COMMERCIAL BUILDING SYSTEMS INTEGRATION RESEARCH

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Fifteen years have passed since the oil embargo caused energy-efficiency to become a national concern and to be aggressively pursued. While many efforts to improve energy-efficiency -- fuel efficient cars, energy-efficient homes, commercial buildings, and industrial processes -- were undertaken out of necessity, public acceptance has not been easy. For example, smaller, fuel efficient cars were often perceived as being spartan, uncomfortable and potentially, unsafe.

In response to the market demands of car buyers, the auto industry has improved the image of smaller cars while retaining their fuel efficiency. Smaller cars are now more attractive, sporty, aerodynamic, and safe, in addition to being fuel efficient.

Similarly, building designers working to design energy-efficient commercial buildings have to meet the demands of their market -- building owners and occupants. But first, the building research community has to improve the technical understanding of how buildings consume energy and where energy is being wasted. Although energy-efficiency may be the focus, it must be achieved without adversely affecting occupant comfort or productivity. This knowledge can then be applied in building design to yield comfortable, energy-efficient, and marketable buildings. The Commercial Building Systems Integration Program (CBSIP) research effort is dedicated to achieving this goal.

THE PROBLEM

While efforts to decrease energy use in commercial buildings had led to optimization of energy performance in building materials, equipment, and components, monitored energy-use data showed that buildings use more energy than they were being designed to use (Claar 1985, Reilly 1986). After initial investigation, this discrepancy was attributed to unplanned and unknown interactions among building subsystems (e.g., envelope, lighting systems, and HVAC systems and equipment). Some component and system combinations were fighting each other, actually increasing total building energy use. For example, when owners de-lamped fluorescent light fixtures in small, skin-dominated buildings, heating requirements often unexpectedly increased, which in combination with relatively inefficient heating equipment caused total energy use to actually increase. Other parts of the design community have recognized the benefits of integrated building systems (Rush 1986), but information on energy-related interactions is not generally available.

Another major problem was that while studies of the design process (Heidell 1987) revealed that more information than ever before was available about energy conserving measures and strategies, little of it was easily accessible to or used by designers. Designers still rely heavily on experience and vendor specifications when selecting subsystems and components. Designers often rejected new strategies or components with too short of a proven record or because their clients felt they were too risky. Further, the extra cost to identify and evaluate options was considered prohibitive within already limited design fees.

An easy-to-use energy design tool that evaluates a variety of strategies and interactions in order to make informed energy decisions is currently not available. Hourly building energy analysis programs provide a means of comparative analysis of options and some interactions, but they add design time (costs) and are seldom used. These programs only calculate energy performance, demand and costs, requiring that costs and economic benefit be determined separately. To deal with complex interaction issues requires complex, detailed building data which is often not available in early design stages. Also, most interactive effects are dealt with either incompletely or with approximations in these programs due to lack of experimental data. Last, the mathematical and computer language basis of these programs does not appeal to the predominantly visual orientation of the design community.

Building owners demands for marketable buildings, in industry jargon, a "sexy lobby", "views of woods" or "easy access", are much more important than energy-efficiency. Since some early, well-publicized attempts to make buildings energy-efficient left occupants uncomfortable ("freezing in the dark") or sick ("sick building syndrome"), energy conservation by itself has been difficult to sell to owners. If owners are presented with a choice between relatively equal features that make the building more marketable or more energy efficient, energy loses almost every time unless improved energy-efficiency also improves building amenities or marketability. By understanding how subsystems interact, we will also better understand and can improve occupant comfort and productivity. This will allow designers to design energy-efficient buildings that are comfortable and pleasant for occupants. Increased amenity will do more to foster the demand for well designed energy-efficient buildings than has energy-efficiency as a separate issue.

A PROPOSED SOLUTION

The CBSIP was started in 1982 by the U.S. Department of Energy (DOE) in response to the problems cited above. The objective of CBSIP research is to develop the scientific and technical understanding of how subsystems interact with each other, and with occupants and the environment. The research program is composed of two major parts as shown in Figure 1: interactions and integration. In interactions studies, building subsystems (e.g., lighting systems, structure, HVAC systems and equipment, etc.), occupants, and climate interactions are identified and quantified. Design concepts are then developed and evaluated for cost-effectiveness. In the integration portion of the research, new building energy design knowledge is transformed into algorithms, design guidelines, technologies, and tools in the form that designers need and can use to optimize commercial building energy performance.

CBSIP research focuses on four major areas:

- Interactions of subsystems within buildings.
- Interactions between building subsystems, occupant comfort and productivity, and microclimate.

