# PROMISING (AND NOT SO PROMISING) DEVELOPMENTS IN ENERGY ANALYSIS SOFTWARE

by

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ABSTRACT

Building energy analysis programs have undergone a slow evolution since arrival over a decade ago. The frequency of use and number of applications for these sophisticated modeling tools seems to have reached a plateau. Changes are underway that may result in renewed vigor in the field. This paper reviews some of the dominant energy analysis issues. Recent thrust areas are examined for the alternative futures they suggest. Lastly, a role is defined for the International Building Performance Simulation Association, which may help guide energy analysis to the most promising of these futures.

## INTRODUCTION

This paper has been prepared for the Building Simulation '89 Conference sponsored by the International Building Performance Association (IBPSA). The authors have seen and shared in some interesting developments in the four years since proposing the formation of a "society for building energy simulation," an idea which helped spawn IBPSA. [1] As the government team that directs the development and support efforts for the Building Loads Analysis and Systems Thermodynamics (BLAST) energy analysis computer program, the authors' experience extends into many aspects of building energy simulation. As developers, we face software and hardware issues for the user. Yet, as Corps of Engineers managers, we must represent building owner concerns. Our perspective may be more specific than some practicing engineering consultants; however, we feel we can make a few general statements.

The paper will recount the rise and stall of the energy analysis field. After the historical review, we will state a premise on the stalled state of the art. This premise will be supported with several observations. Regardless of the outward waning interest in energy analysis, beneath the surface, some new developments are stirring. These may not all be good developments, but at least developments are happening. As the building energy simulation field has the potential to teach building developers, owners and operators so much, the building energy simulation field should grow and prosper. A vision for the field will be presented. After the conference, we suggest IBPSA take a look at what we and all the presenters say at this important event and process it. In the end, we hope IBPSA will discover a formula for effectively leading and serving the building performance simulation community.

## A BRIEF HISTORY OF ENERGY ANALYSIS

In the mid-70s, the United States finally woke to the fact it was an energy wasteful society. Energy analysis software experienced its "big bang." During that genesis, much of the architecture and algorithms for energy analysis software became permanently embedded in rigorous computer code, for better or worse. Buildings, to be modeled, had to first be synthesized. Common synthesis of a building was through the separated load, systems and plants structure: one directional computations to achieve a single number (annual energy usage).

The early whole building energy programs did a very thorough job of encoding recognized heat transfer functions and iterating them through a years worth of weather data. These hour by hour and similar "condensed hour by hour" programs required mainframe computer resources. For those who didn't have a mainframe or couldn't afford time sharing, bin programs were created that ran on the single user microcomputers: Apples, IBM PCs, and others. As long as energy conservation was popular, developers produced more and more energy analysis programs.

The plethora of available software left the typical user in a bind. Issues arose about how to go about deciding which software to use: validation, user friendliness, faster execution, cost, learning curve, etc. [1] Before the users could ferret all this out and settle on a few standards, energy prices fell and the public lost interest in energy. Fortunately, there were enough seeds sown in the early years to leave us today with a few healthy surviving plants (and loads and systems). We can use this surviving software to build on or discard, as needed, in serving the vision for the future.

## PREMISE: BUILDING ENERGY ANALYSIS IS STALLED

Surveys of energy analysis program users by Canadian and American government agencies came to common conclusions. The Canadians, in their 1987 North American survey [2], found the energy analysis software market to be quite small and stagnant. Annual sales of about 1500 copies of programs are given to about 8000 users. Ninety percent of these sales is from the dominant eleven energy programs. The consensus of the 23 software vendors contacted forecast no growth sales or number of users. Few new programs were under development. The predominant users (70-80%) were engineering consultants. These consultants were not convinced that energy analysis was a necessary, or at least marketable, service (except when mandated by such agencies as the ones taking the surveys).

