SOLAR GAIN AND COOLING LOAD COMPARISON USING ENERGY MODELING SOFTWARE

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ABSTRACT

Single zone models are sometimes used by architects, engineers and energy consultants as a decision making tool for façade and system selection. Most often, the intent of these models is to analyze thermal performance and façade measures. Tools such as eQuest, IES, TRACE, and EnergyPlus are frequently used to perform such analysis.

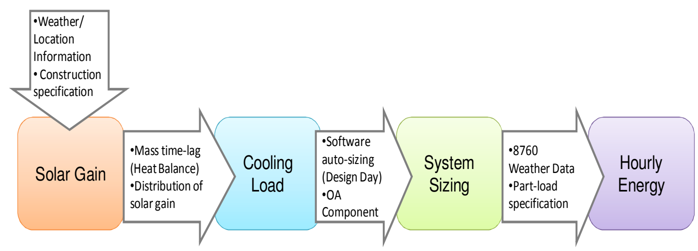
Each of these software tools rely on a certain calculation methodology and embedded are unique algorithms to convert the instantaneous space gain to cooling load. Following this, the cooling load calculation to system calculation transition is not always clear. Understanding these transitions is particularly important in order to use the results appropriately. The intent of this paper is to evaluate the *solar gain calculation methodology* within each software's load calculation and its effect on resultant cooling loads on systems.

The paper will compare the results of each software's solar gain and cooling load calculations and describe the solar gain to cooling load transition. The goal of the study is to present watch-its and lessons-learned in comparing façade options for a single zone model using different software. This is achieved by building single-zone models with two different glazing/shading configurations in eQuest, IES, TRACE700 and EnergyPlus.

INTRODUCTION

This study analyzes a simplified single-zone model built in four different simulation softwares. The study focuses on peak solar gain through a window and its associated cooling load, as this can be a major component in determining application and evaluation of low-energy systems. It is therefore vital to predict the solar gain and the time when peak occurs accurately to make decisions about the façade measures and system selection even at a concept design phase.

Figure 1: Calculation Method Steps



As illustrated in Figure 1, there are a series of transitions that occur within the software. The first step analyzes the instantaneous solar gain into the space based on weather and building information .Next, this gain is converted to cooling load which the system is then sized for. Finally, the hourly energy simulation occurs.

MODEL DESCRIPTION

The software being compared in the study includes the following:

- EnergyPlus Version 4.0.0.024
- eQUESTv3.6.3
- TRACE™ 700 v6.2.3,
- Virtual Environment v6.2(beta)

The model geometry consists of a 15'x15'x12' single-zone model. Models assume an 80% glazed south-facing wall with three internal 'adiabatic' partitions. For Test Case 1, a low-e glazing was incorporated. LBNL Window5 reports were imported where possible for all software with the exception of VE (this is further described in the Watch-its Section under Window Specification). Framing effects were neglected in this study as the primary goal was to evaluate solar gains only. For Test Case 2, a 24-inch overhang was added directly above the window. A summary of the model assumptions are listed in Table 1.

Table 1: Model Assumptions

Single Zone Model Description			
Item	*Value*	*Unit*	*Notes*
Materials (U-factor)			
South wall	0.013	Btu/hr.-ft^2-°F	sun,wind exposed
North, east and west walls	0.529	Btu/hr.-ft^2-°F	adiabatic to outside
Roof	0.529	Btu/hr.-ft^2-°F	adiabatic to outside
Internal Loads			
People	0	Btu/hr/per	
Lighting	0	Btu/hr/ft^2	
Equipment	0	Btu/hr/ft^2	
Infiltration	0	cfm/ft^2	
Space Temperature	75	°F	

ASHRAE 140

It is important to note that the purpose of this study is not to highlight specific differences between modeling software. The purpose is, rather, to describe the solar load calculation methodology for each software and to present results for discussion as well as watch-its encountered during this analysis. ASHRAE 140-2007 is the standard method of testing for the evaluation of building energy analysis computer programs. All of the software considered in this study have been evaluated using ASHRAE 140 methodology. There is little deviation (<3%) from the mean for peak cooling load between the software discussed in this study with regard to the peak cooling load calculation[1]. Also, because the modeling method for ASHRAE 140 is strict, additional software capabilities are often disabled in the testing. The models included in this study will include some of these items as discussed, therefore additional output variation is expected in the result.

METHOD DESCRIPTION

The following summary compares the solar gain, space load calculation, and system sizing methods employed by each software.

