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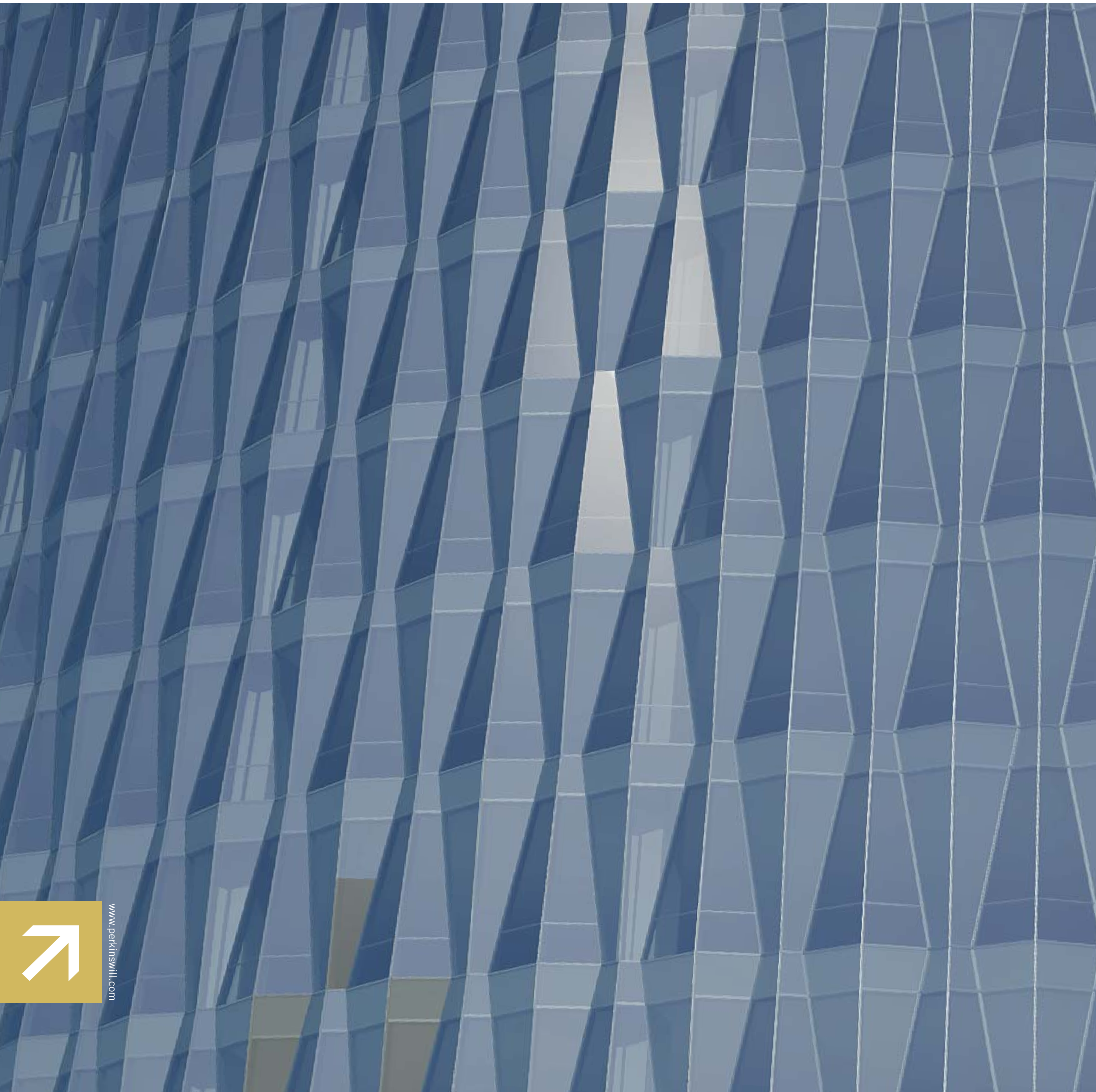

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ENERGY MODELING GUIDANCE:

Guidelines for Energy Analysis Integration into an Architectural Environment

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ABSTRACT

Designing energy efficient buildings requires an understanding of the energy impact of design features and how they interact with each other during the design process. This article outlines how and when an energy analysis can be conducted including guidelines for what to expect in an energy modeling analysis and how to interpret and understand the results. Guidance is provided in how to measure building systems and operations to align actual building performance with expected results from an energy modeling analysis. This article also describes several quick methods to do energy analysis at early design stages of the project. Resources are also provided to assist design teams in understanding the relative performance of proposed building designs compared to other similar building types in the industry.

KEYWORDS: energy, simulation, benchmark, design assistance, ASHRAE, GHG emissions

1.0 INTRODUCTION

Energy efficient and low impact building design continues to be a challenge as teams strive to predict actual building performance for each hour of the day and for all weather scenarios and operational schemes. Projecting how sequenced and demand-controlled mechanical systems react to complicated geometry is required to optimize how design features interact with each other. For architects to be the most successful at energy-efficient building design, an understanding of the basic principles of energy analysis is critical. This can decrease some of the reliance on external consultants, decrease time to analyze design options and facilitate higher levels of quality assurance in efficient building designs.

This article will examine the broad questions of when and why energy analysis should be done, how the analysis is conducted, what results are expected from the analysis, what opportunities are available for aligning actual building performance with simulated and resources on how to benchmark a building design.

The final area to be presented in this article is the outline of a quick energy modeling process. The process is not software dependent and urges the designer to develop an understanding of energy interplay and design impacts.

2.0 ENERGY MODELING SCOPE AND TIMING

It is important to first understand why an energy model needs to be done, what results are wanted and then craft the proposal call for the modeler to meet the project needs. Some of the reasons to use an energy model include:

1. Code compliance and/or estimating project energy use.
2. Early-stage model informing design or providing design assistance.
3. Progress models during design to ensure the project remains on track for energy or emission targets.
4. Model submission for LEED or equivalent.

A general rule of thumb for energy modeling is the more ambitious the project goals, the more extensive the energy modeling process. This tends to be because as the project gains ambitious goals for energy efficiency, energy conservation measures are designed to interact with each other and associated calculations increase.

To understand scope of the analysis, the energy model results should include information on the input data, the annual energy used, breakdown of the energy used by energy use type and per floor area, energy cost for LEED point calculations and GHG emissions (overall tons and per floor area).

2.1 Code Compliance or Project Energy Use

This is the basic level of energy modeling and it may be required to demonstrate code compliance for permits and/or to estimate the projected energy needs for a project. A single energy model done at or near the completion of design could be provided to demonstrate compliance or estimated energy use for the project.

2.2 Design Assistance

Energy modeling can be used to inform the design process and can include either a quick model at project initiation, a concept-stage design assistance model or iterative models analyzing energy conservation measures.

A quick model at the start of the project can provide the order of magnitude project energy needs and review basic design options. This can be done in several days if the project is a simpler design or a couple of weeks for a complicated project. The energy modeling input requirements at this stage include a starting point for the building envelope and basic system parameters. The ASHRAE Advanced Energy Design Guides (http://www.engineeringforsustainability.org/aedg.html) can provide a starting point for the building parameters, as noted in the "Energy Modeling Methodology" section. If detailed modeling is required at a later date, it is likely necessary to start a new model due to the general assumptions made in the preliminary model.

Design assistance at the concept design stage can use the initial building design model to evaluate design and system options and can include:

- Building orientation and shape.
- Envelope performance including insulation levels, window-to-wall ratio (glazing percentage), glazing performance and exterior shading devices on various façades.
- Mechanical system and lighting options.
- Various energy conservation measures (ECMs), which can be reviewed and preferred groupings assembled for an energy simulation to incorporate the interactions between the options. This would form the basis of design and performance for that phase of the project.

Typically, simulators will model the building systems exactly as instructed by the designers, although examining envelope and system options is possible. If the engineers and designers are not innovative, the project will be designed as usual. An advantage of using energy models is that they can be used to consider building and system alternatives and then to inform the design.

2.3 Progress Models and Model Updates

Model updates during design can be carried out if desired. If no significant changes are made during the design process, the need for updates is reduced. Model updates can be made at the end of each of the design phases like schematic design, design development and contract documents (CD). It may be advantageous to have the model updated toward the end of the CD phase to verify that the project is still meeting energy targets with time remaining for adjustment if necessary. Sometimes project design intentions go astray as designers fall back to old practices. Without some intermediary updates, the LEED submission model results may be a surprise.

2.4 Compliance Modeling for LEED Submission or Equivalent

The energy model for submission to LEED or equivalent must include information on the components, equipment and systems installed. For example, the installed glazing performance, the number of installed light fixtures and the horsepower of the fans installed are all required. This detailed model will be reviewed by the GBCI (Green Building Certification Institute) for accuracy. Early design assumptions are now verified. For example, lighting at 1 W/ft^2 would be verified by fixture counts. Therefore, estimates for the initial design assumptions must be realistic and should be verified earlier in the design process.

2.5 Proposal Call for Energy Modeling

The request for proposal for energy modeling services should outline the scope required of the model(s), the time frame for model results (i.e. at the end of schematic design) and list the required reports and results. The goals for the project should be outlined. Payment for energy modeling services should be tied to the completion of the various stages of the model. If the energy model is done by, for example, the mechanical engineering consultant and a model is required for schematic design, the payment for schematic design services should not be fully paid out until the model for that phase is completed appropriately.

The size and complexity of the project design are key factors that can affect the length and effort of the modeling process. For example, if all the floor plates are different sizes, this will generally require the modeler to trace each floor plate separately, compared to a singular floor plate that can be copied within the energy model.

