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Simulation tools to support energy efficient retrofit of small commercial buildings

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Abstract

Considerable opportunity exists for energy use reduction and investment in alternate energy sources for light commercial buildings. In 2003, a total of nearly 4.9 million commercial buildings in the United States, comprising more than 71.6 billion square feet (6.65 Billion square meters) of floor space, consumed more than 6,500 trillion Btu (6,858 trillion kilojoules) of energy. Smaller properties dominate commercial real estate. Unfortunately, many owners and operators of small commercial buildings lack the expertise to assess the potential energy savings possible through building structure or equipment retrofits. In addition, the high up front cost of energy consultants or a lack of trust in contractors and vendors available to guide and implement energy retrofits often lead owners of small buildings to take no action.

Computer simulation of energy use when combined with the related energy costs before and after a retrofit can provide valuable input for planning a retrofit project. Hundreds of software or web-based tools are available for this purpose. Are any of these simulation tools appropriate for building owners and operators or trade contractors' use in support of energy efficient retrofit in small commercial buildings? If so, how can appropriate software be located and procured? What compromise(s) must be made for the software to be useful in guiding individuals with limited training? This paper summarizes a review of low or no-cost English language energy simulation tools conducted to answer these questions. The review was conducted with an emphasis on tools that can be utilized by individuals without extensive training.

Keywords: energy efficiency, retrofit, simulation, planning, energy cost, light commercial

1 Introduction

In 2003, a total of nearly 4.9 million commercial buildings in the United States, comprising more than 71.6 billion square feet (6.65 Billion square meters) of floor space, consumed more than 6,500 trillion Btu (6,858 trillion kilojoules) of energy. Electricity accounted for 55 percent and natural gas for 32 percent of the energy use, of which 36 percent was consumed for space heating and 21 percent for lighting. Smaller properties dominate commercial real estate. Half of all commercial space resides in buildings of less than 50,000 square feet (4,645 square meters), and over one-third is in buildings of less than 25,000 square feet (2,323 square meters) (Energy Information Administration, 2003). An often forgotten segment of this built environment is the considerable inventory of commercial buildings constructed during the years between World War II and the late 1970's (about 40% of the total commercial space). These structures were built prior to the reductions in energy use that became

more common through changes in design, materials, and construction practice brought about by increasing energy costs in the mid to late 1970's. Most of these structures are reaching the end of their design economic life (40 – 60 years) and are prime candidates for retrofit or reconstruction activity.

Considerable opportunity exists for energy use reduction and investment in alternate energy use for light commercial buildings. Methods to reduce energy use in residential structures through changes in new home construction, incentives for energy related home upgrades, and marketing of energy efficient products for use by homeowners are made accessible through programs in the United States that are promoted by utility suppliers, governmental agencies at many levels, and industry associations such as the National Association of Homebuilders (NAHB). Similar educational materials, design guidance, and activities that demonstrate the opportunity for energy use reduction and implementation of alternate energy use in light commercial buildings should be made available to owners and managers of light commercial buildings.

An October 2008 report of the U.S. National Science and Technology Council titled "Federal Research and Development Agenda for Net-Zero Energy, High Performance Buildings" notes the general lack of informational guides and incentives, and the misinformation that exists about energy consumption in buildings. The report recommends effective technology transfer through improved tools and guides, education and training, and market-based building valuation metrics. Significant planning, preliminary design, and assessment tasks must be completed prior to implementing relevant energy conservation and alternate energy sources for use in light commercial building retrofit programs. Unfortunately many owners and operators of small commercial buildings lack the expertise to assess the potential energy savings possible through building structure or equipment retrofits (Dirks, et al, 2008). In addition, the high up front cost of energy consultants or a lack of trust in contractors and vendors available to guide and implement energy retrofits often lead owners of small buildings to take no action.