A 1987 survey of several hundred users and design process managers in the U.S. Army Corps of Engineers [3] revealed similar attitudes. Predominant usage was for mandated requirements during design (energy budget calculations, HVAC system selection). For calculations, many of the respondents were still using *hand calculations* rather than any tool of sophistication. In contrast, one of the principal barriers perceived by the respondents for learning software was "no time to learn" and "design schedule time not flexible enough." Conclusions by Battelle in their December 1988 report on advanced energy design research, conducted by U. S. Department of Energy (DOE) [4], cite a "diminishing demand for designing energy-efficient buildings."

The low demand for building energy simulation products has resulted in a marked slowdown in development of new and improved code. If one reviews the proceedings from the 1985 Building Energy Simulation Conference (BESC) [5] compared to the program for Building Simulation '89 [6], a clear measure is seen. At least sixteen papers in 1985 dealt with new and/or improved building energy analysis programs. Except for about five new special applications programs, the 1989 conference deals with modifying and applying existing programs to new tasks. A check with HVAC equipment manufacturers reveals a similar downturn in their investments for new energy software. They are more interested in finding ways to increase the market share of their current products. One way of doing this is through marketing strategies such as linking their programs with microcomputer based Computer Aided Design and Drafting (CADD) packages. Since two commercial firms are involved (HVAC software vendors and CADD vendors), this linkage is a slow undertaking. Moreover, despite earlier enthusiasm for "a new generation of programs," we find today's product line largely 1970s technology. Indications are that the building energy simulation market is mature to declining. If national and state governments were not demanding simulation for code compliance, the market, except its research sector, would probably collapse.

## CAUSES/ISSUES

Building owners set the tone for the building energy analysis marketplace. Even in the Corps of Engineers, it is the Army customer that occupies the building who most influences design criteria. The findings of Battelle [4] are typical. Lamentably, it is mainly negative factors that will cause an owner to demand more energy conscious buildings: "a sharp increase in energy costs, energy service interruptions, or the perceived threat of either of the two." There is little of this energy consciousness in the marketplace today compared with the energy conservation heyday.

Nor are these building owners encouraged by the energy savings promised by the consultant compared to the energy savings seen at the meter. As Goldman [7] and Westervelt [8] found in independent validations of building energy retrofits, building energy simulations over-estimate realized savings by a considerable amount. Albeit, these over-estimations can be usually attributed to human occupancy factors or overconfident assumptions by the analyst on how well building has been maintained. This poor correlation might as likely, per Heidell and Taylor [9] or Allen and Bloomfield, et al [10], be the result of analyst input errors.

Predicting building energy consumption with confidence has been a central issue for some time. Seven papers were presented at the BESC [5] on validation of energy analysis programs. Four papers are being presented at Building Simulation '89 [6]. Although energy analysis software vendors explicitly state in their programs' disclaimers (as we do with BLAST) that the program is not intended to predict actual energy consumption, users, researchers and developers alike continue to perform "confidence building" validation studies comparing these two absolutes. In their BESC paper, Fazio and Zmeureanu [11] describe the fallacy of this approach. There are too many uncontrollable variables in real life to expect a computer program to pin all of them down with certainty. Moreover, at the program level the variable interactions often even out and give the concluding computation a measure of consistency when compared to other programs and actual buildings. It is at the algorithm level, either due to the choice of algorithms by the developer or the lack of validation of the algorithms themselves, that the confidence level declines. For example, there is a current dispute over ASHRAE cooling load algorithms: does one use the TETD, CLTD, or transfer function method to determine the design cooling load?.

The building energy simulation community tends to counter mismatches between metered and estimated consumption by pleading that the programs are more suited for comparative and parametric studies of design alternatives. In such studies, the relative computed values are paramount, not the absolute. Even at this level, research may not support the argument. In a 1984 study, BLAST was compared to two popular microcomputer products [12]. Deviations of up to 40% were found between programs when comparing retrofit options to each other. In a similar vein, Heidell and Taylor [9] illustrate that using a weak equipment model confuses the selection of HVAC systems. So even in its advertised area of strength, energy analysis can be challenged.