3.0 ENERGY MODELING METHODOLOGY

Energy models are created to demonstrate compliance with a code or standard, to consider the performance of design options and to estimate the potential energy use of a building. Energy codes and LEED use standards such as ASHRAE 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings), IECC (International Energy Conservation Code) and California's Title 24 to establish the minimum performance baseline, generally by specifying the minimum performance of components or equipment. A building performing equal to the standard is referred to as the *base case* (or baseline case or reference case).

The relationship between the various ASHRAE 90.1 standards is quite confusing. LEED V2.2 refers to the 2004 standard and LEED 2009 refers to the 2007 standard. The IRS Section 179D Code for Energy Efficient Building Tax Deduction refers to a baseline built to the 2001 standard. The proposed 2010 standard is said to be 30 percent less energy than the 2004 standard. The following graph, Figure 1, from the March 2010 ASHRAE Journal may assist in understanding the changes in the ASHRAE 90.1 standard.

Figure 2, indicates the ASHRAE Board's plans for future development of the energy related standards. The targets for the Advanced Energy Design Guides (AEDG) and the new Standard 189.1 are net zero energy. The clear trend is towards new buildings that use significantly less energy. It is good practice to consider the building's energy performance on opening day rather than just meeting the current minimum energy code performance.

A building design often uses a combination of elements that are not as outlined in the design standard, such as using 50 percent glazing when only 40 percent glazing is called for in the design standard. The energy model of the building design, called the *proposed case*, is created to demonstrate equal or improved performance compared to the base case. The calculations for the number of LEED energy points, obtained in Energy and Atmosphere credit 1 (EAc1), will require a percentage energy COST reduction compared to the base case. The energy model is used to demonstrate the potential performance of the proposed building.

The energy model can provide the following information for various uses:

- Energy Use - for energy benchmarking (kBTU/ft² or kWh/m²).

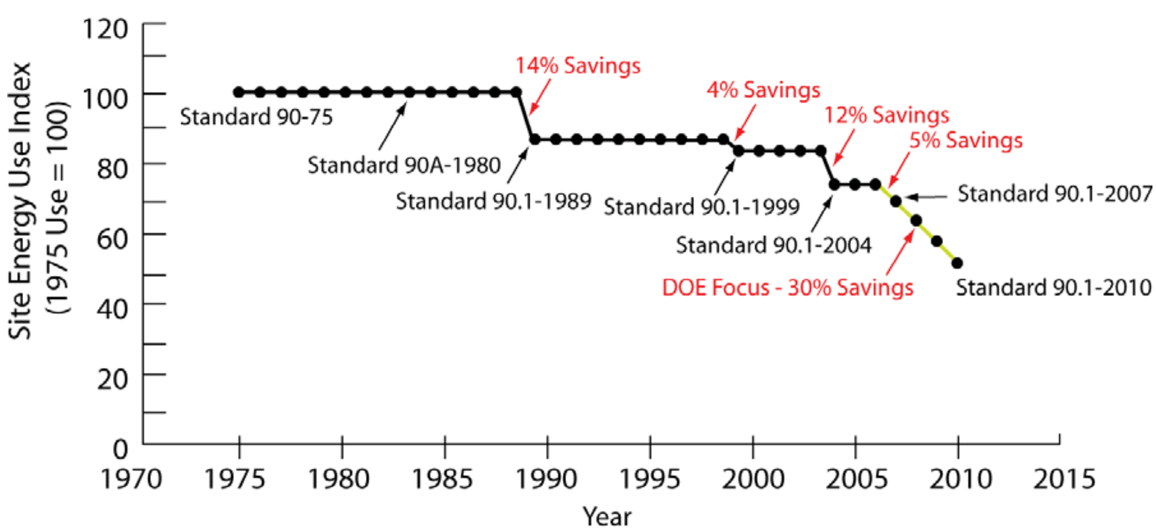


Figure 1: Improvements in the ASHRAE 90.1 code over time. ©2010, ASHRAE (www.ashrae.org). Used with permission from ASHRAE[1].

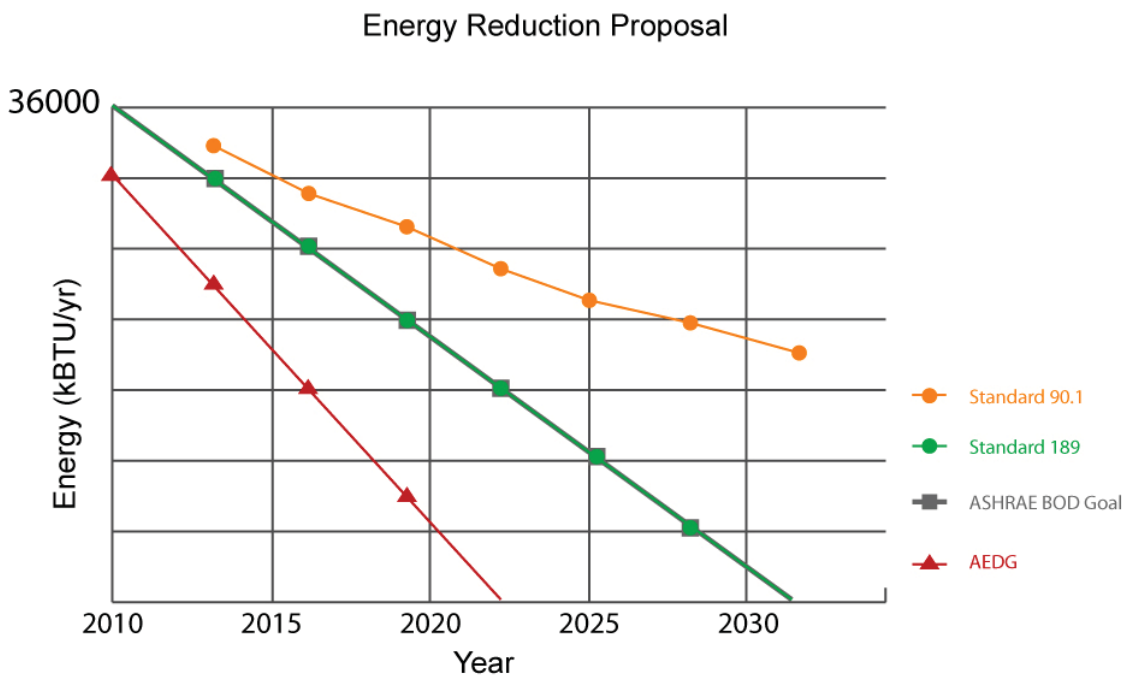


Figure 2: Improvements in Standards, Advanced Energy Design Guides, and the ASHRAE Board of Directors Goals. Used with permission from ASHRAE[2].

- Energy Cost - for LEED EAc1 point evaluation.
- GHG Emissions - for 2030 Challenge and emission calculations (tons/yr or lbs/ft²/yr).

In preparation for energy modeling, the goals for the model should be clearly understood. Goals could be either LEED Energy points with energy cost, 2030 Challenge, Energy Benchmarking in kBTU/ft² or a combination of these. The building and system design options that are considered may not target all three of these issues equally.

Typically, an energy model will be created for both the *base case* and the *proposed design case* and the results will be compared. The "game" in energy modeling is to make the base case perform as badly as possibly while making the proposed case as good as possible for the best percentage energy cost improvement while abiding by the rules and guidelines for energy modeling.

3.1 Project Location and Weather

Weather station information in the form of a TMY (Typical Metrological Year) or similar file has weather information for all 8,760 hours in a year. Each hour has, for instance, dry bulb and wet bulb temperatures, humidity, solar loads and cloud cover. The hottest and coldest hours are not included so the simulation is not a design load tool. The building operation is simulated for each hour of the year. If a weather file is not available for the exact project location, a representative weather file should be used based on temperatures and heating/cooling degree days.

Energy utility rate schedules are input so that the energy cost can be determined. (That energy cost is used for LEED point calculation and not energy quantity.)

3.2 Geometry and Envelope Performance

Both the baseline and proposed cases will use the same building shape so any benefit of building shape will not be realized when the results are compared. Energy saving benefits associated with building orientation are available when comparing to the ASHRAE 90.1 baseline case.

The building is divided up into zones that will act differently from an energy perspective. Zones for a simple office building might include the north, south, east and west perimeter zones (perhaps 15ft deep), corner offices and the office interior. Zones in a school might include the classrooms. The zoning of the building avoids the sun on the south side of a building directly offsetting a heat loss on the north side and creates more realistic building loads.

The insulation values of the walls, roof and floor for each zone are input with the construction factors such as thermal mass. Glazing performance with insulation, framing, solar transmission and visible light factors are input with the orientation. Shading devices can be added. Often the energy codes have a maximum glazing allowance of 40 percent of wall area. If the proposed building has 50 percent glazing, the base building would have only 40 percent glazing and the difference is made up using wall construction elements. Therefore, the additional glazing area may make an energy target more difficult to achieve.

The glazing, wall, roof and floor performance for the base building is dictated by the energy code or reference standard. The performance factors for the proposed building originate with the design team. Energy models done at concept and schematic design might use estimated envelope performance factors. Models done later in the design period should use the actual calculated performance from the architectural details.

Changes in the design at later stages of the project can result in a considerable amount of work for the energy modeler as a lot of data in a large number of zones has to be changed and inputs are not generally grouped for easy alteration.

3.3 Internal Loads

Internal loads include the number of people, lighting loads, equipment loads and the associated schedules of usage/operation. Often design levels of ft^2/person, lighting W/ft^2 and plug load allowances in W/ft^2 are input for the various uses in the building. Profiles or the schedules of how these loads vary over the 24 hour day for weekdays and weekends for the various building uses are entered. A project may have office, retail and residential uses. Each of these different uses would have different occupancy densities, lighting power densities, load allowances and profiles. Whether the lights in an area are on for 12 hours/day or 18 hours/day will obviously use different amounts of energy. While the number of people and plug loads would be the same for both the base and proposed cases, the lighting power for the base case is dictated by the energy standard and the design informs the proposed case. Standard profiles can be used for office, schools or other building types and these may be acceptable for LEED and other purposes. If actual $kBTU/ft^2/yr$ energy use is to be modeled, more detail on actual usage profiles is required. A typical office space occupancy profile and lighting profile are shown below in Figure 3.