EnergyPlus:

EnergyPlus offers multiple choices to users to calculate beam solar radiation entering a zone through exterior windows. For the purpose of this study, the authors have selected the "***FullInteriorAndExterior***" option. By selecting this option, the program calculates the amount of beam radiation using detailed geometrical calculations. The program calculates the transmitted solar gain falling on each surface of the zone by projecting the sun's rays through exterior windows and shading surfaces. "ScriptF" algorithm is used to calculate "Long Wave Radiation Exchange Among Zone Surfaces" which uses view factors to calculate the distribution of diffuse solar transmitted radiation through external windows on to each wall, floor, window, etc.

For space load calculations, EnergyPlus uses an integrated simulation methodology that utilizes a heat and mass balance program for calculating space loads and a building systems simulation at the same timestep. The integrated simulation method allows the zone, system and plant to provide feedback to each other for each time step of the simulation. The integrated simulation methodology can provide better prediction of the space temperature and comfort conditions.

EnergyPlus uses algebraic energy and mass balance equations combined with steady state component models to simulate HVAC systems. EnergyPlus offers users the option of performing zone sizing, system sizing and plant sizing calculations. Either design days or annual weather files can be used to perform sizing calculations. Upon inputting the dry-bulb high temperature and the dry bulb range, EnergyPlus calculates hourly dry bulb temperatures for the 24 hour design period. System sizing begins after the loop connectivity is verified by making sure that all of the required inputs for system sizing are provided. Next, outside weather conditions and *ZoneSizing* are used to calculate peaks and moving averages for the system for each sizing period. The system sizing calculation is then performed to calculate the peak heating and cooling loads and flow rates over all sizing periods.

eQUEST(DOE2.2):

For Solar Gain, DOE-2 implements a user-defined fraction multiplier for all exterior (excluding windows) and interior surfaces to calculate the distribution of the incident direct solar radiation and diffuse radiation in the space. If the user defined multiplier is allowed to default, DOE-2 assumes that 60% of direct and diffuse solar is absorbed by the floor. The remaining 40% is distributed to the remaining surfaces based on their areas.

eQUEST employes a simplified heat balance method to calculate the space and system loads. Within the LOADS program, instantaneous heat gains for the zone are calculated using the fixed user specified zone temperature. The cooling load is then calculated based on the envelope gains and internal energy sources. Weighting factors are then applied to zone materials to approximate the energy stored for later release to the space.

[1] Case 600, unshaded

eQUEST offers users two system sizing methodologies. The first uses design days based on ASHRAE or user-specified data. The program uses this input in the "LOADS" subroutine and determines the peak values for sizing the primary and secondary equipment. Solar radiation values are calculated from a clear sky model using the design day month and hour information. The calculation method also uses a cloud cover input which can affect the peak heating and cooling loads significantly. If the users chooses not to input design day information, eQUEST determines the peak values for system sizing using the weather file.

The "SYSTEMS" program is used to size the primary and secondary equipment in the model. The "LOADS" subroutine uses a single space temperature value to calculate hourly loads. This can be corrected in the "SYSTEMS" subroutine to take into account the varied heating and cooling set points used by a space. Further, an adjustment to account for thermal conduction through the interior and exterior and infiltration loads is carried out by the "SYSTEMS" subroutine to predict correct peak loads as seen by the HVAC systems. eQUEST gives users an option to base the system sizing directly on the peak calculation from the LOADS sub-routine or to apply an adjustment to account for the above mentioned factors. The "SYSTEMS" subroutine next calculates zone level system and coil capacity, air flow rates and outside ventilation air flow rates. Finally, the central system coil capacities are calculated.

TRACE700:

Within TRACE, the beam transmitted solar heat gains through glazing are all distributed on the floor of the zone. The portion of the beam that would otherwise be reflected is assumed to be diffuse. Therefore, this fraction and the diffuse transmitted solar heat gains are uniformly distributed over all surfaces. The long-wave and short-wave heat gains from internal sources and diffuse (including beam reflected) solar heat gains are distributed to all surfaces uniformly.

When using the RTS (Heat Balance) load calculation methodology within TRACE, the solar and non-solar Radiant Time Series values are calculated based on the Heat Balance. Algorithms found in the ASHRAE Toolkit for Building Load Calculations are used and the algorithm for this method was modified to account for the amount of solar gain lost through retransmission back out the window.

