Energy Modeling Basics

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Making a precise energy model capable of estimating the building's energy use is difficult because of the assumptions that have to be made and evaluated through the modeling process. So, learning about energy modeling means more than simply constructing or reconstructing a building in a software program. It means being familiar with ASHRAE and other resources, and working with the HVAC engineer and designer, to make good assumptions that result in an accurate energy model.

Constructing the Building Envelope

The first step in creating an energy model is constructing the physical building in the modeling software. This allows the software to determine the effect of the local climate on the facility. Most energy simulation programs allow or, in some cases, require explicit input of the building geometry, i.e., the location and size of the building surfaces, such as walls, roofs, windows, and doors, in three-dimensional space.[1]

An important element is defining the thermal properties of all exterior and interior building surfaces, including the layer-by-layer heat transfer coefficients and thermal mass.[2]

For fenestration, solar optical properties by solar angle are also needed. One of the best places to find information on how to determine heat load calculations in building assemblies is Chapter 25 in the *2009 ASHRAE Handbook—Fundamentals.* This chapter provides detailed guidance about how to calculate a U-factor of a building component, as well as the effects of airflow and moisture transfer. In order to accomplish this, the modeler will have to work with the building design architect to obtain wall and roof building sections as well as specific information on the type of fenestrations used.

Once all the materials of an assembly have been determined, Chapter 26 of the *2009 Handbook—Fundamentals* provides several tables containing resistance, conductance, and specific heat information for select materials.

Tables 1, 2, and 3 of Chapter 26 include information on determining resistivity and emissivity of air spaces; Table 4 includes information on resistance, conductivity, and specific heat for several different common building and insulating materials.

If an example is needed to determine the best course of action in calculating this information, Chapter 27 of the *2009 Handbook—Fundamentals* provides several different U-factor calculations.

ANSI/ASHRAE/IES Standard 90.1-2007 is a widely used resource for energy modeling and is currently used as the baseline for voluntary labeling programs. Appendix A of ANSI/

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Four Uses for Energy Modeling

Energy modeling is used for four main reasons: determining code compliance, estimating design performance, comparing to actual performance for measurement and verification activities, and developing building asset ratings. Each of the four uses requires different levels of energy modeling and are started at different times of the design phase.

Energy Modeling for Code Compliance

Code compliance energy modeling compares the calculated energy use of the actual designed building to that of a reference baseline building to demonstrate that the designed building complies with minimum performance criteria. This method is typically performed at the end of the design phase; however, it may be performed earlier in the project to determine if additional energy conservation measures (ECMs) are needed to make the designed building comply with the code.

Energy Modeling for Design Performance

Design performance energy modeling is performed throughout the design phase of a project to determine energy use of a variety of parameters applied to the building. Such modeling is often done for voluntary labeling, such as LEED, or utility incentive programs, where the goal is to produce a building design that outperforms the code minimum or standard practice. Typically, multiple alternatives are created to compare select building systems and components to determine the associated amount of energy reduction with each alternative to assist in deciding while alternatives to use in the project.

Energy Modeling for Measurement and Verification

Energy models for measurement and verification are constructed after a building has been occupied. The model is constructed based on the actual equipment and building systems installed, and the analytical results are compared to the actual measured utility data. Since the building's true energy performance is known, this type of modeling typically involves calibrating the model by adjusting various inputs, in particular for the building's actual operational conditions, until the modeled energy use matches the actual measured data. Once the model has been calibrated, it can then be used to estimate the savings due to various measures and normalize the data for differences in operations and climate, etc.

Energy Modeling for Building Asset Ratings

Modeling commercial buildings for developing asset ratings is a new and growing field, supported by ASHRAE's bEQ (Building Energy Quotient) program.

ASHRAE/IES Standard 90.1-2007, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* provides several tables of assembly U-factors for common types of roofs, walls, floors, and glazing. Although this information may already be determined, the energy modeler may be consulted to perform several modeling scenarios to determine the cost effectiveness of incorporating energy conservation measures (ECMs).

Determining Internal and Process Loads

The next phase of constructing the model will be to determine what internal heat loads are in the building. Internal loads are primarily comprised of people, equipment, and lighting.

To obtain this information, the building owner and architect will be crucial.[2] Unfortunately, if the project is still at the design stage, these values will always be subjective predictions based on rules of thumb.

Occupancy and Equipment

The building owner will be able to assist with determining the number of people who will occupy each zone. Several modeling software programs have the ability to apply an occupancy per square foot value if the occupancy density is unknown. The building owner will also be able to help determine what type of equipment will be located in each zone. In addition, the owner may also be able to provide information on the heat load generated by the equipment.