The profiles, or schedules of operation, are used to apply the internal loads in a building. For instance, in the office occupancy profile above, it can be seen that occupants arrive between 8AM and 10AM, some occupants leave the office around lunch-time and then occupants leave gradually from 5PM onwards. In contrast, the lighting profile shows that the lights, once turned on, remain on for the course of the work day. Using schedules to apply the internal loads helps to produce realistic annual energy use numbers during simulation.

3.4 Mechanical Systems

The proposed mechanical systems for the building zones are simulated in varying levels of detail. System types such as VAV with reheat, fan coil or roof top units

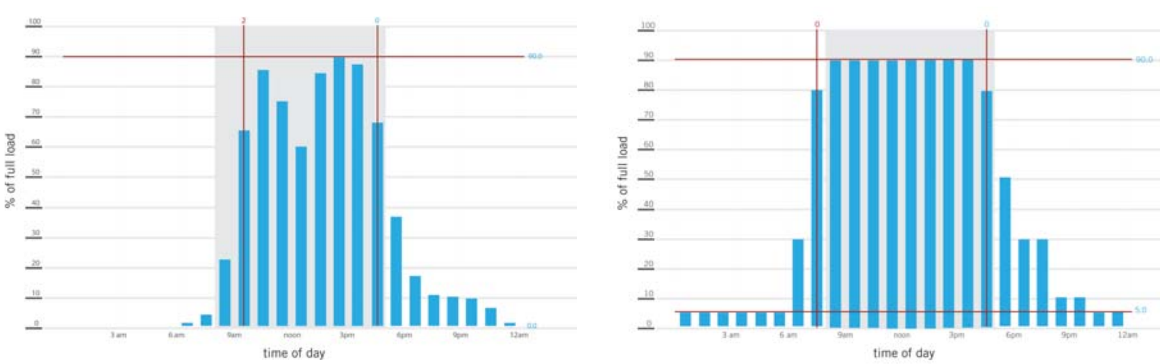


Figure 3: Typical office space occupancy profile and lighting profile for a certain day shown in the eQUEST interface.

may be used. Heating may be provided by gas, electric or other sources. Cooling may be provided by a group of chillers, direct expansion rooftop units or other systems. The equivalent base building systems are determined in the energy codes and standards by the type of proposed system, energy sources and the project size in the proposed case.

The performance parameters of the various systems are input including horsepower rating of fans and pumps, efficiencies of equipment and operating parameters. Requirements for heat recovery and operating strategies are also included.

Control strategies such as daylight control of lighting, occupancy control of lighting and ventilation and others can be considered initially or in individual studies.

3.5 Work-Arounds

Each of the energy simulation programs has standard approaches to equipment types and operations. For some innovative design approaches, simulation work-arounds are necessary. For example, if a chilled beam system were used it may need to be modeled as a fan coil system with no fan energy. Each of these work-arounds should be identified by the energy modeler. Work-around approaches may require considerable time and effort from the energy modeler, possibly with feedback from the designers.

3.6 Quick Inputs

For initial quick energy models or starting points for more efficient building designs, a summary or table of the building and system input parameters should be provided to the modeler. The team may consider using the performance tables in the ASHRAE Advanced Energy Design Guides as a starting point. There are six building type guides that are free and target a reduction of 30 percent energy cost compared to ASHRAE 90.1-1999.

3.7 Energy Conservation Measures (ECM's)

Once the base and proposed case energy models are built, a number of alternatives can be considered individually and assembled into different combinations. This analysis can inform the early design so that decisions can be made based on energy, comfort and cost considerations. ECM's might consist of:

- Different glazing performances or glazing areas,
- Different wall and roof insulation levels.
- Exterior shading options with or without daylighting.
- Mechanical system types and efficiencies.
- Different energy sources, boiler efficiencies, and chiller efficiencies.
- Different lighting levels and control strategies.
- Heat and coolth recovery options.

The ECM's can be reviewed and combined in different ways to evaluate the interactions between the ECM's. For example, a lower lighting power level may cause an increase in the heating load.

3.8 Model Review

The review of the energy model by the architect will probably not be a detailed review, but a few issues should be considered:

- Do the results make sense? For example, the lighting system did not change much from the base case, but the lighting power is significantly down – Why?
- Does the breakdown of energy per end use make sense?
- Are the schedules used correct? Is the building intended to be open 24 hours/day, but only modeled as a typical 9AM – 5PM schedule?
- Are the project goals of LEED energy points, energy use target and/or 2030 Challenge target being achieved? If not, what improvements can be made and at what cost?

3.9 Simulated Versus Actual Building Performance

Energy modeling is a useful comparison tool for building envelope and system options. To have the energy model produce a reasonable estimate of the actual building performance, a number of areas require more detailed information than is typically used. These include:

- Detailed building occupancy loading and schedules of occupancy including, for example, when the janitors are working.
- Actual lighting loads, including task lighting and incorporating in controls, if they exist. The accompanying schedules of usage for the lighting are also needed.
- Actual equipment loading and schedules of how they operate at night and on weekends. Plug-in equipment like personal heaters, fans and additional computer equipment needs to be included with schedules of use.
- Actual mechanical system operation such as temperature set-points or control strategies.

ASHRAE 90.1 (and other) energy modeling rules prior to the ASHRAE 90.1-2007 Standard excluded process loads (like a data room and similar loads) as well as exterior lighting, elevators and similar. These loads could increase the electrical energy use by 25 percent. In the 2007 Standard, these loads are to be included in the energy model. The trend is moving towards energy model results getting closer to actual operating results.

The actual energy use in a building is influenced by the building design, the building occupants, the building operation and commissioning. Designers have control over only some of these factors.

Energy codes using actual energy performance and building operation labeling are becoming more common. Actual building energy use is becoming a major consideration in the design and operation of buildings.

3.10 Overview of Selected Typical Energy Simulation Software

Each energy modeling program has capabilities and limitations. The following information provides a brief outline of the capabilities of commonly used energy modeling programs.

Trane Trace 700 and Carrier HAP: These energy analysis programs were written by large international HVAC system manufacturers. These programs are useful for modeling conventional building designs and equipment as provided by these manufacturers and for sizing equipment. These programs do not respond well to new and non-conventional design approaches.

eQUEST, EE4 and Visual DOE: These energy analysis programs are based on Department of Energy (DOE) engines or analysis approaches. Typically, these have a broader range of mechanical systems that can be modeled, but have a North American bias to systems and envelopes that are considered. eQUEST (Quick Energy Simulation Tool) and EE4 are free downloads.

IES Virtual Environment and TAS: IES and TAS are UK based programs that have a broad range of capabilities. A number of European approaches have been included as well as more North American approaches. IES now offers ASHRAE calculation protocols for the North American market. Building heating and cooling loads, effects of thermal mass and natural ventilation, daylighting, basic Computational Fluid Dynamic analysis and energy modeling can be carried out. IES is becoming more common in North America. TAS is similar to IES but does not have as significant a market penetration in North America.

TRNSYS: TRNSYS is not commonly used for energy modeling in North America. TRNSYS is a unique tool that can analyze complex and interactive building systems that other tools cannot consider.

EnergyPlus: The Department of Energy has combined a number of energy analysis tools into one. Building researchers often work with this tool, however, few commercial energy modelers use the tool as it is complicated. Efforts are underway to provide a windows interface to the tool that could make it more easy to use.

Additional tools and resources are provided in Section 6.3 of this article.

4.0 DELIVERABLES FROM AN ENERGY MODELING ANALYSIS

4.1 Report Overview

The energy modeling report should include all of the critical information used to develop the model and the required results. It is not sufficient to only state the anticipated LEED energy points. The list of input information is required to confirm that the model and design data are in agreement. Verification of clear understanding of the project is critical to the accuracy of the results of the model. The energy modeling report should include:

- *Executive summary* – key results of the energy model.
- *Building description* – location, uses and areas.
- *Energy goals for project* – the Reference Energy Code (i.e. ASHRAE 90.1 2007), the modeling program used and the weather data used. Note that various modeling software programs are strong in some areas and weak in others. The software selection should suit the project. At the end of Section 3 "Energy Model Methodology", selected energy modeling programs are discussed.
- *Summary table of inputs* – for base case and proposed case parameters including insulation performance, glazing specifications, mechanical system parameters, lighting power/daylighting/occupancy and additional project features. An example summary table is included later in this

section. Also included is an example from an ASHRAE Advanced Energy Design Guide outlining similar program input data as an industry example.

- *Energy conservation measures* - ECM's and preferred bundles of ECM's. The ECM's are project design options that the team wishes to explore. They may include various envelope insulation levels, glazing options for performance, area shading and mechanical and electrical system options. A description of the ECM's should be provided.
- *Work-arounds* – Work-arounds are needed when the modeling program is only able to use one type of system, but another is proposed. For example, a chilled beam system may be modeled as a fan coil system with no fan energy. This work-around would be described so it can be verified for appropriateness.
- *Key assumptions* – these should be highlighted. Envelope data may be taken at, for instance, R-20 as an assumption rather than detailed takeoffs of construction details; lighting power density may be assumed at 1 W/ft^2 rather than from a detailed count of fixtures. These assumptions would change as more detailed project information is available. Energy models done in the later stages of design should not be using assumptions, but real project data.
- *Energy usage results for base case and proposed case with usage breakdown* – including space heating, space cooling, fans, pumps, lights, domestic hot water (DHW) and plug loads. Results are discussed in Section 4.4.
- *Energy use, energy cost, and GHG emission parameters and emissions* – Results are discussed in Section 4.4.