The system sizing methodology within TRACE must be based on the peak results from the design calculation (therefore, it is not possible to run an energy simulation without first running a design simulation). In the design simulation, the peak cooling loads and airflows are calculated for each zone based on the peak of the monthly design days. By specifying Full Year in the Change Energy Parameters tab, the system simulation will then occur based on the hourly weather file. For this, solar irradiance values are taken directly from the weather file (if using 8760 TMY3 data), or the values are calculated using the clear sky input and the weather cloud cover modifiers if no solar data is available.

During the system simulation, TRACE initially will calculate the 24-hour conduction profile based on the internal set point temperature because the actual air temperature is not yet known. After the system simulation is underway, the final conduction loads are prorated based on the calculated internal temperature (including the drift). The system simulation calculates the hourly coil loads on the basis of the schedules and hourly heat gains and losses. If the actual coil loads are greater than what was calculated in the design simulation, then the room temperature will drift, passing the loads forward until the equipment has the capacity to catch up with the load. The coil loads and associated airflows as calculated by the system simulation are a result of applying the thermodynamic characteristics of the system as specified. The airside equipment capacity depends on the hourly airflows seen by each air handler and applicable unloading curves, if any.

VE:

The Suncast module within the VE calculates the solar gain onto specific geometric surfaces as solar altitude and azimuth vary using view factors. The module also accounts for the direct radiant exchange between the surfaces of the room. Because of this calculation, the specification of the internal constructions, specifically with regard to layers, mass, conductivity, solar absorptance, and re-radiation achieve a higher significance in the model. Therefore, interior surfaces should be specified with care when using the VE.

The VE ASHRAE Loads method also performs heat loss and heat gain calculations according to the Heat Balance Method for one design day per month based on ASHRAE weather data. System sizing is based on the design day data, and then hourly cooling load calculations are performed to obtain energy information.

IES has recently developed the automatic sizing algorithm within ApacheHVAC. The process is similar to that used in TRACE, as the user must first run a design-day analysis to determine peak load values, however there are some differences in the processes which are required to achieve an annual energy simulation. The first step after creating the systems within ApacheHVAC is to recalculate the ASHRAE zone-level loads. By selecting the Load Calculations within the Navigator, the calculation will run in the same manner as run from ApacheThermal, however a spreadsheet will be populated with zone-level load information. The spreadsheet is the calculation engine used in determining zone and system-level airflows. It is possible for the user to edit the values from within the spreadsheet to then be imported into the model for energy simulations.

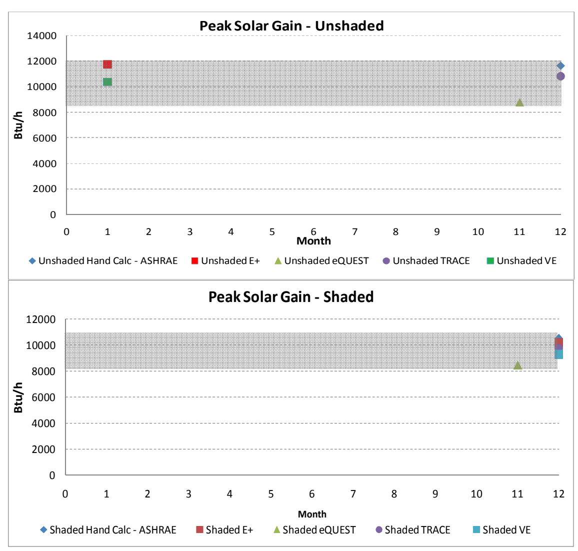
Next, the System & Plant Loads calculation re-runs the ASHRAE loads based on the system described within ApacheHVAC instead of the 'ideal' system which runs from the ApacheThermal tab (which assumes a system which always meets the space temperature setpoint). This step will repopulate the spreadsheet including system-level information. Finally, the user returns to the ApacheThermal calculation and selects the ApacheSim Dynamic simulation. This will run the load calculation based on 8760 weather data using the systems sizing information determined in the previous steps.

RESULTS

In order to better understand the model results, the solar radiation, instantaneous solar gain and space cooling load were studied as well as calculated manually using the ASHRAE Radiant Time Series method. Although there are alternate algorithmic options available in various softwares for cooling load calculations, the authors have chosen to use the RTS method where available for all runs because of the consistency between software and the understanding of the methodology by the authors. The softwares' design day calculations use algorithms (typically the ASHRAE model) to calculate outside direct normal and global horizontal irradiance values, rather than pulling the information from the weather file. Values for direct normal and diffuse radiation are readily available from VE and EnergyPlus, so these were compared. Design-day hourly results from VE and EnergyPlus for direct radiation were very similar to hand-calculated values, however diffuse values had variations for the different software. This is likely due to the simplification of the diffuse irradiance calculation incorporated in the hand calculation as well as differences in the diffuse calculation algorithms for the different software. Hourly values for direct normal and global radiation used in the 8760 simulation are pulled from the weather file.

