ENERGY MODELING BASICS

WOOLPERT WHITE PAPER

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Over the past five years, energy modeling has become the most prevalent tool used to estimate a building's annual energy usage and costs. Nowadays, it is almost a necessity to obtain LEED certification (EA credit 1) or to meet EPACT 2005 requirements for new federal buildings. Before LEED or EPACT, we used energy models to determine the most cost-effective HVAC system for a specific building in terms of the annual energy consumption and total lifecycle costs (i.e., air-cooled, water-cooled chiller or ground-source heat pumps). However, the results of an energy model are only as accurate as the stipulated input data and anticipated building use. Many individuals involved in building construction projects don't understand all the necessary components that are needed to complete the model. And even for those that do, there are still a number of factors involved with each of the components that have to be taken into consideration, including:

- Building envelope
- Siting orientation
- Lighting
- Process loads
- Zone temperature requirements
- Occupancy schedule
- HVAC systems
- Hot water heating size and efficiency
- Exterior building
- Parking lot lighting loads
- Utility costs

Building Envelope and Site Orientation

Whether the building is new or existing, one of the first steps is identifying the typical wall and roof insulation R-values, window types, and thermal masses, which are all critical in determining the overall HVAC loads and annual energy usage of a building. To identify these values, you first need to determine the U-factor (thermal transmittance) of a material (instructions are available in ASHRAE Standard 90.1). Many modeling programs also have standard construction types and insulation R-values available to choose from.

The orientation of the building and any external shading factors should also be identified. For existing buildings, the orientation is already fixed, but new buildings may still have the opportunity to orient based on solar position.

Questions to ask:

- Does one side of the building have a lot of west-facing windows and solar loads that would benefit from external shading fins?
- Can the building be orientated so the majority of the windows are north/south facing to minimize solar heat gain loads?

Lighting

Next, you will need to establish the building's overall interior lighting loads (typically provided in total Watts or Watts per square foot) and the type of fixtures used in each room.

Questions to ask:

- Will general high-efficiency, fluorescent, recessed lights be used or LED lighting?
- Is additional specialized task lighting required using high-wattage incandescent fixtures? Can daylighting be used, and if so, where?

Areas with high cooling loads can benefit most from daylighting or high-efficiency fixtures.

Process Loads

One of the factors that can greatly increase the energy consumption of a building, but can be the most difficult to accurately obtain are the process loads. These loads include items such as computer equipment, medical equipment, kitchen equipment, elevator equipment and data equipment. The ASHRAE Fundamentals 2009 Handbook is a good source for obtaining typical process loads (heat gain directly into space) for computers, kitchen and medical equipment. Ideally the building owner would provide as much detailed information as possible to determine the appropriate process loads, especially in high-heat output spaces such as data rooms.

Zone Temperature and Occupancy Schedules

After obtaining the building envelope, lighting loads and process loads, the zone temperature requirements and occupancy schedules should be provided.

Questions to ask:

- Are 75° F cooling and 70° F heating setpoints sufficient or typical for all zones?
- Do data rooms require cooler setpoints?
- Can the rooms be set back during unoccupied hours, and if so, to what temperatures?
- What are the typical building operation and occupancy schedules?
- Is the building occupied from 8 a.m. to 5 p.m. during the week only, or is it occupied 24 hours a day, seven days a week?

Typically these schedules can be input separately for different zones as needed or used in general for the entire building. Important schedule types include:

- People
- Occupancy
- Thermostat (setback)
- Process load
- Ventilation

Utilities

Information on the HVAC system should be defined; however, in some cases, the HVAC system may not be known yet.

Questions to ask:

- Will the designer choose the system, or does the owner specifically dictate the system type?
- Will the HVAC system be chosen after performing an energy model and comparing the annual energy usage or lifecycle costs of multiple system types?
- In any case, the modeler needs to know equipment efficiencies and how the equipment operates. Many of the energy modeling programs have default equipment libraries for standard types of equipment and varying efficiencies (e.g., 300 ton centrifugal water-cooled chillers, packaged 20 tons rooftop units). The HVAC designer should try to

specify higher-efficiency rated equipment where feasible; however, these values need to be realistic and confirmed through availability of specific manufacturers.

Additional ancillary information to incorporate into the model includes domestic hot water heating sizes and efficiencies and typical exterior building and parking lot lighting loads.

