CLIMATE DESIGN RESOURCE

TECHNICAL REPORT

Advanced Energy Efficiency Program – 2011

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Idaho Power Co.

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Executive Summary

This project aims to develop design resources that are specific to Idaho that will facilitate the use of passive strategies for reduced energy consumption in new commercial and industrial construction projects. These resources are actually available in numerous textbooks in the form of tables, graphs and charts. However, not many building designers use these resources directly from the textbooks, most likely due to the complexity of these resources and disparate locations. Simulation is another resource available to answer some of these design questions and guide the design process but it is commonly not in the scope of work, especially in the earliest design stages where passive strategies must be incorporated into the design. Therefore, this project collects the relevant passive design resources into a simple spreadsheet format so that they are more accessible to designers and provides comparison with simulated results in order to build confidence and in some cases bring attention to areas that require caution when implementing the spreadsheets.

Four different spreadsheet tools were developed: 1) heat gain calculation worksheet, 2) cross ventilation worksheet, 3) stacked ventilation worksheet, and 4) night ventilation of thermal mass worksheet. The spreadsheets contain step-by-step explanations and all information needed to perform the calculations. By using these four spreadsheets, building designers will be able to conduct a load optimization for their building designs, an important step in the early design stages for energy efficient buildings.

The tools have been introduced to and pilot tested by local building designers, and are available through the University of Idaho Integrated Design Lab website (www.uidaho.edu/idl/design-tool/passive-design-strategy-calculators). The tool has also been used in various building design projects, and two examples are included in this report.

1. Introduction

1.1. Background

Historically, people relied solely on passive strategies to condition interior spaces. However, the emergence of mechanical and electrical systems and inexpensive and reliable energy, has decreased the use of passive architectural strategies. It is easier and more convenient to simply install mechanical systems to heat and cool a building, rather than doing the calculations needed to effectively implement passive design strategies There is also a certain amount of perceived risk of employing passive strategies by mechanical engineers driven by owner expectations for unchanging thermal conditions. In part, this perceived risk is compounded by a lack of familiarity with the means of designing and implementing passive systems to maintain comfort.

There is no shortage of resources for passive design strategies. Calculations for these strategies are widely available in numerous textbooks, which have been simplified in the forms of graphs, charts and tables. And yet, very few buildings have incorporated passive environmental control elements into the design. A bridge between the textbooks and the designers, making these resource more user-friendly and centrally accessible will help to boost the use of passive design strategies.

1.2. Scope of Work and Objectives

The main objective of this project is to develop and compile spreadsheet tools for passive design strategies based on graphs, charts and tables available in various textbooks. This main objective is expanded into the following scope of work:

1. Develop a case study analysis that establishes passive design strategies for a minimum of three building types. The case study will include the following:
   a) demonstrate a step-by-step method for the use of each design strategy, and
   b) define the common assumptions required to use existing resources
   c) develop climate data 'quick reference guide' for use with existing charts and tables
2. Conduct daylight/energy/airflow/CFD simulations to test the passive design strategies. Compare the results of the simulations to those found in the case study analysis above. Define the assumptions used in the simulations and list any limitations (relative error, scope of usefulness) found with the charts and tables as compared to the simulations.
3. Develop educational materials that include hand calculations.
4. Host a passive design tool day.
5. Consult with Idaho Power Company staff on developing and implementing passive design strategies into incentive measures for Building Efficiency and Custom Efficiency Programs.

1.3. Project deliverables and report outline

This document reports how the project objectives were carried out. Each section of this document reports a specific item in the Scope of Work.

Deliverables for this project are:

1. Case study analysis results (completed charts and table), see Section 2.
2. Step-by-step design strategy method document, including a list of all assumptions for passive design strategies for a minimum of three and a maximum of five building types, see Section 2.

3. Climate data “cheat sheets”, see Section 2.

4. Comparative reports on daylight/energy/airflow/CFD simulations and hand calculations, see Section 4.

5. Attendance list from passive design tool day, see Section 5.

6. Suggestions for new passive design incentives measures within Building Efficiency and Custom Efficiency Programs, see Section 6.

2. Passive design strategies tool

The main deliverables of this project, i.e. the passive design strategy worksheets, are included as printed PDF documents in the Appendices of this report. The spreadsheets are also included in the CD accompanying this report, and are available through University of Idaho, Integrated Design Lab (IDL) website (www.uidaho.edu/idl/design-tool/passive-design-strategy-calculators).

From passive design strategies available in various textbooks (e.g. Grondzik et al. (2009), Kwok and Grondzik (2011), Brown and DeKay (2000)), this project has prioritized four strategies as relevant to the Idaho climate, which will be implemented as worksheets. These four strategies are:

1. Heat gains calculation, see Appendix B.

2. Cross ventilation calculation, see Appendix C.

3. Stack ventilation calculation, see Appendix D.

4. Night ventilation of thermal mass, see Appendix E.

With these four spreadsheets, building designers will be able to perform a load analysis and optimization for their building’s design. The load analysis can then be used to identify potential load reduction measures that will improve the performance of the building.

The spreadsheets include a step-by-step calculation method with all the assumptions included in the explanation. These spreadsheets are self-explanatory, and the information will not be repeated in this report.

The following items can be found in the in the section listed:

1. Case study analysis results, which explains the use of the worksheets. This is covered in a case study in Section 3 on the design of a fish hatchery.

2. Step-by-step design strategy method document, including a list of all assumptions for passive design strategies for three building types. There is no separate document on step-by-step design strategy and its assumptions because all of this information is included in the worksheet itself. The example calculation for three buildings are included on the CD:

a) a fish hatchery, see Section 3.

b) a small office, see Section 4.

c) a small classroom, included in the CD.

3. Climate data are also included in the worksheet, and worksheets are pre-populated with three separate climates in Idaho, as represented by Boise, Pocatello and McCall.

3. Case Study – Fish Hatchery

3.1. Overview

In 2011, local architects contracted with the IDL to perform a cooling load reduction and passive cooling strategy analysis on a project near Wendell, Idaho. The project's program consisted of a 20,000 ft^2 fish hatchery. Of this, 18,500 ft^2 were dedicated to a large volume hatchery room, and various support and office spaces comprised the remaining 1,500 ft^2.

The scope of the IDL's technical support only focused on the large hatchery room and proposed different packages of energy efficiency measures for heat gain reduction, climate analysis, and passive systems feasibility/schematic design. The goal was to reduce the internal heat gain load enough to be able to feasibly implement passive design strategies such as natural ventilation and night flushing of thermal mass.

Throughout all three types of analysis, the series of IDL's Climate Design Resource Worksheets were a pivotal tool in understanding the effect of design decisions and strategies. The spreadsheet tools were also helpful in facilitating more advanced analysis of various energy efficiency items when integrated with high powered simulation tools like Radiance (Larson and Shakespeare, 1998) for daylighting and THERM(LBNL, 2012).

3.2. Internal Gain Analysis

The "Heat Gains Calculation Worksheet" was utilized to develop a baseline peak cooling load for the model, which referenced information from the design team as well as the appendix code references of the spreadsheet. All geometry and site information were coordinated with the design team to ensure the accuracy between the spreadsheet's assumptions and the design of the project. The worksheets automatically generated disaggregated heat gain pie provided the information required to discern which components contributed the most to the peak cooling load, which totaled 8.74 Btu/hr-ft^2. Figure 1 shows that energy efficiency measures that target "lights" (35%), conduction from the "roof and walls" (28%), and "latent heat gains" (17%) would have the most effect. Consequently, the next two iterations responded to this information and used the spreadsheet tools in conjunction with more advanced simulation tools to quantify the effect of the load reduction measures and packages.

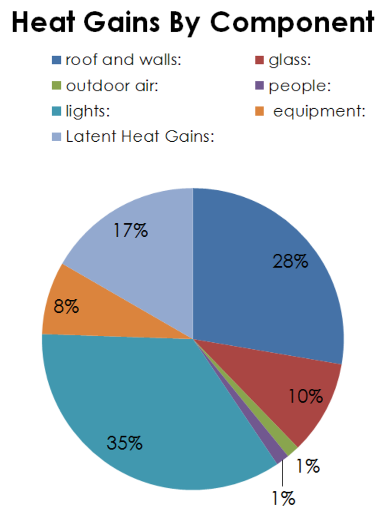


Figure 1: Baseline Heat Gains by Component

3.3. Package 1 – Improved Envelope

The load reduction measures included in the improved envelope package focused on increasing the overall U-value, U-0.11 (equivalent to R-9), of the original concrete block and concrete base wall construction, which did not meet the International Energy Conservation Code (IECC) 2009 (IECC, 2009)code requirements. New wall constructions were analyzed consisting a combination of air gaps and 2"x4" wood framed wall construction with fiberglass batt insulation. The new overall U-values ranged from a code compliant U-0.085 (equivalent to R-11) to a U-value of U-0.04 (equivalent to R-24).

The U-values were analyzed using THERM 6 software, which calculated the true U-values of the wall assemblies based upon thermal bridging and insulation design. These values were then used in the "Heat Gains Calculation Spreadsheet" to see the effect of the improved walls, along with a light colored roof and a tighter envelope. Figure 2 shows that 44% of the heat gain rate was due to latent heat gains, which was reduced to 35% and leads to an overall reduction of 10%, or a 7.26 Btu/hr-ft^2 heat gain rate.

3.4. Package 2 – Improved Lighting

The second load reduction package aimed at reducing the baseline lighting assumptions of the project and tested a space where the entire area was daylit, and supplemental electric lighting was controlled via daylight sensors. Multiple geometric, size, and location changes were applied to the dormers and clerestories of the existing design to improve the interior illumination of the baseline.

Radiance software was used for daylighting simulation, which revealed that the initial baseline design did not reach 10 footcandles (fc) on a cloudy day in any of the space. Only

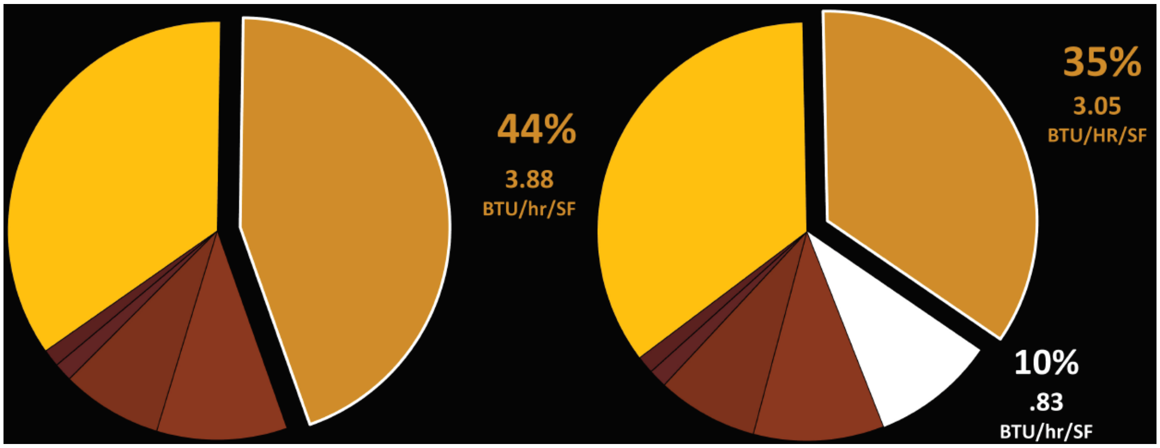


Figure 2: Heat Gains Improvement with Improved Envelope Energy Efficiency Measure

40% of the floor plan exceeded 10 fc during the sunny sky condition. After the changes, 91% of the floor area exceeded illumination levels of 10 fc during cloudy conditions and 100% during sunny periods.

These data from Radiance confirmed the usage of the most aggressive daylight factor input for the "Heat Gain Calculations" worksheet, which in turn, reduced the amount of heat gain from the electrical lights as much as possible, assuming a fully continuous daylight harvesting system. This measure reduced the contribution of the electric lights to 8%, or a 53% total reduction on top of the savings already accrued by the improved envelope. Figure 3 shows a comparison of all three measures, broken down into their constituent components with total Btu/hr-ft^2 results.

3.5. Passive Systems Analysis

Once the load reduction measures were tested, climate analysis, built directly into the spreadsheets, was used to analyze the feasibility of natural ventilation. A 12x24 (average of each hour for a 24 hour period for each of 12 months)plot of all the temperature ranges of the climate are graphically depicted in both the "Cross/Stack Ventilation Capacity Calculations" worksheets.

The chart, as shown in Figure 4, plots the temperature ranges for every month on the horizontal axis and every hour of the day on the vertical axis. The chart also quantifies the percentage of time during each temperature range throughout a typical year. These ranges were used to discern when the building could operate in the "free-running" mode to accept natural ventilation, when the building could utilize a "night flush" system, and when the project had to operate in pure "heating" mode.

The cross and stack ventilation worksheets were used to determine the optimum amount of operable area of windows that met the 4.11 Btu/hr-ft^2 load calculated in the previous

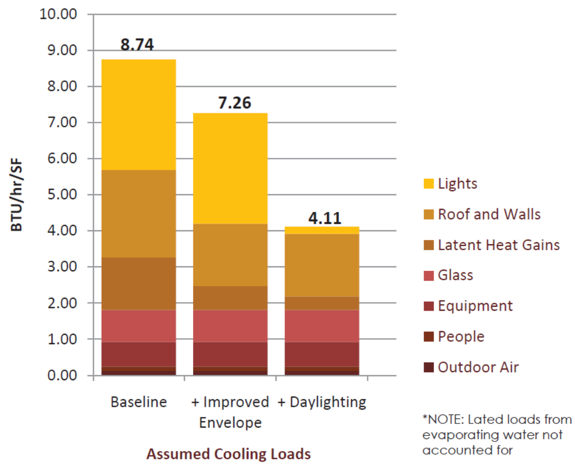


Figure 3: Heat Gains Reduction from All Three Load Reduction Packages

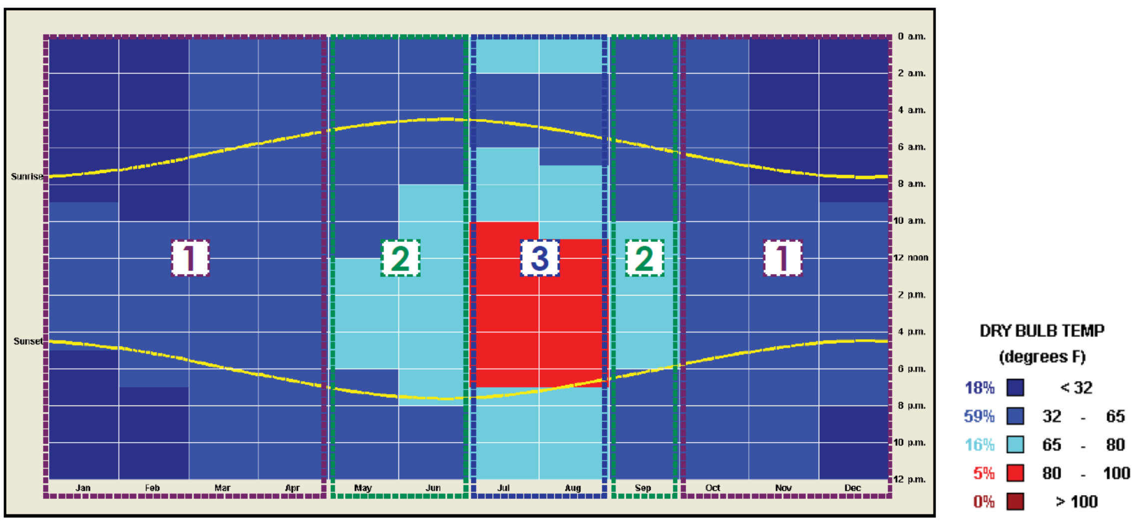


Figure 4: 12-24 Temperature Plot of Project's Climate

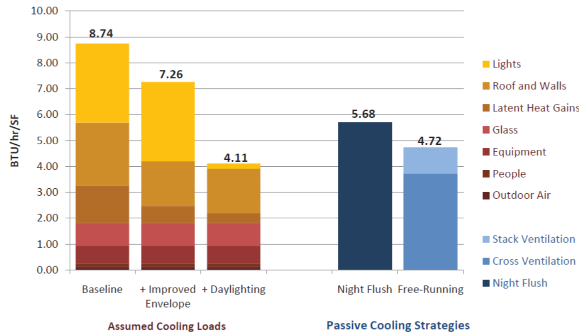


Figure 5: Final Summary Chart of Peak Cooling Loads and Passive Cooling Strategy Capacities

section. In the end, a combination of stack and cross ventilation was proposed, which contained 130 ft^2 of louvers on both the east and west facades. The scheme also incorporated operable windows in the roof monitors and clerestories as outlets for the natural ventilation scheme.

The strategy achieved a cooling capacity of 4.72 Btu/hr-ft^2 with a total flow rate of 26,463 CFM, which met the peak heat gain of the building. However, this cooling capacity is based on the minimum temperature difference that must use a lower outdoor temperature than that of the design cooling day. Consequently, these strategies cannot be used to meet the peak load of the project but could meet the cooling loads during lower outdoor air temperatures. The 65-85 °F temperature range in Figure 4 illustrates when these natural ventilation schemes could be utilized in the building.

The "Night Flush Ventilation/Thermal Mass Calculations" worksheet determined the cooling capacity of night ventilation to cool the large amounts of thermal mass in the hatchery room. This project has a large amount of mass due the concrete material of the floor slab, CMU walls, and concrete fish tanks/troughs, and this large amount of mass is represented by the ratio of the thermal mass surface area to floor area, in this case 1.65.

The worksheet calculated the sensible cooling capacities of the mass during the design cooling day of the climate based upon the interaction of the outdoor air temperature, assumed ventilation rate, specific heat of the concrete, and other complex factors. Additionally, the calculations showed an hourly basis for when the building should be opened for night flush and when the windows should be closed. The worksheet produced an ideal amount of airflow needed for optimum removal of heat stored in the mass, which could be checked against the previous ventilation worksheets and adjusted for during nighttime conditions. This measure proved to be very effective in meeting the peak cooling load of the project and had a potential 5.68 Btu/hr-ft^2 cooling capacity.

Figure 5 shows the final comparison chart between the assumed peak cooling loads and the capacities of the passive cooling strategies tested by the spreadsheets.