4.2 Summary of Inputs

An example input summary table is shown in Table 1 for the base case and proposed models.

For each of the assumptions made for the proposed building design, the energy modeler should provide a footnote that indicates the assumption and the source. The sources for the utility rates used should also be provided.

As a starting point for establishing envelope and system performance factors for a lower energy building, the ASHRAE Advanced Energy Design Guides are available for consideration in some market sectors. The guides are aimed at building performance that is 30 percent less than ASHRAE 90.1-1999. Table 2 is an example from the Small Hospitals and Healthcare Facilities Advanced Energy Design Guide[4].

4.3 Work-Arounds

Due to modeling limitations, it is often necessary to create a work-around method or calculation to determine energy savings for a design component or system. The work-around method should be discussed in the report to enable the design team to review the methodology. An example table of model work-arounds is shown below in Table 3.

4.4 Energy Modeling Results

After the models are built and simulated, the proposed design model is compared to the base case model and results are compared by total and by end-use.

The model results can be entered into the LEED Energy and Atmosphere Credit 1 (EAc1) forms with utility rates to determine the energy cost savings. The energy cost savings are used to determine how many LEED points could be achieved through energy efficiency measures.

To help the design team understand the impacts of various ECM packages and to review the models, it is useful to create a visual representation of the savings by end-use. An example comparison chart is shown in Figure 4 (on page 84) with results of energy savings and GHG savings.

Table 1: Example table of simulation inputs with base case data from ASHRAE 90.1-2007[3].

General Building Information	PROPOSED				BASELINE (ASHRAE 90.1-2007)			
Name:	Project Name				Project Name			
Location:	Seattle, WA				Seattle, WA			
Climate Zone	5B				5B			
Orientation of Plan North:	North-West				North-West			
Total number of storeys: (above grade / below grade)	8 storey residential tower				8 storey residential tower			
Total floor area:	104,000 ft^2 (9,600 m^2)				104,000 ft^2 (9,600 m^2)			
Footprint area:	13,000 ft^2 (1,200 m^2)				13,000 ft^2 (1,200 m^2)			
Footprint aspect ratio: (specify orientation)	4.3 on the north-south axis				4.3 on the north-south axis			
Space type(s): (include % breakdown)	100% residential				100% residential			
Hours of operation:	24 hr light occupancy				24 hr light occupancy			
Occupant density:	250 ppl total				250 ppl total			
Floor-to-floor height:	10 ft (3m)				10 ft (3m)			
Average size per unit, or by main unit type:	775 ft^2 (72m^2) per unit				775 ft^2 (72m^2) per unit			
Glazing Information	NW	NE	SE	SW	NW	NE	SE	SW
Window-to-wall ratio per face:	40%	40%	40%	40%	40%	40%	40%	40%
% of windows with horizontal shading (per face):			100%	100%			0%	
Horizontal shading dimension (per face):			1.5 ft	1.5 ft			-	
% of windows with vertical fin shading (per face):								
Vertical fin dimension (per face):								
Glazing assembly u-value (including frame):	Double-glazed, low-E, reflective, with argon (U-0.32)				U-0.55			
Glazing solar heat gain coefficient (SHGC):	SHGC = 0.40, SC = 0.46				SHGC = 0.40, SC = 0.46			
Envelope Information								
Overall wall R-value:	R-24.5 overall (R-19 + R-5.5 c.i.)				U-0.064 / R-15.6 overall (R-13.0 + R-7.5 c.i.)			
Roof Type:	Green roof or high-reflectance				Insulation entirely above deck			
Overall roof R-value:	R-41 c.i.				U-0.048 / R-20.0 c.i.			
Skylight % roof coverage:	none				none			
Quantity and dimensions of skylight assemblies:	-				-			
Floor construction R-value:	U-0.057 / R-14.6 c.i.				U-0.057 / R-14.6 c.i.			
Balconies:	Thermal break between floor slab and balcony				Continuous floor and balcony slab			
Lighting Information								
Targeted % lighting savings above baseline: [1]	25%				LPD = 0.7 W/ft^2			
Lighting controls:	Occupancy				Occupancy			
Daylighting controls:	None				None			
Exterior % lighting savings above baseline: [1]	25%				LPD = 0.2 W/ft^2			
Equipment Information								
Equipment Loads: [1]	0.75 W/ft^2				0.75 W/ft^2			
List additional equipment:	none				none			
Design Conditions	Heating		Cooling		Heating		Cooling	
Indoor design temperatures: (heat / cool) [1]	71°F / 22°C		76°F / 24°C		71°F / 22°C		76°F / 24°C	
Thermostat set-back temperatures: (heat / cool) [1]	64°F / 18°C		82°F / 28°C		64°F / 18°C		82°F / 28°C	
Humidity design conditions: [1]	No mimimum humidity req.		Max 50% RH		No mimimum humidity req.		Max 50% RH	
Air System Information								
System type: [1]	Fan coil units with integral heat recovery				Packaged Terminal AC / Gas-fired heating			
Additional ventilation requirements:	30 cfm central and 80 cfm per unit				30 cfm central and 80 cfm per unit			
Overall fan power efficiency: [1]	2.33 W/cfm (premium efficiency)				4.45 W/cfm			
Room Fan Operation:	Intermittent				Continuous, cycle when unoccupied to meet loads			
Exhaust Air Heat Recovery? (Y/N)	Y				N			
Other system features:								
Plant Information								
Heating plant type: [1]	Distributed heat pump system at 150°F, Backup gas boiler				Gas-fired boiler			
Heating plant efficiency: [1]	Gas boiler = 85%				80%			
Variable speed pump control? (Y/N)	Y				N			
Cooling plant type: [1]	Centrifugal chiller				Air cooled split system			
Cooling plant efficiency: [1]	0.6 kW/ton (20 SEER)				0.92 kW/ton (13 SEER)			
Variable speed pump control? (Y/N)	Y				N			
Domestic hot water heating type: [1]	Heat Pumps (2/3), solar / gas-fired boiler top-up (1/3)				Gas-fired boiler			
Domestic hot water heating efficiency: [1]	85%				80%			
Domestic hot water use: (gal/person/day)	16 gallons/person/day (35% reduction)				25 gallons/person/day			
Utilities								
Electricity:	Seattle City Light: Energy: \$0.0459/kWh for 10kWh; \$0.0955/kWh above (April-Sept) Energy: \$0.0459/kWh for 16kWh; \$0.0955/kWh above (Oct-Mar)				Seattle City Light: Energy: \$0.0459/kWh for 10kWh; \$0.0955/kWh above (April-Sept) Energy: \$0.0459/kWh for 16kWh; \$0.0955/kWh above (Oct-Mar)			
Natural Gas:	Puget Sound Energy: \$1.04885/therm				Puget Sound Energy: \$1.04885/therm			

Notes:

1. Baseline is ASHRAE 90.1-2007 and LEED 2009 unless specified otherwise.

Table 2: Climate zone 4 recommendation table for small hospitals and healthcare facilities. Used with permission from ASHRAE[4].

28 Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities

Climate Zone 4 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-to Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-30 c.i.	EN2, EN11, EN13	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-7.5 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-7.5 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-14.6 c.i.	EN6, EN11, EN13	
		Steel-framed	R-38	EN7, EN11, EN13	
	Slabs	Unheated	R-15 for 24 in.	EN8, EN11, EN13	
	Doors	Swinging	U-0.50	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.29	EN14	
		SHGC (all types and orientations)	SHGC-0.34	EN14, EN23–24	
		Visible transmittance	VT-0.69	EN14, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22 EN26–31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.60	DL18	
		SHGC (all types)	SHCG-0.40	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
		Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Table 2: Climate zone 4 recommendation table for small hospitals and healthcare facilities. Used with permission from ASHRAE[4] (continued).

Climate Zone 4 Recommendation Table
for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation	How-to Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Water-side economizer Marine zones C: Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.

Figure 4 also includes the annual energy use intensity numbers for both proposed and base case models. This can assist in project benchmarking allowing for comparison with industry norms or similar buildings.

Simple calculations for greenhouse gas emissions savings should also be conducted to inform the design team. Two figures showing example greenhouse gas emissions, per fuel source, are shown in Figure 5 for the proposed design case and the baseline case. The figure on the left represents the GHG emissions reduction using GHG emission rates per fuel source in British Columbia[6,7] while the figure on the right shows the GHG emissions reduction using average GHG emissions rates for the United States[8].

Table 3: Example table listing work-around methodology for a given proposed design feature.

Proposed Design	Work-Around Description
Radiant heating and cooling floors	Modeled as a 4-pipe fan coil system with zero fan power.
Occupancy sensors	Modeled by reducing lighting power density by % as listed in Appendix G of ASHRAE 90.1-2007.