To address this need, a search was conducted for publicly available (at low or no cost) English language software or web-based energy use analysis tools that would be appropriate for use in assessing the potential for success in selecting sustainable energy upgrades for light commercial properties. Many computer based decision tools are available from simple pre-design tools to more advanced simulation programs such as the DOE EnergyPlus program. The goal of the review was the identification of accessible, effective, versatile, and user friendly energy use simulation tools. It was considered important that these tools be user-friendly (Urban & Glicksman, 2007) to the point that building owners or managers could utilize them without the need to employ outside energy consultants or design professionals.

2 Search methodology

The search for publicly available energy use analysis tools began with the following list of required and desirable simulation tool attributes.

- Required attributes:
    - User-friendly interface
    - Little training needed
    - Low cost (<$500 US)
    - Recently updated (new version in previous 24 months)
    - Valid results
    - Input data readily available to property owners, managers, and trade contractors
- Desirable attributes:
    - No cost
    - Web based

An Internet and journal search for simulation tools with these attributes was conducted. The search was aided by the U.S. Department of Energy (DOE) Building Energy Software Tools Directory which lists 384 simulation tools and a detailed review of simulation programs published by Crawley, et al. in 2005 and Kim, et al. in 2009. This directory information was reduced to a workable list by identifying programs available at a cost of $1,000 US or less as shown in Table 1.

The analysis tools listed were tested using a sample 30,000 square foot office property and a preliminary retrofit list. The comments describing the suitability of analysis tools included in the sections that follow are based on the required attributes and the author's perception of suitability for use by property owners, managers, and trade contractors. Evidence of updates was taken from published material supplied by software developers. Evidence of validity was provided by descriptive material from the DOE Directory (in most cases based on BESTEST from the U.S. National Renewable Energy Laboratory or ANSI/ASHRAE Standard 140) or the assumed validity of Windows® interfaces for previously validated software.

Table 1. Low-cost commercial energy analysis simulation tools

Name	Cost	Web-Based	Recently Updated	Validated	Training Needed	Inputs Available
Design Advisor v1.1	Free	Yes	?	± 15%?	No	Yes
DOE-2.2 v47d	Free	No	Yes	Yes	Significant	?
EE4 CBIP v1.7	Free	No	Yes	?	Yes	No
ENERGY-10™ v1.8	$375	No	Yes	Yes	No	Yes
EnergyPlus v3.1	Free	No	Yes	Yes	Significant	?
eQUEST v3.63	Free	No	Yes	Yes	No - Basic	Yes
EZSim v6.0	$199	No	?	?	Tutorial	Yes
HEED v3.0	Free	No	Yes	Yes	No	Yes
RESEM v1.0	Free	No	No	?	Yes	?
RETScreen v4.1	Free	No	Yes	Feasibility	1-2 days	w/ Research
VisualDOE v4.0	$1000	No	Yes	Yes	No - Basic	Yes

3 Whole building energy simulation software descriptions

Design Advisor – Design Advisor is a tool for comparing early building design concepts. It is very easy to use and little input is required. Very few options are available, limiting its ability to simulate the broad range of conditions and technologies used in buildings constructed through the years. Design Advisor is meant to be a basic simulation that guides the preliminary design process. Due to the limited input required, the applicability to a broad range of existing buildings is insufficient to recommend for widespread use.

DOE-2.2 – DOE-2 has undergone significant revision through the years. It is a sophisticated professional-level program that calculates energy performance and life-cycle cost of operation. It is detailed and flexible, but has no Windows® interface. This is not a program suited to small building owners who would probably be uncomfortable with the basic programming needed for DOE-2. Those who do attempt to use the program need significant training and practice. In addition, the input requirements of the program require advanced knowledge of building mechanical systems.

EE4 CBIP – EE4 was developed to check compliance with the Canadian Commercial Building Incentive Program (CBIP). The user interface is not as easy to use as some of the other Windows® based simulation programs. In addition to training and practice to become comfortable with the program, many inputs have no default value. If the user does not know the value or where to find it, no simulation is possible.