3.6. Conclusion

The series of passive design worksheets proved to be an effective tool in the analysis of the example fish hatchery project. The tools were quick and easy to use, with little room for error concerning the input of data due to its step-by-step nature and limited input cell approach. The results were also instantaneous, which allowed for quick and iterative analysis, a benefit over most simulation approaches. This aspect of the worksheets was especially useful when trying to arrive at the optimum natural ventilation scheme for the project. Multiple combinations of effective opening areas were inputed into the spreadsheets and their impact on the cooling capacity of the system was instantly updated.

Additionally, the tools were compared with advanced simulation tools to help verify assumptions. Both Radiance and THERM were used to conduct detailed analysis on envelope upgrades and daylighting potential, which was then input into the "Heat Gains Calculation Worksheet". Without these advanced simulation tools the worksheets could have still been utilized for this type of analysis, but the inputs for the upgraded envelope and electric lighting reduction would have operated as less-detailed assumptions. The worksheets showed versatility in that they could be used as stand-alone analysis tools or in tandem with other types of simulation tools or calculation methods.

4. Case Study – Small Architecture Office

4.1. Background

The intent of this study is to analyze an existing small office building's performance characteristics using both the Climate Design Tool hand calculation method and an energy modeling approach for comparison. The Climate Design Tool uses a series of spreadsheets based on typical hand calculation processes, while EnergyPlus Version 6.0 was used for the modeling software.

The differences between the two methods were analyzed and are discussed to draw conclusions about the accuracy of the hand calculation's limited assumptions concerning peak loads and passive cooling design strategies. Additionally, energy savings figures were modeled using the Climate Design Tool's assumptions, in an attempt to quantify potential energy savings relative to output from the hand calculations. The study used a small, 1,600 ft^2 office building in Boise, Idaho as the baseline case. The project has a north-south orientation, multiple operable windows both low and high, ample daylighting, a double height volume, and an exposed concrete slab.

4.2. Disaggregated Peak Loads

Both tools are capable of disaggregating the components of a building's peak cooling load. Each methodology was calibrated using the ASHRAE 1% cooling design day with a 94 °F design temperature in the Boise, Idaho climate. Table 1 lists all the assumptions for the internal loads that were used for both the hand calculation and energy modeling tool inputs.

Table 1: Assumptions Comparison

Methodology Assumptions		
Critical Inputs	**Simulation**	**Hand Calcs**
Floor Area	1582	1547
Occupancy	10	10
Wall R-Value	20	20
Roof R-Value	62.5	62.5
Glazing U-Value	0.37	dbl heat abs
Kalwall U-Value	0.29	dbl heat abs
Floor R-Value	uninsulated slab	no input
Ventilation Rate	17 CFM	17CFM
Lighting Power Density	1.1	1.1
Equipment Power Density	0.9	0.9

Despite a small floor area discrepancy and glazing parameter differences, the two methods had relatively similar inputs.

Figure 6 shows the magnitude of the disaggregated load components and their contribution to the small office building's total peak cooling load in Btu/hr-ft^2. The figures show that the hand calculation method is around 38% higher than the energy simulation results. The lower simulation figure is to be expected, mainly due to the fact that it uses the building's coincident peak cooling load. This means that the software adds up the constituent internal heat gains for the hottest hour of the peak day profile, making sure that they happen at the same time. The hand calculation method's simplified approach takes the max load of each component regardless of the other components or the time of day. This leads to a fictional "worst case scenario" that is much easier to account for in a hand calculation approach. The hand calculations show a larger load per component for everything except for equipment.

Some other key structural differences between the two approaches exist. For instance, Figure 6 shows that the hand calculation method calculates latent loads and infiltration substantially differently, which makes direct comparison with the energy model difficult. This method assumes that the latent gains are closely associated with outdoor air infiltration and estimates additional latent heat as a percentage of total sensible gains. The process uses the design dry bulb and wet bulb temperatures, along with assumptions about construction tightness, to achieve a percentage which is then applied to the total sensible heat gains. These are very broad assumptions and might start to explain why the infiltration value for the energy model is so low and why the hand calculation is so high.

Another factor for the discrepancy deals with the way the modeling software calculates latent heat gain and infiltration. The latent heat load from occupants and other internal gains are automatically calculated, along with their sensible heat gains. Consequently, each simulation value includes both sensible and latent loads. Additionally, the infiltration internal heat is based on the actual airflow rates from outdoor air into the building, specified

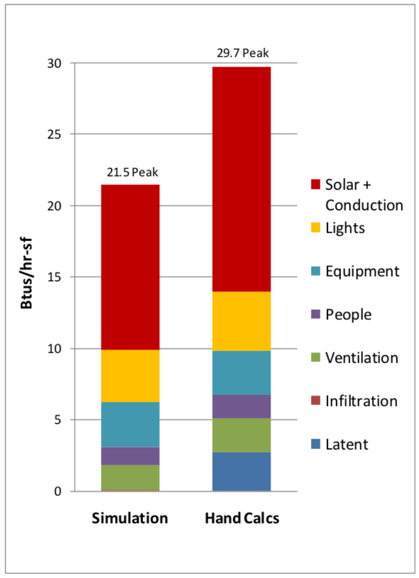


Figure 6: Peak load comparison

Table 2: Disaggregated Peak Cooling Loads

Btus/hr/sf	Latent	Infiltration	Ventilation	People	Equipment	Lights	Solar + Conduction	Total
Simulation	0	0.06	1.76	1.27	3.14	3.66	11.59	21.48
Hand Calcs	2.7	0	2.42	1.62	3.07	4.2	15.68	29.69
% difference	4749%	4749%	-37%	-28%	2%	-15%	-35%	-38%

as 0.4 air changes per hour (ACH) in the simulation. This airflow is also based on a "quarter-on" infiltration schedule. This assumes that the building is pressurized during occupied hours, which decreases the infiltration rate to 25%. The hand calculations do not account for positive air pressurization due to HVAC conditioning and ventilation. Figure 7 and Table 2 illustrate this difference along with a very substantial discrepancy between the "Solar + Conduction" fields.

The glazing performance specifications are highly simplified in the hand calculation methodology. Instead of using the typical U-value of the window assemblies, this method applies a "Design Cooling Load Factor," which is based on the window orientation, shading device type, outdoor design temp, and some general glazing types. These types do not include performance specifications, rather they are based on the following general performance characteristics: regular single glass, regular double glass, heat absorbing double glass, and clear triple glass.

Additionally, the baseline building has a significant amount of sandwich panel translucent glazing on both the east and west facades. According to Table 1, the sandwich panel has a higher insulation value than the rest of the building's double glazed windows. The hand calculation model uses the highest performing "heat-absorbing double glass" for all of the

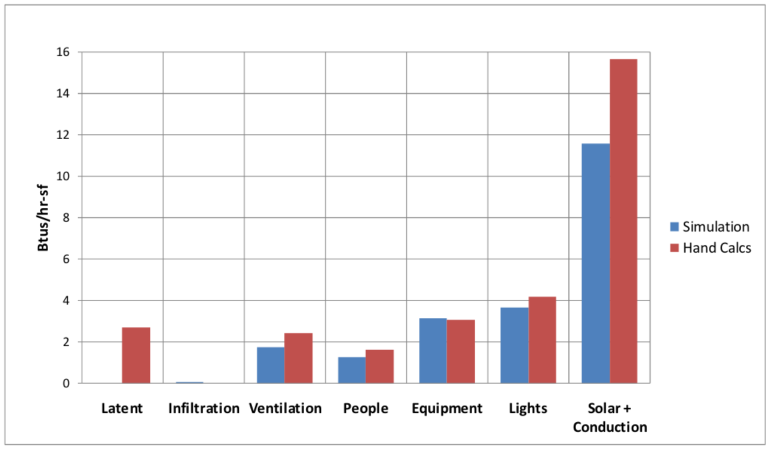


Figure 7: Disaggregated Peak Cooling Loads

windows and thus most likely over-penalizes the buildings east and west sandwich panel translucent glazing. This might account for the 35% difference between the simulation and hand calculation outputs for the "Solar + Conduction" values.

Finally, the hand calculation method does not take into account the heat gain or cooling capacity of the floor system. In the model, the slab on grade assembly would create a cooling effect through its thermal coupling with the ground. Additionally, EnergyPlus has a variety of different ground-contact models to simulate a floor assembly's thermal interaction with ground temperatures directly underneath the building. In the case of the small office building, the slab and floor assembly most likely decreases the heat gain from the "Solar+Conduction" component, accounting for some of the 35% discrepancy between the two methods.

4.3. Passive Design Strategies

The study also analyzed the difference in the assumptions between various passive cooling measures and their effect on peak loads. The comparison method goes as follows:

1. First, the hand calculation tools were used to define the as-built conditions of the baseline small office building.

2. Next, the performance assumptions were translated into the energy model and simulated. Outputs on peak load reduction were then compared.

3. Finally, the energy model calculated potential cooling and total building energy savings, something that the hand calculation tool is not capable of.

Figure 8 and Table 3 show the results from separately analyzing a night flush with thermal mass design scenario and a combined stack and cross ventilation approach.

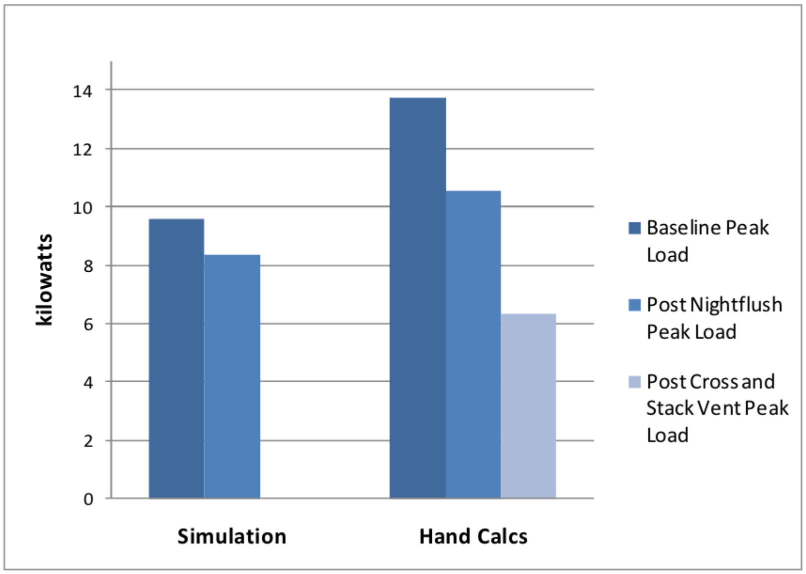


Figure 8: Passive Design Cooling Load Savings

Table 3: Passive Design Cooling Load Savings

	Simulation	**Hand Calcs**
Baseline Peak Load	9.6 KW	13.75 KW
Post Nightflush Peak Load	8.36 KW	10.56 KW
% savings	**15%**	**23%**
Post Cross and Stack Vent Peak Load	0.00	6.32 KW
% savings	**0%**	**46%**

Table 4: Peak Day Profile

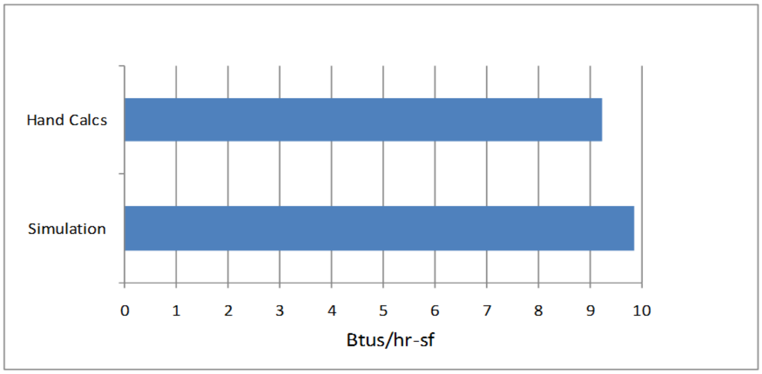
Date/Time	Outdoor Temp (F)	Indoor Temp (F)	Heat Gain (W)
07/21 01:00:00	67.49	72.62	0.00
07/21 02:00:00	66.28	71.67	0.00
07/21 03:00:00	65.37	70.76	0.00
07/21 04:00:00	64.46	69.99	0.00
07/21 05:00:00	63.86	69.36	0.00
07/21 06:00:00	64.46	69.39	0.00
07/21 07:00:00	66.58	70.67	0.00
07/21 08:00:00	71.72	74.70	977.37
07/21 09:00:00	77.47	75.20	2255.47
07/21 10:00:00	82.61	75.20	5770.30
07/21 11:00:00	87.14	75.20	6592.79
07/21 12:00:00	90.17	75.20	7038.92
07/21 13:00:00	92.59	75.20	7210.78
07/21 14:00:00	94.10	75.20	7657.95
07/21 15:00:00	94.10	75.20	8069.54
07/21 16:00:	**92.29**	**75.20**	**8247.68**
07/21 17:00:00	89.87	75.20	8194.46
07/21 18:00:00	86.84	75.20	8007.33
07/21 19:00:00	82.31	75.20	4004.82
07/21 20:00:00	78.98	79.69	0.00
07/21 21:00:00	76.26	79.72	0.00
07/21 22:00:00	73.54	79.40	0.00
07/21 23:00:00	71.42	75.23	0.00
07/21 24:00:00	69.30	74.16	0.00

In terms of the night ventilation and thermal mass strategy, both methods showed similar peak cooling savings percentages, however, the simulation was once again slightly more conservative. The hand calculation method defined the inputs for the energy model which included: the volume of thermal mass, its thermal characteristics, the ventilation schedule/airflow rate, and even the temperature control scheme. Despite the calibration, the slight difference could also be due to the specific ground-contact models in the simulation software, the two way heat balance algorithms of EnergyPlus, or other complexity factors that the simulation can take into account. Additionally, the lack of floor insulation or ground temperature inputs from the hand calculations likely accounts for some of this difference as well.

Figure 8 also shows a value for “Post Cross and Stack Ventilation Peak Load” based on the hand calculations and not the simulation. The hand calculations require a minimum indoor to outdoor temperature difference of at least 3 °F to define the system. Consequently, the peak load savings are based on this temperature condition. The energy model result differed when analyzing the effect of natural ventilation on the peak cooling load of the building. Table 4 shows the hourly outdoor temperature of the peak cooling day, the indoor temperature, and the heat gain rate. The peak hour is highlighted in red and reveals that the outdoor air temperature is 17 °F higher than the indoor temperature, effectively disallowing any type of natural ventilation during that hour. Consequently, most natural ventilation strategies would not be able to contribute to peak load reduction.

Regardless of this limit, simulation and hand calculation comparisons were carried out at a 3 °F temperature difference. The hand calculation method estimated an airflow rate

Figure 9: Natural Ventilation Cooling Capacity Calculations



	Simulation	Hand Calcs	% difference
Cooling Capacity @ 3 delta T (Btus/hr-sf)	9.86	9.25	7%

of 4,420 CFM according to the as-built window opening and operability information, and this value was inputed into the energy model. The difference in the zone design cooling rate was then calculated as the natural ventilation scheme's cooling capacity and compared against the hand calculation outputs. Figure 9 shows that the difference between the two method's cooling capacities to be 6.5%.

Despite the lack of load reduction at peak cooling conditions, the Climate Design Tool is flexible enough to calculate and analyze multiple temperature conditions for natural ventilation schemes. The ability to understand a variety of cooling capacities at higher temperature difference conditions throughout other times of the year can still be used to evaluate the effectiveness of the strategy. Figure 10 shows the annual energy consumption of the different end uses of the building's different passive design strategies.

While the total energy savings might not be substantial, due to the fact that cooling only represents about 13% of the total load, natural ventilation saves about 18% of the cooling energy and 31% of fan energy (Figure 11 and Table 5). The savings could also be larger, but the unitary HVAC system in the energy model is required to have a fixed dry bulb economizer in Boise's climate. The economizer already captures some of the free cooling from outdoor air, leaving a decreased savings effect for other natural ventilation strategies. An adaptive comfort range and increased cooling set point of 78 °F would also lead to more occasions when the building could operate in "open mode", thereby leading to more savings. Additionally, the night flush savings would be higher if an optimal thermal mass to surface area ratio was utilized, instead of current minimum 1-to-1 ratio used due to thermal mass only residing within the floor slab.

Figure 10: EUI Comparison

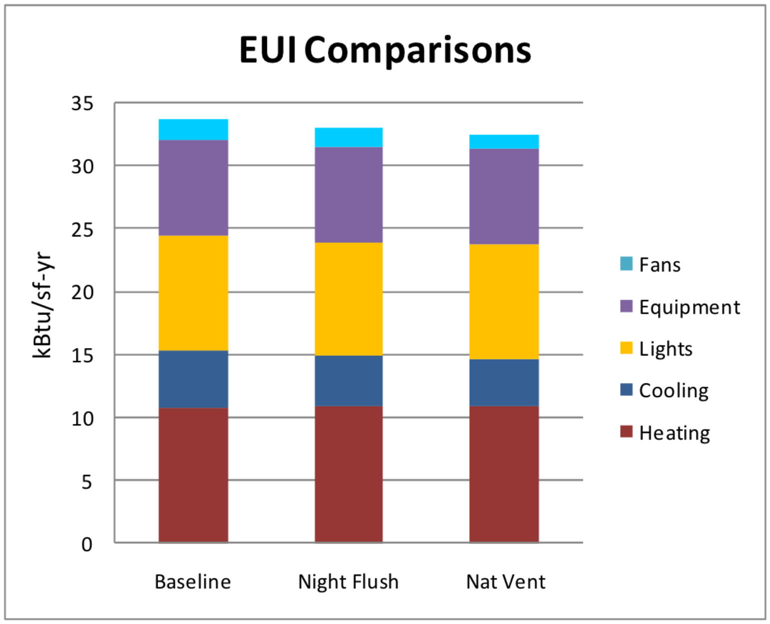


Figure 11: Cooling Energy Comparison

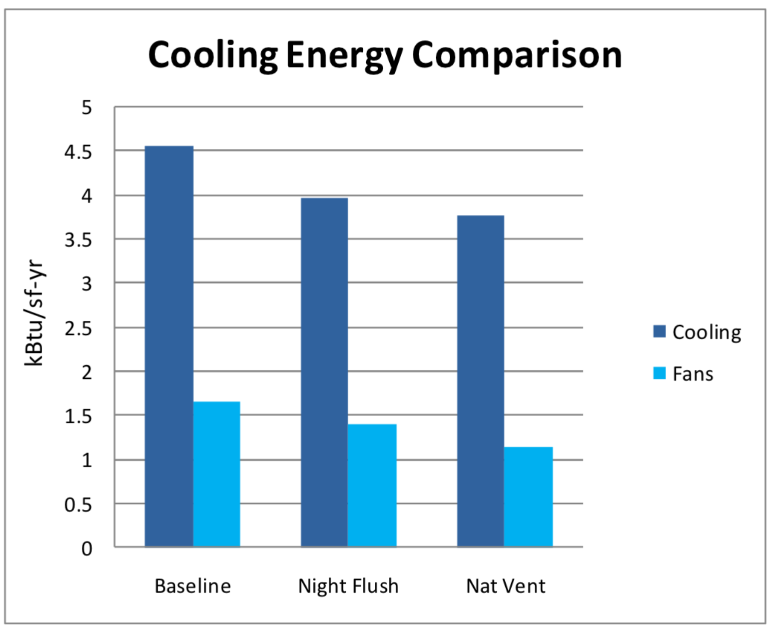


Table 5: Cooling Energy Comparison

(kBtu/sf-yr)	Baseline	Night Flush	% savings	Nat Vent	% savings
Heating	10.82	10.86	**0%**	10.86	**0%**
Cooling	4.55	3.97	**13%**	3.76	**18%**
Fans	1.65	1.41	**0%**	1.14	**0%**
Equipment	7.58	7.58	**0%**	7.58	**0%**
Fans	1.65	1.41	**15%**	1.14	**31%**
total EUI	33.69	32.91	**2%**	32.44	**4%**

Table 6: Peak Cooling Comparison

(kBtu/sf-yr)	Baseline	Simplified Method	AirflowNetwork
Cooling	4.55	3.76	3.61
Fans	1.65	1.14	1.25

4.4. EnergyPlus and AirflowNetwork

In the previous section, the natural ventilation simulation was conducted using a simplified airflow modeling methodology in EnergyPlus. This involves specifying objects that would ventilate at the rate specified by the hand calculation tools.

