elements; as well proper accompanying educational and marketing efforts.

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