If this is not the case, Chapter 18 of the *2009 Handbook—Fundamentals* supplies several tables of heat generation equipment. Tables 5A through 5E provide information for cooking appliances; Tables 6 and 7 provide information on medical and laboratory equipment; Table 8 through Table 12 provide information on typical computer and office equipment.

Lighting

To determine the internal loads due to lighting, the electrical design engineer will be a helpful resource. Based on the lighting design, the engineer or designer should be able to provide a lighting power density for each zone as well as for the building exterior.

However, if typical values are needed for lighting power densities, Table 2 in Chapter 18 of the *2009 Handbook—Fundamentals,* and Table 9.6.1 in ASHRAE Standard 90.1-2007 provide lighting power densities based on the space-by-space method.

Table 9.5.1 in ASHRAE Standard 90.1-2007 also provides lighting power densities using the building area method.

Table 9.4.5 in ASHRAE Standard 90.1-2007 provides lighting power densities for building exteriors.

The engineer or designer should be able to provide hourly profiles on lighting operations; if not, modeling software typically has built-in profiles that can be applied dynamically to model lighting use based on building type.

The engineer or designer will also be able to assist with any type of lighting controls being provided, such as occupancy sensors, automatic lighting control system, or a daylighting control system. Specifications for daylighting control systems should also include information on continuous dimming systems or step control systems.

HVAC System Sizing

There are primarily two scenarios the energy modeler will encounter concerning HVAC system sizing. In either scenario, the energy modeler will work closely with the mechanical engineer or HVAC system designer to determine how the building is zoned and what type of equipment and efficiencies will be used.

In one scenario, the HVAC system has already been designed, and the energy modeler should obtain from the mechanical engineer or HVAC designer the specification for the selected system, including the capacity, efficiency, and performance curves of the equipment (boilers, chillers, fans, etc.).

The second scenario involves the HVAC designer turning to the energy modeler for assistance determining what type of HVAC system to use. This scenario typically occurs early in the design process to determine life-cycle costs analyses for different types of HVAC systems.

Load Analysis

The designer may have already performed a load analysis to assist the energy modeler. If not, the energy modeler may have to perform a load analysis based on information already obtained. Most modeling software can perform a load analysis in addition to running energy models; however, care should be taken in their interpretation because these "sizing" calculations are often different from standard engineering practice.

HVAC Systems Evaluation

Once heating and cooling loads for the building have been calculated, different HVAC systems must be evaluated. The *2012 ASHRAE Handbook—HVAC Systems and Equipment* provides detailed information about several different types of HVAC systems. It also provides several schematics and examples of component sizing and operation to give a better understanding of the system.

ASHRAE Standard 90.1-2007 provides information on minimum equipment efficiencies in Section 6 *Heating, Ventilating, and Air Conditioning*. Tables 6.8.1A through 6.8.1J provide minimum equipment efficiencies for air conditioning units, heat pumps, chillers, and boilers based on equipment capacity.

Fresh Air Ventilation Requirements

An additional consideration that must be taken into account on the HVAC system is fresh air ventilation requirements, which are based on the classification of the space being served, the number of people in the space, and the overall square footage of the space.

Section 6 *Procedures* of ASHRAE Standard 62.1-2007 provides detailed equations for determining the ventilation rates, and Table 6-1 in ASHRAE Standard 62.1-2007 provides the minimum ventilation rate based on occupancy category.

Energy Modeling Software

Several energy modeling software programs provide tutorials on how to set up HVAC systems. Some programs define HVAC systems by system type, such as variable air volume (VAV), packaged single zone (PSZ), parallel fan powered (PFP), etc., while others may require the modeler to configure them from fundamental HVAC components, such as fans, chillers, boilers, etc.

Software user manuals are also good references in providing information on how to use the program to set up HVAC systems. There are also good online forums for energy modeling professionals to ask questions and give feedback on different software programs and modeling methods. One example is energy-models.com/forum.

Several software programs have also prepopulated these rates and equations to assist the energy modeler. However, depending on where the building is located and how fresh air is introduced into the building, energy use associated with conditioning outdoor air can be significant.

The HVAC system designer will need to be involved to determine if the fresh air will be introduced through the HVAC system, an energy recovery system, or through natural ventilation. Section 6 of ASHRAE Standard 90.1-2007 contains several requirements concerning when systems are supposed to use specific fresh air requirements such as energy recovery systems and economizers.