EnergyPlus also contains an auxiliary program that uses more advanced methods of airflow calculation based upon specified window openings, control schemes, and actual wind data from Typical Meteorological Year (TMY) weather files. Despite the wind data inaccuracies associated with using TMY weather files, this method can be used to both quantify energy savings and to verify airflow performance characteristics of the openings defined in the hand calculations.

Figure 12 shows a comparison between the cooling and fan annual energy consumption of the baseline, simplified simulation method, and AirflowNetwork method. The graph reveals that the more detailed calculations are fairly consistent with the simplified method.

AirflowNetwork can also provide insight into the accuracy of the airflow rate assumptions of the openings defined in the hand calculation tool. The hand calculation method estimates an airflow in cubic feet per minute (CFM) of the cross and stack ventilation system based upon a temperature difference, a wind speed, an opening area, and an opening pressure discharge coefficient. All of these factors can be tested with the AirflowNetwork model and the resulted airflow rate can be calculated.

Figure 13 shows the difference between the two calculation methods. The graph reveals that the simulation airflow rate is significantly larger than the hand calculations by about 50%.

Figure 12: Peak Cooling Comparison

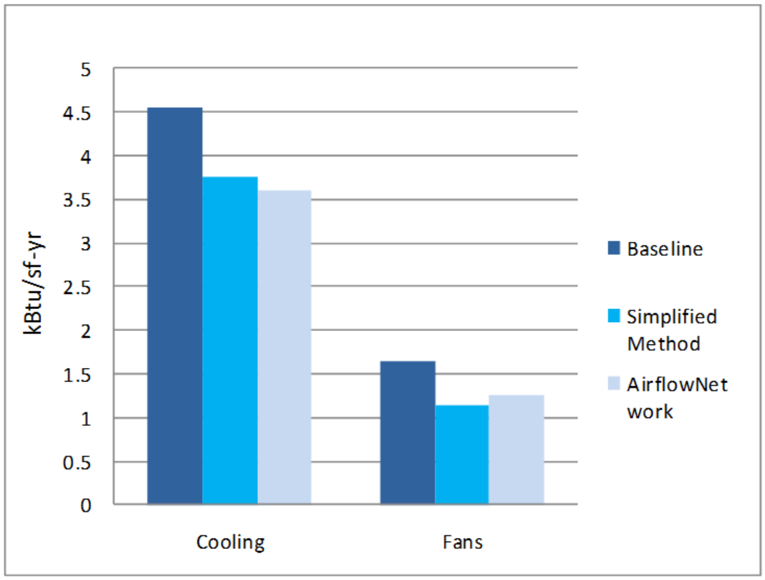
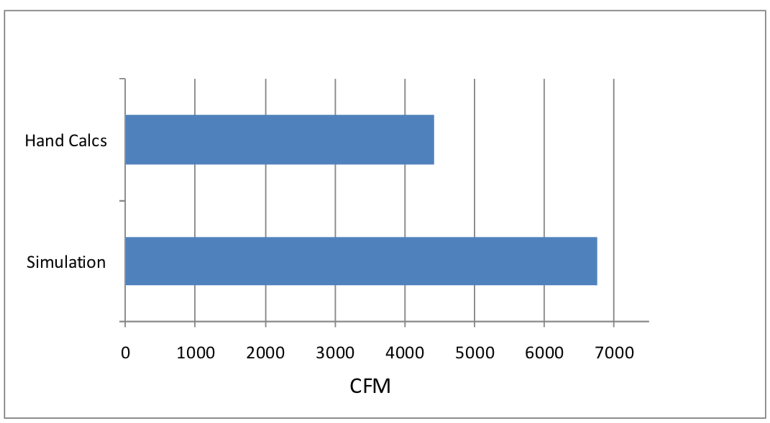


Figure 13: Airflow Rates



(CFM)	Simulation	Hand Calcs	% difference
Airflow	6770	4420	153%

4.5. Discussion

Generally speaking, the computer simulations, using EnergyPlus, validated the simplified assumptions of the hand calculation method critical to the Climate Design Tools. The study also provided some key insight into the differences between computer simulation and hand calculation methods. The simulation's ability to model realistic occupancy schedules and coincident peak loads are critical advancements when calculating peak loads. Additionally, more complex heat balance algorithms can take into account the complex relationships between the building and its external boundary conditions. This is critical with envelope dominated buildings and thermal mass strategies that take into account sensitive ground temperatures. Regardless, the study showed the hand calculations produced similar results compared to the simulation at an acceptable level of confidence for early design analysis.

Most of the variations between the two methods existed within the disaggregated peak loads, mostly due to the complex glazing conditions of the as-built case study building. The hand calculations could be more reliable and attain more accurate results if utilized on projects with straightforward glazing approaches. Additionally, reduction factors for infiltration scheduling can always be applied after the calculation to take into account building pressurization effects.

The energy simulations also proved that the Climate Design Tools had limited applicability concerning peak load reduction analysis. Night flush ventilation and thermal mass strategies were easily quantified concerning both cooling capacities and peak load reduction, but natural ventilation proved to be more difficult.

Despite not being able to contribute to the peak cooling condition, the strategies did prove to be effective and accurate in significant load reduction during other temperature conditions of the cooling season. This reflects the need for a more annualized output of the Climate Design Tools to both better understand performance and to make the tool more useful. The hand calculations can only specify a cooling capacity based upon a single temperature difference condition at one point in time, when in fact this will change according to the time of day and month. Consequently, more detailed analysis measures such as whole-building simulation or other quantification measures are needed to form a more complete picture of the load reduction potential. Regardless of this limitation, both the simple and detailed computer simulation of the natural ventilation performance assumptions were very similar to the hand calculations.

The annual energy savings outputs from the simulation showed that there are many complicated factors when simulating energy performance from natural ventilation. The climate, the percentage of hours with acceptable indoor and outdoor temperature differences, and the economizer mode in the HVAC system affected the performance of the natural ventilation system.

In conclusion, the hand calculation methods fulfilled their intent as a quick and easy rule-of-thumb device, which holds an acceptable degree of accuracy when compared to computer simulation, and hold merit in early design stages. Despite not being able to quantify energy savings, the tools can effectively be used to evaluate the appropriateness of certain passive design strategies through load analysis. The tools can be successfully used to determine whether or not to pursue further development and analysis of certain passive design strategies and can help designers make informed decisions during early design stages.

5. Educational sessions

The IDL disseminated the passive design spreadsheets to the local building designers by using two learning methods:

1. Targeted learning sessions
2. Passive design tool day

The targeted learning sessions were carried out in various architecture and engineering firms in Boise. The sessions were conducted throughout the development stages of the spreadsheets. Apart from disseminating the tool and the knowledge, the sessions were also used as a feedback mechanism for the spreadsheet tool development. There were three separate learning sessions conducted at three different architecture and engineering firms.

After the completion of the spreadsheet tool development, a Passive Design Tool Day was held on 24-JUN-2011. The tool day was a workshop setting where participants learned via hands on exercises how to use the passive design spreadsheets. The tool day contained step-by-step tutorials for use with a small classroom design (Figure 14). The tool day had 13 participants (see Appendix F) and received good feedback.

6. Concluding remarks

This report summarized the development of design resources that are specific to Idaho that will facilitate the use of passive strategies in new commercial and industrial construction projects. The resources have been used in various building design projects and were introduced to local building designers throughout the development stage and afterwards.

Four different spreadsheet tools were developed in this project: heat gain calculation worksheet, cross ventilation worksheet, stacked ventilation worksheet and night ventilation of thermal mass worksheet. These spreadsheets have proven very useful in the early design stages, as load analysis is the key factor in achieving high energy performance. This report outlines two case study examples for the use of these tools.

The IDL believes that the use of the passive design strategies can be increased via incentives for these strategies. The IDL has consulted IPC staff (in a meeting in April 2011) on how to incorporate these passive design strategies into an incentive program. The general conclusion of this consultation is that there are many additional challenges before these strategies can be incorporated into an incentive program. By its very nature, the structure of utility incentive programs requires that additional capital costs be associated to certain

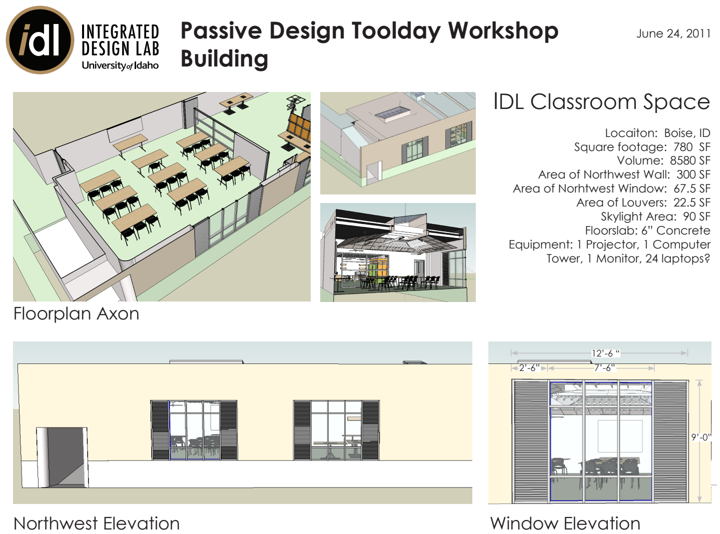


Figure 14: Building description for the tool day

efficiency measures. Without this additional cost, the efficiency measure cannot be considered for an incentive program. Once an incremental additional cost can be identified, then the measure must meet multiple cost effectiveness thresholds. Finally, many passive design strategies require user interaction, for example to operate a night flush strategy.

The most passive measures often do not cost more and require more user participation. This creates a very challenging scenario to support incentives because the incremental first costs is not present and it is difficult to guarantee energy savings due to the requirement of occupant engagement. The most passive strategies often require additional design time. It may be possible to estimate the cost of these additional design services on a per square foot basis to support the case for developing an incentive. However, tenant engagement must still be addressed.

Hybrid active-passive strategies, in fact, provide solutions to both of these issues. That is, the active portion (motorized dampers, fans, etc) can help to justify the incremental cost increase and they can also ensure energy savings because they do not rely solely on occupants to operate the facility as designed. The drawback, however, is that they cost more and do not necessarily save more energy assuming engaged tenants.

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A. Worksheet Cover

IPC and IDL Climate Tools Package

Cover Sheet

Description:

The Idaho Power Company and Integrated Design Lab Climate Tools Package encompasses a series of excel spreadsheets intended to assist in the process of designing and evaluating the application of passive strategies on a project. The different spreadsheets are designed to first calculate the peak heat gain rate of the building and then compare this value to a variety of different passive design measures' cooling capacities.

Currently, there are four different spreadsheets:

1. **Heat Gain Calculations**
2. **Cross Ventilation**
3. **Stack Ventilation**
4. **Night Ventilation Thermal Mass**

Instructions:

Each spreadsheet contains multiple tabs and a step-by-step process that directs the user to define the critical parameters of the building. These factors are linked to pre-defined equations within the spreadsheet that automatically provide the peak cooling loads, cooling capacities, and other performance metrics of the building. Charts, line graphs, and other forms of graphic information also automatically populate the workspace to provide visual feedback to the user. The last tab of the spreadsheets contain a reference tab that includes a myriad of textbook, code, and other sources needed to complete the step-by-step instructions. Additionally, a certain amount of weather data is embedded into the calculations and spreadsheet based upon the different Idaho Power Company service territories. Once each tab is filled out, the first page of the spreadsheet contains all of the important outputs needed to evaluate how much the passive design measure can contribute to the peak loads of the building. Changes to the building parameters are instantaneous, making the Climate Tools Package an ideal instrument used to explore different design iterations and how they might facilitate passive design strategies.

Goals:

The ultimate goal of the Climate Tools Package is to reduce the loads of a building through passive design measures. This happens mainly by embedding, early in the design process, the analysis of the performance capabilities of different passive cooling and heating strategies. Once a performance capacity is calculated and compared against peak loads of a building, a qualitative decision can be made whether or not to pursue more detailed analysis. If certain passive strategies are proven to meet some or all of the peak load, this may warrant further development. Potential next steps could involve more advanced analysis such as building simulation to quantify annual energy savings based on actual weather data.

B. Heat gain calculation example

IPC and IDL Climate Tools Package

Heat Gain Calculations

Description:

The heat gain rate of the project is an important metric in determining how to size passive design strategies and systems. The heat gain rate of your building, often measured in Btus/hr/square foot, will determine the cooling capacity requirement of either the building's passive or active systems. The amount of heat gain in a particular building or zone is the product of multiple factors including heat gains through the building envelope, air infiltration, ventilation, and the internal gains of a building from inhabitants and other types of equipment.

Instructions:

This page contains the final results of the calculations of the worksheet. Start with the tab labeled "Step 1" and follow the step-by-step process using the reference tab if needed. Finish going through all tabs before returning to this page to see the heat gains broken apart into their constituent loads and the resultant total heat gain rate of the building.

Cell Color Legend:

Certain cells are colored in a manner that dictates whether or not they are a user defined input, or if they automatically calculate based off of internal equation or climate specific parameters. A pink cell will require you to manually input a number, while the gold cells are self-calculating or contain predetermined values.

auto calculates	user defined

To find the heat gain rate of your building, proceed to the tab labelled "Step 1".

Final outputs

Building Area: 1547.6 *SF*

Heat Gain Source	Heat Gain		Heat Gain Rate	
roof and walls:	2299	*btus/hr*	1.49	*Btus/hr - SF*
glass:	15380	*btus/hr*	9.94	*Btus/hr - SF*
outdoor air:	37622	*btus/hr*	24.31	*Btus/hr - SF*
people:	25149	*btus/hr*	16.25	*Btus/hr - SF*
lights:	619	*btus/hr*	0.40	*Btus/hr - SF*
equipment:	5280	*btus/hr*	3.41	*Btus/hr - SF*
Latent Heat Gains:	8635	*btus/hr*	5.58	*Btus/hr - SF*
Total Sensible Heat gains:	94983	*btus/hr*		
Total building heat gain rate:			61.37	*Btus/hr - SF*

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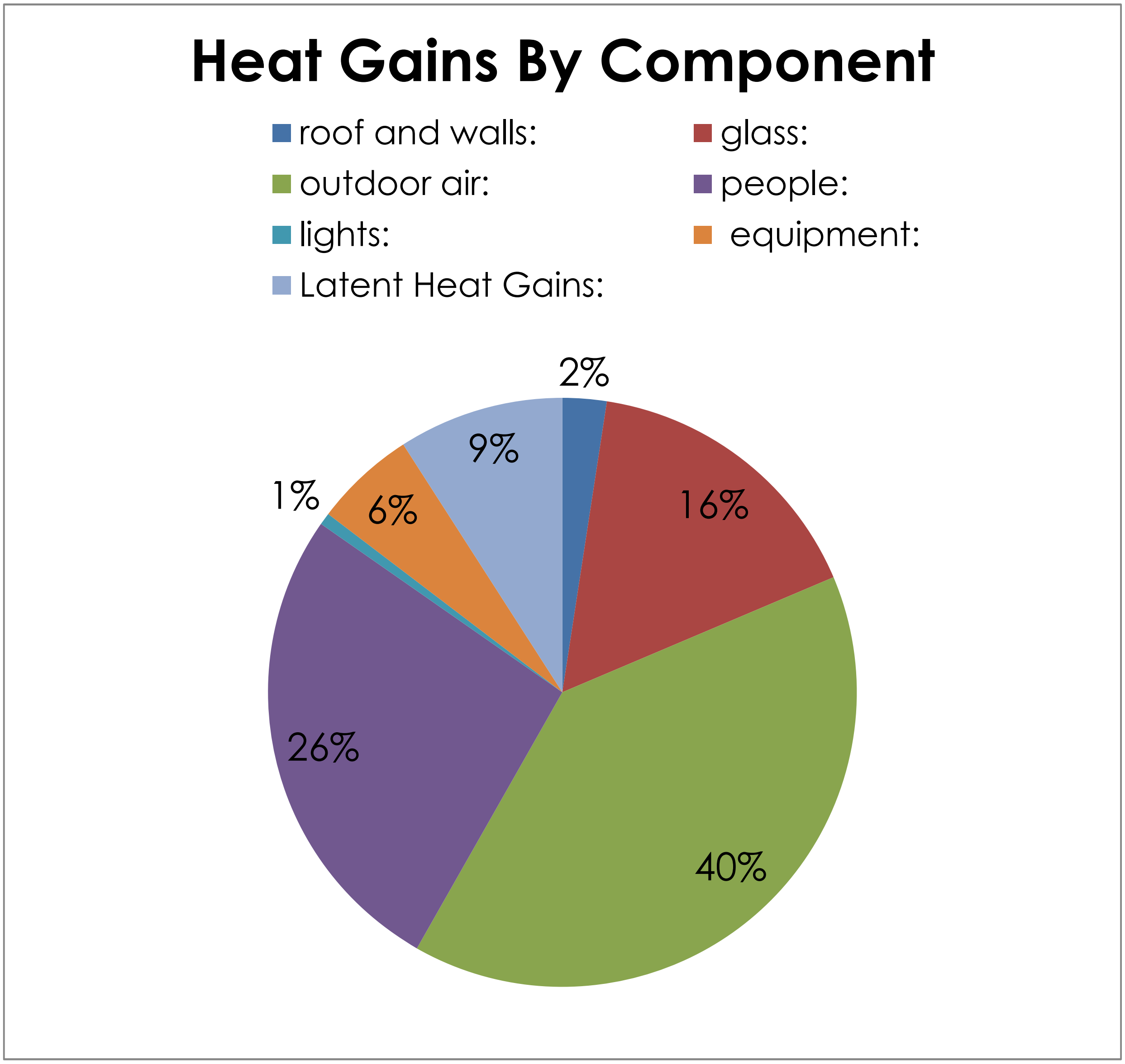
The chart below shows a disaggregated chart that breaks the building's heat gain rate into its constituent load factors.



