Measuring Building Performance

Energy Efficiency Software Tools

Sustainability and the Built Environment

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One cannot speak of sustainable green building without taking into consideration energy efficient construction. How is efficiency measured, however; and what tools are available to designers and engineers to guide them in their planning? A wide range of building calculation and modeling tools exist, some with multiple levels of application and others designed for particular areas of analysis. This paper will very briefly survey this range, review basic methods in calculating thermal performance, and take a closer look at the functionality and usability of one particular energy tool.

Advancements in science, technology, and industry as well as a growing awareness of the need to respect and preserve environmental resources have contributed to the development of tools that calculate, model, and simulate various aspects of building performance. The Department of Energy offers a directory on their website[1] highlighting a continually expanding list of building performance software. The currently 332 tools on the site range from those that deal at the whole building level to those that analyze specific materials, components, equipment, and systems. Programs vary in their levels of accuracy, required effort, and cost. They likewise often deal with different phases in the design process. The sheer number of available options, let alone their wide variety, leaves one thoroughly overwhelmed. Key to the end-users success in finding the appropriate program is their ability to match the tool to the task. Categorizations by subject and brief overviews of each program assist the user in determining if a program suites their specific needs, level of expertise, and budget. The greater the user's knowledge of these factors, undoubtedly, the greater their experience navigating the alternatives.

When looking at energy efficiency at the whole building level, as is the focus of this paper, one is essentially interested in thermal performance. Thermal performance is typically calculated for one of two reasons—to size and select mechanical equipment or to predict the annual energy consumption of a structure. Architects, engineers, and mechanical contractors rely on sizing programs to calculate, often based on procedures and algorithms established by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), the peak heating and cooling season loads that determine necessary HVAC equipment. In considering efficiency, designers and engineers increasingly use energy programs that model and predict annual building energy consumption in terms of energy units (e.g. BTUs), financial cost, or environmental impact. These two types of calculations are not mutually exclusive. Determining annual energy consumption, for example, requires knowledge of the seasonal building loads. Most of these programs however emphasize one or the other at the cost of various simplifications. It is important to have a basic understanding of how thermal performance programs operate in order to determine the costs and benefits of each.

A very simple outline of steps involved in computing annual energy cost is represented in the flowchart shown in Figure 1, found on the Whole Building Design Guide website[2]:

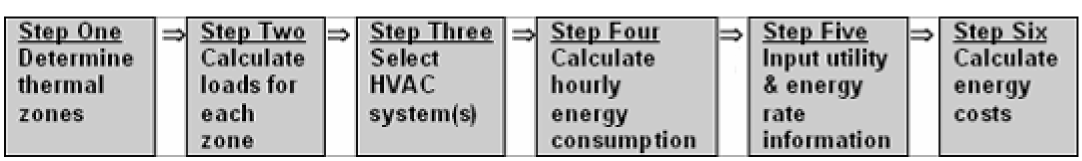

Figure 1. Flowchart to determine energy costs.[2]

A building is a complex system with multiple simultaneously interacting physical processes. Where these processes act to produce similar thermal requirements, the region is labeled a thermal "zone". The number of zones in a building is determined by various factors including building size, shape, orientation, use, and occupancy schedules to name a few. These factors also in effect represent the sources and sinks of energy that can go into the calculation of each zone's load, the required hourly rate of heat removal (or supply) to keep the building comfortable. The schematic in Figure 2 highlights these sources and sinks, where Q represents the rate of heat transfer or flow. Based on the peak hourly heating and cooling loads for each zone and also, depending on the complexity of the program, the interactions between zones, the building's mechanical equipment is then selected. The amount of energy required by the chosen equipment to support the building loads is computed; and, using the local electric utility and fuel rate information, the hourly costs are calculated and finally summed across a year's time to give metrics of annual performance.[2, 3]