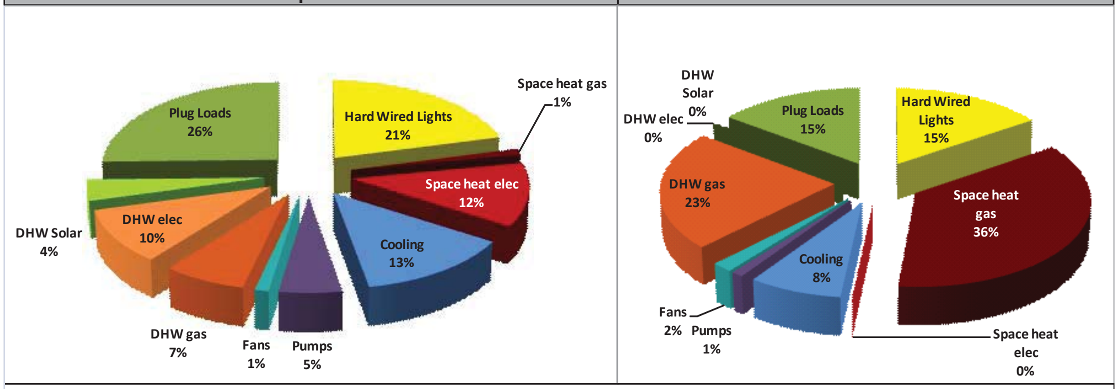
In Figure 5, the scale for the tonnes of CO_2e is different for the two locations, British Columbia in Canada and (average) USA. It can be seen that the emissions rates are much higher on average in the United States than they are in British Columbia. This type of results diagram demonstrates how design decisions are affected differently based on project location and GHG reduction goals.

5.0 UTILITY METERING GUIDELINES FOR BENCHMARKING

The most basic building performance data is for building utility electrical, gas and water usage. A more detailed breakdown can be helpful to verify building operational

Annual Energy Use

Proposed	Reference



	Proposed	Reference
Total (kWh/m2)	72	124
Heating - Elec	9	0
Heating - Gas	1	45
DHW - Elec	7	0
DHW - Gas	5	28
DHW - Solar	2	0
Cooling	10	10
Pumps	4	1
Fans	1	2
Lighting	15	19
Plug Loads	18	18

Total Elec (kWh)	879,000	703,000
Total Gas (kWh)	81,000	1,007,000
Total Energy (kWh)	960,000	1,710,000
Total Cost	$ 73,000	$ 97,000
Total Regulated Energy Cost Savings*	**30%**	Compared to ASHRAE 90.1-2007
Anticipated LEED points	**9**	**Points according to LEED NC 2009**
Total GHGs from Electricity† (lbs CO_2e)	237,000	181,000
Total GHGs from Natural Gas†† (lbs CO_2e)	32,000	402,000
TOTAL GHGs (tonnes CO_2e)	**122**	**265**
GHG Savings	**54%**	

** The cost savings is different than the energy savings, as the cost of electricity is much greater than the cost of natural gas.*

† GHG emissions factor for Electricity: 0.287 lbs CO_2 e / kWh

†† GHG emissions factor for Natural Gas: 0.4 lbs CO_2 e / kWh

Figure 4: Results comparison for proposed and baseline models including annual energy utilization by end use, estimated LEED points and GHG emission savings[5].

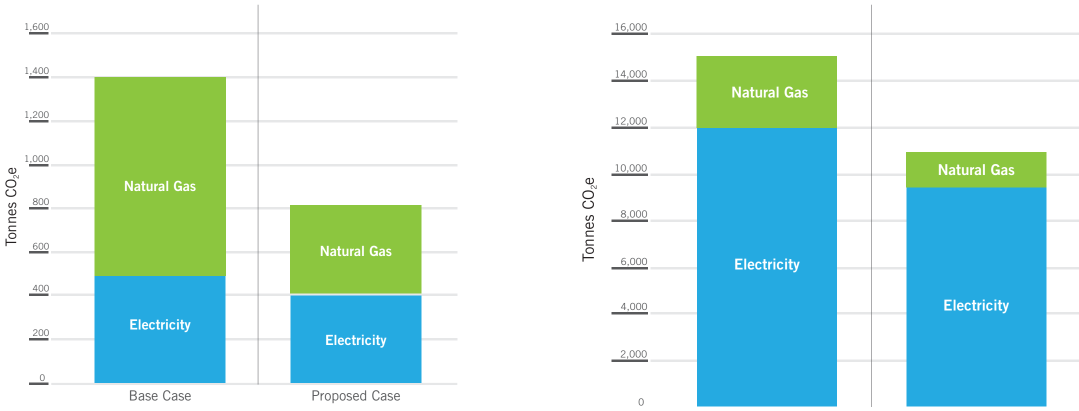


Figure 5: GHG emissions per fuel source for the proposed case compared to the baseline case. The figure on the left represents the GHG reductions in BC, Canada while on the right, GHG reductions in the US.

energy and end use breakdown. Full "Measurement and Verification" as per the LEED Energy and Atmosphere Credit 5 (EAc5) is often prohibitively expensive.

The following measures in addition to the base utility meters should be provided and should be suggested to the design team. When incorporated at the early stages of the project, the additional cost is quite modest.

- Separate electrical panels (and risers where appropriate) to serve on floor lighting and plug-in power needs. It is important that the electrical team does not make connections to any electrical panel with spare space and instead connects to the correct panel. This way, one meter can measure all of the lighting or plug power in an area. Plug power loads often consume much more energy than anticipated.
- Monitor power to mechanical rooms with sub-metering for chillers, related pumps and equipment. Some metering may be included in control panels with BacNet or LON connectivity to a Building Automation System (BAS).
- Sub-meter gas loads in a building such as for a kitchen.
- Elevator loads, kitchen loads and exterior lighting should be sub-metered.
- Install water meters on DHW, irrigation, reclaimed water systems and makeup for cooling towers and heating/cooling systems.

The meter readings should feed into the building automation system for recording of the data. Avoid new data over-writing older data. An advantageous arrangement with the client/owner would be that this utility data would be available to us for collection. A number of systems like Pulse Energy (being used in some of our offices) can provide tracking of data with alerts for abnormal energy or water usage.

6.0 RESOURCES

6.1 Benchmarking in Canada

The Canadian Green Building Council (CaGBC) has started a green building performance program called "Green Up" to track actual building performance across the country, normalized for weather and other factors. Results from the years 2005 and 2007 have been compiled for this pilot program and are available online at: http://www.cagbc.org/initiatives/green_building_performance/pilot_projects.php.

Charts showing commercial office buildings, administrative office buildings and K-12 schools are shown in Figure 6, Figure 7 and Figure 8[9].

6.2 Benchmarking in the United States

In the United States, the US Environmental Protection Agency and the Department of Energy have co-created the Energy Star program offering guidance and tools for energy efficiency. While the 2007 data is still being compiled, the 2003 Commercial Building Energy Consumption Survey (CBECS) provides the national average for building performance based on building type. This is shown in Table 4[10]. Detailed breakdown of energy per end-use type per building type are also available and can be found at: http://www.eia.doe.gov/emeu/cbecs/

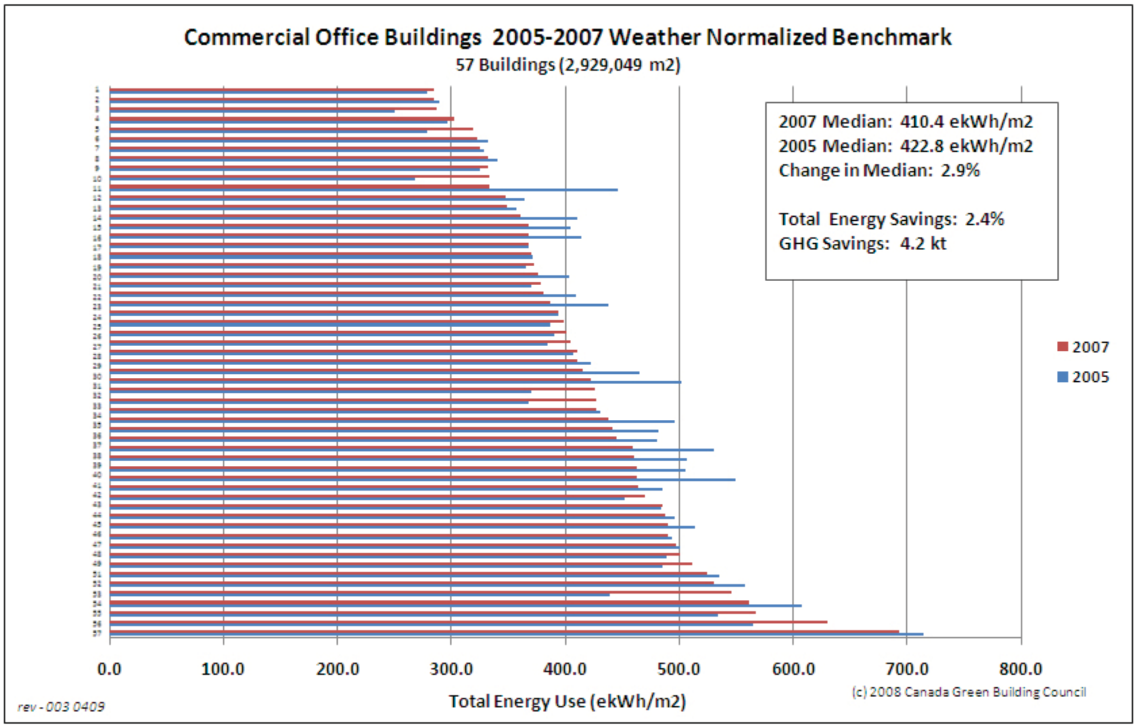


Figure 6: Building performance benchmarking for commercial office buildings in Canada[9]. For reference, 100 kWh/m[2] is approximately equal to 32 kBTU/ft[2]