Step 1: Heat Gains through Roof and Walls

Description:

The first step in the process calculates the heat gains of the opaque parts of the envelope through conduction based off of the outdoor air temperature. Each wall of the zone or building will be analyzed and calculated separately with respect to each other.

This process will use the equation:

$$q = U \times A \times DETD$$

where:

q = the heat gain of the wall, roof, floor, etc.

U = u value of the component assembly

A = area of the wall, roof, floor, etc.

DETD = design equilavent temperature difference

Step 1 - A - Area of Envelope

Input the area of the following components and the u value of their assemblies (Average the wall area if multiple walls in same direction exists). The floor does not account for any heat gain in the summertime.

Area of North Wall:	510.2	SF	U-Value of North Wall:	0.05
Area of South Wall:	1139.4	SF	U-Value of South Wall:	0.05
Area of East Wall:	478	SF	U-Value of East Wall:	0.05
Area of West Wall:	475	SF	U-Value of West Wall:	0.05
Area of Roof:	1670	SF	U-Value of Roof:	0.016
Area of Floor:	1547	SF	U-Value of Floor:	0

Step 1 - B - Climate Data

The following information is automatically updated to the target city and will be used to calculate the rate of heat gain through the roof and walls. Temperature statistics are referenced from ASHRAE 90.1 2007, but can be overridden to reflect any weather or climate standard.

Design Dry Bulb	94	deg F
Mean Daily Temperature Range	31	deg F

Step 1 - C - Design Equilavent Temperature Differences

Use the the two values found in Step A-1 in conjuction with **Figure 1** in "Reference Tab A" to find the DETD of each the following components.

DETD of North Wall:	11.3
DETD of South Wall:	11.3
DETD of East Wall:	11.3
DETD of West Wall:	11.3
DETD of Roof:	31

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DETD of Floor: 0

Step 1 - C - Design Equilavent Temperature Differences

The heat gain through the envelope should automatically calculate based upon the above equation and the input parameters defined in steps 2 A-C.

Heat Gain of North Wall:	288	Btus/hr
Heat Gain of South Wall:	644	Btus/hr
Heat Gain of East Wall:	270	Btus/hr
Heat Gain of West Wall:	268	Btus/hr
Heat Gain of Roof:	828	Btus/hr
Heat Gain of Floor:	0	Btus/hr
Total Heat Gains:	2299	Btus/hr

You may now proceed to the tab labeled "Step 2".

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Step 2: Heat Gains Through Glass

Description:

The next step in the process calculates the heat gains of the transparent parts of the envelope through both conduction and solar heat gain admittance. Each orientation of glazing (both horizontal and vertical) will be analyzed and calculated separately with respect to each other.

process

$$q = A \times DCLF$$

where:

q = heat gain from windows
A = the area of the windows
DCLF = design cooling load factors

Step 2-A - Glass Area

Input the area of the following components

Area of North Window:	112	SF	of Northwest Window:		SF
Area of South Window	431	SF	of Northeast Window:		SF
Area of East Window:	140	SF	of Southwest Window:		SF
Area of West Window:	140	SF	of Southeast Window:		SF
Area of skylights:		SF			

Step 2-B - Design Cooling Load Factors

Refer to the **Figure 2** in the tab labeled "Reference A" to find the design cooling load factors for each glazing orientation based off window type.

DCLF of North Window:	17	of Northwest Window:	
DCLF of South Window	16	of Northeast Window:	
DCLFof East Window:	0	of Southwest Window:	
DCLF of West Window:	47	of Southeast Window:	
DCLF of skylights:			

Step 2-C - Heat Gain Calculations

The heat gain through the window orientations should automatically calculate based upon the above equation and the input parameters defined in steps 2 A-C.

Heat Gain of North Window:	1904	Btus/hr	of Northwest Windov	0	Btus/hr
Heat Gain of South Window	6896	Btus/hr	of Northeast Windov	0	Btus/hr
Heat Gain of East Window:	0	Btus/hr	of Southwest Windov	0	Btus/hr
Heat Gain of West Window:	6580	Btus/hr	of Southeast Windov	0	Btus/hr
Heat Gain of skylights:	0	Btus/hr			

Total Heat Gains:	15380 *Btus/hr*

You may now proceed to the tab labeled "Step 3".

Step 3: Heat Gains from the Outdoor Air

Description:

Sensible heat gain from outdoor air is a factor of both infiltration and the amount of airflow the ventilation system introduces into the building. The amount of outdoor air depends on number of people and the activity type of the building. For commercial buildings, use **OPTION 1;** for residential buildings, use **OPTION 2. Be sure to manually input the final heat gains from outdoor air from whichever option is used to calculate Step 3.**

OPTION 1 - Commercial Buildings

Commercial buildings primarily incur a peak cooling load from outdoor air introduced into the building by a mechanical ventilation system. During occupied times, the building is assumed to be positively pressurized and thus negates most significant heat gains from infiltraiton.

The process uses the equation:

q (ventilation) = Q x V

where:

q = heat gain from ventilation
Q = volume of the outdoor air (total cfm orL/s)
V = ventilation factor

OPT 1 - Step 3 - A - Calculate the Number of Occupants

The volume of airflow required is based off of the number of people in the space and the type of building. This can be estimated using **Figure 3** in "Reference Tab A" which references typical code occupancies that are based off of floor area. **OR you can just override the equation and input the actual amount of people in the "Number of People" field.**

Building Floor Area:	1547.6	SF
Building Floor Area in Thousandths:	1.548	
People per 1000 square feet (**Figure 3**):	65	SF/person
Number of People:	101	people

OPT 1 - Step 3 - B - Calculate the Ventilation Rate

Refer to **Figure 4** in "Reference Tab A" to find the recommended outdoor air requirement for the ventilation of your type of building.

CFM per person:	17	CFM/person
Total CFM of Volume of Outdoor Air =	1710.10	CFM

OPT 1 - Step 3-C - Calculate the Ventilation Factor

The ventilation factor is based off of the design temperature of the climate (refer to Step 1 - B) and **Figure 5** in "Reference Tab A". This value represents the heat gain contribution of the air admitted into the building through mechanical ventilation based on CFM.

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Ventilation Factor: 22 Btu/hr/SF

OPT 1 - Total Heat Gains	37622 Btus/hr

OPTION 2 - Residential Buildings

In residences, outdoor air is not introduced into the building through a mechanical system. Rather, outdoor air's contribution to the peak cooling load of a home is typically the result of infiltration through the envelope.

The process uses the equation:

$$q\ (infiltration) = EA \times I$$

where:

q = heat gain from infiltration
EA = square footage of area of envelope exposed to the outside
I = infiltration factor

OPT 2 - Step 3 - A - Calculate the Exposed Area of the Building

Infiltration is based off of an infiltration factor applied to the amount of exposed area of the building. First, combine the area from any walls (including window area) and roofs that are exposed to the outdoor environment.

Area of Exposed Walls:		SF
Area of Exposed Roof		SF
Total Exposed Area	0	SF

OPT 2 - Step 3 -B - Infiltration Factor

The infiltration factor is based off of the design temperature of the climate (refer to Step 1 - B) and Figure 5 in "Reference Tab A". This value represents the heat gain contribution of the air admitted into the building through infiltration ventilation based off square footage.

Infiltration Factor Btus/hr- SF

OPT 2 - Total Heat Gains	0 Btus/hr

Final Step

Enter the total heat gain from either **Option 1** or **Option 2** in the field below:

Total Heat Gains	37622

You may now proceed to the tab labeled "Step 4".

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Step 4: Heat Gains from People

Description:

Depending on the building type and activity level, the internal heat gains from people can be a significant factor in the overall heat gain rate. The human body acts as a heat source that must be considered in any building design.

The process uses the equation:

$$q = O \times SHGO$$

Where:

- q = sensible heat gain from people
- O = number of occupants
- SHGO = sensible heat gain per occupant

Step 4-A - Calculate the Number of Occupants

Refers to Step 3 - A

Number of Occupants: 101 *people*

Step 4-B - Calculate the Sensible Heat Gain Per Occupant

Determine the activity level of the occupants based on building type and refer to **Figure 6** to find the sensible heat gain per occupant.

SHGO: 250 *Btu/hr*

Total Heat Gains	25149	*Btus/hr*

You may now proceed to the tab labeled "Step 5".

Step 5: Heat Gains from Lights

Description:

Calculating the heat gain from the electrical lighting system can take one of two different pathways. Option 1 uses a standard equation that factors in the heat gain rate associated with the lighting power density of the lights and ballasts. Option 2 should be used if daylighting is going to play a factor in the space and affect the electrical lighting operation. This option calculates a heat gain rate based off of the daylight factor of the building and reduced electrical lighting operation based off of a photocontrolled dimming system with an 80% dimming factor

OPTION 1 - Standard Calculation

This process uses the equation:

$$q = LPD \times SF \times Btu\ factor$$

where:

LPD = lighting power density
SF = space square footage
Btu Factor = multiply by 3.412 to get watts into Btus

OPT 1 - Step 5 - A - Lighting Power Density Calculation

Refer to the Ashrae tables listed as **Figure 7** in "Reference Tab A" to find the building type's maximum power density. Use either the "building area" approach or "space-by-space" approach.

Building Square Footage:	1547.6	SF
Lighting Power Density:	1.1	watts/SF
Btu Factor:	3.412	Btus
Lighting Heat Gains:	5808	Btus/hr

OPT 1 - Step 5 - B - Lighting Ballast Heat Gain

The ballasts of the light fixture also contribute to the heat gain of this step. **To account for this factor, multiply the lighting heat gains by either 1.12 for energy efficient ballasts, or 1.2 for normal ballasts, OR you can enter in a specific product performance factor form spec sheets or manufacturer information.**

Ballast Factor:	1.12	
Opt 1 Total Heat Gains	6505	Btus/hr

OPTION 2 - Daylight Factored Calculation

This process uses an electric lighting heat gain rate that is contingent upon a daylight factor of the building. Consequently, the daylight factor must first be calculated based upon the area of windows of both sidelighting and toplighting strategies.

OPT 2 - Step 5 - A - Sidelighting Daylight Factor Calculation

This process uses the equation below. For multiple floors or different rooms, average all the constituent daylight factors together and override the "Daylight Factor from Sidelighting" field:

DF = .2 x (window area/floor area)

Building Floor Area:	1547.6	SF
Window Area:	793	SF
Daylight Factor from Sidelightir	10.25%	%

OPT 2 - Step 5 - B - Toplighting Daylight Factor Calculation

The toplighting equation is similar to the sidelighting equation, but the factors vary depending on the geometry of the skylight. For multiple floors or different rooms, average all the constituent daylight factors together and override the "Daylight Factor from Toplighting" field:

toplighting factor:

use .2 for vertical monitors, use .33 for north-facing sawtooths, and use .5 for horizontal skylights.

Skylight Area:		SF
Daylight Factor from Toplightin	0.00%	%

To calculate the total daylight factor, add the two total daylight factor percentages together:

Total Daylight Factor:	10.25%	%

OPT 2 - Step 5 - C - Calculating Internal Heat Gain

Use the total daylight factor found in OPT2- Step 5 - B and **Figure 8** to input the sensible heat gain. This rate multiplied by the building's area will yield the total heat gain contribution of a daylighting controlled electric lighting system combination.

Sensible Heat Gain Rate **(Fig 8)**	0.4	
Opt 2 Total Heat Gains	619	Btus/hr

Final Step

Enter the total heat gain from either option 1 or 2 in the field below:

Total Heat Gains	619	Btus/hr

You may now proceed to the tab labeled "Step 6".

Step 6: Heat Gains from Equipment

Description:

There are two different ways to calculate the contribution of electrical equipment to the heat gain rate of the building. Option one involves taking an inventory of all pieces of equipment used in the building and adding together their watts or sensible heat gain. The other option uses a standard equation based off of the code maximum equipment power density to calculate heat gain. If the number of total watts can be gathered, this value can be multiplied by a factor of 3.413 to convert to a heat gain metric.

OPTION 1 - Inventory Method

Take inventory of all the pieces of electrical equipment in your building. Next, use Figure 9 in "Reference Tab A" to calculate and total the amount of watts (not the "recommended rate of heat gain") that each piece of equipment uses. OR you may also look online for a specific brand's power ratting and wattage output, which will reflect the most recent efficiency advancements in current product development.

Total watts:	1547.6	*watts*
Btu/hr conversion factor:	3.412	*Btus/hr*
Opt 1 Total Heat Gains	5280	*Btus/hr*

OPTION 2 - Standard Equation Method

This process uses the equation:

$$q = EPD \times SF \times 3.412 \text{ Btus/hr}$$

Where:

q = heat gain from equipment

EPD = equipment power denisty

SF = square footage of the building

3.412 = watts to Btu/hr conversion

Option 2 - Step A

Use **Figure 10** in "Reference Tab A" to find the proper equipment power density of your building according to type.

Building Area:	1547.6	*SF*
Equipment Power Density:	0.9	*watts/SF*
Opt 2 Total Heat Gains	4752	*Btus/hr*

Final Step

Enter the total heat gain from either option 1 or 2 in the field below:

Total Heat Gains	5280	Btus/hr

You may now proceed to the tab labeled "Step 6".

Step 7: Latent Heat Gains

Description:

upon outdoor air infiltration and climate design temperatures. This method estimates additional latent heat gain as a percentage of the total sensible heat gains found in Steps 1-6. The design dry bulb temperature and mean coincident wet bulb temperature, along with the relative tightness of building construction, determine the latent percentage of total sensible heat gain.

Step 7 - A - Climate Information

The design dry bulb temperature and wet bulb temperature for the city that your project resides within play an important role in determining the latent heat gain.

Design Dry Bulb Temperature:	94	*deg F*
Wet Coincident Wet Bulb Temperature:	64	*deg F*

Step 7 - B- Percentage Calculation

Use these two values to navigate **Figure 11**, along with an assumption about the relative tightness of construction, to find the percentage of latent heat gain.

Percentage of Latent Heat Gain:	0.1	*(input in decimal format)*
Total Sensible Heat Gain of Steps 1-6:	86348	*Btus/hr*
Total Heat Gains:	8635	*Btus/hr*

You may now refer back to the "Intro and Final Outputs" tab for comparison.

References

Figure 1 - Design Equivalent Temperature Differences (DETD)

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Start at the left of the graph with the type of assembly before moving right along its axis to find the DETD that lies under both the outdoor design temperature and daily temperature range of your project. Above 30 is considered high, in between 15-30 is medium, and anything below 15 is low.

Part A. Roofs, Mass Walls, and Floors

Outdoor Design Temperature	85 F		90			95			100		105	110
Daily Temperature Range[a]	L	M	L	M	H	L	M	H	M	H	H	H
Walls and Doors												
1. Masonry walls, 200-mm (8-in.) block or brick	10.3	6.3	15.3	11.3	6.3	20.3	16.3	11.3	21.3	16.3	21.3	26.3
2. Partitions, frame	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
masonry	2.5	0	7.5	3.5	0	12.5	8.5	3.5	13.5	8.5	13.5	18.5
Ceilings and Roofs[b]												
1. Ceilings under naturally vented attic or vented flat roof—dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0
—light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0
2. Built-up roof, no ceiling—dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0
—light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0
3. Ceilings under unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
Floors												
1. Over unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
2. Over basement, enclosed crawl space or concrete slab on ground	0	0	0	0	0	0	0	0	0	0	0	0
3. Over open crawl space	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0

Outdoor Design Temperature / Daily Temperature Range[a]	85°F		90			95			100		105	110
Orientation	L	M	L	M	H	L	M	H	M	H	M	H
Frame walls, Doors:												
North	8	3	13	8	3	18	13	8	18	13	18	23
NE and NW	14	9	19	14	9	24	19	14	24	19	24	29
East and West	18	13	23	18	13	28	23	18	28	23	28	33
SE and SW	16	11	21	16	11	26	21	16	26	21	26	31
South	11	6	16	11	6	21	16	11	21	16	21	26

Source: Part A, 1981 *ASHRAE Handbook of Fundamentals;* Part B, 1997 *ASHRAE Handbook of Fundamentals;* both copyright © by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

[a]Daily temperature range: (MDR, Appendix A) L (Low) less than 9 K (16 F°) M (Medium) 9 to 14 K (16 to 25 F°) H (High) greater than 14 K (25 F°)

[b]For roofs in shade, 18-h average DETD = 6.1 C° (11 F°). At 32° C (90° F) design temperature and medium daily range, DETD for light-colored roof = 6.1 + (0.71)(21.6 − 6.1) = 17.1 C° [11 + (0.71)(39 − 11) = 31 F°].

Figure 2 - Design Cooling Load Factors Through Glass

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Start with the orientation of the glass on the left side of the chart before moving vertically to find the correct shading segment, moving then horizontally to find the correct glass type segment, before moving again horizontally to correspond to the outdoor design temperature.