Operating Profiles

Once again, the building owner will need to be consulted to determine how the building is going to operate. This will include profiles concerning when the building will be occupied and at what density, lighting operation, energy management control systems, cooking operations, ventilation schedules, and miscellaneous equipment operation such as computers, printers, and copiers.

The building owner or architect may or may not be able to provide you all of this information. However, almost all energy modeling software programs provide typical operating profiles to assist the energy modeler with quick results. In any case, until there is an actual building being used, these profiles are assumptions based on prior experience or rules of thumb.

In many instances, such as for code compliance or building energy labeling and voluntary utility programs, operating profiles and internal loads, are purposely kept fixed to ensure all calculations are done under the same rules, preventing any "gaming" of the results. In those cases, the objective of the energy modeling is less to predict building energy use, but to provide a neutral asset rating for a building, including its HVAC system.

Operating profiles also play a critical role when using energy models for determining measurement and verification on existing facilities. By establishing a baseline performance energy model, ECMs that have been implemented in a facility can have their performance measured. By using energy modeling analyses to determine the amount of energy a facility should be consuming during a retro-commissioning project, operating adjustments can be made in the facility to fine-tune the building's operation and reduce operating cost.

Energy Rate Structures

The last piece of the puzzle is to enter the utility rate structures into the modeling software. This information, typically obtained from the building owner, is a document that provides information on previous energy rate structures. It gives information on a utility consumption rate, such as a kilowatt-hour for electrical consumption and hundred cubic feet or cubic meters for natural gas. It also gives a demand charge if one is present. However, in some cases, the building may have purchased chilled water, heating water, or steam in addition to a standard electric or natural gas rate. This information is crucial in determining energy cost savings as well as payback information on various elements of the design. When considering payback periods, the energy modeler will also need to provide an inflation rate to anticipate the rise in utility costs over the study period.[3]

Energy Modeling in ASHRAE Standard 90.1

ASHRAE Standard 90.1-2007 provides energy modeling information when modeling using certain modeling methods. Section 11 contains the requirements for the energy cost budget (ECB) method, whereas Informative Appendix G contains the requirements for the performance rating method (PRM), which is used by voluntary labeling programs such as LEED.

Verifying Energy Model Accuracy

Energy models produce results that are used for determining design decisions on buildings. In some cases, energy models may be the only tool capable of producing the data required to make these design decisions.

But, how do we know the data we are using is accurate? Seasoned energy modeling professionals have typically found a comfort level when reading energy model results. They have been through the process enough times to recognize when they need to throw a red flag, especially those who have been involved in measurement and verification scenarios.

This leaves newer, less experienced energy modelers sometimes questioning their results, and they may be given the "That looks about right" quote from their more seasoned peers. So, how do they get the experience they need to become more comfortable?

One of the most effective means of verifying energy model accuracy is through actual measured utility data. A building user will need to agree to provide this information to the modeling professional to assist with the comparison. Having measured utility data allows the energy modeler to compare the overall modeled results with actual data, which is beneficial to help people learn how occupancy and operations affect the overall energy consumption of a facility. The data also provides information on unusual consumption caused by climate peaks and valleys and can assist in determining if there is an operations problem within a facility.

However, the downfall of this approach is that for most cases, only total building energy consumption data is available.[4] This makes it difficult to break out the energy use for building subsystems such as HVAC, lighting, and receptacle loads.

To provide a meaningful exercise, the energy modeler may have to resort to comparing subsystem energy use with typical consumption percentages developed by third-party analysts. This approach will help determine if the model is predicting highly unusual results in a specific area, but will still not produce 100% model accuracy.

Installing submetering systems in buildings has given the energy modeling field a terrific opportunity to verify energy model results. Submetering allows the actual measured data to be broken down into subsystem categories. The subsystem energy use can then be compared and analyzed against the model to produce more accurate results in the future, but will still require information from the building user to help determine how the building is being operated.

During the energy modeling process, several assumptions have to be made on everything from lighting operation to thermostat set points to occupancy schedules. By obtaining this information, the energy model will be capable of producing results that are closely similar to the actual energy consumption of the facility.

Through these exercises, energy modeling professionals can view the accuracy of their energy models and determine what adjustments best fit their modeling approach. The more that is understood about the modeling process and actual building operation, the more accurate predictions can be made, resulting in more informed design decisions in the future.

Conclusion

Energy modeling is complex and incorporates several disciplines to obtain an accurate finished product. The results produced by the energy model will be used to make decisions on the current project as well as future projects. In complex facilities, energy modeling may be the only design tool available for decision making. Using appropriate resources to make as detailed a model as possible will assist in producing an accurate energy model.

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