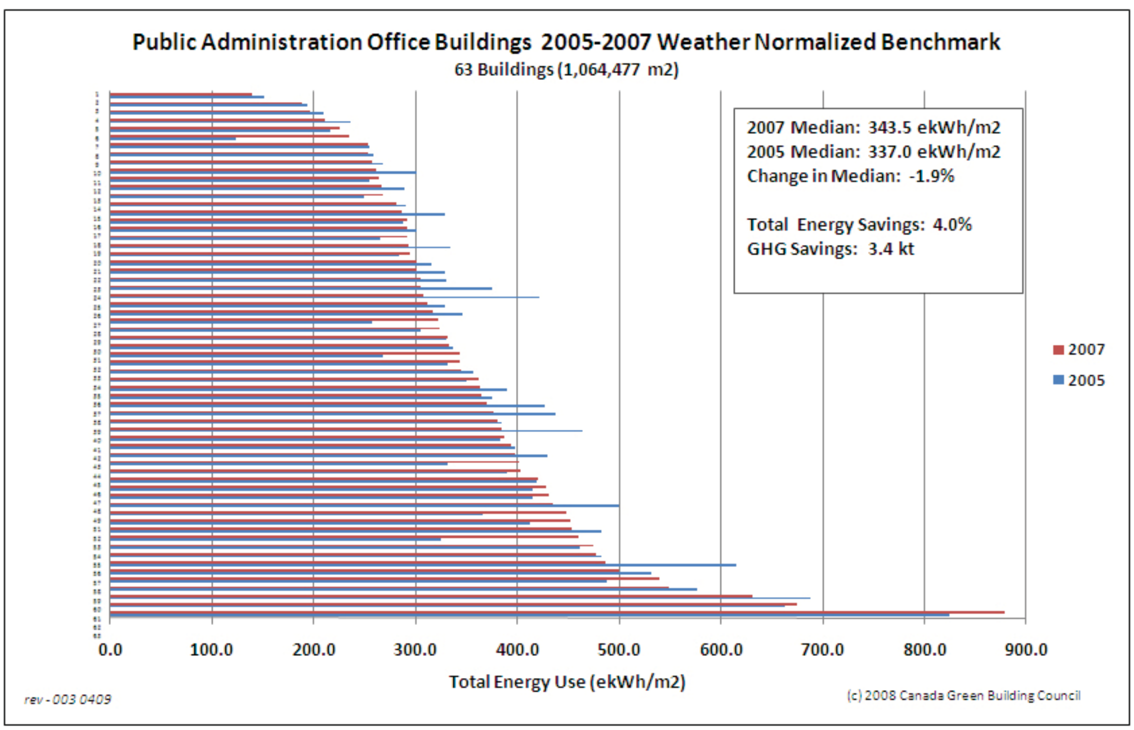


Figure 7: Building performance benchmarking for administrative buildings in Canada[9]. For reference, 100 kWh/m[2] is approximately equal to 32 kBTU/ft[2].

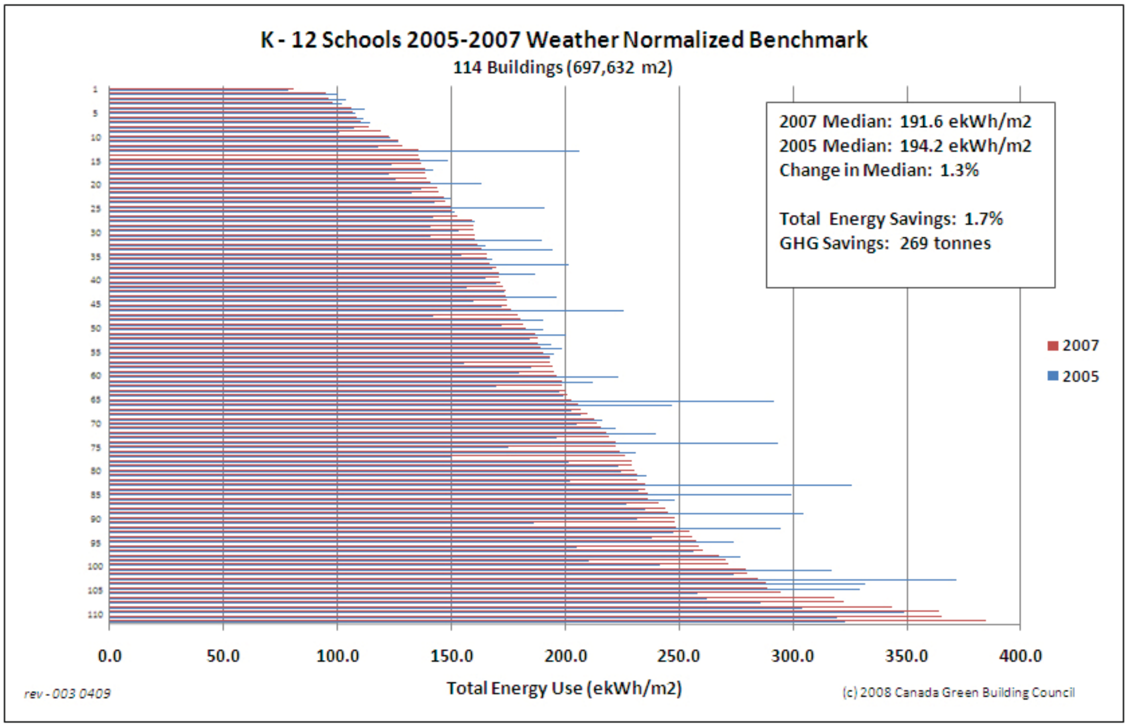


Figure 8: Building performance benchmarking for K-12 school buildings in Canada[9]. For reference, 100 kWh/m^2 is approximately equal to 32 kBTU/ft^2.

Table 4: 2003 CBECS national average energy benchmarking[10].

How to Use this Table:

- *The building types listed in blue define a broad building activity category. Some of the broader building type categories are broken down into more specific building activities.*
- *When identifying your building within this table, first identify where your building's function falls within the broader blue categories. Then determine if you are able to identify your building's function more specifically by the white categories underneath. Matching your building's main use activities most closely with the building use descriptions below, will give you the most accurate energy performance target.*

2003 CBECS[1] National Average Source Energy Use and Performance Comparisons by Building Type			
Building Use Description[2]	**Average Source EUI[3] (Kbtu/Sqft)**	**Average Percent Electric**	**Average Site EUI (Kbtu/SqFt)**
Education	170	63%	76
K-12 School	*See Target Finder / Portfolio Manager*		
College/university (campus-level)	280	63%	120
Food sales	681	86%	225
Grocery store/food market	*See Target Finder / Portfolio Manager*		
Convenience store (with or without gas station)	753	90%	241
Food service	786	59%	351
Restaurant/cafeteria	612	53%	302
Fast food	1306	64%	534
Inpatient health care (hospital/ rehabilitation)	*See Target Finder / Portfolio Manager*		
Lodging	194	61%	87
Dormitory/fraternity/sorority	*See Target Finder / Portfolio Manager*		
Hotel, Motel or inn	*See Target Finder / Portfolio Manager*		
Mall (Strip Mall and Enclosed)	271	71%	107
Nursing/Assisted Living	255	54%	124
Office	*See Target Finder / Portfolio Manager*		
Outpatient and health care	183	72%	73
Clinic/other outpatient health	219	76%	84
Medical Office	*See Target Finder / Portfolio Manager*		
Public Assembly	143	57%	66
Entertainment/culture	265	63%	95
Library	246	59%	104
Recreation	136	55%	65
Social/meeting	102	57%	52
Public order and safety	189	57%	90
Fire station/police station	157	56%	78
Service (vehicle repair/service, postal service)	150	63%	77
Storage/Shipping/Nonrefrigerated warehouse	56	56%	25
Self-storage	12	44%	4
Non-refrigerated warehouse	*See Target Finder / Portfolio Manager*		
Distribution/shipping center	90	61%	44
Refrigerated warehouse	*See Target Finder / Portfolio Manager*		
Religious worship	*See Target Finder/Portfolio Manager*		
Retail (non-mall stores, vehicle dealerships)	191	67%	82
Other[4]	213	56%	104

2003 CBECS National Average Source and Site Energy Use and Performance Comparisons by Building Type
Notes:

[1] Commercial Building Energy Consumption Survey (CBECS), conducted in 2003, was used to calculate values presented in this table. The data is gathered from the Dept. of Energy's – Energy Information Administration (EIA). These are building types that are not currently available in EPA's Portfolio Manager.

[2] Buildings Use Descriptions are taken from valid building activities as defined by EIA in the 2003 CBECS data. The average Source EUI and Site EUI are calculated in kBtu/sqft as weighted averages across all buildings of a given type in the 2003 CBECS data set. The building type listed in blue is defined according to the CBECS variable for "Principal Building Activity" (PBA8) which is a broader defined category. The subset of building types listed below those broader categories are defined according to the CBECS variable for PBAPLUS8. These are defined as a more specific building activity within the broader PBA8 category. Note all building type definitions can be found at: http://www.eia.doe.gov/emeu/cbecs/building_types.html

[3] Source Energy is a measure that accounts for the energy consumed on site in addition to energy consumed during generation and transmission in supplying energy to the site. Converting site to source energy: Source energy value are calculated using a conversion factor for electricity of 1 kBtu site energy = 3.34 kBtu source energy; a conversion factor for natural gas of 1 kBtu site energy = 1.047 kBtu source energy; a conversion factor for district heat of 1 kbtu site energy = 1.40 source energy; and a conversion factor for fuel oil of 1 kbtu site energy = 1.01.

Explanation of Source Energy: The source energy intensity target cannot simply be converted into an equivalent site energy value because different design strategies may yield different fuel mixes. Thus the different fuel mixes translate into the corresponding site to source ratios for a specific building. It is important to note that reducing source energy by 50% is not always mathematically equivalent to reducing site energy by 50%. For the most equitable peer comparison, the associated fuel mix should be used to convert the modeled site energy into the total source energy. The source energy use can then be compared to the values in this table.

[4] Other: For all building types not defined by the list above, these buildings may choose to use the performance benchmark categorized by "other". Note that this category is not well defined therefore source energy use varies greatly with source EUI ranging over 1500 kBtu/sqft. As categorized by EIA, "other" may include airplane hangers, laboratory, crematorium, data center, etc.