Outdoor Design Temp.[a]	Regular Single Glass						Regular Double Glass						Heat-Absorbing Double Glass						Clear Triple Glass		
	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95
No Awnings or Inside Shading																					
North	23	27	31	35	39	44	19	21	24	26	28	30	12	14	17	19	21	23	17	19	20
NE and NW	56	60	64	68	72	77	46	48	51	53	55	57	27	29	32	34	36	38	42	43	44
East and west	81	85	89	93	97	102	68	70	73	75	77	79	42	44	47	49	51	53	62	63	64
SE and SW	70	74	78	82	86	91	59	61	64	66	68	70	35	37	40	42	44	46	53	55	56
South	40	44	48	52	56	61	33	35	38	40	42	44	19	21	24	26	28	30	30	31	33
Horiz. skylight	160	164	168	172	176	181	139	141	144	146	148	150	89	91	94	96	98	100	126	127	129
Draperies or Venetian Blinds																					
North	15	19	23	27	31	36	12	14	17	19	21	23	9	11	14	16	18	20	11	12	14
NE and NW	32	36	40	44	48	53	27	29	32	34	36	38	20	22	25	27	29	31	24	26	27
East and west	48	52	56	60	64	69	42	44	47	49	51	53	30	32	35	37	39	41	38	39	41
SE and SW	40	44	48	52	56	61	35	37	40	42	44	46	24	26	29	31	33	35	32	33	34
South	23	27	31	35	39	44	20	22	25	27	29	31	15	17	20	22	24	26	18	19	21
Roller Shades Half-Drawn																					
North	18	22	26	30	34	39	15	17	20	22	24	26	10	12	15	17	19	21	13	14	15
NE and NW	40	44	48	52	56	61	38	40	43	45	47	49	24	26	29	31	33	35	34	35	35
East and west	61	65	69	73	77	82	54	56	59	61	63	65	35	37	40	42	44	46	49	49	50
SE and SW	52	56	60	64	68	73	46	48	51	53	55	57	30	32	35	37	39	41	41	42	43
South	29	33	37	41	45	50	27	29	32	34	36	38	18	20	23	25	27	29	25	26	26
Awnings[b]																					
North	20	24	28	32	36	41	13	15	18	20	22	24	10	12	15	17	19	21	11	12	13
NE and NW	21	25	29	33	37	42	14	16	19	21	23	25	11	13	16	18	20	22	12	13	14
East and west	22	26	30	34	38	43	14	16	19	21	23	25	12	14	17	19	21	23	12	13	14
SE and SW	21	25	29	33	37	42	14	16	19	21	23	25	11	13	16	18	20	22	12	13	14
South	21	24	28	32	36	41	13	15	18	20	22	24	11	13	16	18	20	22	11	12	13

Source: Copyright © by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA. Reprinted by permission from the *ASHRAE Handbook of Fundamentals,* 1981.

[a]Based on indoor design temperature of 23.8°C (75°F) and outdoor design temperatures as indicated. Interpolate to obtain factors for outdoor design temperatures other than those given.

[b]For other external shading devices which completely shade the glass at any orientation, use the values for "Awnings, north."

Figure 3 - Code Occupancy Requirements - ASHRAE 90.1

Source: ASHRAE 90.1-2007. "Energy Standard for Buildings Except Low-Rise Residential Buildings". Atlanta, Georgia, 2007.

Occupancy Category	Occupant Density per 1000 ft		Occupant Density per 1000 ft
Correctional Facilities		**Misc Spaces**	
cell	25	bank vaults	50
day room	30	computer (not printing)	4
guard stations	15	pharmacy	10
booking/waiting	50	photo studios	10
Educational Facilities		shipping/receiving	-
daycare	25	transportation waiting	100
classrooms (ages 5-8)	25	warehouses	-
classrooms (age 9 +)	35	**Public Assembly Spaces**	
lecture classroom	65	auditorium seating area	150
lecture hall (fixed seats)	150	places of worship	120
art classroom	20	courtrooms	70
science laboratories	258	legislative chambers	50
wood/metal shop	20	libraries	10
computer lab	25	lobbies	150
media center	25	museums (childrens)	40
music/theater/dance	35	meseums/galleries	40
multi-use assembly	100	**Retail**	
Food Service		Sales	15
restaurant dining rooms	70	mall common areas	40
cafeteria	100	Barber shop	25
bars, cocktail lounges	100	beauty and nail salons	25
General		pet shops	10
conference/meeting	50	supermarket	8
corridors	-	coin-operated laundries	20
storage rooms	-	**Sports and Entertainment**	
Hotels, Dorms		sports arena	-
bedroom/living room	10	gym, stadium	30
barracks sleeping areas	20	spectator areas	150
lobbies/prefunction	30	swimming pool	-
multipurpose assembly	120	dance floors	100
Office Buildings		aerobics room	40
office space	5	weight room	10
reception areas	30	bowling alley (seating)	40
telephone/data entry	60	casinos	120
main entry lobbies	10	arcades	20
		stages/studios	70

Figure 4 - Ventilation Rates by Space Type

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Occupancy Category	cfm/person		cfm/person
Correctional Facilities		**Misc Spaces**	
cell	10	bank vaults	17
day room	7	computer (not printing)	20
guard stations	9	pharmacy	23
booking/waiting	9	photo studios	17
Educational Facilities		shipping/receiving	-
daycare	17	transportation waiting	8
classrooms (ages 5-8)	15	warehouses	-
classrooms (age 9 +)	13	**Public Assembly Spaces**	
lecture classroom	8	auditorium seating area	5
lecture hall (fixed seats)	8	places of worship	6
art classroom	19	courtrooms	6
science laboratories	17	legislative chambers	6
wood/metal shop	19	libraries	17
computer lab	15	lobbies	5
media center	15	museums (childrens)	11
music/theater/dance	12	meseums/galleries	9
multi-use assembly	8	**Retail**	
Food Service		Sales	16
restaurant dining rooms	10	mall common areas	9
cafeteria	9	arber shop	10
bars, cocktail lounges	9	beauty and nail salons	25
General		pet shops	26
conference/meeting	6	supermarket	15
corridors	-	coin-operated laundries	11
storage rooms	-	**Sports and Entertainment**	
Hotels, Dorms		spors arena	-
bedroom/living room	11	gym, stadium	-
barracks sleeping areas	8	spectator areas	8
lobbies/prefunction	10	swimming pool	-
multipurpose assembly	6	dance floors	21
Office Buildings		aerobics room	22
office space	17	weight room	26
reception areas	7	bowling alley (seating)	13
telephone/data entry	6	casinos	9
main entry lobbies	11	arcades	17
		stages/studios	11

Figure 5 - Infiltration and Ventilation Factors

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Be sure to use either the appropriate infiltration factor or ventilation factor in the worksheet.

°C: 29.4	32.2	35.0	37.7	41.5	43.3	Units	Design Temperature	Units	°F: 85	90	95	100	105	110
2.2	3.5	4.7	6.0	6.9	8.2	W/m²	Infiltration, per gross exposed wall area	Btu/h ft²	0.7	1.1	1.5	1.9	2.2	2.6
6.8	9.9	13.6	16.7	19.8	23.6	W per L/s	Mechanical ventilation	Btu/h per cfm	11.0	16.0	22.0	27.0	32.0	38.0

Source: © by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA. Reprinted by permission from the 1981 *ASHRAE Handbook—Fundamentals*.

Figure 6 - Heat Gain Rate from Occupants

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Be sure to use the "sensible" heat gain column". The latent heat gain is not a factor in this step because the total latent heat gains are covered in step 7.

		Total Heat Gain							
		W				***Btu/h***			
Activity	Location	Adult Male	Adjusted[b]	Sensible[a] Heat	Latent[a] Heat	Adult Male	Adjusted[b]	Sensible[a] Heat	Latent[a] Heat
Seated at theater	Theater, matinee	115	95	65	30	390	330	225	105
Seated at theater, night	Theater, night	115	105	70	35	390	350	245	105
Seated, very light work	Offices, hotels, apartments	130	115	70	45	450	400	245	155
Moderately active office work	Offices, hotels, apartments	140	130	75	55	475	450	250	200
Standing, light work; walking	Department or retail store	160	130	75	55	550	450	250	200
Walking, standing	Drug store, bank	160	145	75	70	550	500	250	250
Sedentary work	Restaurant[c]	170	160	80	80	590	550	275	275
Light bench work	Factory	235	220	80	140	800	750	275	475
Moderate dancing	Dance hall	265	250	90	160	900	850	305	545
Walking 4.8 km/h (3 mph), light machine work	Factory	295	295	110	185	1000	1000	375	625
Bowling[d]	Bowling alley	440	425	170	255	1500	1450	580	870
Heavy work	Factory	440	425	170	255	1500	1450	580	870
Heavy machine work, lifting	Factory	470	470	185	285	1600	1600	635	965
Athletics	Gymnasium	585	525	210	315	2000	1800	710	1090

Figure 7- Lighting Power Density References

Source: ASHRAE 90.1-2007. "Energy Standard for Buildings Except Low-Rise Residential Buildings". Atlanta, Georgia, 2007.

Building Area Method

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Gymnasium	1.1
Health-care clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking garage	0.3
Penitentiary	1.0
Performing arts theater	1.6
Police/fire station	1.0
Post office	1.1
Religious building	1.3
Retail	1.5
School/university	1.2
Sports arena	1.1
Town hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Space by Space Method

Common Space Types[a]	LPD, W/ft²	Building-Specific Space Types	LPD, W/ft²
Office—Enclosed	1.1	Gymnasium/Exercise Center	
Office—Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges' Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office—Sorting Area	1.2
For Exercise Center	0.3	Convention Center—Exhibit Space	1.3
For Convention Center	0.7	Library	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7
For Sports Arena	0.4	Reading Area	1.2
For Performing Arts Theater	2.6	Hospital	
For Motion Picture Theater	1.2	Emergency	2.7
For Transportation	0.5	Recovery	0.8
Atrium—First Three Floors	0.6	Nurses' Station	1.0
Atrium—Each Additional Floor	0.2	Exam/Treatment	1.5
Lounge/Recreation	1.2	Pharmacy	1.2
For Hospital	0.8	Patient Room	0.7
Dining Area	0.9	Operating Room	2.2
For Penitentiary	1.3	Nursery	0.6
For Hotel	1.3	Medical Supply	1.4
For Motel	1.2	Physical Therapy	0.9
For Bar Lounge/Leisure Dining	1.4	Radiology	0.4
For Family Dining	2.1	Laundry—Washing	0.6
Food Preparation	1.2	Automotive—Service/Repair	0.7
Laboratory	1.4	Manufacturing	
Restrooms	0.9	Low Bay (<25 ft Floor to Ceiling Height)	1.2
Dressing/Locker/Fitting Room	0.6	High Bay (≥25 ft Floor to Ceiling Height)	1.7
Corridor/Transition	0.5	Detailed Manufacturing	2.1
For Hospital	1.0	Equipment Room	1.2
For Manufacturing Facility	0.5	Control Room	0.5
Stairs—Active	0.6	Hotel/Motel Guest Rooms	1.1
Active Storage	0.8	Dormitory—Living Quarters	1.1
For Hospital	0.9	Museum	
Inactive Storage	0.3	General Exhibition	1.0
For Museum	0.8	Restoration	1.7
Electrical/Mechanical	1.5	Bank/Office—Banking Activity Area	1.5

Common Space Types[a]	LPD, W/ft²	Building-Specific Space Types	LPD, W/ft²
Workshop	1.9	Religious Buildings	
Sales Area [for accent lighting, see Section 9.6.2(b)]	1.7	Worship Pulpit, Choir	2.4
		Fellowship Hall	0.9
		Retail	
		Sales Area [for accent lighting, see Section 9.6.3(c)]	1.7
		Mall Concourse	1.7
		Sports Arena	
		Ring Sports Area	2.7
		Court Sports Area	2.3
		Indoor Playing Field Area	1.4
		Warehouse	
		Fine Material Storage	1.4
		Medium/Bulky Material Storage	0.9
		Parking Garage—Garage Area	0.2
		Transportation	
		Airport—Concourse	0.6
		Air/Train/Bus—Baggage Area	1.0
		Terminal—Ticket Counter	1.5

[a] In cases where both a common space type and a building-specific type are listed, the building specific space type shall apply.

Figure 8 - Heat Gain Through Lights Based on Daylight Factor

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

	Sensible Heat Gain[h] (Btu/h ft² of Floor Area)			Sensible Heat Gain[h] (W/m² of Floor Area)		
Function	*DF<1*	*1<DF<4[h]*	*DF>4[h]*	*DF<1*	*1<DF<4[h]*	*DF>4[h]*
Office	5.1	2.0	0.5	*16.1*	*6.3*	*1.6*
School: elementary	6.3–6.8	2.5–2.7	0.6–0.7	*19.9–21.5*	*7.9–8.5*	*1.9–2.2*
School: secondary, college	6.3–6.8	2.5–2.7	0.6–0.7	*19.9–21.5*	*7.9–8.5*	*1.9–2.2*
Healthcare:						
Sleeping (hospital)	6.8	2.7	0.7	*21.5*	*8.5*	*2.2*
In-patient (clinic)	6.8	2.7	0.7	*21.5*	*8.5*	*2.2*
Assembly	3.8	1.5	0.4	*12.0*	*4.7*	*1.3*
Restaurants[i]	6.3	2.5	0.6	*19.9*	*7.9*	*1.9*
Mercantile	5.1–6.8	2.0–2.7	0.5–0.7	*16.1–21.5*	*6.3–8.5*	*1.6–2.2*
Warehouse	2.4	1.0	0.2	*7.6*	*3.2*	*0.6*
Hotels, nursing homes	6.8	2.7	0.7	*21.5*	*8.5*	*2.2*
Apartments[g]	Up to 6.8	Up to 2.7	Up to 0.7	*Up to 21.5*	*Up to 8.5*	*Up to 2.2*

Figure 8 - Heat Gain Through Lights Based on Daylight Factor

Source: G.Z. Brown and Mark DeKay. "Sun, Wind & Light." New York, John Wiley & Sons, Inc. 2001

The "lo" and "hi" columns represent the range specified in old ASHRAE specifications. For our calculation,

Boise Latitude: 43 degrees

BUILDING TYPE	LATITUDE	SENSIBLE HEAT GAIN (Btu/hr, ft² of Floor Area) Average Daylight Factor									
		DF < 1.5		1.5 < DF < 2		2 < DF < 3		3 < DF < 5		DF > 5	
		lo	hi	lo	hi	lo	hi	lo	hi	lo	hi
Assembly	20	2.8	4.8	1.2	2.1	1.1	1.8	0.8	1.3	NR	NR
	30	2.8	4.8	1.4	2.3	1.2	2.1	1.1	1.8	0.8	1.3
	40	2.8	4.8	1.6	2.6	1.4	2.3	1.2	2.1	1.1	1.8
	50	2.8	4.8	1.8	3.0	1.6	2.6	1.4	2.3	1.2	2.1
	60	2.8	4.8	NR	NR	1.8	3.0	1.6	2.6	1.4	2.3
Education	20	4.0	6.5	1.7	2.8	1.5	2.5	1.1	1.8	NR	NR
	30	4.0	6.5	1.9	3.1	1.7	2.8	1.5	2.5	1.1	1.8
	40	4.0	6.5	2.2	3.6	1.9	3.1	1.7	2.8	1.5	2.5
	50	4.0	6.5	2.5	4.1	2.2	3.6	1.9	3.1	1.7	2.8
	60	4.0	6.5	NR	NR	2.5	4.1	2.2	3.6	1.9	3.1
Grocery	20	3.8	7.8	1.6	3.4	1.4	3.0	1.0	2.1	NR	NR
	30	3.8	7.8	1.8	3.8	1.6	3.4	1.4	3.0	1.0	2.1
	40	3.8	7.8	2.1	4.3	1.8	3.8	1.6	3.4	1.4	3.0
	50	3.8	7.8	2.4	4.9	2.1	4.3	1.8	3.8	1.6	3.4
	60	3.8	7.8	NR	NR	2.4	4.9	2.1	4.3	1.8	3.8
Lodging	20	2.9	4.1	1.2	1.8	1.1	1.6	0.8	1.1	NR	NR
	30	2.9	4.1	1.4	2.0	1.2	1.8	1.1	1.6	0.8	1.1
	40	2.9	4.1	1.6	2.3	1.4	2.0	1.2	1.8	1.1	1.6
	50	2.9	4.1	1.8	2.6	1.6	2.3	1.4	2.0	1.2	1.8
	60	2.9	4.1	NR	NR	1.8	2.6	1.6	2.3	1.4	2.0
Healthcare	20	6.8	9.2	2.9	4.0	2.6	3.5	1.8	2.5	NR	NR
	30	6.8	9.2	3.3	4.4	2.9	4.0	2.6	3.5	1.8	2.5
	40	6.8	9.2	3.8	5.1	3.3	4.4	2.9	4.0	2.6	3.5
	50	6.8	9.2	4.3	5.8	3.8	5.1	3.3	4.4	2.9	4.0
	60	6.8	9.2	NR	NR	4.3	5.8	3.8	5.1	3.3	4.4
Office	20	4.4	5.1	1.9	2.2	1.7	1.9	1.2	1.4	NR	NR
	30	4.4	5.1	2.1	2.5	1.9	2.2	1.7	1.9	1.2	1.4
	40	4.4	5.1	2.4	2.8	2.1	2.5	1.9	2.2	1.7	1.9
	50	4.4	5.1	2.8	3.2	2.4	2.8	2.1	2.5	1.9	2.2
	60	4.4	5.1	NR	NR	2.8	3.2	2.4	2.8	2.1	2.5

BUILDING TYPE	LATITUDE	SENSIBLE HEAT GAIN (Btu/hr, ft² of Floor Area) Average Daylight Factor									
		DF < 1.5		1.5 < DF < 2		2 < DF < 3		3 < DF < 5		DF > 5	
		lo	hi	lo	hi	lo	hi	lo	hi	lo	hi
Recreation	20	5.5	13.3	2.3	5.7	2.1	5.1	1.5	3.6	NR	NR
	30	5.5	13.3	2.6	6.4	2.3	5.7	2.1	5.1	1.5	3.6
	40	5.5	13.3	3.0	7.3	2.6	6.4	2.3	5.7	2.1	5.1
	50	5.5	13.3	3.4	8.4	3.0	7.3	2.6	6.4	2.3	5.7
	60	5.5	13.3	NR	NR	3.4	8.4	3.0	7.3	2.6	6.4
Residential	20	0.7	4.1	0.3	1.8	0.3	1.6	0.2	1.1	NR	NR
	30	0.7	4.1	0.3	2.0	0.3	1.8	0.3	1.6	0.2	1.1
	40	0.7	4.1	0.4	2.3	0.3	2.0	0.3	1.8	0.3	1.6
	50	0.7	4.1	0.4	2.6	0.4	2.3	0.3	2.0	0.3	1.8
	60	0.7	4.1	NR	NR	0.4	2.6	0.4	2.3	0.3	2.0
Restaurant	20	2.4	4.8	1.0	2.1	0.9	1.8	0.6	1.3	NR	NR
	30	2.4	4.8	1.1	2.3	1.0	2.1	0.9	1.8	0.6	1.3
	40	2.4	4.8	1.3	2.6	1.1	2.3	1.0	2.1	0.9	1.8
	50	2.4	4.8	1.5	3.0	1.3	2.6	1.1	2.3	1.0	2.1
	60	2.4	4.8	NR	NR	1.5	3.0	1.3	2.6	1.1	2.3
Retail	20	3.4	11.3	1.5	4.8	1.3	4.3	0.9	3.0	NR	NR
	30	3.4	11.3	1.6	5.4	1.5	4.8	1.3	4.3	0.9	3.0
	40	3.4	11.3	1.9	6.2	1.6	5.4	1.5	4.8	1.3	4.3
	50	3.4	11.3	2.1	7.1	1.9	6.2	1.6	5.4	1.5	4.8
	60	3.4	11.3	NR	NR	2.1	7.1	1.9	6.2	1.6	5.4
Warehouse	20	0.3	3.1	0.1	1.3	0.1	1.2	0.1	0.8	NR	NR
	30	0.3	3.1	0.2	1.5	0.1	1.3	0.1	1.2	0.1	0.8
	40	0.3	3.1	0.2	1.7	0.2	1.5	0.1	1.3	0.1	1.2
	50	0.3	3.1	0.2	2.0	0.2	1.7	0.2	1.5	0.1	1.3
	60	0.3	3.1	NR	NR	0.2	2.0	0.2	1.7	0.2	1.5

Part B Internal Heat Sources-Electric Lighting (continued)

Method: developed based on lighting power densities from EIA (1992, Table 7, p. 42); PSIC (1998, based on EIA survey 1994); and summaries from ASHRAE (1989a) as found in Tao and Janis (1997, p. 355). Daylight savings estimated fr Nomographs (Selkowitz & Gabel, 1984) as found in Moore (1991, pp. 140-141).