ENERGY-10™ – ENERGY-10™ is a relatively inexpensive ($375) program that can within minutes identify cost-effective measures when the structure has a maximum of two thermal zones. Default values are available in an express input format. Defaults may also be modified. Input of non-default values takes slightly longer to complete but allows greater flexibility. Daylighting and photovoltaic analysis is included. The program automatically compares a base case to a more advanced energy conservation alternative. Reports are available in both text and graphic forms to provide cost, energy performance, payback, and energy conservation measure relative ratings. ENERGY-10™ is best used as a preliminary design tool. Results have been tested to verify credible results, but it is not as complete a simulation tool as EnergyPlus or DOE-2.

EnergyPlus – EnergyPlus models heating, cooling, lighting, ventilating, and other energy flows as well as water. It is a detailed and flexible professional-level program, but has no Windows® interface. This is not a program suited to small building owners who would probably be uncomfortable with the basic programming required. Those who do attempt to use the program will need significant training and practice. In addition, the input requirements of the program require advanced knowledge of building mechanical systems.

eQUEST – eQUEST is a DOE-2.2 based, professional-level program, yet it can be used with a minimum level of effort. The wizard driven Windows interface is intuitive and requires little training prior to use. Default values are provided for all inputs. As a result, a simulation can be completed even with a lack of input data or with inexperience on the part of the program's user. This program can be used as both a preliminary design guide and a detailed modeling program. To utilize the full accuracy of the advanced features of the software, considerable training and knowledge is required.

EZSim – EZSim uses utility bills to produce an energy simulation of commercial facilities in EXCEL. The interface is user friendly. Input data has default values for all but utility use information. The simulation is simplified with a limited range of envelope and HVAC inputs. It is not clear how valid and reliable the results of this simplified simulation may be. Variation from actual energy use experience can be "tuned in" to adjust for inconsistencies. The program will only simulate a single heating zone, limiting EZSim to very simple buildings.

HEED – HEED is a user-friendly energy design tool for small buildings only. It is limited to four HVAC zones and is most suited to residential structures. If the analysis is completed in four parts, a building of up to 50,000 square feet can be modeled. A graphic interface is included for building layout. Overall the program is sophisticated, but its primary orientation toward residential structures in California limits widespread use.

RESEM – RESEM calculates long-term energy savings directly from actual utility data. It is a DOS-based menu-driven program, first developed in the early 1990's. It currently has no technical support. Due to the lack of a user-friendly interface, it is not a good choice for individuals without a technical background.

RETScreen – RETScreen provides feasibility of alternative energy production and conservation savings from building retrofits including emission reductions and financial risk analysis. It is easy to use and provides both financial and social justifications for energy related investments. RETScreen is a preliminary screening tool because many of the inputs are limited in their scope. The results may compel owners to seek more detailed analysis. Alternative power sources and energy conservation choices are simulated in separate tools.

VisualDOE – VisualDOE is a Windows® interface for the DOE-2 simulation program. It uses the power and flexibility of the DOE-2 professional level program by providing a more user-friendly interface for entering information. Although not as easy to use as a wizard, the entry screens provide default values to simplify the process. This is the most expensive program reviewed ($1,000 US). To utilize the full range of DOE-2 tools available through VisualDOE, significant training and practice is required to complete the advanced entries.

4 Other simulation programs

Although beyond the detailed scope of this paper, several other categories of modeling software are available. They include programs for benchmarking or modeling current building performance, financial and environmental analysis tools, programs to examine the use of alternative energy sources, and software that models performance of natural and artificial lighting systems. Many of these programs are better suited to designers, consultants, and contractors. However, programs for energy use benchmarking and goal setting can be quite useful to building owners and managers.

Benchmarking tools are valuable in helping building owners and managers make their first planning steps in upgrading the energy performance of their properties. These tools help to place the performance of a building or portfolio of buildings in perspective. They can help the owner see how much energy their property is using compared to other similar buildings. Benchmarking can also give a perspective on how much less energy the building could be using, how much this could save in utility costs, and the resulting reduction in greenhouse gas emissions.