In addition to the validity of results, users have another set of concerns with energy analysis programs. Traditionally these concerns have centered on cost (including speed of execution), ease of use, and technical match with the design problem at hand, and, as Ayres and Lau [13] relate, the wishes of the client. One "ease of use" matter, user interface, was discussed at BESC [5] in at least 5 papers and is the subject of another 3 at this conference [6]. Six more papers at BESC examined issues related to the selection of the right tool. There user concerns have been a focal point of software vendors' time and resources for the past four years. The BLAST Users Group has lead the way for the Corps of Engineers in this area. New user interfaces have consumed a large piece of BLAST's development resources. Some BLAST developments have been output reports such as the automated design review report developed and documented by Amber. [14] Others have been input preprocessors such as the BTEXT program. [15]

The problems could be solved more easily were it not for difficult hardware, technical and institutional constraints. Speed of execution as well as cost are both associated with the lack of powerful computer hardware, at an affordable price. Rigorous whole building energy analysis software has typically been run on large expensive computers which, because of cost and access, have driven away many potential users. As noted previously, many of the building energy codes are structured into load, systems, and plants modules that work in only one direction. Therefore, one cannot easily use these tools to examine cause and effect at the space condition level, the exact place where the building owner has the most interest. This restriction severely impedes the programs' use in expanding areas of importance such as indoor air quality and human comfort. Changing this structure or making even less profound changes is difficult because the code is very complex, or in many proprietary products, unavailable [1].

These problems may be solved, if needed resources and attention are given them. Several institutional constraints have precluded this to date The bulk of energy analysis software users are consulting engineers [2]. Consultants, mechanical and electrical consultants in particular, are not normally the decision makers on building projects. Nor are they as involved with the building owner as the architectural firms that hire the consultants. This predominant condition, as well as the fragmented nature of the engineering consultant industry, leaves these users with very little leverage to effect change in the nature of the tools or the nature of the services provided the building owner.

Lastly, it seems building energy analysis is in this condition partly because the Architectural - Engineering - Construction (AEC) community lacked the vision to foresee it, lacked to will to face it undauntedly, and lacked the teamwork to organize an effective campaign to change it. It is in the area of teamwork that the authors see, and will relate later, a glimmer of hope.

## PROMISING (AND NOT SO PROMISING) DEVELOPMENTS

Not withstanding the general condition of building energy simulation, the stalwarts of the trade have been occupying themselves with solving many of the problems stated previously. These developments are discussed in three sets: *code work*, *applications*, and *institutional*.

CODE WORK - Each of the major building energy simulation software vendors has invested in upgrades in the last few years. New interfaces have been developed such as the marriage between Trane's ULTRALOAD and TRACE programs that provides a common input file for the TRACE and ULTRALOAD programs, and runs TRACE on a microcomputer as well. Carrier Corporation has a condensed hour by hour product that competes in the TRACE market. DOE 2 and BLAST have added models for some of the more popular HVAC systems and equipment types. The BLAST Support Office has added a program which translates Trane ULTRALOAD files to BLAST input files so TRACE and BLAST users (who are often the same people) can communicate more effectively. As will be discussed in Buhl's [16] and Sowell's [17] papers at this conference, work is proceeding on more ambitious projects which could transform the nature of building energy simulation products. The Corps of Engineers are concentrating on a few risking ventures as well.

> Witte will describe in his paper [18] a high priority research project for revising the BLAST architecture. The Corps and the University of Illinois are working to integrate the loads and systems code of BLAST and perhaps plants as well [19]. If successful, one of the major technical constraints of building energy analysis programs will have been overcome. In addition, expanded applications of BLAST, with minor new development effort, will then be possible.
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> For the last two years, the Corps has participated with Intergraph Corporation in the co-development of a software link between BLAST and Intergraph's CADD system. [20] The Corps is driven in these efforts by motivations similar to those that Barnaby spelled out in his BESC paper on CALPAS4 [21]: to "integrate all aspects of the design process." Lacking the standardized data interchange Barnaby saw necessary, this Intergraph-

BLAST project was engineered by developing a "neutral file format." This file is created from the CADD database by an Intergraph developed interface program. Using this file and a Corps developed interface program, BLAST can be executed. When completed, Intergraph users will be able to use their graphics files as the building description input to BLAST. This is one step towards integrating the design functios. This project, with its linkage of a detailed energy analysis program to a high end CADD system, represents a significant step in the evolution of building applications software.