6.3 Energy Simulation Software

Section 3.10 of this report listed and outlined capabilities of some of the most common building simulation software packages.

United States

In the United States, the Department of Energy maintains a list of building energy software tools including whether the software is free for download and has been recently updated. This list is available here: http://apps1.eere.energy.gov/buildings/tools_directory/subjects.cfm/pagename=subjects/pagename_menu=whole_building_analysis/pagename_submenu=energy_simulation

The list of qualified software for calculating commercial building tax deductions is also available through the US-DOE website located here: http://www1.eere.energy.gov/buildings/qualified_software.html

The building simulation research group at the Lawrence Berkeley National Laboratory (LBNL) contributed to the joint development of the EnergyPlus software and offer tutorials and resources on the software available here: http://simulationresearch.lbl.gov/

The National Renewable Energy Laboratory in Boulder Colorado also offers a list of software and training resources available here: http://www.nrel.gov/buildings/energy_analysis.html

In addition to the above list, the USGBC also references the US-DOE software tool list (mentioned previously). The USGBC's summary on energy modeling tools and resources for LEED projects is available here: http://www.usgbc.org/ShowFile.aspx?DocumentID=3478

Canada

In Canada, the Canadian Green Building Council (CaGBC) provides direction on which software can be used to demonstrate LEED compliance. Currently the list includes:

- EE4
- eQUEST
- DOE-2
- EnergyPlus
- IES Virtual Environment
- Hourly Analysis Program (HAP)
- Trace 700

In addition to providing energy model reviews for models created in the EE4 software, Natural Resources Canada (NRCan) maintains a website for free simulation software tools, available here:
http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools.html

7.0 QUICK ENERGY MODELING PROCESS – CONCEPT DESIGN STAGE OR LATER

7.1 Introduction

Estimates of the energy and GHG performance of buildings are often needed at very early stages of the project to inform the design and achieve ambitious goals. Often a detailed energy model is not completed until much later in the design process and the opportunity to inform the design is lost. In conjunction with the process outlined herein, early quick computer energy models can be used to refine façades, system options or other design features. This process can inform the team about where work is needed or areas of interest.

The goal of this process is to quickly give the design team a good idea of what the potential energy consumption of a project is and the impact on GHG emissions. More detailed studies on specific issues can then be carried out with a detailed energy model confirming and refining the work done to date. This leads to a much more informed design process.

These quick energy estimates provide an important benchmark in the design process, but should be followed up by more conventional energy models.

A quick energy estimate can be done in an hour or so, if necessary information is available and the project goals are not overly ambitious. A half a day may be needed if the project is examining more complicated building geometry or HVAC systems.

There are a couple of methods to do a quick energy model in an hour or so:

- *Input Wizard* and basic building shapes in software like eQUEST (Quick Energy Simulation Tool) or IES: VE-GAIA (Integrated Energy Solutions: Virtual Environment – GAIA) or the Revit Conceptual Energy Analysis Tool.

- *Spreadsheet analysis* based on previous energy models or breakdowns.

7.2 Project Goals

The project team has to decide on the project goals. The goals could include:

- LEED certification level and suggestion of level of energy savings.
- Specific energy savings compared to the energy code.
- Specific energy use target – in kBTU/ft^2/yr or kWh/m^2/yr.
- 2030 Challenge GHG emissions for a specific completion time (such as 2015).

7.3 How is a Detailed Energy Model Done?

Refer to Section 3.0 on “Energy Modeling Methodology” for details.

7.4 Input Wizard Method

The Input Wizard work is carried out by an engineer, an energy modeler or an ambitious architect using general building shapes. Data like 5 floors at 12 feet floor-to-floor spacing, 50 percent glazing with a certain envelope performance, lighting power density, mechanical system inputs and standard operating schedules gets to a quick answer on potential energy use. By using the parameters for the local code or ASHRAE 90.1, the base case for energy use can be modeled. Options for different glazing, exterior shading, lighting levels or basic mechanical systems can be considered. If the team is familiar with the code insulation, glazing and system parameters a couple of energy models can be run in about an hour.

Some software providers claim that early stage SketchUp and BIM models can be directly imported into the software in order to allow light-weight intuitive energy modeling. One such software is IES VE-GAIA. The new Revit Conceptual Energy Analysis tool may allow architects to quickly convert conceptual design models into analytical energy models and conduct integrated whole building energy analysis within Autodesk Revit Architecture 2011.

Figure 9 is the 3D output from the quick model for a simple office building (eQuest). Note that exterior shades have been added to the west glazing and not to the north glazing. Table 5 shows the energy use output from the quick energy model.

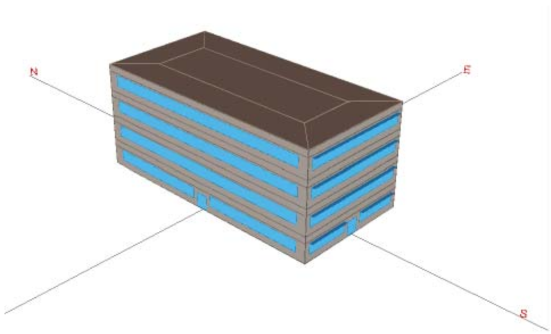


Figure 9: 3D output from a quick model for a simple office building.

7.5 Spreadsheet Analysis

Starting Point

A basic energy performance breakdown is required for the type of project being studied. The energy model base case from a similar project in a region can be used as a starting point for the quick analysis. If the total energy use in kBTU/ft^2 is known or estimated, a representative end-use breakdown can be estimated.

An example office building in Vancouver, BC is evaluated below that has ASHRAE 90.1- 2004 as an energy code requirement.

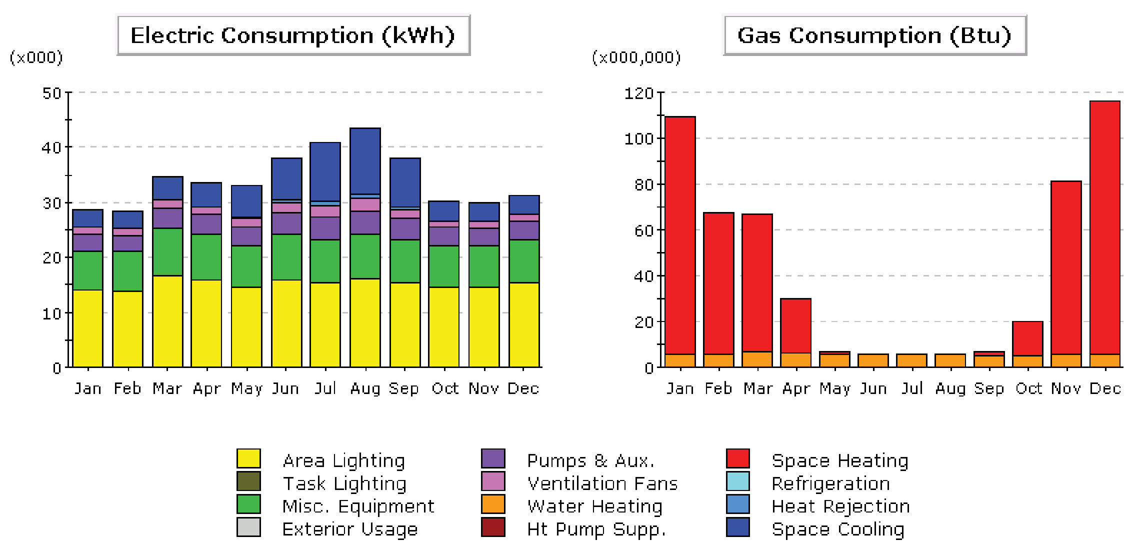
Develop the Data

As an example, the following data outlines some energy use for an office building by end-use group. These are example numbers only. The main end uses such as heating, cooling and others can then be subdivided to assist in analyzing the alternative design options. Generally, this data is not easily available to architects unfamiliar with energy models. An energy modeler can review the model output files on similar projects to obtain the breakdown. No two projects are exactly alike, but it will give a starting point. If this is not available, a quick eQUEST model could produce the data.

Consultants can be put on the spot to provide estimates of the breakdown of energy into the groups and the sub-groups. In the example Table 6, the mmBTU/hr for gas usage has been converted to kWh/yr.

Each of the main groups of cooling, heating, lighting and fan/pumps can next be broken down into sub-groups for analysis.

Table 5: Energy use output from a quick energy model.



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	3.13	3.12	4.09	4.36	5.75	7.56	10.89	11.87	8.77	3.57	3.38	3.43	69.92
Heat Reject.	0.00	-	0.02	0.05	0.20	0.32	0.68	0.76	0.49	0.02	0.01	-	2.55
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.36	1.20	1.46	1.33	1.44	2.00	2.21	2.28	1.73	1.22	1.26	1.37	18.87
Pumps & Aux.	3.06	3.06	3.74	3.62	3.45	3.92	4.03	4.26	3.83	3.25	3.23	3.38	42.82
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	7.23	7.11	8.49	8.13	7.55	8.13	7.86	8.18	7.82	7.55	7.50	7.86	93.39
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	13.94	13.87	16.73	16.00	14.64	16.00	15.33	16.03	15.31	14.64	14.61	15.33	182.45
Total	28.72	28.36	34.52	33.49	33.03	37.93	40.99	43.38	37.96	30.24	29.99	31.37	409.99

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	104.15	62.24	60.01	23.68	1.35	-	-	-	1.65	14.82	76.09	110.43	454.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	5.53	5.55	6.66	6.30	5.58	5.81	5.39	5.49	5.25	5.16	5.34	5.82	67.88
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	109.68	67.79	66.67	29.98	6.93	5.81	5.39	5.49	6.90	19.98	81.43	116.25	522.30

- The cooling load is broken down into solar load through glass, heat gain from walls and roof, ventilation and other internal loads.
- The heating load is broken down into envelope heat loss and ventilation load.
- The fan and pump energy are also separated.