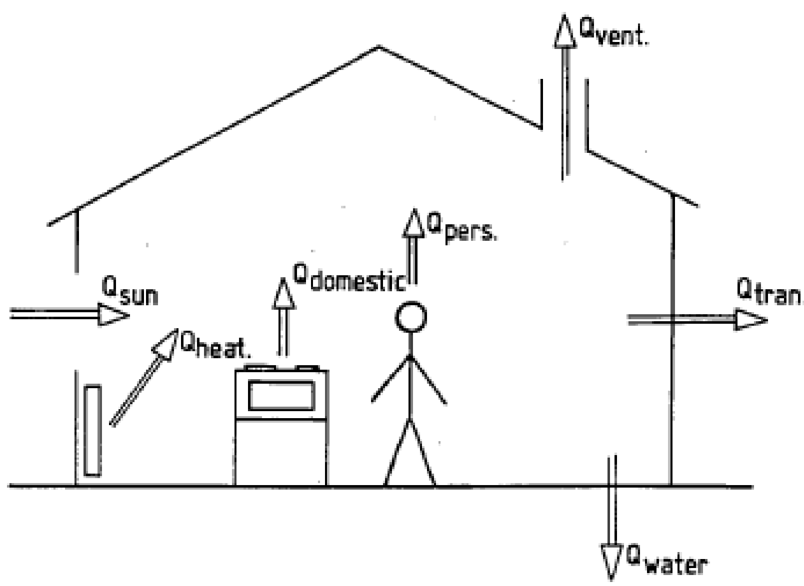

Figure 2. Schematic energy balance of a building.[3]

Among and within programs, variable complexity exists at all levels of the process. Some programs excel at only one or two steps. Others address them all. Some programs use simplified correlation methods and others use the detailed and dynamic hourly simulation. Again, choice of program will depend heavily on the type of project and questions being investigated as well as its ease-of-use. The strengths and weaknesses of some of the most widely used programs are summarized in Table 1.

In order to get a taste for the hands-on experience of using one of these tools, a few simple simulations were performed with the freely downloadable program eQUEST[4]. eQUEST, which stands for QUick Energy Simulation Tool, uses an extended version of the simulation engine in DOE-2, the widely reviewed and validated industry standard for detailed whole building performance modeling, and uses wizards and graphics to make the experience more user- and specifically novice- friendly. Touted as being so intuitive that "any design team member can use it, in any or all design phases," eQUEST follows the same basic outline of process steps in Figure 1 within a graphical, Windows-like environment. All the project specific information is input through the wizards. The Building Creation Wizard helps the user design a model of the building based on building plans and specifications at either schematic or detailed levels, and the Energy Efficiency Measures Wizard allows the user to designate up to ten design alternatives to the "base" building (multiple parametric design alternatives are also available for those working through the optional detailed interface). On completion of the simulation, with the help of a range of automatically generated individual and comparative graphs, utility consumption and cost savings for the efficiency measures can "be used to determine simple payback, life-cycle cost . . . and ultimately, to determine the best combination of alternatives."[5]

Program	Strengths	Weaknesses
DOE-2	detailed, hourly, whole-building energy analysis of multiple zones in buildings of complex design; widely recognized as the industry standard; residential and commercial buildings	not very user friendly; high level of user knowledge required
EnergyPlus	detailed simulation including time steps of less than an hour; interfacing to obtain geometries with CAD; input and output data structures tailored to facilitate third party interface development; free	text input may make it more difficult to use than graphical interfaces
Energy10	fast, easy-to-use conceptual design tool focused on making whole-building tradeoffs during early design phases in residential and small commercial buildings	limited to smaller buildings and HVAC systems that are most often used in smaller buildings
Micropas6	easy-to-use, detailed energy simulation; can calculate annual energy usage and provide load (sizing) calculations at the same time; California Title 24 and EnergyStar code compliance	no detailed modeling of heating and cooling systems is provided, seasonal performance values used; limited to residential buildings
EnergyPro	detailed, hourly, energy analysis using DOE-2 performance simulation; use of wizards make for fast learning curve; California Title 24 code compliance at residential and commercial building scales	number of more advanced concepts encompassed by DOE-2, such as co-generation, daylighting and off-site steam production, are not handled by the EnergyPro interface

Table 1. Strengths and weaknesses of widely used building energy analysis tools.[1]

One of eQUEST's particularly useful extensions to DOE-2's capabilities is the implementation of dynamic, intelligent defaults. Every input specification has an industry standard default value that is dynamically determined based on the user's previous entries.

