HOW TO CONDUCT ENERGY SAVINGS ANALYSIS IN A FACILITY VALUE ENGINEERING STUDY

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Biography

Benson Kwong is an independent consultant providing services in value engineering, energy analysis, sustainability design, and life cycle cost analysis. He holds master degrees in mechanical and electrical engineering, as well as in business administration. As the president of enVErgie consulting, LLC, Benson Kwong provides consulting services to facility owners, designers, and contractors, to help achieve projects that are energy efficient, sustainable, and economical.

Abstract

Energy cost analysis during the design phase can lead to substantial life cycle savings in facility projects. It is a good issue to be addressed by a Value Engineering (VE) team since it requires an interdisciplinary approach. A systematic understanding of energy cost analysis is helpful to develop quick, accurate, and versatile calculations of energy savings in a VE setting. This paper will survey the different approaches for energy cost analysis (computer modeling, engineering calculations, and standard energy cost) in a VE study and discuss the merits and drawbacks for each.

ENERGY USE FOR FACILITIES

According to the US Department of Energy, buildings consume 40% of total US energy use. Energy conservation in facilities and buildings would make a significant impact in the overall sustainability of the modern society. Facility tenants, designers, contractors, and owners are increasing aware of the role that they play in demanding, designing, building, and operating energy efficient buildings to lower the carbon footprint. The value engineering community must be prepared to address energy conservation as a major design goal in a facility project and to create, evaluate, and develop proposals that would quantify energy savings.

A building uses energy typically for the following functions:

- Cool Space
- Warm Space
- Circulate Air
- Circulate Water
- Light Interior
- Illuminate Site
- Refrigerate Perishables
- Cook Food
- Operate Equipment
- Transform Power
- Conduct Power
- Move People/Material
- Heat Water

It is useful for analysis purpose to create an energy model to illustrate the energy consumption by function. This is similar to using a cost model to identify high cost items in a Pareto analysis. A typical breakdown is provided in Figure 1.

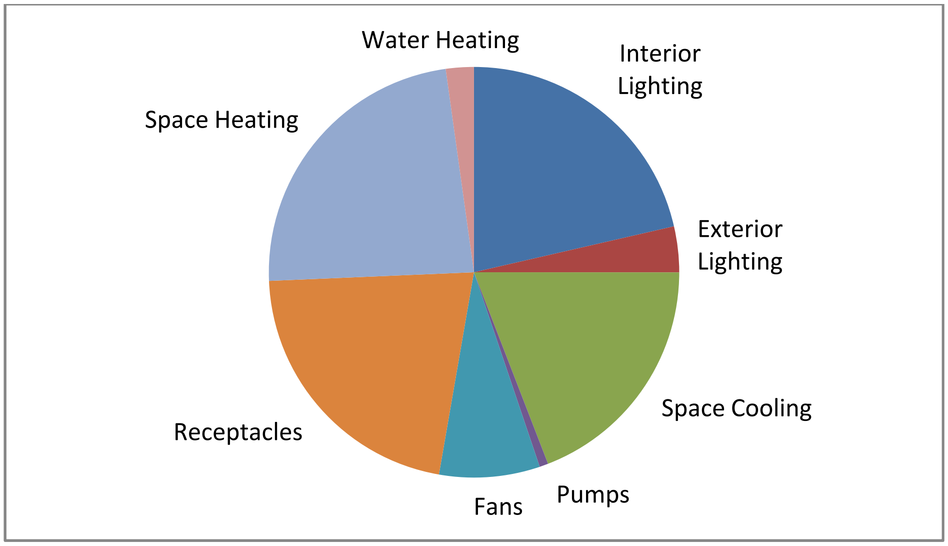

FIGURE 1 – EXAMPLE OF BUILDING ENERGY USE DISTRIBUTION

CRITERIA FOR SELECTING ENERGY COST ANALYSIS METHODS IN A VE STUDY

VE provides an opportunity to reduce energy use in a facility project. Because energy consumption is an interdisciplinary subject that involves the architect, mechanical engineer, and the electrical engineer, the VE study is an excellent occasion to bring the various disciplines together to seek the optimum means to reduce energy use. A VE study also provides a forum to get the owners and users' perspectives and input, which usually reflects the long term value of operating the facility. Energy conservation is a natural fit with the value methodology, which by its nature looks for ways to optimize the project design.

Conducting energy cost analysis in the context of a facility VE study poses some challenges. A facility VE study is typically a short (3 to 5 days) effort to provide a second look of a design in progress. Project documents, including drawings, are often provided shortly before the start of a VE study. Many of the building system parameters may be missing due to the early phase of a design. The VE team does not always have the time, information, and resources to conduct an in-depth energy cost analysis. Trade-offs between various requirements of an energy cost analysis may be necessary.