The instantaneous solar gain is the total solar transmission (including direct beam, direct absorbed, diffuse beam, diffuse absorbed) into the space before the heat balance calculations are performed. EnergyPlus, eQUEST and VE report "window heat gain" (reported as "Solar Gain" in VE) which includes the outward flowing fraction due to convective and radiative heat transfer. Instantaneous solar heat gain must be obtained in TRACE via the Trace700Viewer. The hourly output entitled "QSolTrans" does account for the amount of heat reflected/retransmissed out the window from the space, however this output does not account for instantaneous wall glass transmitted diffuse energy. The magnitude of this outward flowing fraction in the total window solar heat gain varies depending on external environmental conditions at each hour and fenestration properties, including U-value. Further, it is to be noted that the hand calculation results for Solar Gain using the RTS method does not account for the outward flowing fraction. The peak solar heat gain magnitude and month are compared in Figure 2. The values shown for peak solar gain are the maximum results from the monthly design day calculations. As shown, results from the hand calculation and the software see similar peaks with some variability in the month. eQuest is noted to underestimate the peak solar gain. It is estimated that since only QSolTrans was only reported from Trace700, these values do not account for the diffuse fraction. Also, although the unshaded VE peak shown occurs in January, the value for December was roughly equivalent.

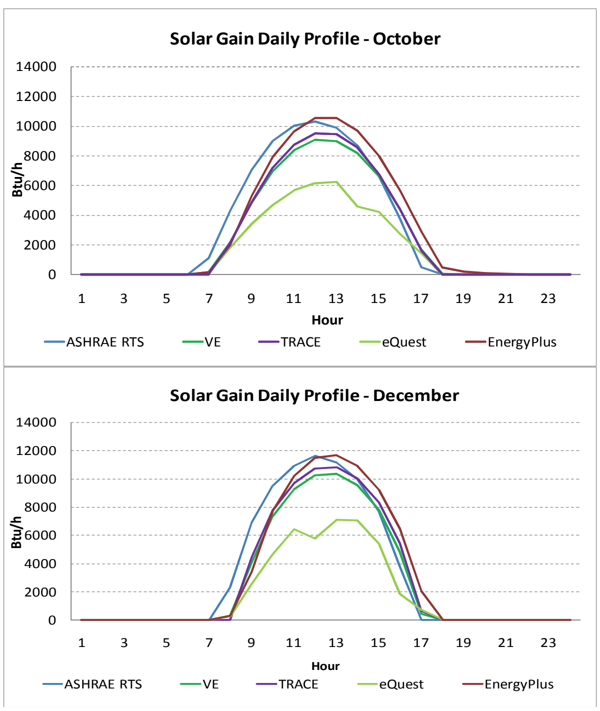
Figure 2: Peak Solar Gain, Unshaded and Shaded



The values for the shaded case follow a similar model, however the range of values is smaller. Some difference in the solar gain values demonstrated by EnergyPlus is related to known problems with the software and the Window5 glazing specification. Other methods of calculating solar transmission within the software were not explored in this study. Because the VE calculates the angular spectral data within the software, this is another means of variation.

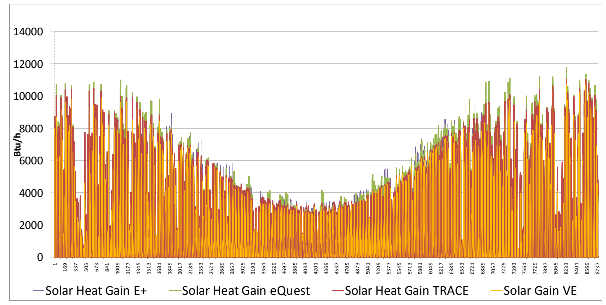
Figure 3 presents a comparison of coincidental solar gain profiles for October & December design days for all four software and the hand calculation (unshaded case). Each software uses its own solar calculation methodology to predict the solar position in the sky and the related irradiance data. The order of magnitude of the variation in the solar heat gain values remains consistent in all the three data comparisons shown here as well as for the shaded case.