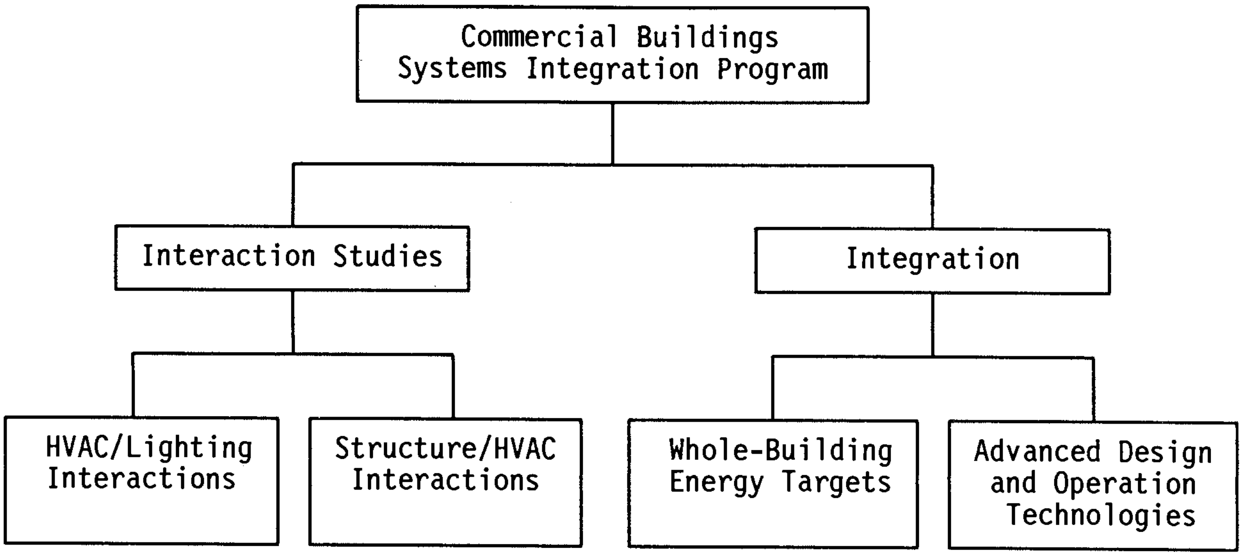

Figure 1. Structure of Commercial Buildings Systems Integration Program

- Integration of energy-efficiency knowledge into methodologies for establishing building-custom whole-building energy targets.
- Integration of building energy design technologies with industry design tools.

The research is directed toward improved energy-efficiency in early stages of the building life-cycle: design, construction, commissioning, operation, and maintenance. Building retrofit and renovation are the subject of other research programs within the U.S. Department of Energy.

INTERACTION STUDIES

The first two in a series of building subsystem interaction studies are near completion. The first is investigating the interactions between lighting equipment and HVAC systems. The second is studying interactions between building structure, HVAC equipment, and HVAC distribution systems. The first study is being performed in a test facility at the National Bureau of Standards (NBS). Experimental data is being collected in the test chamber on combinations of lighting fixture systems and HVAC systems and their interactive effects. Particular emphasis is being placed on time-dependant cooling load impacts of lighting systems and the impacts of fixture design and lamp temperatures on light efficiency. The major product of the research will be a new set of algorithms to predict time-dependent cooling load impacts of lighting systems.

The second study is evaluating an integrated systems concept using an energy analysis program. In this study, we have encountered many limitations of existing programs related to modeling complex interactions -- the limitations that the CBSIP proposes to alleviate. The basic concept under study proposes using the building structural system as heating/cooling storage for a water loop heat pump system. Effects of this concept on occupant comfort are also being investigated. Initial estimates show energy savings of up to 10% over individually optimized components are possible with this concept. After testing is completed and benefits are demonstrated, the concept will be tested experimentally.

WHOLE-BUILDING ENERGY TARGETS

The whole-building energy targets project (Crawley 1987) is developing a methodology for designers to determine predesign energy performance goals customized to their building. The custom-generated targets are based on the economic objectives of the building owner and the mix and distribution of space functions (office areas, cafeterias, lobbies, etc.). The methodology is being implemented in software, the Targets Model, with graphic entry of data and display of information. The Targets Model incorporates a building economic model, energy analyses models, building and energy cost data bases, and an optimization engine. The Targets Model will optimize combinations of components and systems up to limits set by the building designer or owner based on marketability and quality. The energy targets methodology will be included in the final federal standard for new commercial buildings as an alternative compliance path, but the Targets model will also function as a design (and learning) tool.

INTEGRATION OF BUILDING ENERGY DESIGN TECHNOLOGIES

The Advanced Design and Operating Technologies (ADOT) project (PNL 1988) was started in 1987 with an objective of developing technologies that foster integration of building energy design with developing industry design tools. The building industry has been rapidly investing in computer-aided design systems that automate either two-dimensional drafting or design. Design systems developers are evaluating and beginning to develop integrated, three-dimensional design and drafting systems with structured design data bases, often called advanced Computer-Aided Building Design systems (CABD). The ADOT project will develop an Energy Design Advisor (EDA) set of technologies: imaging and graphics technologies, energy analysis capabilities, and knowledge-based systems of information on energy conserving measures and strategies. The EDA will assist building designers in making informed energy-related design decisions and provide information to efficiently operate and maintain buildings throughout their life-cycles. The project team will be working closely with private industry to integrate these energy design technologies into the CABD systems.

FUTURE RESEARCH

Future interaction research projects will include studies of other subsystem interactions (Reilly 1986). The least understood interactions, (e.g., energy-related interactions of occupant response and comfort) will be studied first. Additional priorities will be established based on concepts that affect the greatest number of buildings (based on projected building starts) and that affect the predominant building loads. The ADOT project and other energy design tools will become the repository of past and future developments in building energy design knowledge.

CONCLUSIONS

The U.S. Department of Energy, through the Commercial Building Systems Integration Program, is conducting research to better understand interactions among building subsystems and why energy is being wasted. This information is crucial to improving building design so that more comfortable, energy efficient buildings can be built.

Through design and operation technologies that are easy to use and that provide information relating to energy-efficiency to building designers when and in the form they need it, energy-efficient design stands a chance of becoming an integral part of the design process. This, coupled with the observation (Burt Hill 1987) that energy-efficient buildings often have greater occupant amenities and user satisfaction, should lead building designers to want to design energy-efficient buildings.

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