The basic requirement of an energy cost analysis is accuracy. There will be some inherent uncertainty in estimating energy cost. Because energy cost, unlike construction cost, is expended over a long period of time, the future energy rates, inflation rates, discount rates, all contribute to a large degree of uncertainty. However, we are not aiming to calculate the total energy use, but just to evaluate the impact of the proposed changes in design to energy use. This is similar to the cost estimating required in a VE study – the cost savings is the difference in cost between the proposed and the original design. The total cost of the original or the proposed design is immaterial.

Besides accuracy, another requirement for selecting energy cost analysis method is speed, or ease of use. Given the short lead time of information, and the short duration of a VE study, it is important to have a tool that can calculate energy cost quickly.

The last requirement would be versatility. The approach selected should be capable of evaluating different calculation needs that may arise during a VE study. The VE team would not be able to anticipate the most promising area for energy savings until it has gone through the information and the analysis phases of the VE study. The energy cost analysis approach selected must be sufficiently versatile to accommodate calculations in HVAC systems, lighting systems, building envelopes, and other systems that may impact energy use.

We will discuss and evaluate three approaches to energy calculations: computer modeling, engineering calculations, and standard energy cost.

COMPUTER MODELING

The most accurate method to calculate energy savings is to use computer model for building energy simulation. These simulations are increasingly popular, especially for projects involving LEED certifications. Under LEED 2.2, computer modeling is the only way to enable the project to claim up to 10 energy conservation credits. Other options can only claim up to 5 credits. If an energy simulation model is already been developed by the design team, it could be used by the VE team to calculate energy impacts of the VE proposals.

Many different software are available on the market for energy simulation. The one with the longest history and widest acceptance is DOE 2, developed by the US Department of Energy. DOE2 is a free program, however, there are many commercially available user interfaces which make the program more user-friendly. EnergyPlus is a newer and improved version of the DOE 2 program. There are also programs independently developed by HVAC equipment manufacturers, such as HAP and TRACE.

All these energy modeling software simulate the building envelope, the internal load (lighting, equipment, and occupants), and the HVAC systems. The input includes the following:

- Project location
- Utility schedules
- Building configuration and orientation.
- Envelop details, including composition of walls, roof, floor, windows, and skylights.
- Lighting power density.
- Automatic lighting control systems.
- Receptacle power density.
- Occupant load.
- Building operation schedule.
- HVAC system, including characteristics of fans, and controls.
- HVAC plant, including characteristics of chillers, boilers, cooling towers, and pumps.
- Domestic hot water system.

If the information is not available, the model can still be set up with typical values. ASHRAE standard 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings," provides a good baseline of default values. There is minimal loss of accuracy in using default values. For example, the boiler efficiency may have been entered as a default value of 80%. This allows the model to function and permit fine-tuning to take place later. During the analysis phase the VE team discovers that the specified efficiency is 82%, the model can then be changed to reflect the more accurate value. But even if it is not changed, any proposal that involves heating energy would only be about 2% less accurate.

The output of the energy simulation is energy use by systems, as shown in Figure 1. The program can also calculate energy cost, if the utility rate structure is loaded in the model.

The drawback of using energy simulation is the time that it takes to create the model before the VE workshop. However, once the model is created, it is easy to test the impact of various changes on the building energy use. If a building energy simulation is available from the design team, it would be a useful tool for the VE study. It may be beneficial to include the energy modeler from the design team in the VE study, unless there is another VE team member who is familiar with the particular software used to develop the energy simulation.

ENGINEERING CALCULATIONS

Most of the typical VE proposals deal only with a single aspect of the building, such as insulation, equipment efficiency, and lighting density. The energy cost impact can be calculated by using engineering formulas that approximate the value of energy use. The approximation comes from simplification of the calculations through estimating quantities, ignoring the minor or secondary effects, and using average values.

We will illustrate the methods with three examples:

Example 1 – Increase roof insulation value

The thermal loss through the roof involves both the conduction through the roofing and insulation material, convection on the horizontal or sloped surface of the roof, and radiation through thermal emissivity and reflectance of the roof surface. The predominant heat transfer mode is conduction. The basic heat transfer equation for conduction is:

Energy = delta T x U value x area x time / HVAC Efficiency

The convection effect can be incorporated into the U-value. The radiation effect can be incorporated by increasing the outside temperature to account for the effect of solar radiation to the roofing surface. This is called the sol-air temperature.

We will need to estimate both heating energy for winter and cooling energy for summer. U-value is determined by the roofing material and area is simply the roof area. Delta T is the average temperature difference between indoor and outdoor (including the sol-air effect). Time is the number of hours for the heating or cooling seasons. For example, in the mid-Atlantic region, typically cooling hours for an office building may be 60 hours per week for 13 weeks and typical heating hours may be 168 hours per week for 13 weeks. Average cooling delta T would be about 15F, with a sol-air temperature increase of another 10F. The sol-air temperature would depend on the emissivity of the roofing material. Heating delta T would be about 25F. The rest of the year would be the shoulder seasons when thermal losses through the roof are negligible. More accurate figures can be obtained from using heating and cooling degree days data and calculations of the sol-air temperature. These data and formulas are available from the ASHRAE handbooks.