The Corps intentionally waited developing a workstation or PC version of BLAST until hardware technology nearly caught up with mainframe technologies. Advances in chip and workstation technology have finally provided adequate, affordable platforms for programs like BLAST. The AEC industry is automating and will be investing in these more powerful machines. Full featured versions of BLAST for UNIX, DOS and Apple workstations/computers [22] are now being offered.

Not so promising in the code work area is failure of vendors to develop standard interfaces between programs or to share model development work. Individual developments are very expensive. As long as these programs stand alone, every advance in HVAC, lighting and envelop technology will require separate investments by each vendor to develop new simulation models. In addition to consuming faint resources, the duplication of effort in model development contributes to the pervasive problem of inconsistent simulation results between programs. And, since no one has proven that one of these simulations is right and another wrong, the credibility of the tools will continue to suffer.

APPLICATIONS - The period (1985-1989) has seen solid growth in the applications of building simulation software. However, energy software has not been the emphasis in this growth. The Building Simulation '89 conference offers presentations on Indoor Air Quality, Modeling Techniques, Moisture Modeling, Ground Transfer, Lighting and Controls; all topics that were given light or nonexistent treatment in the BESC. Hopefully, this trend will continue. Building energy simulation software is also being used extensively in the generation of energy conservation standards, not always with success. Although automation in the building design field should be encouraged, building energy simulation software may not be reliable enough to base a myriad of energy standards solely on their results. To argue differently would ignore the results of much of the validation work conducted to date.

The BLAST Development and Marketing Plan [23] deals with future applications as well. Projects have been identified for improving BLAST's capability for studying comfort and indoor air quality questions. The results of the work to integrate loads and systems will influence the decision to undertake these projects.

Of less solace is that much of this applications work is being undertaken without a community-wide consensus. No priorities, nor goals and objectives, outside of those for individual companies and institutions, are being established for either code or applications developments efforts. Without this consensus resources are being assigned to less than optimal development efforts. Without the communication that consensus would foster, the results of the efforts are less likely to be shared for the benefit of the community.

INSTITUTIONAL - Technology and competition is finally starting to break down some of the institutional barriers in the AEC community. As time goes on, architectural firms will no longer be able to compete. The hiring of mechanical, electrical and energy consultants to perform discrete, isolated design tasks will eventually give way to a more integrated relationship if not integrated business entities. One technology that is causing this to occur is CADD. Design firms, at first, invested in CADD to produce productivity gains and thus cut costs. They soon recognized that by using CADD in a design team approach these productivity improvements could be compounded. As with all things in business, it is the customer that is driving design firm to use more CADD. Their insistence on design firms using CADD is not based so much on lowering the price of design services. It is the CADD database that the enlightened building owners want that makes CADD and design integration so important. With a CADD database that contains all the architectural *and* mechanical, electrical and energy data for a building, the owner has a living representation of his building that will help him document changes made in the building and even help him decide what changes to make.

The influence CADD is beginning to have on the design institutions is profound. There is a growing concern among CADD vendors and design firms over the isolation of mechanical and electrical disciplines. Witness the interest of Intergraph and Autocad of bringing more AEC mechanical and electrical applications software into their product line. In the Government, users are demanding it for our Army and Air Force customers. AEC industry steering groups that advise CADD vendors are demanding it as well.

There is a heightened awareness of the wisdom of the design team approach. This recognition outshines all the other developments as the most promising for building energy simulation advocates. With a truly integrated automated design process as envisioned by the developers of CAEADS [24] at USACERL or

CABDES at APEC, building energy simulation can come into its own. Of all the simulation routines available, whole building energy programs are unique. These program alone carry the complete analytical models of the building needed to serve as the platform for a rigorous calculational framework for *whole building* simulation.