Whether exploring a project for which certain parameters have not yet been decided upon or the user simply has no knowledge of them, eQUEST's intelligent default system boosts usability by making the simulation setup faster and independent of level of expertise.

The sample simulations performed using eQUEST were based on an imaginary simple rectangular office building in the Sacramento region. Basic details of the baseline building design and cumulating alternative designs are summarized in Table 2. To give an idea of the range of energy efficiency alternatives available in eQUEST, the options offered for this base building are listed in Table 3. Sample graphical representations comparing design alternative results are likewise shown in Figures 3-5. From these results and similarly useful graphical outputs, users can weigh the energy and financial costs and benefits of their designs. Examining Figure 3, it is clear that lighting and window modifications decreased electricity consumption throughout the year while daylighting controls and decreased lighting power density increase gas consumption in the winter months. On the other hand, implementation of triple low-E windows drastically reduced gas consumption during those same months. Figure 4 demonstrates that monthly utility bills remain consistently lower with the lighting and window modifications, and Figure 5 shows that cumulative life savings are greatest with the lighting density design alternative.

Design	Description
1. Baseline	25,000 sqft, two-story rectangular office building
2. Roof Insulation	added R-21 batting roofing insulation
3. Side Daylighting	added one photosensor to each building zone having side windows
4. Light Power Density	decreased the lighting power density by 10-20%
5. Window Glass Type	changed from double clear/tint to triple low-E

Table 2. Descriptions of baseline and energy efficiency alternative designs used in eQUEST sample simulation. Energy efficiency measures accumulate down the list.

Building Envelope	Roof Insulation
	Exterior Wall Insulation
	Ground Floor Insulation
	Window Area
	Window Glass Type
	Window Exterior Shading
	Skylight Area
Internal Loads	Daylighting
	Lighting Power Density
	Equipment Power Density
HVAC System	Thermostat Management
	Fan Power and Control
	Ventilation & Economizer
	Deck Reset
	Package HVAC Efficiency

Table 3. Categories of energy efficiency design alternatives for sample simulation in eQUEST.

While the simulations explored here were restricted to a simple building model analyzed in one specific software tool, from a new and non-expert user perspective, the experience was a surprisingly painless and encouraging one. Individuals with average computer familiarity will be able to navigate the program with ease. Topical knowledge however will determine their ability to take advantage of it. Though the cardinal rule of choosing a program remains matching the tool to the task, thanks to the increasing availability of flexible and user-friendly programs, more and more individuals across the board will be willing and able to use them to improve the energy efficiency, financial cost, and environmental impact of their buildings and homes.