*NR = Not Recommended.

Figure 9- Heat Gain Through Electrical Equipment

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006

Appliance	Maximum Input Rating (W)	Recommended Rate of Heat Gain	
		W	Btu/h
Check processing workstation, 12 pockets	4,800	2,460	8,410
Computer Devices			
Communication/transmission	1,800–4,600	1,640–2,810	5,600–9,600
Disk drives/mass storage	1,000–10,000	1,000–6,570	3,412–22,420
Microcomputer	100–600	90–530	300–1,800
Minicomputer	2,200–6,600	2,200–6,600	7,500–15,000
Optical reader	3,000–6,000	2,350–4,980	8,000–17,000
Plotters	75	63	214
Printers			
Letter quality, 30–45 characters/min.	350	292	1,000
Line, high speed, 5000 or more lines/min	1,000–5,300	730–3,810	2,500–13,000
Line, low speed 300–600 lines/min	450	376	1,280
Tape drives	1,200–6,500	1,000–4,700	3,500–15,000
Terminal	90–200	80–180	270–600
Copiers/Duplicators			
Copiers, large; 30–67[a] copies/min	1,700–6,600	1,700–6,600	5,800–22,500
Copiers, small; 6–30[a] copies/min	460–1,700	460–1,700	1,570–5,800
Feeder	30	30	100
Microfilm printer	450	450	1,540
Sorter/collator	60–600	60–600	200–2,050
Audio Equipment			
Cassette recorders/players	60	60	200
Receiver/tuner	100	100	340
Signal analyzer	60–650	60–650	90–2,220
Mail Processing			
Folding machine	125	80	270
Inserting machine, 3600–6800 pieces/h	600–3,300	390–2,150	1,330–7,340
Labelling machine, 1,500–30,000 pieces/h	600–6,600	390–4,300	1,330–14,700
Postage meter	230	150	510
Vending Machines			
Cigarette	72	72	250
Cold food/beverage	1,150–1,920	575–960	1,960–3,280
Hot beverage	1,725	862	2,940
Snack	240–275	240–275	820–940
Miscellaneous			
Barcode printer	440	370	1,260
Cash registers	60	48	160
Coffee maker, 10 cups	1,500	1,050 sensible 450 latent	3,580 sensible 1,540 latent
Microfiche reader/printer	1,150	1,150	3,920
Microwave oven, 28 L (1 ft^3)	600	400	1,360
Paper shredder	250–3,000	200–2,420	680–8,250
Water cooler, 30 L/h (32 qt/h)	1,750	1,750	5,970

Source: Excerpted with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, from the 1997 *ASHRAE Handbook—Fundamentals.*

[a]Input of power is not proportional to capacity.

Figure 10 - Equipment Power Densities

Source: ASHRAE 90.1-2007. "Energy Standard for Buildings Except Low-Rise Residential Buildings". Atlanta, Georgia, 2007.

The "receptical power density" column represents the equipment power density used in the worksheet.

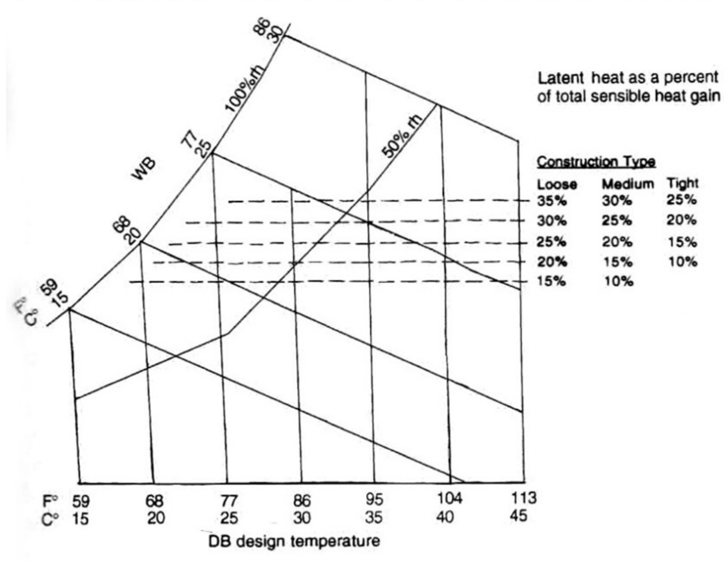
Building Type	Occupancy Density[2] Sq.Ft./Person (Btu/h · ft²)	Receptacle Power Density[3] Watts/Sq.Ft. (Btu/h · ft²)	Service Hot Water Quantities[4] Btu/h · Person
Assembly	50 (4.60)	0.25 (0.85)	215
Health/Institutional	200 (1.15)	1.00 (3.41)	135
Hotel/Motel	250 (0.92)	0.25 (0.85)	1,110
Light Manufacturing	750 (0.31)	0.20 (0.68)	225
Office	275 (0.84)	0.75 (2.56)	175
Parking Garage	NA	NA	NA
Restaurant	100 (2.30)	0.10 (0.34)	390
Retail	300 (0.77)	0.25 (0.85)	135
School	75 (3.07)	0.50 (1.71)	215
Warehouse	15,000 (0.02)	0.10 (0.34)	225

1. *The occupancy densities, receptacle power densities, and service hot water consumption values are from ASHRAE* Standard 90.1-1989 *and addenda.*
2. *Values are in square feet of conditioned floor area per person. Heat generation in Btu per person per hour is 230 sensible and 190 latent. Figures in parenthesis are equivalent Btu per hour per square foot.*
3. *Values are in Watts per square foot of conditioned floor area. Figures in parenthesis are equivalent Btu per hour per square foot. These values are the minimum acceptable. If other process loads are not input (such as for computers, cooking, refrigeration, etc.), it is recommended that receptacle power densities be increased until total process energy consumption is equivalent to 25% of the total.*
4. *Values are in Btu per person per hour.*

Figure 11 - Latent Heat Gain Factor

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John

Start with the dry bulb design temperature at the bottom axis of the graph, next move up until the correct wet bulb line is intersected. Last, move to the right and identify which construction type your project falls under and record the percentage value, which represents the amount of latent heat gain based off of the total sensible heat gain. If your values fall below the dotted lines, assume a minimum 10%.



C. Cross Ventilation Example

IPC and IDL Climate Tools Package

Cross Ventilation Capacity Calculations

climate tools - Boise

University of Idaho

Description:

Cross ventilation can be an effective way to passively cool a building by capturing the prevailing winds during the summertime and channeling them through a space. To admit the required amount of natural ventilation into a building, the system will require a certain amount of inlets and outlets provided by operable windows or envelope-integrated louver systems. Additionally, thin plan building forms that are free from significant interior partitions will provide the ideal environment for cross ventilation. The following calculations operate under the assumption of a minimum of three degrees Fahrenheit temperature difference between the interior and exterior environment. A smaller temperature difference will potentially cause the system will start to admit hot air into the building and contribute to the heat gain rate of the space. It should be noted that these calculations can only be used to assess how much cooling capacity (or demand) the systems can contribute under the specified conditions, which can vary widely throughout the cooling season. Consequently, they should only be used as a general rule of thumb and building performance simulation should be conducted to quantify actual cooling capacities and annual energy savings.

Instructions:

This page contains the final results of the calculations of the worksheet. Start with the tab labeled "Step 1" and follow the step-by-step process using the reference tab if needed. Finish going through all tabs before returning to this page to see if the cross ventilation strategy's cooling capacity will cover all or part of the building's heat gain rate.

Cell Color Legend:

Certain cells are colored in a manner that dictates whether or not they are a user defined input, or if they automatically calculate based off of internal equation or climate specific parameters. A pink cell will require you to manually input a number, while the gold cells are self-calculating or contain predetermined values.

auto calculates	user defined

To begin this worksheet, proceed to the tab labeled "Step 1"

Final Outputs

Use the worksheet named "Heat Gain Calculations" to fill out the text field below if you do not already know your building's heat gain rate. The cooling capacity of the designed passive system will always be analyzed next to this number to compare its capacity against the calculated demand of the building.

Building or Zone Heat Gain Rate:	30.47	*Btus/hr/SF*
Cross Ventilation Cooling Capacity:	7.864714	*Btus/hr/SF*

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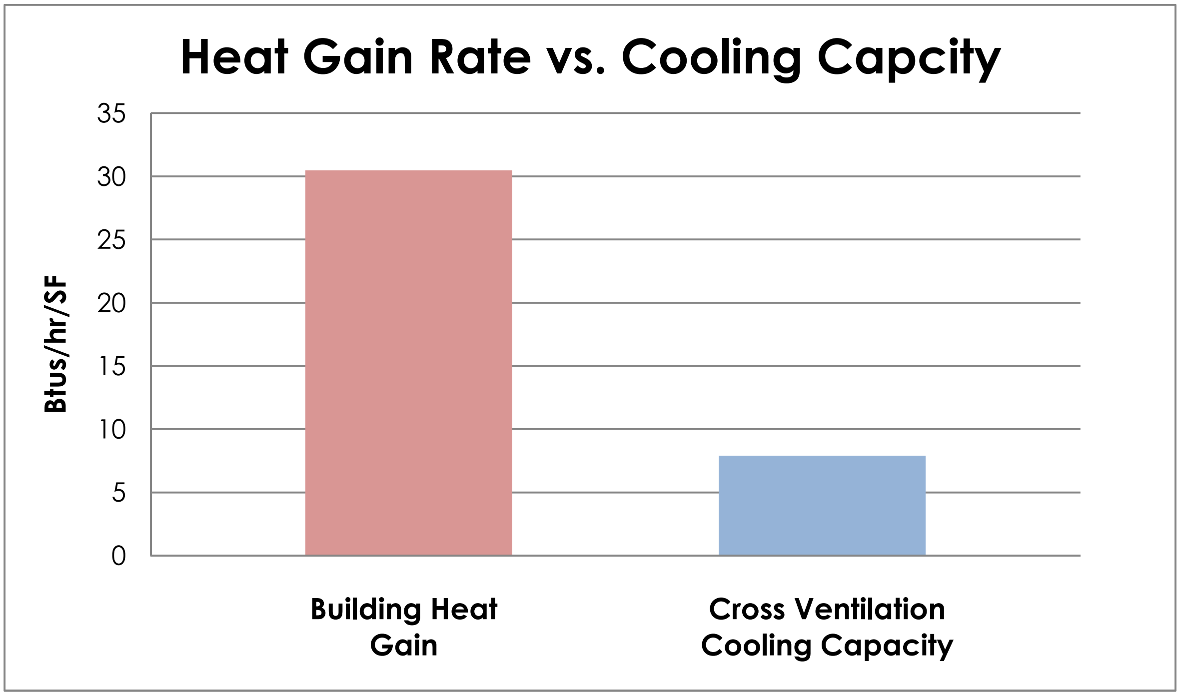
The chart below graphically represents the ability for cross ventilation to satisfy the heat gain rate of the building.



Step 1 - Find the Flow Rate of the System

Description:

The first step in the process involves calculating the flow rate of the system in CFM (cubic feet per minute) to understand how much air the cross ventilation strategy can deliver depending upon certain input parameters. Step 2 will involve converting that CFM into a btu/hr heat gain rate for comparison with the building's heat gain rate.

This step uses the equation:

$$V = (Cv)\ A\ v$$

where:

- V = volume flow rate of air in CFM
- Cv = effectiveness factor that adjusts for different wind orientations.
- A = area of openable window on inlet or outlet sides (whichever is smallest)
- v= velocity of wind in feet per minute (use the equation: mph x 88 = feet per minute)

Step 1 - A - Window Operability

Enter the Cv (effectiveness factor) of your building. If the windows are perpendicular to the winds use .5 -.6, if the wind is diagonal to the window opening then a .35 factor should be used. Refer to the wind rose in **Figure 1** on "Reference Tab A" to determine your climate's primary wind direction for your selected season and time of day for analysis.

Cv EffectivenessFactor: 0.33

Step 1 - B - Building Design

Calculate the opening of the inlet or outlet of the building, whichever is smaller as this will dictate the performance of the system. Note that the window area is not the amount of operable opening. Typically an effective opening factor can be applied to certain types of windows or this number will be available on most manufacturers' specifications. **Figure 2** on "Reference Tab A" lists some typical effective opening factors for different window types.

Area of windows (not operable opening): 112 *SF*

Area of operable opening: 36.96 *SF*

Step 1 - C - Wind Speed Calculation

Refer to **Figure 3** of "Reference Tab A" to determine the average wind speed of your area. Simply take the average values of the cooling season and find their mean. Use this number for the average wind speed value for this worksheet.

Preliminary wind speed 7.5 *mph*

Once this value has been determined, it is important to note that this data likely came from an airport weather station whose surrounding area and terrain may differ greatly from your project's site conditions. Consequently, airport wind data is often significantly higher than urban and even rural conditions. To compensate for this discrepancy, a wind speed variance factor needs to be applied to the preliminary wind speed value obtained earlier in Step 3 - A. Use **Figure 4** of "Reference Tab A" to determine the correct wind speed reduction factor.

Wind Speed Reduction Factor:	0.38	
Adjusted Average Windspeed:	3.5	*mph*

The equation calls for this number to be in feet per second versus miles per hour, which can be found by multiplying the adjusted average wind speed value by 88.

Final Average Windspeed:	308	*feet per second*

Step 1 - D - Final Airflow Rate

Total CFM of Cross Ventilation System:	3756.6144	*CFM*

You may proceed to tab labelled "Step 2".

Step 2 - Convert the Flow Rate to a Cooling Capacity

Description:

The next step in the process involves taking the CFM flow rate found in step 1 and converting it into a sensible heat exchange in Btus/hr. This sensible heat exchange is contingent upon the temperature difference between the indoor and outdoor air, which we usually assume to be the minimum three degrees Fahrenheit for effective cross ventilation. This sensible heat exchange can then be converted into a cooling capacity with the square footage value of the building, which can then be compared to its heat gain rate on the "Intro and Final Outputs" tab to determine if the cross ventilation system is adequate. Keep in mind that the sensible heat exchange, and thus cooling capacity, will change with magnitude of the delta T, so this calculation only represents ONE condition of cross ventilation. More accurate consideration can be obtained through utilizing building performance software to model dynamically changing temperature differences over the entire cooling season.

This step uses the equation:

qv = (V) (1.08) (delta T)

where:

qv = sensible heat exchange due to ventilation
V = CFM rate found in Step 1
1.08 = a constant value derived from the multiplication of the density of air with the specific heat of air.
delta T = the temperature difference between outdoors and indoors

Step 2 - A - Sensible Cooling Rate

CFM obtained from Step 1:	3756.614	CFM
delta T:	3	
Constant Value:	1.08	Btu-min/(CF)(h)(deg F)

Sensible Cooling Rate:	12171.43	Btu/hr

Step 2 - B - Cooling Capacity

To find the cooling capacity, simply take the square footage of the building divided by the sensible cooling rate defined in Step 2 - A.

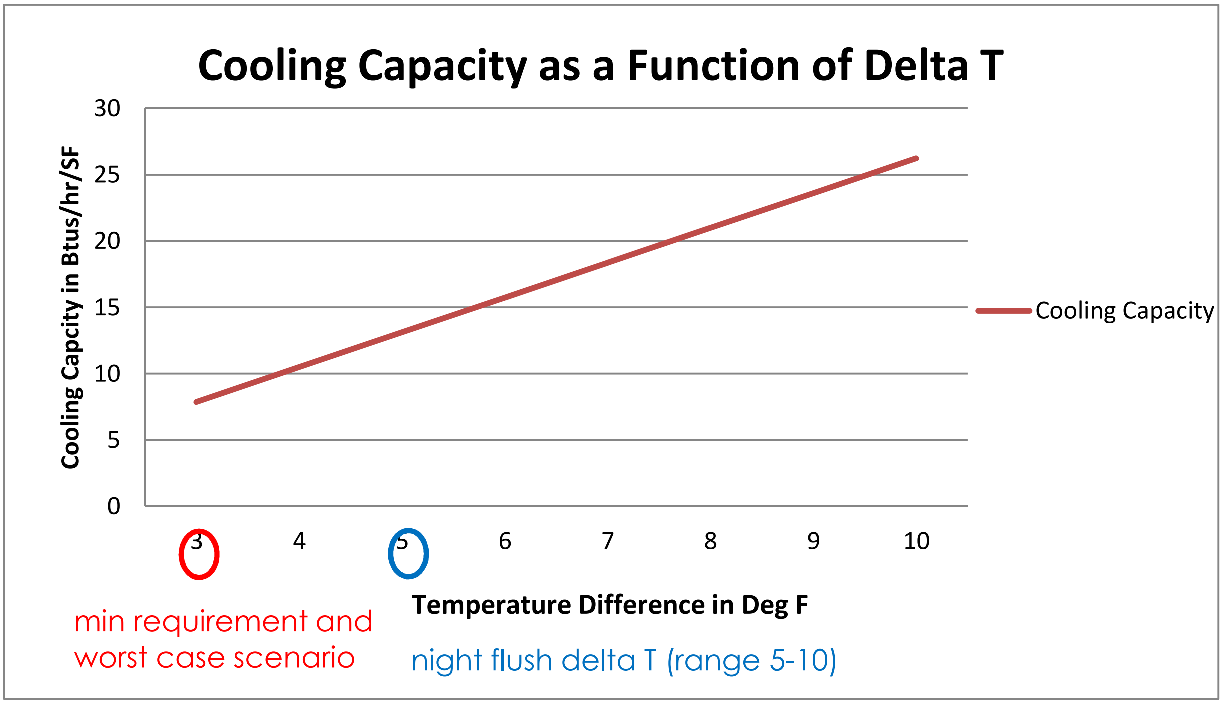
Building square footage:	1547.6	SF

Cross Ventilation Cooling Capacity:	7.86471	Btus/hr/SF

Return to the "Intro and Final Outputs" tab to compare the cooling capacity with the building's heat gain rate.