Thermal loss needs to be translated to energy for cooling and heating. Cooling efficiency may be around 1kW/ton, and would need to be determined for each project. Heating energy is also dependent on the efficiency of the heating equipment and is typically at about 80%.

Example 2 – Improve chiller efficiency

Chiller efficiency can be improved by simply specifying a different type of model of chiller equipment. The basic equation for calculating chiller energy is:

Energy = chiller load x time / efficiency

The average chiller load can be estimated by a percentage of the peak load. Typically 25% to 50% of the peak load could be used, depending of the type of cooling load for a given project. For most commercial buildings the chillers are required whenever the building is occupied. For a computer center it would be required at all time. The most accurate efficiency value to use would be an integrated part load value (IPLV) which takes into account the time that the unit generate chilled water at full load as well as at various part load level. New chiller IPLV can vary widely from 1.25 kW/ton (standard efficiency air-cooled screw compressor) to 0.38 kW/ton (high efficiency water cooled centrifugal compressor).

Example 3 – Reduce lighting power density

Lighting power density (LPD) is the Watts per square foot of installed lighting fixtures. The basic equation for calculating lighting energy is:

Energy = LPD x area x time

The LPD can be calculated by counting the number of light fixtures in a typical area and multiply by the wattage per fixture. For a ballpark estimate the fixture wattage can be approximated by the number of lamp times the standard lamp wattage. However, the actual wattage per fixture depends also on the ballast and a more accurate accounting can be obtained by consulting tables provided by the ballast manufacturers. Minimum requirements of LPD for various occupancies are provided in ASHRAE 90.1. The time factor would depends on the building operation schedule. It may be affected by the lighting control system, such as occupancy sensors, time switches, and automatic dimming.

The above formula ignores the heat produced by the lighting which would affect cooling and heating loads. More lighting energy would require more cooling in the summer and less heating in the winter. These secondary effects can be calculated, if additional accuracy is desired.

The best applications for engineering calculations are where the proposed changes are in a single attribute of the building design. One drawback for using engineering calculations is that often approximations are used and the results would be less accurate than a full scale energy model.

STANDARD ENERGY COST

A standard energy cost is a constant quantity of energy use per square foot of building. A good source to estimate such a square foot quantity is the Commercial Building Energy Consumption Survey (CBECS) conducted by the Energy Information Administration of the DOE. The survey provides an average energy use for various building types. For example, for a library, the average source Energy Use Intensity (EUI) Is 246 kBtu/SF, 59% of which is in the form of electricity, the rest (41%) is in the form of natural gas. Source energy is a measure that includes the energy consumed on site, as well as the energy consumed during generation and transmission of the energy to the site. We can calculate the site energy use as follows:

	% Source energy	Source energy (kBtu/sf)	Site energy (kBtu/sf)	Site energy (billing unit)	Billing Unit
Electricity	59%	145	43.46	12.72	kWh/SF
Natural Gas	41%	101	96.33	0.96	Therm/SF

TABLE 1 - ALCULATIONS OF STANDARD ENERGY USE

Note that for some building types, such as offices and hospitals, the EUI requires using the Target Finder, a tool available on the Environmental Protection Agency's EnergyStar website. This tool is able to calculate EUI for buildings with multiple function types, and also takes into account the weather condition by requiring the site's location. It is also capable of providing not just the average EUI, but for any percentile required. For a facility being designed, a 75 percentile is more appropriate than using the average. This means that 75% of all buildings similar in size, location, and occupancy have higher energy use.

Once a site energy is established on a per square foot basis, the total energy and energy cost for the facility can be calculated. Changes in building size or source energy type will impact energy cost directly. This tool is only useful in VE proposals that change the building size, building type, or source energy. It is not applicable for proposals that address specific building systems.

CONCLUSION

Table 2 provides a summary of the comparison among the three approaches to calculating energy cost impacts.

	Speed	Accuracy	Versatility
Computer Model	Low	High	High
Engineering Calculations	Medium	Medium	Medium
Standard Energy Cost	High	Low	Low

TABLE 2 – COMPARISON BETWEEN DIFFERENT APPROACHES TO CALCULATING ENERGY COST

The most accurate method to estimating energy cost impact of VE proposals is to use an energy simulation. However, it will require detail information or assumptions regarding the building and its systems prior to the VE workshop. Once the simulation model is set up, it can be used to evaluate the energy use impact of multiple changes in design.

If an energy simulation is not feasible due to lack of time, resources, or information, then the VE team could use engineering formulas to calculate and approximate the energy cost impact. The accuracy and ease of use for such methods are typically adequate in a VE setting, where there are only a couple of days to develop proposals.

A standard energy cost could be useful, especially for VE study that are at the conceptual level, for evaluating energy impact in varying the building sizes or fuel type.

In all three approaches, an energy engineer with the appropriate qualification is needed as a team member. In most cases, this team member would have a background in mechanical engineering, because that is the most involved area in energy calculations. Qualification such as a Certified Energy Manager (CEM) may be one indication of knowledge and experience in energy engineering.