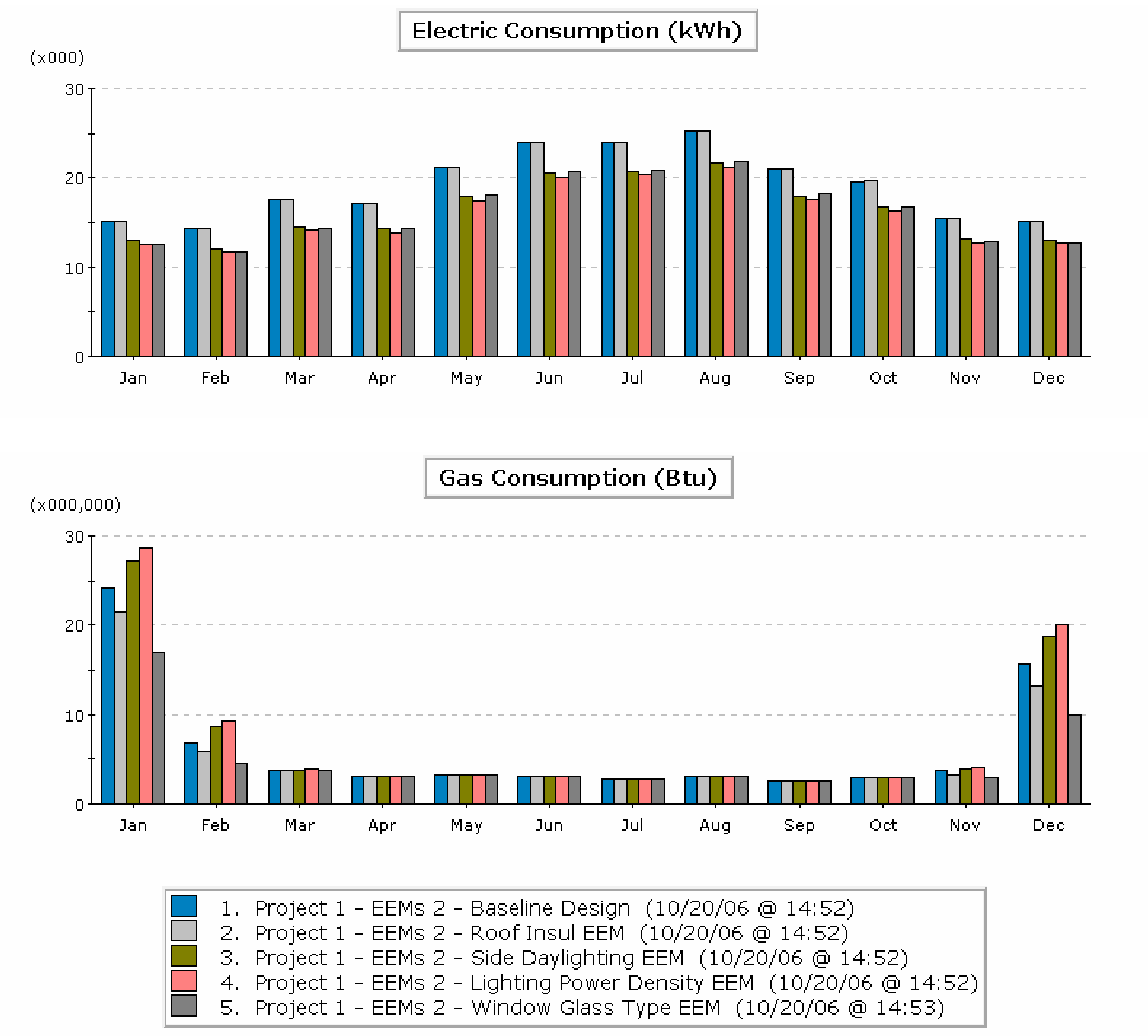

Figure 3.