Finally, applicable utility costs should be provided, which may consist of electricity gas, steam and water rates. Any known demand and consumption charges for a specific utility should be defined to more accurately reflect the building's total energy costs. If these numbers cannot be provided by the owner or local utility company, the average annual rates for each state can be found on the Department of Energy's website (www.eia.doe.gov).

Once all the data is compiled and results are calculated by the program, chances are, the model is not complete. The final energy and costs results should be reviewed to make sure they actually make sense. Energy consumption and costs are typically organized by categories, including cooling, heating, lighting, heat rejection, fans, receptacle and other utility usage (see figure 1).
Questions to ask:

- Is one area particularly higher than another?
- Was the correct HVAC system or utility type selected?
- Can additional energy savings strategies be implemented, such as solar water heating or photovoltaic arrays?
- Can the building envelope be modified through better roof and wall insulation, tinted windows or interior/exterior shading devices to improve the cooling loads?
- Does the building have a large ventilation load, and if so, could carbon dioxide sensors be used to vary the ventilation load in densely occupied spaces?
- Could energy recovery be utilized to reduce the equipment sizes and overall load on the building?

Input data should be modified to determine the best performing and most cost-effective variables to reduce building energy consumption and costs.

Summary

There are many other components that can affect the overall energy usage and costs of a building. Collaboration among a variety of disciplines and the end user is essential to performing an accurate energy model. In addition, the energy modeler should be able to provide valuable feedback on ways to reduce building energy consumption by knowing how to modify the different building system components and how to analyze the associated results. In the case of a newly constructed or renovated building process, it is still up to all involved parties (e.g., design team, construction team, commissioning agent, and owner) to implement these strategies.

Figure 1.

Energy Cost Budget/PRM Summary

By Woolpert, Inc.

Project name: WVDC - General Instruction Building					Date: November 11, 2010		
City: Ft. Leonard Wood - MO		Weather Data: Ft. Leonard Wood, Missouri					
Note: The percentage dispalyed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption. *Denotes the base alternative for the ECB study.		***Alt - 2 Baseline System-PZC-**			**Alt 1 - Proposed HVAC System - G**		
		Energy 10^6 Btu/yr	**Proposed/ Base %**	**Peak kBtuh**	**Energy 10^6 Btu/yr**	**Proposed/ Base %**	**Peak kBtuh**
Lighting - Conditioned	Electricity	43.2	12	27	29.3	68	18
Space Heating	Electricity	0.0	0	0	4.9	0	15
	Gas	91.2	26	526	26.4	29	276
Space Cooling	Electricity	65.3	19	99	31.3	48	49
Heat Rejection	Electricity	3.9	1	8	3.9	101	7
Fans - Conditioned	Electricity	40.6	12	16	19.8	49	10
Receptacles - Conditioned	Electricity	55.3	16	22	58.9	107	24
Stand-alone Base Utilities	Electricty	15.2	4	4	15.2	100	4
	Gas	31.5	9	21	26.7	85	18
Total Building Consumption		**346.1**			**216.5**		

		***Alt - 2 Baseline System-PZC-**	**Alt 1 - Proposed HVAC System - G**
Total	**Number of hours heating load not met**	1	5
	Number of hours cooling load not met	51	0

	***Alt - 2 Baseline System-PZC-**		**Alt 1 - Proposed HVAC System - G**	
	Energy 10^6 Btu/yr	**Cost/yr $/yr**	**Energy 10^6 Btu/yr**	**Cost/yr $/yr**
Electricity	223.4	4,354	163.3	3,183
Gas	122.7	2,468	53.1	1,068
Total	**346**	**6,822**	**216**	**4,251**

Energy consumption and costs results from an energy model performed for a new 5,900-square-foot classroom building at Ft. Leonard Wood, Missouri. The project consisted of three nearly identical general instructional buildings with different site orientations. Individual energy models were performed for each building. The final results were evenly weighted and combined to demonstrate 28% energy cost savings over the ASHRAE Std 90.1-2004 baseline building. Energy saving features included high-efficiency packaged HVAC units, high-efficiency instantaneous water heaters, total energy recovery wheels with variable frequency drives and carbon dioxide sensors. The buildings have been submitted for LEED Silver® certification under the LEED NC 2.2 Rating System for Multiple Buildings and On-Campus Projects.