The quick eQUEST model can provide the breakdown of, for instance, heating energy using the LS-B, LS-C and LS-D pages in the results "Detailed Output Simulation" file. A chart showing the heating energy breakdown for an example office building in Chicago is shown below in Figure 10.

The heating energy breakdown for the example office building in Chicago shows that most of the heating energy is used to heat the outdoor air and offset the window and frame losses. The breakdown will provide an indication of which energy conservation measures will achieve the most energy savings.

The following breakdown figures are for example only and are not figures to use for every project as regional differences and building uses will vary. It is advisable to work with the consultants to generate these figures (and there will probably be some discomfort for the first time, as designers often do not think in energy use terms).

Table 6: Energy use estimates and breakdown. Note that the following data represents the baseline case using inputs from the ASHRAE 90.1-2007 Standard[3].

Energy Use	kWh/yr	mmBTU/yr	Total kWh/yr	% Energy
Cooling	200,000		200,000	5.8%
Heating		4,800	1,406,740	41.0%
Lights	600,000		600,000	17.5%
Misc Equipment	500,000		500,000	14.6%
Fans & Pumps	650,000		650,000	19.0%
DHW		250	73,270	2.1%
TOTAL			3,430,000	100.0%

Table 7 (on page 94) shows the sub-groups and the energy for each is expressed in terms of base building energy use.

The potential savings for various energy conservation measures are then considered and discussed. Estimates of each of these options are made. The percentage reduction of each option is provided and the effect and the resulting percentage of building energy use for that option is determined as seen in Table 8 (on page 94). Some options, like the lighting, are cascaded. The daylight saving only operates on the lower lighting power proposed, not the base load.

These quick methods are used to get a good idea of what the energy use or percentage of energy savings might be for some global design options. Often a detailed energy model could take weeks to complete and this may be too slow for the design process. The results of this quick analysis should be confirmed by more complete energy models.

7.6 GHG Emissions

The preceding energy use data can also be used to calculate GHG emissions. Using the emissions rate for the Vancouver region, electricity is about 25 tonnes/GWh and gas is about 178 tonnes/GWh[6,7]. The summary data from Table 9 can be seen in Table 10.

The GHG emissions rate for electrical utilities varies significantly. Regions with mostly coal fired power can be in the 900 tonnes/GWh range, regions with a blend of nuclear and coal may be in the 600 tonnes/GWh range (near the USA average) and West Coast regions with hydro-electric power can be in the 20 to 80 tonnes/GWh range.

7.7 Summary

The quick energy modeling processes presented are not a replacement for detailed energy modeling, but can provide guidance quickly and early in the design process. The concepts used in this process are also effective for generally reviewing the results of energy models to see if they are operating correctly. The spreadsheet process has been used in the concept stages of a number of projects and the results have been within a few percent of the final energy model results.

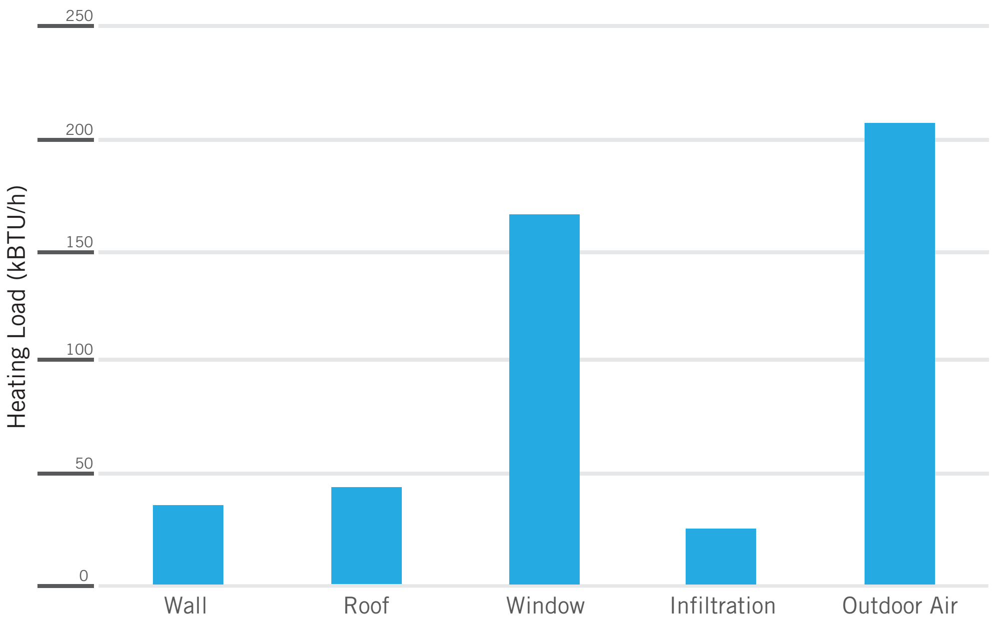


Figure 10: Heating energy breakdown for an example office building in Chicago, IL.

Table 7: Sub-divide energy uses into sub-components.

Main Group	% Bldg Energy	Sub Group	% Group	% Bldg Energy
Cooling	5.8%	Glazing	30%	1.75%
		Skin	10%	0.58%
		Ventilation	20%	1.17%
		Internal	40%	2.33%
Heating	41.0%	Skin + Glazing	60%	25%
		Ventilation	40%	16%
Lights	17.5%		100%	17%
Misc Equipment	14.6%		100%	15%
Fans & Pumps	19.0%	Fans	55%	10%
		Pumps	45%	9%
DHW	2.1%		100%	2%
TOTAL				100%

Table 8: Sub-divide energy uses into sub-components.

Energy Conservation Measures	% Reduction	% Bldg Energy
Provide exterior shading to reduce solar cooling load by	40%	1.05%
Provide better glazing and wall insulation - cooling reduction of	30%	0.41%
Reduce lighting load by 25% - internal cooling load reduction of	40%	1.40%
Provide better glazing and wall insulation - heating reduction of	30%	17.23%
Provide ventilation heat recovery - heating reduction of	50%	8.20%
Reduce lighting load by 25% - lighting power reduction of	25%	13.12%
Daylight control on perimeter - 35% of area, 30% reduction	10.5%	11.74%
Occupancy control for lighting - lighting power reduction of	10%	10.57%
Minimum vent system like chilled beam - fan power reduction of	70%	3.13%
Low air pressure fan system - fan power reduction of	40%	1.88%
Low pump head design - pump power reduction of	30%	5.97%

Table 9: Energy conservation measures are applied to the energy sub-components.

Energy Use	kWh/yr	mmBTU/yr	Total kWh/yr	% Energy	Revised % Bldg Energy	Revised kWh/yr	% Savings
Cooling	200,000		200,000	5.8%	4.0%	138,000	31%
Heating		4,800	1,406,740	41.0%	25.4%	872,180	38%
Lights	600,000		600,000	17.5%	10.6%	362,480	40%
Misc Equipment	500,000		500,000	14.6%	15%	500,000	0%
Fans & Pumps	650,000		650,000	19.0%	7.9%	269,100	59%
DHW		250	73,270	2.1%	2%	73,270	0%
TOTAL			3,430,000	100.0%	64.6%	2, 215,030	35%

Table 10: GHG emissions for the example scenario.

	Base Case kWh/yr	Base Case GHG tonnes/yr	Revised Case kWh/yr	Revised Case GHG tonnes/yr
Electricity	1,950,000	49	1,269,580	32
Gas	1,480,000	264	945,440	170
TOTAL	3,430,000	313	2,215,020	201
				36% GHG reduction

8.0 CONCLUSIONS

In achieving energy-efficient building design, metrics for understanding the impact of specific design features are needed. Without some frame of measurement, the economic and environmental impacts cannot be gauged but only estimated and the risk of using high-cost and low energy savings design features is increased. The timeframe for using energy analysis tools is associated with when the design features are being considered. At very early design discussions, a simple energy model can give an estimate of the project energy needs and review basic design options. As the design progresses to conceptual stage, quick energy modeling can assist in evaluating design and system options or added energy conservation measures. Revising the quick energy model at the late stages of design (i.e. design development) can help ensure the project is on track for energy performance before the final LEED compliance (or similar rating system) energy model.

Energy modeling analysis is conducted on proposed building designs using code-guided assumptions and detailed building inputs, actual building geometry, historical weather files and appropriate usage patterns and internal loads. Project teams provide insight into the proposed mechanical system design and other project-specific parameters. As energy analysis software is generally limited, an experienced energy modeler can simulate a proposed building design by either manipulating the software within the limitations or using external analysis tools to compliment the software analysis. A review of the energy analysis is necessary to avoid unrealistic results or bypass software errors.

After energy analysis has been completed on a proposed building design or after the building has been constructed and is operating as normal, the building performance can be measured in comparison to other similar buildings to determine relative performance. In the United States, the Energy Information Association produces the Commercial Building Energy Consumption Survey. In Canada, the Canada Green Building Council has developed a pilot program to compare Canada's Building Performance by building sector. To assist in ensuring that the building operates as designed and as predicted, measurement devices can be provided that help identify changes in operation or unexpected loads.

Several methods for early-stage quick energy modeling and analysis were presented as an alternative to waiting for the final compliance energy model to estimate building performance. Quick analysis tools, such as eQUEST or the demonstrated spreadsheet analysis, may be used to evaluate design decisions and predict energy use or GHG emissions. In contrast to a final and detailed energy model, quick energy analysis can be conducted within a few hours to a few days providing prompt feedback to design teams.

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