Figure 3 Solar Gain Daily Profiles, December and October Design Days, Unshaded



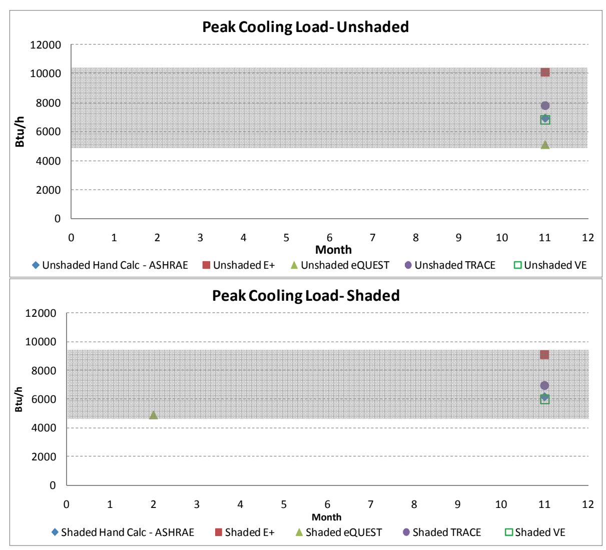
Because the annual 8760 simulation uses values for solar radiation directly from the weather file, theoretically the annual values for solar gain should be more similar than those from the design day runs. Figure 4 illustrates the annual data. As shown, the annual solar gain results for each software trend in a similar way to the design day calculation.

Figure 4: Solar Gain Annual Profile, Unshaded



Although EnergyPlus, TRACE, and VE all implement the Heat Balance Method, from the results it is obvious that they implement different algorithms for applying the same method. Variation in values is also attributed to different calculations performed for estimating incident irradiance, which gets carried forward. Figure 5 illustrates the peak cooling load for the unshaded and shaded cases. As shown, there is an increasing spread on the range of values obtained from the different software. Results for the shaded case showed a similar trend.

Figure 5: Peak Cooling Load, Unshaded and Shaded



Daily profiles for peak cooling load for October and December are illustrated in Figure 6. As shown, the daily profiles show similar relationships between software for different monthly design days. The annual results shown in Figure 7 reflect these same relationships between software.

Figure 6: Cooling Load Daily Profile, December and October Design Days (Unshaded)

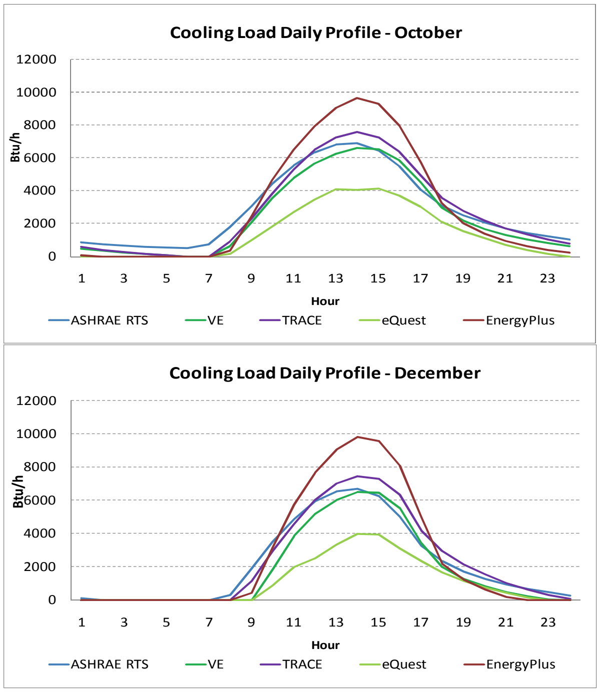
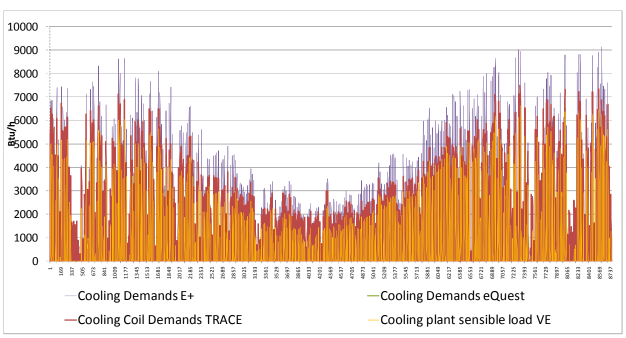


Figure 7: Annual Cooling Demand, Unshaded



When looking at cooling load, variations in results can not only occur from the solar gain differences previously described, but they also occur because of differences in conduction calculations and thermal mass calculations. The list of variations between software grows exponentially as the energy calculation progresses.