The U.S. Environmental Protection Administration (EPA) through the Energy Star program (www.energystar.gov) offers easy to use benchmarking and goal setting on-line tools (Portfolio Manager and Target Finder). Close to 9.5 billion square feet of commercial space had been rated by this program in over 71,000 buildings through June of 2008 (Environmental Protection Administration, 2008).

5 Discussion

An initial assumption of the simulation review was the priority for a user friendly program interface. When actually using the software, an equally important condition became apparent that has been noted by others. Appropriate building data must be available (Zhu, 2006). Information about the building, the building's mechanical systems, and the building's operating schedules may be unavailable or beyond the technical experience of many building owners or managers. The availability of easily adjusted default values for nearly all inputs helps to facilitate simulation program use by less experienced individuals. Utilizing default values may limit output accuracy, necessitating the ability to modify these inputs when inputs with greater accuracy are available.

Two of the programs reviewed exhibited the highest level of user-friendliness while allowing a sufficiently broad range of inputs to be utilized by building owners and managers. Energy-10™, which can be ordered at http://sbicouncil.org/displaycommon.cfm?an=1&subarticlenbr=112, provides an easy to use inexpensive software program that has been validated by the BESTEST validation procedure developed by the U.S. National Renewable Energy Laboratory. It provides rapid results and offers modifiable default values within an intuitive data entry format. It is quite flexible, allowing both very simple and more complex simulations. The program does have technical limitations, the most significant being the inability to simulate buildings with more than two HVAC zones. Complex buildings and owners that require higher levels of precision may require the use of EnergyPlus or DOE-2 for final investment decisions.

The second program that exhibited most of the desired attributes was eQUEST, which can be downloaded at http://doe2.com/equest/index.html. The input wizards utilized by eQUEST provide an ideal interface for users with limited computer experience and a good working knowledge of building details. Although the library of default building components offered by eQUEST is not as extensive as in Energy-10™, new default components are easily created. Overall it takes longer to input basic building data than in Energy-10™, but eQUEST makes it possible to do basic simulations within eQUEST for preliminary review while using the more advanced capabilities for final detail. The simulations conducted to develop the *Advanced Energy Design Guide for Small Office Buildings*, a simplified guidance publication targeting small office building energy efficiency, utilized eQUEST

for preliminary analysis and DOE-2 for detailed modeling. The developers of this design guide noted the time savings that accrued from the wizards provided by eQUEST (Jarnagin, et al, 2006).

A third program, RETScreen, available for download at http://www.retscreen.net/ang/home.php, was also user-friendly and offered some level of default input while providing useful energy use, greenhouse gas impact, and financial outputs. In some ways basic RETScreen simulation was easier to use than eQUEST or Energy-10^{TM}. Nevertheless, it was somewhat less user-friendly in the detailed areas of building mechanical or construction input detail. It was also necessary to simulate alternative energy sources separately from energy conservation measures. Building owners and operators should still consider RETScreen as a useful free energy simulation tool.

6 Conclusions

This review identified three simulation tools appropriate for building owners and operators or trade contractors' for use in support of energy efficient retrofit in small commercial buildings. All three have a user-friendly interface and provide data for energy retrofit decision making with a minimum of training or financial investment. Each can be located and procured by ordering or downloading from the Internet. While none is a panacea, they each allow individuals with a basic understanding of building construction and HVAC systems to tap into the powerful energy use modeling abilities of software that until recently could only be utilized by those with specialized training. The most significant compromise that might be required of many building owners or managers employing these simplified simulation tools is the need to contract with organizations having a higher level of energy analysis expertise to complete the building retrofit. In doing so, the more powerful advanced capabilities of the simulation software programs can be used to more accurately model the outcomes to be expected from retrofit activities by using more detailed input. Nevertheless, when combined with the building performance goal setting capability provided by benchmarking tools such as EPA's Portfolio Manager, these energy simulation tools provide reasonably accurate low-cost data for small commercial building energy retrofit planning.

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