## A CERTAIN VISION FOR BUILDING ENERGY SIMULATION

The authors are not necessarily the best qualified to offer a specific vision for the future of building energy simulation. However, an offering may help the process move toward the adoption of a vision, any one, by consensus of the community. As stated earlier, one of the impediments to robust progress in our field has been the lack of such a vision, an ideal that researchers, vendors and practitioners alike can rally around to keep focused on some bright tomorrow.

As the AEC community grows closer together, with CADD as its impetus, the community has an opportunity to become masters of our destiny. Let us assume that CADD will do for AEC what automation has already done for many manufacturing industries. One of the primary benefits of CAD/CAM has been that the design engineer can now sit at a computer and model a gear, an airplane wing or a computer chip. The database that the designer builds serves as the root for all downstream design and manufacturing functions of the company. In an AEC firm of the future, these integrated databases will also exist. They will describe buildings instead of gears and wings. They will tell contractors how to build. With as-built updates, they will inform building owners how to operate and maintain the building.

Current CADD software is not designed to perform all the functions needed for such an integrated building database to happen. Missing in CADD are crucial attributes that describe the physical characteristics of the materials, equipment and systems that make up the building: such things as strength, weight, color, heat transfer coefficients, etc.

In building energy simulation, however, these details have been overcome as the programs have had to describe, in detail, building materials, equipment, and systems sufficiently to make a true model of a building (at least the parts we have cared about so far). Although other engineering disciplines have respectable modeling tools at their disposal, their tools deal with either narrow building decisions (e.g. structural member sizing) or broad horizontal construction (e.g. civil engineering siting). Likewise, architects with their CADD tools have domain over of the graphical representation of the building and site.

Since the "whole building" database the authors and many others are envisioning requires detail and intelligence, we submit that building energy simulation is the proper root for total building simulation. The simulation experience and expertise are deep and broad enough to serve as the catalyst for and the progenitors of the AEC equivalent of CAD/CAM. Building energy algorithms combined with a CADD user interface, supplemented with algorithms to serve other design disciplines, can adequately describe a whole building for all uses.

While our feel for the state of the practice is similar, what we envision goes beyond that proposed by Battelle in their idea for an Advanced Energy Design and Operations Technology (AEDOT) [4]. AEDOT proposes an "energy design advisor" as one of several discipline specific design advisors that are manipulated by a "design executive" to build "design and knowledge" databases. A short cut to a complete integrated database should be achievable by building off the neutral file concepts similar to the one constructed when CADD interfaced with energy simulation software.

Building energy developers and users can and should lead the way. Advances in hardware and software technology gives a solid platform on which to operate. The attitude within the AEC industrial is ripe for interdisciplinary integration. And the hard lessons in simulation have prepared us for this mission.

## ROLE FOR IBPSA

As originally conceived, IBPSA had a narrow building energy focus. During discussions on its charter, IBPSA's founders realized that the kind of simulation being performed in the energy area was not unlike what was or could be performed in the design of the entire building. Hence, it became the International "Building Performance" Simulation Association (without the restrictive "energy").

The authors feel that IBPSA's role is to prompt and engineer the debate which leads to a consensus vision for building simulation. Once agreed upon, it follows that IBPSA serve as the central body to coordinate and invigorate the AEC community to make that vision become reality. IBPSA can help initiate or develop concepts and standards that will be needed to produce the new tools evisioned. It can also work closely with ASHRAE and others to select and validate the energy algorithms that go into any centralized database, a prerequisite for a credible new product.

IBPSA is at an important crossroad. The Building Simulation '89 conference has built expectations of bigger things to come. With this conference, IBPSA has begun to reach out beyond building energy into peripheral areas such as indoor air quality. To be truly a "whole building" association dealing with simulation technology, IBPSA must quickly broaden it base by bringing new members from planning, other design, construction and building operation functional areas. To preach AEC teamwork properly, IBPSA must *be* an AEC Team. With this new membership, IBPSA receive more resources. IBPSA can make connections with the professional groups used in the other disciplines. It can build a pyramid with a broad enough base to reach the heights its vision demands. Let the discussion begin.

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