MODELING WATCH-ITS

WEATHER

EnergyPlus:

EnergyPlus allows users to input weather data in a variety of formats. Multiple design days can be input into the program. For Design Day calculations, the program offers the ASHRAE design dry-blub high input which is further translated into daily profiles using daily range multipliers and the following equations:

Tcurrent = Tmax-Trange X Tmultuplier
Where,
Tcurrent= Air temperature of current Hour of Day
TMax= User supplied Max Dry-bulb Temperature
Trange= User supplied Daily Temperature Range
TMultiplier= Range multiplier

EnergyPlus offers users a choice of various "Surface ConvectionAlgorithms". DOE-2 is widely accepted and documented to be the reliable model for this purpose. Similarly, EnergyPlus offers various solar models for calculation of solar position and irradiance data. The implications of using these models are well documented in the EnergyPlus documentation and should be consulted before choosing.

eQUEST:

eQUEST can simulate only 2 design days in one simulation. For the purpose of this study, the authors have "stitched" the hourly reports by creating separate design day simulations and combining the results in a spreadsheet. Modelers should note that while inputting design day information into eQuest, if the dry bulb range is not input, the program will use the max dry bulb temperature for each hour of the 24 hour design day period. This could have a significant impact on the peak cooling load calculation, depending on the geometry and internal loads of the space. eQuest uses a sinusoidal curve as a standard for the design day temperature profile, which is different that the ASHRAE curve. eQuest uses a default value of 10 as the cloud cover input for summer design day simulations, which is the maximum value allowed for this input and represents a completely overcast condition. This can significantly affect the peak heating and cooling results and thus capacity sizing of HVAC equipment.

TRACE 700:

The default weather data for San Francisco includes values for the annual heating and cooling conditions which are consistent with ASHRAE data, however the design weather days *per month* were not. Because the study required systems to be sized for peak condition *per the monthly data*, it was required to re-generate the hourly design day per month by manually inputting the design day data. The % of daily range values as defined in ASHRAE are embedded within the design day weather information. Because this was the curve chosen to use, hourly DB values for each design day per month were consistent with the hand calculation, however the WB values varied significantly. This leads the modelers to believe that the daily percentage ranges are as provided by ASHRAE Fundamentals for DB temperatures, but the WB daily percentage ranges are unclear and vary. Percentage of Daily Temperature Ranges are not specified separately by ASHRAE for WB temperatures.

If the modeler wishes to run the design calculation based on ASHRAE data and hourly energy analysis based on weather data (.epw or other) it is important to be sure to re-specify the design conditions (by month as described above or by annual data) for the imported weather file. TRACE will scale the reduced year hourly generated data according to the condition specified in the Weather Overrides tab. It is therefore important to check that the overrides are what you want them to be, as just checking the weather file will not necessarily be representative of the conditions used in the design calculation.

VE:

The default Design Weather Data specification within VE uses *monthly* design conditions per ASHRAE Fundamentals. The user can specify an the ASHRAE Standard Profile or a sinusoidal profile. VE by default incorporates a daylight savings time shift for the months of March-November. Also, when running short time steps within the VE, the program will interpolate the hourly weather data for each time step. For the ASHRAE design day calcuation, the modelers believe the outdoor diffuse solar radiation values are calculated using the ASHRAE model. This is awaiting confirmation from IES

WINDOW & EXTERNAL SHADING SPECIFICATION:

It is preferable to use data reports or results from Window5 where possible because of the specular information provided. Because frame effects are not directly transferrable from Window5 reports, the models did not include framing effects in the comparison. To our current understanding, none of the software in which importing is an option account for framing effects when uploaded from Window5, even though the frame is included in the window specification.

EnergyPlus:

When importing a Window5 file directly to EnergyPlus, the program does not use the glazing system angular dependent properties from the imported Window5 report when imported.

eQUEST:

eQUEST also has the capability to import reports directly from Window5. When doing this, eQuest uses the Center-of-Glass value as the overall assembly U-value. This is a limitation of eQUEST and the user is required to manually input the frame width, conductance, absorptance and spacer type information in the model despite using a Window5 report that has been generated using frame and glass U-values. eQuest allows users to easily input basic fenestration shading elements. The solar seasonal quantities required for shading calculations like the equation of time, sky diffusion factor, etc. do not change rapidly, and are calculated once a day. When solar data is not available from the weather file, direct and diffuse solar radiation is calculated using DOE-2's formula.

