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ENERGY MODELING—for energy efficiency

An *energy model* is a mathematical representation of a building in a specialized computer program. The representation is composed of thousands of equations created by the program from the inputted design specifications for the building—such as location, size, orientation, materials, equipment, operating schedules, and use. With this information, the program can calculate an estimation of the building's energy usage when constructed.

Description:

In many respects, designing an energy-efficient building appears to only involve choosing better materials and equipment. For example, to achieve better energy efficiency, a building needs 12 inches of insulation in the roof instead of 10 inches, south and west facing windows with low shading coefficients, and a condensing furnace with a variable speed blower. Such design choices will improve the energy efficiency of most buildings.

What is not obvious, though, is how these design choices were made— *why* was 12 inches of roof insulation selected and not 16 inches; *why* were windows with low shading coefficients chosen on both the south and west sides of the building? These decisions, and many more, were made using a design tool called an energy model.

Energy modeling programs have been available for more than 25 years. The early program tools were very difficult to use and, as a result, very few buildings were designed using energy modeling. Typically, those early tools required six months or more of training before a user could effectively model a building. Models were also very time-consuming to create because the building's design specifications needed to be entered in a command-line computer-programming environment (e.g., not a Microsoft Windows™ user-friendly environment with pull-down menu items). At that time, an energy model for an average building could take two weeks or longer to create. Today, an experienced building design engineer or architect can learn how to use many energy modeling programs in less than a week and can produce high quality energy models in a few days. Most of today's programs can be run on a laptop computer, further increasing the ease of their use.

There are many energy modeling programs available. Some of the more well-known programs are DOE 2.1, EnergyPlus, eQuest, Energy10, and TREAT. Many of the available programs have unique features that may make each of them more suitable to a specific project. For example, EnergyPlus and Energy10 allow some renewable energy systems to be included in a design. EnergyPlus has the ability to include indoor air quality analyses in a project. TREAT, eQuest, and Energy10 have

graphical user-interfaces that are easier to use. TREAT and Energy10 are well-suited for use on residential building projects.

Like many other products, modern buildings are very complex systems to design and construct. For many products, the design teams usually get to try several full-sized prototypes before the final design is selected and commercialized. However, buildings differ from many other complex products in this one important respect. The nature of building construction rarely lends itself to trying several full-sized prototypes before selecting the design to use. For this reason, every reasonable effort is made, *before* a building is constructed, to determine if it will operate properly. Usually there are no second chances for a building's design; once the building is constructed, any design flaw can be very costly to address.

This reality is equally true for a building's energy systems. If the installed energy systems do not operate together as intended, the cost to repair any design flaw can be large. Energy modeling is the most powerful tool a design team can use to ensure a building's specified energy system will operate as intended and deliver the performance expected by the owner. The resulting energy savings from improved design decisions and the potential avoidance of costs from design flaws can easily offset the small added expense of the energy modeling process. With the recent advances in energy modeling programs and computers, it is very easy to justify the use of some type of energy model during the design of any building that will have significant energy usage.

Benefits:

- Energy models can estimate the energy usage of a building before it is constructed, based on its design specifications; this information can be useful to a building owner for planning the building's operating expenses.

- An energy model can evaluate and compare the energy impacts of many different design decisions. For example, the orientation of a building can be easily rotated in an energy model to determine how solar energy increases or decreases the building's overall energy consumption for different positions on the project site.

- An energy model can optimize the interactive factors in a building's design. For example, if better wall insulation and windows are being considered, the energy model's results can be used by the design team to determine if a smaller heating system can be specified. The design team can then determine if the dollar savings from the smaller heating system will offset a significant portion of the increased expense of the better insulation and windows. The design team can determine the specific combination of insulation, windows, and heating system that minimizes the building's life-cycle cost (e.g., construction costs plus operating expenses during its life).

- Using an energy model can be beneficial for a project attempting to achieve a LEED certification from the U. S. Green Building Council—using an energy model is one option for showing compliance with EA 1 Credit: Optimize Energy

Performance. It should also be noted the energy-model-compliance approach is the only option that allows design teams to potentially earn the maximum points allowed for this credit (10 points vs 1 or 4 points for other compliance approaches) on a high-performing building.

Impediments or barriers to development or implementation:

- Energy modeling will modestly increase the design cost of a project. This cost increase varies from project to project, based on the building's size, envelope design, and HVAC system design. However, for average buildings with construction costs in the range of $150 to $200 per square foot, a very rough energy-modeling-cost estimate would be less than $0.50 per square foot.

- The accuracy of the energy model is dependent on the quality of the design information/specifications inputted into the modeling computer program. If crude design information is used, the energy model's results will be less likely to represent the final performance of the constructed building. "Garbage-In, Garbage-Out" or "GIGO" is a computer-modeling rule that succinctly explains the importance of having accurate design information to input into the energy model.

- It is unlikely the energy model will *exactly* predict the building's actual energy usage, as the energy model's results are based on *typical* weather data for a location; and typical weather conditions are rarely encountered by real buildings. Energy models also assume that building occupants behave in well-defined ways, such as always setting the thermostat to the modeled temperature, arriving and departing at the same times every day, and using equipment with expected patterns. Real occupants rarely behave as assumed in energy models. Even an experienced energy modeler, using an advanced program, can be off by as much as 10 per cent in their prediction because of these weather and occupant assumptions.

Resource—example:

- *The Solaire* , 20 River Terrace, New York City—a 27-story, 293-unit, glass-and-brick residential tower. The final wall design selected was based in part using energy models created in DOE 2.1. (http://eere.buildinggreen.com/overview.cfm?ProjectID=273).

Resource—written and web:

- Marc Rosenbaum, Energysmiths (2003) "Understanding the Energy Modeling Process: Simulation Literacy 101," *The Pittsburgh Papers; BuildingGreen.com.* http://www.buildinggreen.com/features/mr/sim_lit_101.cfm.

- Richard Paradis, Steven Winter Associates (June 15, 2007), "Energy Analysis Tools," *National Institute of Building Scientists—Whole Building Design Guide.* http://www.wbdg.org/resources/energyanalysis.php?r=minimize_consumption.

- D. Crawley, J. Hand, M. Kummert, and B. Griffith (July, 2005), *Contrasting the Capabilities of Building Energy Performance Simulation Programs*, Version 1.0.

Washington, DC: U. S. Department of Energy. http://apps1.eere.energy.gov/buildings/tools_directory/pdfs/contrasting_the_capabilities_of_building_energy_performance_simulation_programs_v1.0.pdf.

- U. S. Department of Energy, "Building Energy Software Tool Database," *Building Technologies Program.* "A directory providing descriptions and information on 380 building software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings; each tool listed includes databases, spreadsheets, component and systems analyses, and whole-building energy performance simulation programs, as well as information on the expertise required, users, audience, input, output, computer platforms, programming language, strengths, weaknesses, technical contact, and availability": http://apps1.eere.energy.gov/buildings/tools_directory/.
  Among the 380 tools described, included are:
  - DOE 2: http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=34/pagename=alpha_list.
  - EnergyPlus: http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=36/pagename=alpha_list.
  - Energy 10: http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=36/pagename=alpha_list.
  - TREAT: http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=430/pagename=alpha_list.

Resource—technical assistance contact names:

- New York State Energy Research and Development Authority (NYSERDA)
  17 Columbia Circle
  Albany, New York 12203
  1-866-697-3732
  info@nyserda.org
  http://www.nyserda.ny.gov/
  NYSERDA has programs that may support energy modeling for new or existing buildings. Most projects are cost-shared by NYSERDA on a 50/50 basis.