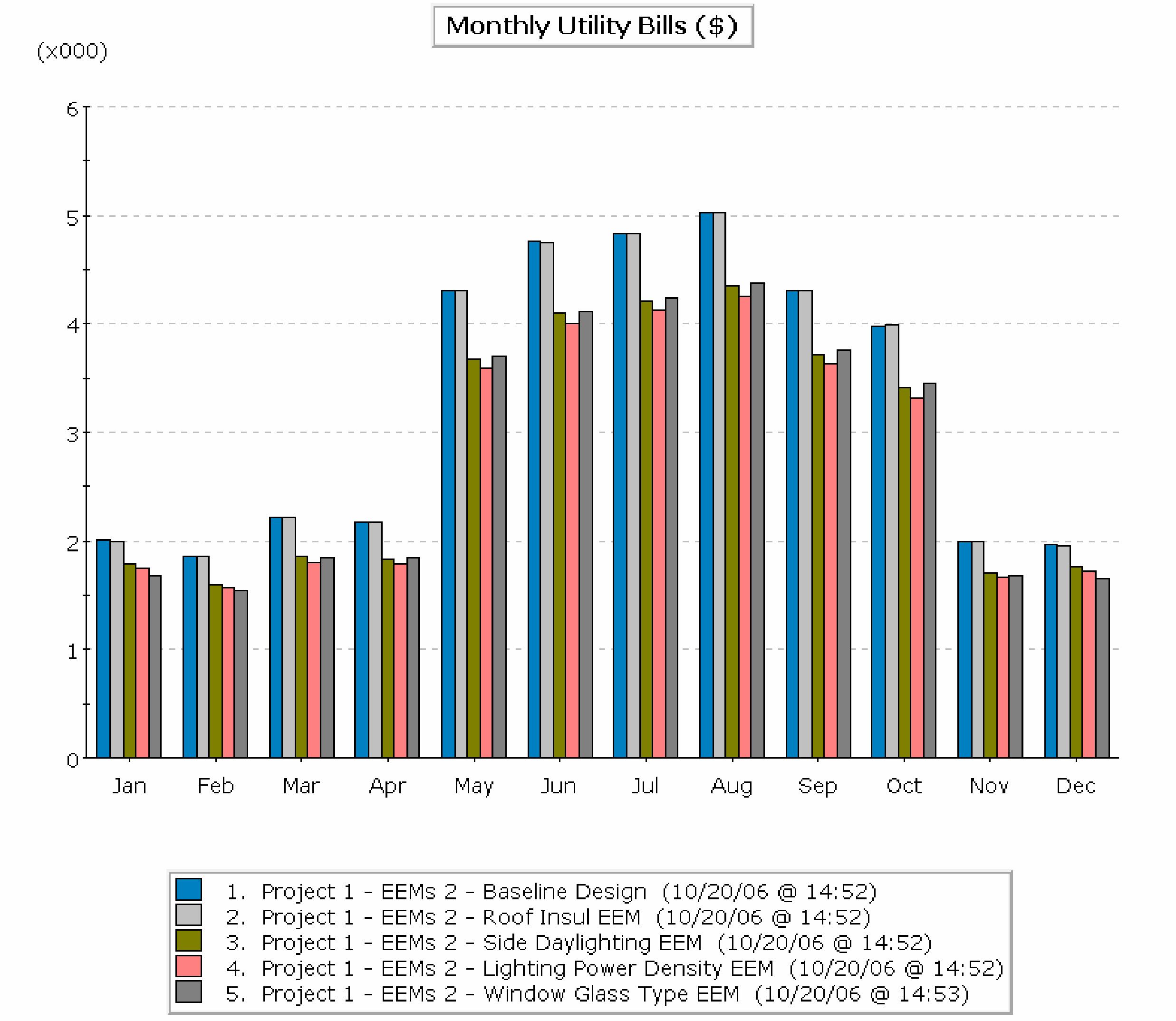
Monthly Utility Bills ($)
(x000)
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1. Project 1 - EEMs 2 - Baseline Design (10/20/06 @ 14:52)
2. Project 1 - EEMs 2 - Roof Insul EEM (10/20/06 @ 14:52)
3. Project 1 - EEMs 2 - Side Daylighting EEM (10/20/06 @ 14:52)
4. Project 1 - EEMs 2 - Lighting Power Density EEM (10/20/06 @ 14:52)
5. Project 1 - EEMs 2 - Window Glass Type EEM (10/20/06 @ 14:53)

Figure 4.