TRACE:

It is also possible within TRACE to import Window 5 data directly. Center-of-Glass values are imported similar to the other software, so the U-value should be edited within the model to include the frame if applicable. Additionally, modelers should take care with the U-value specification within the template. The relevant equation is provided for the winter U-value calculation within the TRACE User Manual. TRACE subtracts the summer film coefficient in the hourly calculation and then re-calculates the U-value based on the hourly wind speed. The coefficient which is subtracted is ho=4.025 Btu/hr-ft^{2}-F, whereas the coefficient initially included in the Window5 calculation is ho=4.578 Btu/hr-ft^{2}-F. Inside film coefficients also differ as hi=0.44 Btu/hr-ft^{2}-F (NFRC) versus hi=1.46 Btu/hr-ft^{2}-F (TRACE). For the window studied, an 11% increase in U-factor was input into TRACE to accurately account for the difference in film coefficient assumptions. Also, because TRACE has limited knowledge of the geometry of the building, the external shading calculation within TRACE does not include self-shading of the building. The shading algorithm within TRACE only effects the direct solar transmission in the space with regard to heat load. Daylight calculations within TRACE do not account for shading if specified.

VE:

A direct Window5 report import is not currently available within the VE. Rather, the calculated results from the Window5 tab for transmittance, reflectance, and emissivity can be hard-entered in to the Glazed Constructions tab. VE automatically calculates specular data, similar to Window5, for each angle of incidence. These values can then be viewed and checked against the Window5 values in the Derived Parameters tab. It is also important to select the ASHRAE U-value method when comparing values for consistency in film coefficient assumptions. This approach yields similar but not exact values compared to Window5. The following table compares the derived parameter results in VE with the Window5 results for the glazing studied. As shown, the calculated SHGC and U-value calculations are similar, with the most significant deviations lying within the angular solar transmission data. Because these values are lower than the Window5 calculations, this may explain why hourly solar gain results are less than the software which use specular data generated in Window5. The VE simulation used in this study implements a SunCast shading file which contains shading data for the current month. ApacheSim (used for the 8760 calculation) applies the shading data across the whole year rather than reading it directly from the weather file. At each time step, the radiation intercepted by each exterior receiving surface is calculated from the incident beam solar flux, taking account of the surface geometry and any external shading factor. Any radiation falling on an opaque element is partially absorbed and partially reflected. Radiation reflected from opaque or transparent surfaces is returned to the room for later distribution as diffuse radiation.

		Window5	VE Derived Parameter	% Difference
SHGC		0.274	0.2739	0.0%
U-value		0.296	0.2932	-1.0%
Short Wave Solar Transmission	0°	0.245	0.226	-8.4%
	10°	0.246	0.224	-9.8%
	20°	0.243	0.221	-10.0%
	30°	0.238	0.216	-10.2%
	40°	0.231	0.207	-11.6%
	50°	0.219	0.193	-13.5%
	60°	0.191	0.171	-11.7%
	70°	0.139	0.131	-6.1%
	80°	0.064	0.06	-6.7%
	90°	0	0	0.0%

Table 2: Glazing Comparison: Window5 vs VE Derived Parameters (SB70xl on Starphire)

THERMAL MASS INPUTS:

Perhaps one of the most sensitive inputs in the peak cooling load calculation using the heat balance method is with regard to the thermal mass of the space. The following sections discuss findings about the related inputs.

EnergyPlus:

EnergyPlus uses Conduction Transfer Functions (CTF) in calculation of detailed, time intensive convective heat transfers from the zone surfaces. The CTF method uses a fixed time step and the zone mean air temperature is also calculated for the same time step. Owing to the structure in which the time step series calculation is performed, the CTF calculation becomes unstable at a very small time step. For constructions with heavy masses, simulation results become more sensitive to the thermal effect.

eQUEST:

As described in the load methodology section, eQuest uses weighting factors in the both the LOADS and HVAC programs. The user can choose from two classes of weighting factors, custom weighting factors (CWFs) and ASHRAE weighting factors (AWFs). CWFs are calculated based on the space description and provide more accurate results. This methodology is generally recommended for use over AWFs. eQuest uses constant values of properties that affect the weighting factors of a zone for computation of cooling load over the desired timestep. This means that average values are used for properties such as convective film coefficients and distribution of solar radiation on interior surfaces. Though the cumulative cooling or heating is not significantly affected by this limitation, the granularity of the results needs to be carefully evaluated over each timestep.