Step 2 - D - Auxilary Informaiton

The following chart illustrates the impact that temperature difference has on the cooling capacity of a stack ventilation system. Typically we will always use the minimum 3 degree temperature difference (as with the calculations above) to anticipate "worst case scenario" conditions, but a more acute approach can be taken dependent upon building, climate, and what month you are analyzing. In the chart below you can see the different cooling capacities based off of varying temperature differences. **If the 3 degree temperature difference is not used, then it is up to the discretion of the designer to decide which value is most appropriate. Simply use the graph to find whichever cooling capacity your temperature difference will elicit, and then compare it with the heat gain rate on the "Intro and Final Outputs" tab.**



The chart below references hidden cells in this spreadsheet that automatically calculate the different delta T's and cooling capacities based off of the parameters input earlier in this step.

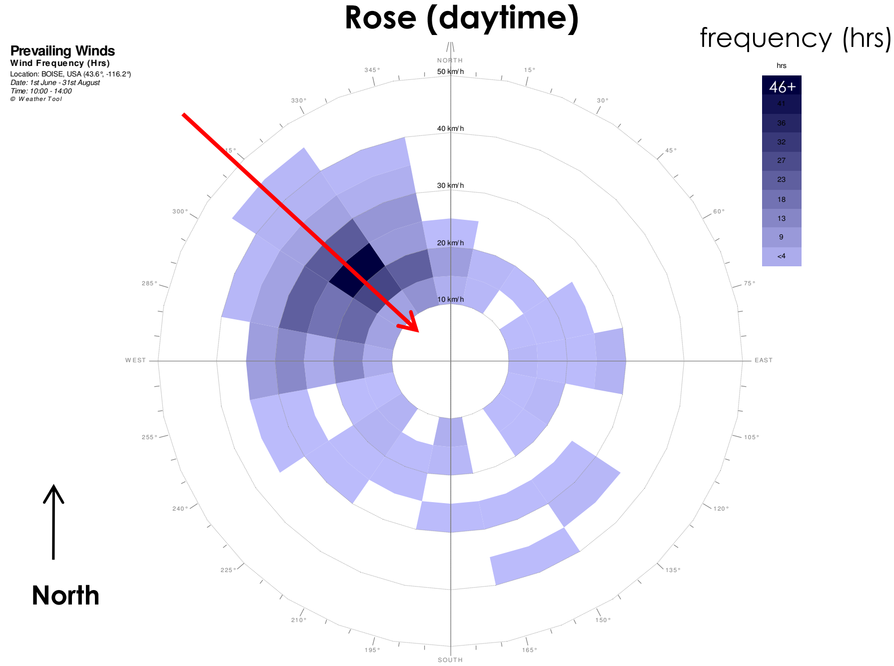
Delta T	Cooling Capacity
3	7.864713528
4	10.4862847
5	13.10785588
6	15.72942706
7	18.35099823
8	20.97256941
9	23.59414058
10	26.21571176
Deg F	*Kbtu/hr/SF*

References

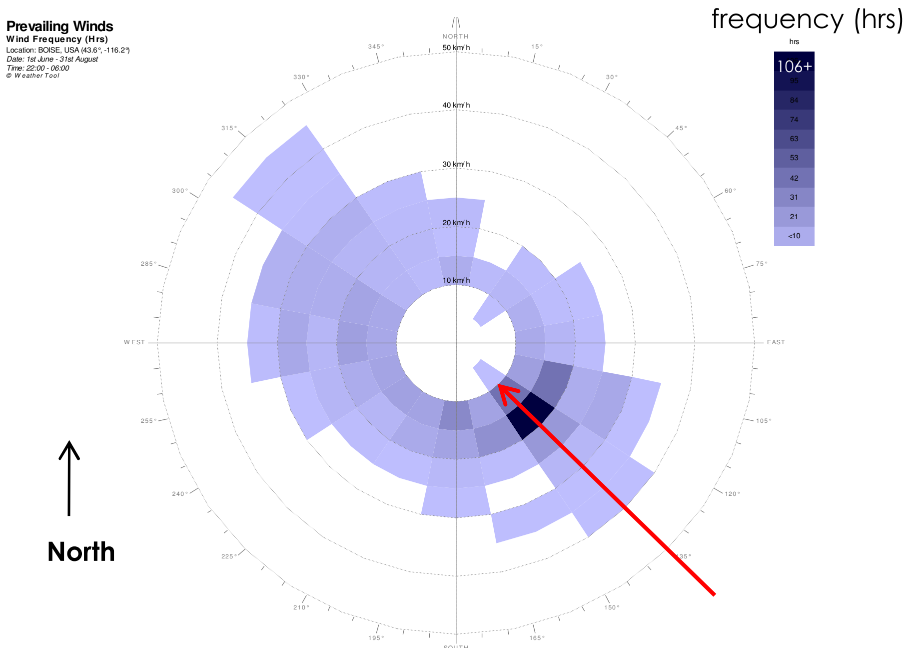
Figure 1 - Wind Roses

Source: Ecotect Weather Tool 2011

Summertime Wind Rose (daytime)



Summertime Wind Rose (nighttime)



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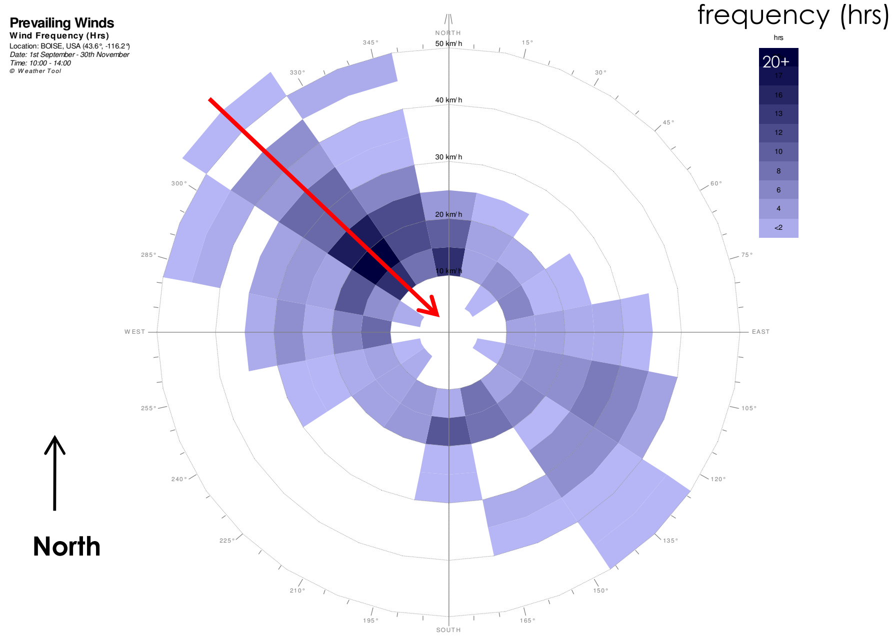
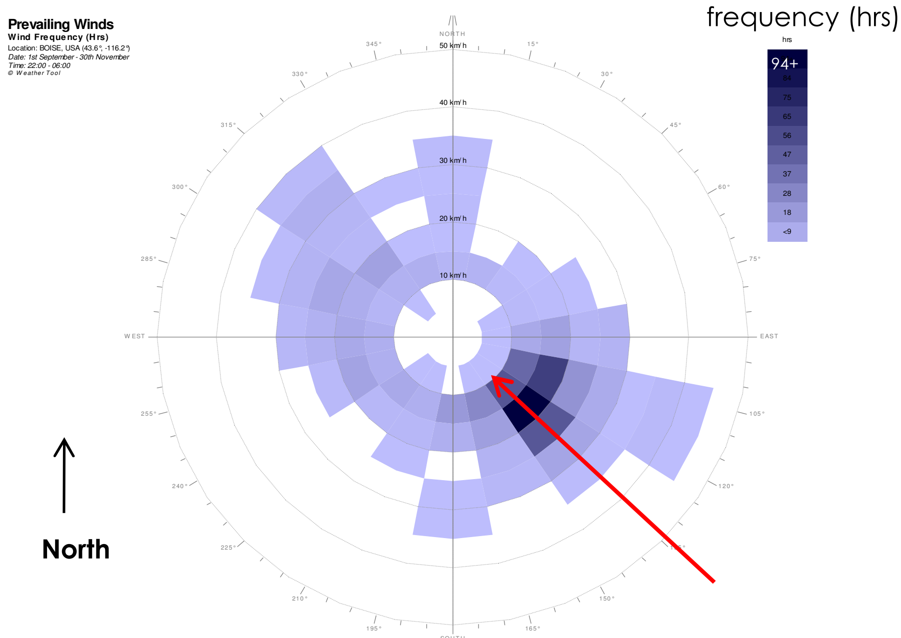
Autumn Wind Rose (daytime)



Autumn Wind Rose (nighttime)



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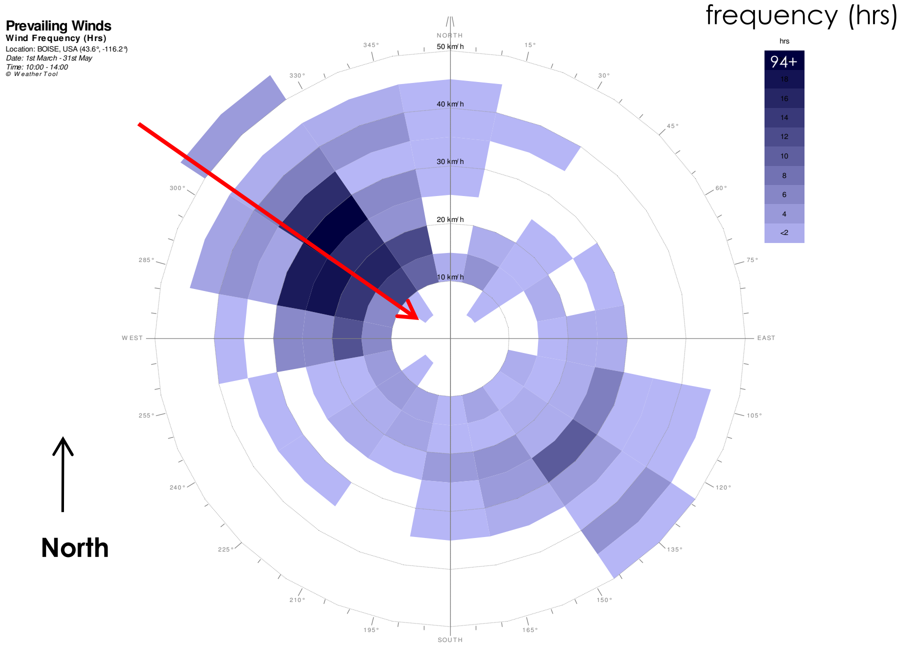
SpringWind Rose (night time)



Spring Wind Rose (nighttime)

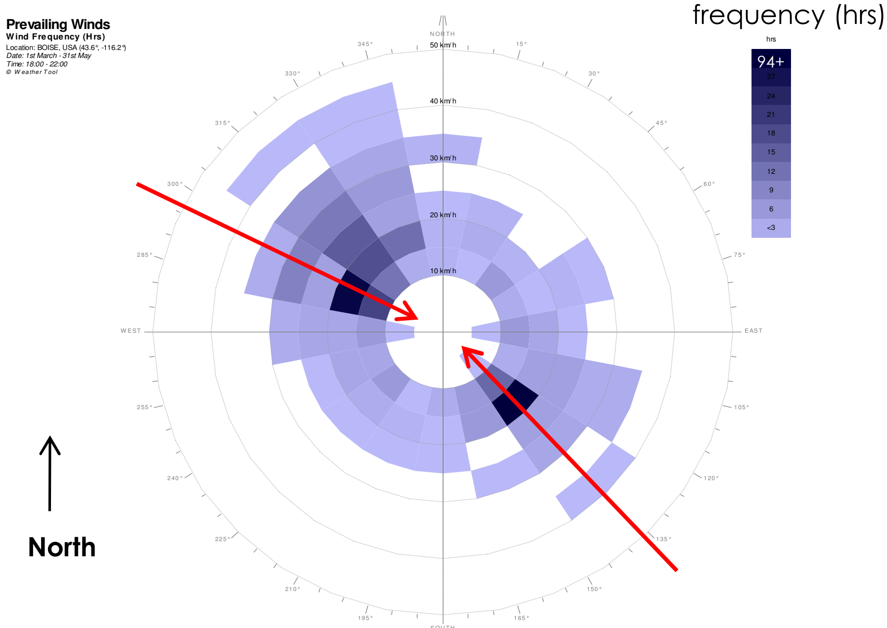


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Figure 2 - Effective Opening Factors

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Canada. John Wiley & Sons. Copyright 2000

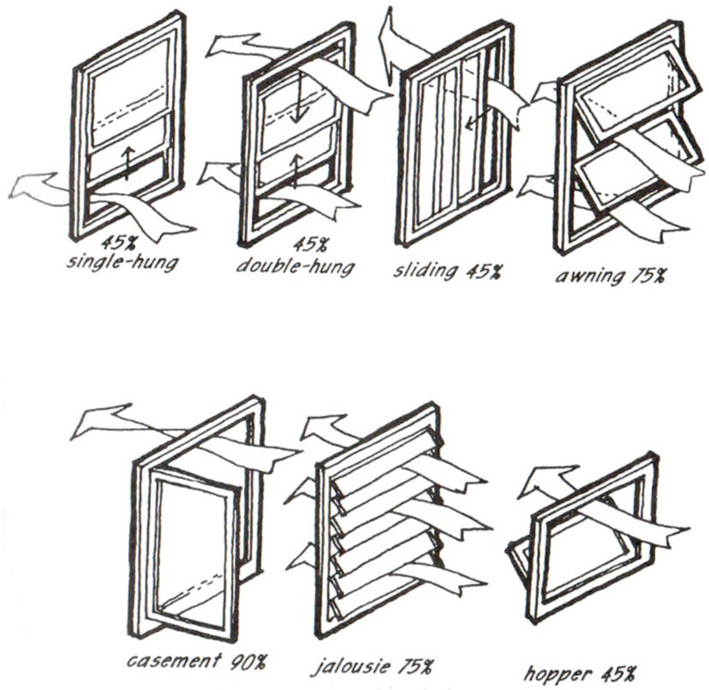


Figure 3 - Wind Speed Chart

Source: Climate Consultant 5

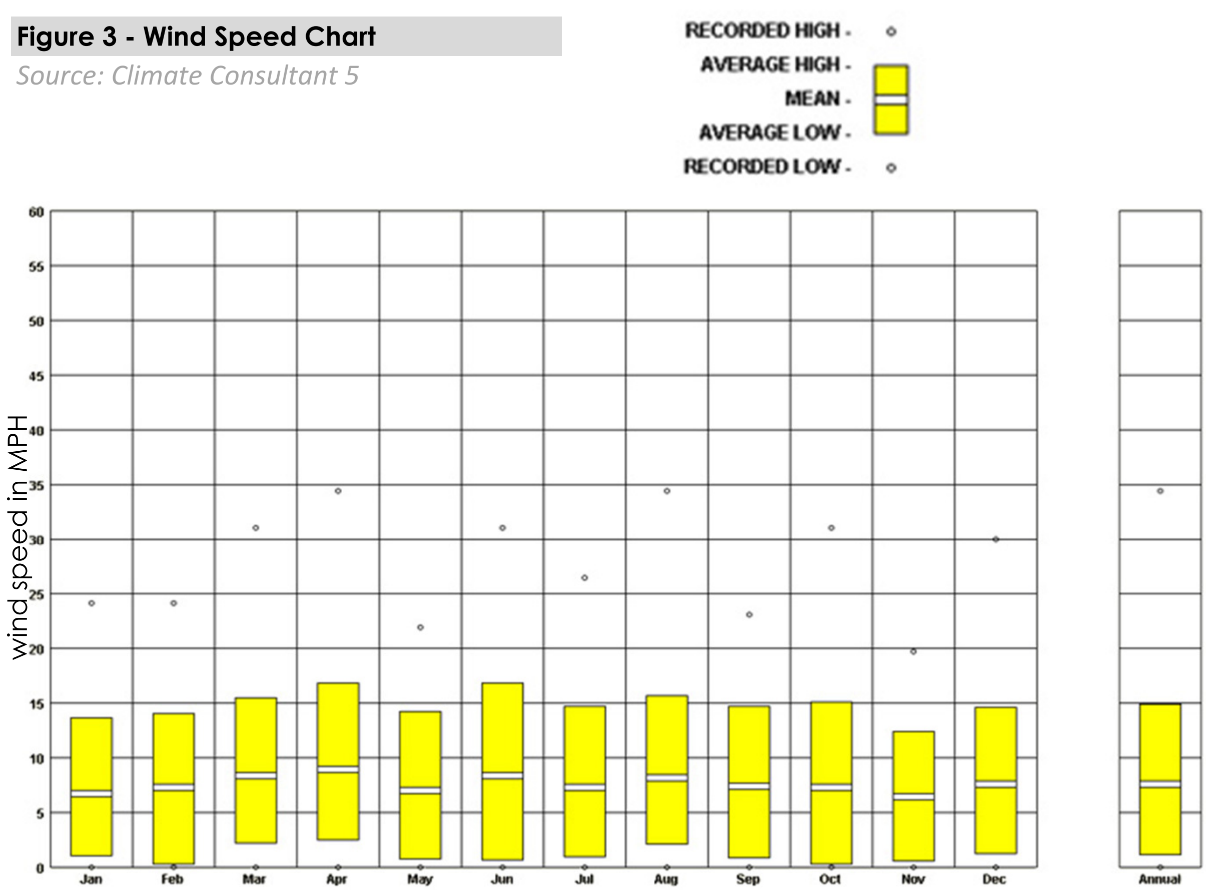
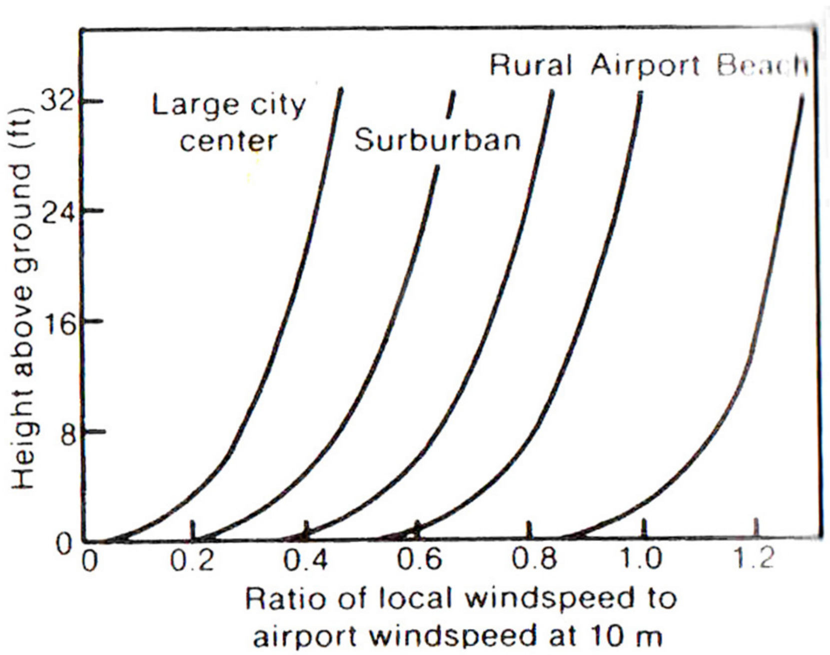