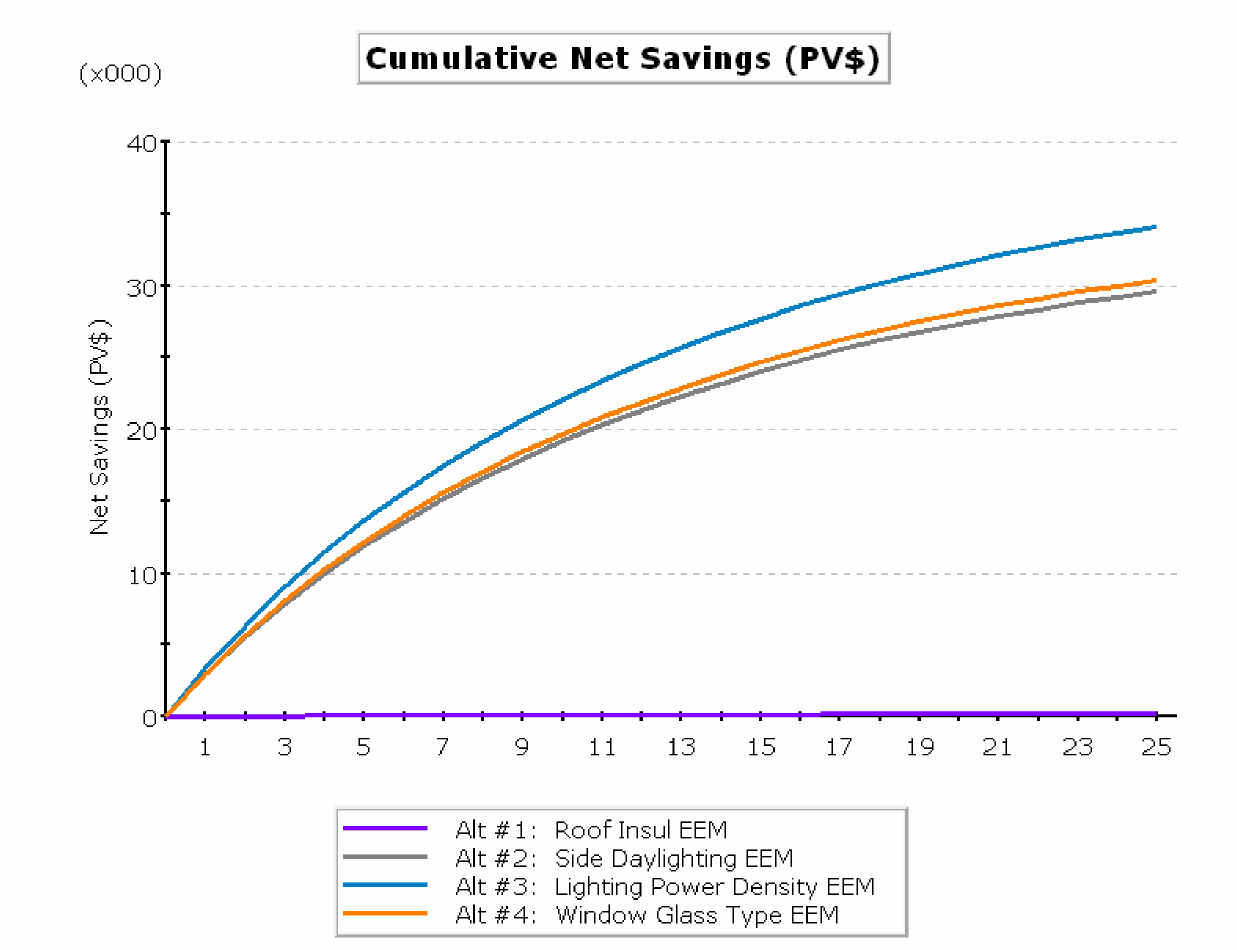
Cumulative Net Savings (PV$)
(x000)
Net Savings (PV$)
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
Alt #1: Roof Insul EEM
Alt #2: Side Daylighting EEM
Alt #3: Lighting Power Density EEM
Alt #4: Window Glass Type EEM

Figure 5.

References

1. Department of Energy Building Tools Directory:
   http://www.eere.energy.gov/buildings/tools_directory/

2. Whole Building Design Guide:
   http://www.wbdg.org/design/energyanalysis.php?r=minimize_consumption

3. *Calculation Methods to Predict Energy Savings in Residential Buildings*, Swedish Council for Building Research, 1983.
   http://www.ecbcs.org/docs/annex_03_calculation_methods.pdf

4. eQUEST:
   http://www.doe2.com/equest/

5. eQUEST Introductory Tutorial:
   http://www.doe2.com/download/equest/eQUESTv3-40_Tutorial.exe