TRACE 700:

In order to accurately account for thermal mass within the space, it helped to include partitions in the model. In this study, three internal partitions were generated and specified as Interior Mass. TRACE does not track solar gain onto specific surfaces as the solar altitude and azimuth vary and does not model direct radiant exchange between the surfaces in the space. Although the surface temperatures will not account for the solar gain which strikes the partition, the load will still be somewhat shifted. An approximate 4% decrease in peak cooling load was seen in this study after the addition of internal partitions with some thermal mass.

VE:

The heat transfer algorithms within the VE account for all of the materials within the room. Although a space can be placed next to an inactive layer, the program will still account for conduction gains and losses through all surfaces if there is mass. This means that placing a zone over an inactive space does not make it adiabatic. The authors have chosen to keep the internal construction as specified rather than to trick the model.

These effects, in this study's case, decreased the overall cooling load because heat was allowed to flow out of the occupied space through the partitions. This is another reason for variability in overall cooling load results out of the VE.

NOMENCLATURE

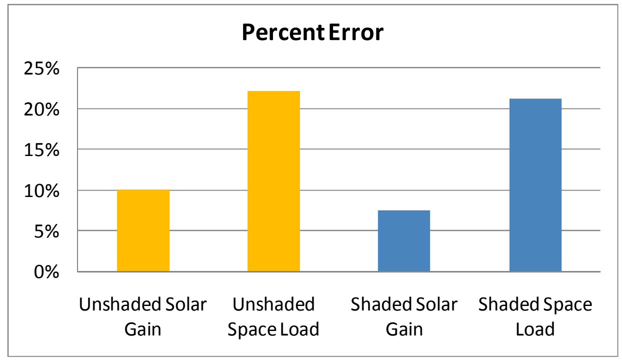
When understanding results from simulation models it is imperative that the user understand the nomenclature used to define them. Vaguely different terms can be used within different software to describe very different things. Also, there are typically limited definitions provided in the software manuals to explain all of the components of a particular result.

IES reports Solar Gain as the instantaneous solar gain into the room, and reports the cooling plant sensible load as the associated cooling load with that solar gain. TRACE, on the other hand, reports loads only after the Heat Balance Calc in the room and system reports, therefore it would be inaccurate to compare the Glass solar load results from TRACE to the Solar Gain results from IES. Instantaneous loads can be obtained from the hourly T700 viewer. "QSolTrans" corresponds to the instantaneous glass transmitted direct solar (incorrectly called hourly solar heat gain in the viewer), whereas "GLSOLR" corresponds to the wall glass solar room load (including thermal delay effects). "QGLDif" is the instantaneous wall glass transmitted diffuse solar. None of this heat is retransmitted. The total wall glass hourly solar gain is equal to QSolTrans + QGLDif. Please note that only eQuest reports both the values similar to IES, This is a potential point of confusion for modelers using TRACE700. Similarly, EnergyPlus reports the hourly "Window Heat Gain", which is defined as the instantaneous heat flow to the zone from the glazing. This heat is reported as a combined value for solar heat gain and conduction heat gain from the frame only. The components of the of the window solar heat gain are described in more detail in the EnergyPlus documentation.

CONCLUSION

Figure 8 summarizes the percent error generated in this study with regard to both the solar gain and cooling load stages. In solar gain calculations, the variables in the simulation are less in number than the space load calculation. This is because when computing solar gain, the software requires user inputs like climate, location, building geometry, and fenestration data. The error (based on the standard deviation) associated with these steps is approximately 7-10%. This deviation can be a result of a variety of factors including user input consistency, accuracy, and software calculation methodology.

Figure 8: Percent Error based on Standard Deviation



The error based on standard deviation associated with space loads in this study is significantly larger than the solar gain deviation (between 20-25%). Given the complex nature of building physics and thermal systems, the unknown variables affect the space loads more, thus there is more variability in the results.

As both façade and mechanical systems continue to become more complex and low-energy passive systems become more popular, feasibility studies like this can take on greater importance at early stages in design. Because even the simplest geometric model can achieve significantly varied results when using different software, it is important that the modeler have a general understanding of why the results can differ and how different inputs can significantly affect the overall results. Because small variations early on in the calculation can lead to amplified errors down the road in the system calculation, it is important to verify and check results at each step of the calculation.

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