Figure 4 - Wind Speed Reduction

Source: Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Canada. John Wiley & Sons. Copyright 2000



D. Stack Ventilation Example

IPC and IDL Climate Tools Package

Stack Ventilation Capacity Calculations

climate tools - Boise

University of Idaho

Description:

Stack ventilation can be an effective method of natural ventilation when cross ventilation is not available. Stack ventilation relies on the buoyancy, pressure differentials, and fluid dynamic properties of air to drive ventilation throughout a building. For example, as heat transfers through the medium of air, warmed air rises and can be exhausted while it pulls in cooler air through lower openings. This particular method is useful when site, building, or climate constraints limit the amount of wind and effectiveness of cross ventilation. Stack ventilation's performance will be dependent on the smaller of the following parameters: inlet size, outlet size, and stack throat area (i.e. the shaft opening area of a tower or chimney). As with cross ventilation, the following calculations operate under the assumption of a minimum three degrees Fahrenheit temperature difference between the interior and exterior environment. A smaller amount of temperature difference will potentially cause the system will start to admit hot air into the building and contribute to the heat gain rate of the space. These calculations can only be used to assess how much cooling capacity (or demand) the systems can contribute under the specified conditions, which can vary widely with actual weather inputs over the cooling season. Consequently, they should only be used as a general rule of thumb and building performance simulation should be conducted to quantify actual cooling

Also note that stack ventilation can be driven by cross ventilation, thereby increasing the amount of airflow and cooling capacity of the system. If your building proposes to use both, be sure to fill out step 3 as well as the rest of this worksheet.

Instructions:

This page contains the final results of the calculations of the worksheet. Start with the tab labeled "Step 1" and follow the step-by-step process using the reference tab if needed. Finish going through all tabs before returning to this page to see if the stack ventilation strategy's cooling capacity will cover all or part of the building's heat gain rate.

Cell Color Legend:

Certain cells are colored in a manner that dictates whether or not they are a user defined input, or if they automatically calculate based off of internal equation or climate specific parameters. A pink cell will require you to manually input a number, while the gold cells are self-calculating or contain predetermined values.

auto calculates	user defined

To begin this worksheet, proceed to the tab labeled "Step 1"

Final Outputs

Use the worksheet named "Heat Gain Calculations" if you do not already have a heat gain rate. This number will always be compared against the cooling capacity of the system calculated throughout this worksheet to analyze the ability of the system to meet the cooling demand of the building.

Building or Zone Heat Gain Rate:	30.47	*Btus/hr/SF*

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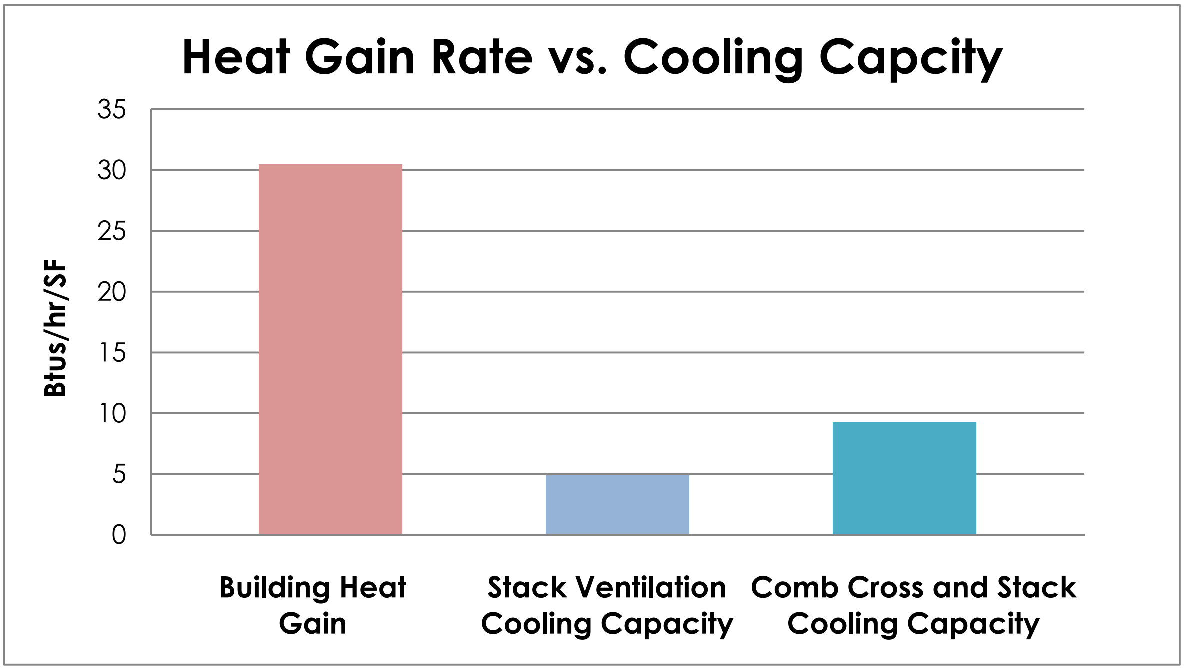
Stack Ventilation Cooling Capacity: 4.87964 *Btus/hr/SF*

Combined Stack and Cross Ventilation Cooling (if applicabl 9.253562 *Btus/hr/SF*

The chart below graphically represents the ability for stack ventilation to satisfy the heat gain rate of the building.



Step 1 - Find the Flow Rate of the System

Description:

The first step in the process involves calculating the flow rate of the system in CFM (cubic feet per minute) to understand how much air the stack ventilation strategy can deliver depending upon certain input parameters. Step 2 will involve converting that CFM into a Btu/hr heat gain rate for comparison with the building's heat gain rate.

This step uses the equation:

$$V = 60KA \sqrt{gh(Ti - To)/Ti}$$

where:

V = volume flow rate of air in CFM
K = discharge coefficient for openings (assume .65 for multiple inlets)
A = in square feet, the smaller of either the total area of the inlets or outlets or horizontal cross-sectional area (throat area) of the stack
g = gravitational constant, 32.2 ft/s2
h= stack height
Ti = temperature indoors in degrees Rankine (deg R)
To = temperature outdoors in degrees Rankine (deg R)

Step 1 - A

Calculate the area of the smaller of the inlet area, outlet area, or stack throat area, as the lowest value will dictate the performance of the system.

Smallest area of inlet, outlet or stack throat:	71.28	square feet

Step 1 - B

Calculate the height of the stack. This value is the distance between the bottom of the inlet and the top of the outlet.

stack height:	15.8	feet

Step 1 - C

and outdoor temperature. Keeping in mind that our minimum temperature difference should be three degrees, we can use this to determine our indoor and outdoor performance parameters. A common indoor temperature value would be the cooling setpoint of the HVAC system (75 deg F)

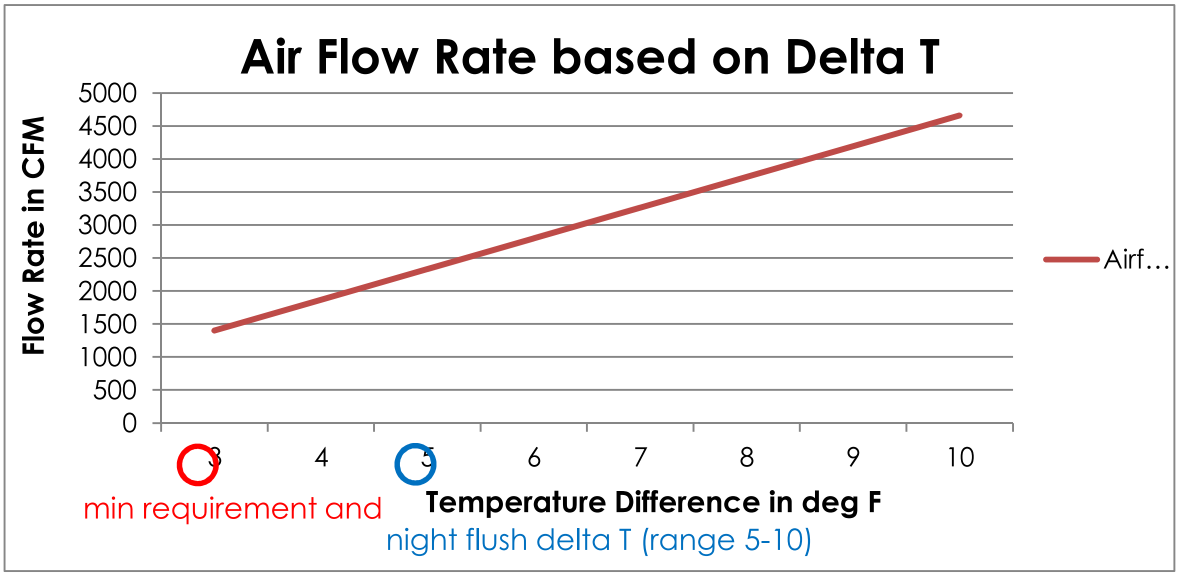
Indoor temperature:	75	deg F
	534.67	deg R
Outdoor temperature:	70	deg F
	529.67	deg R

Total CFM of Stack Ventilation System:	2330.781211	CFM

You may now proceed to tab labelled "Step 2".

Step 1 - D - Auxilary Informaiton

The following chart illustrates the impact that the temperature difference has on the air flow rate of a stack ventilation system. Typically we will always use a 3 degree temperature difference (as with the calculations above) to anticipate "worst case scenario" conditions, but a more acute approach can be taken dependent upon building, climate, and what month you are analyzing. Additionally, if stack ventilation is evaluated under a night flush ventilation scenario, a larger delta T can be used to represent the cooler outdoor temperatures of nightfall. Typically, 5 deg F can be assumed for minimum requirements and "worst case scenario" conditions.



The chart below references hidden cells in this spreadsheet that automatically calculate the different delta T's based off of the parameters input earlier in this step.

Delta T	Airflow
3	1398
4	1865
5	2331
6	2797
7	3263
8	3729
9	4195
10	4662
deg F	*CFM*

Step 2 - Convert the Flow Rate to a Cooling Capacity

Description:

The next step in the process involves taking the CFM flow rate found in step 1, and converting it into a sensible heat exchange in Btus/hr (cooling effect). Like the air flow rate for stack ventilation, the system's sensible heat exchange is also contingent upon the temperature difference between the indoor and outdoor air, which we usually assume to be the minimum three degrees Fahrenheit for effective stack ventilation. This sensible heat exchange can then be converted into a cooling capacity using the square footage value of the building. This value can then be compared to its heat gain rate on the "Intro and Final Outputs" tab to determine if the stack ventilation system is adequate. Keep in mind that the sensible heat exchange, and thus cooling capacity, will change with magnitude of the delta T, so this calculation only represents ONE condition of cross ventilation. More accurate consideration can be obtained through utilizing building performance software to model dynamically changing temperature differences.

This step uses the equation:

qv = (V) (1.08) (delta T)

where:

qv = sensible heat exchange due to ventilation
V = CFM rate found in Step 1
1.08 = a constant value derived from the multiplication of the density of air with the
delta T = the temperature difference between outdoosr and indoors

Step 2 - A

CFM obtained from Step 1:	2330.781	CFM
delta T:	3	Deg F
Constant Value:	1.08	

Sensible Cooling Rate:	7551.731	Btus/hr

Step 2 - B

To find the cooling capacity, simply take the square footage of the building divided by the sensible cooling rate defined in Step 2 - A.

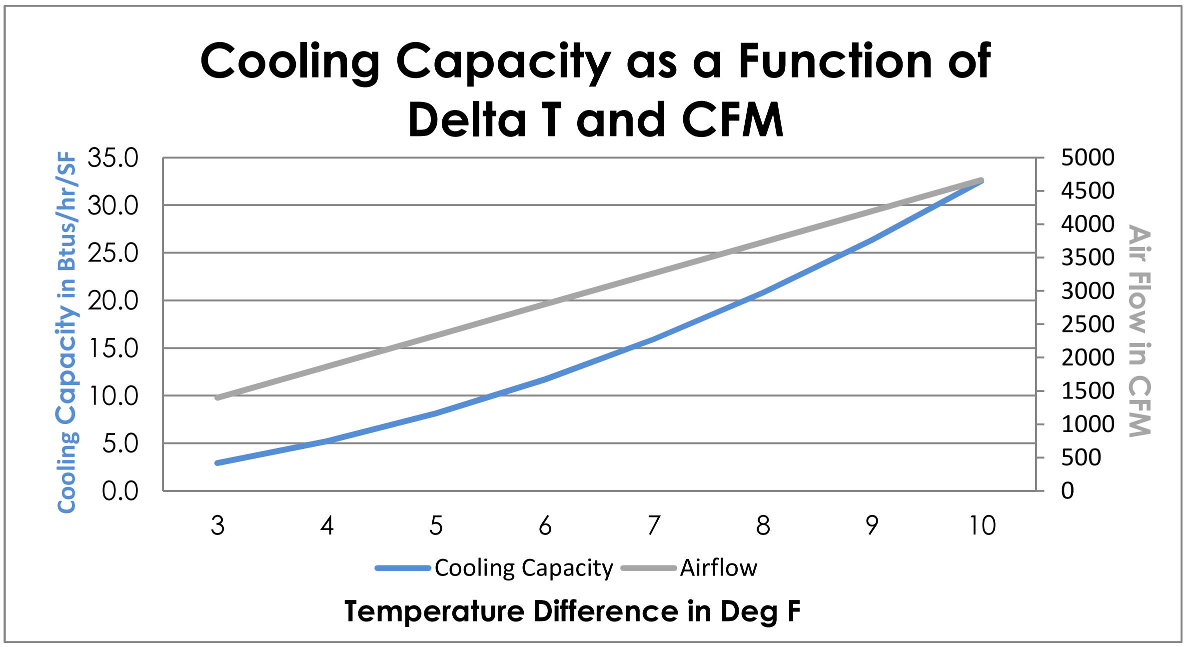
Building square footage:	1547.6	SF

Stack Ventilation Cooling Capacity:	4.87964	Btus/hr/SF

Return to the tab "intro and Final Outputs" to compare the cooling capacity with the building's heat gain rate OR proceede to tab "Step 3".

Step 2 - D - Auxilary Informaiton

The following chart illustrates the impact that the temperature difference has on both the air flow rate and cooling capacity of a stack ventilation system. Typically we will always use a 3 degree temperature difference (as with the calculations above) to anticipate "worst case scenario" conditions, but a more acute approach can be taken dependent upon building, climate, and what month you are analyzing. Here you can see the different cooling capacities and flow rates based off of varying temperature differences. **If the 3 degree temperature difference is not used, then it is up to the discretion of the designer to decide which value is most appropriate. Simply use the graph to find whichever cooling capacity your temperature difference will elicit, and then compare it with the heat gain rate on the "Intro and Final Outputs" tab.**



The chart below references hidden cells in this spreadsheet that automatically calculate the different delta T's and cooling capacities based off of the parameters input earlier in this step.

Delta T	Airflow	Cooling Capacity
3	1398	2.9
4	1865	5.2
5	2331	8.1
6	2797	11.7
7	3263	15.9
8	3729	20.8
9	4195	26.4
10	4662	32.5
deg F	*CFM*	*Btus/hr - SF*

Step 3 - Combined Stack and Cross Ventilation **(OPTIONAL)**

Description:

If your building does not incorporate both strategies, skip this step. In the case of buildings that utilize both cross and stack ventilation, the two system's interaction can be accounted for with the equation below. Typically the addition of cross ventilation will drive the stack effect and therefore will increase the airflow rate and the overall cooling capacity of the design.

This step uses the equation:

$$V = \sqrt{(\text{cfm from cross ventilation})^2 + \text{cfm from stack ventilation})^2}$$

where:

V = total combined airflow in CFM

Step 3 - A

Input the CFM from cross ventilation (refer to the cross ventilation worksheet. Be sure to adjust your CFM if you are trying to evaluate a different temperature difference.

Cross Ventilation CFM: 3756 CFM

Input the CFM from stack ventilation (refer to step 1-c). Be sure to adjust your CFM if you are trying to evaluate a different temperature difference.

Stack Ventilation CFM: 2330 CFM

Combined Airflow Rate 4420.004 CFM

Step 3 - B

Use the CFM obtained in step 3-A to find the sensible cooling rate of the combined systems.

This step uses the same equation as tab "Step 2":

$$qv = (V)\ (1.08)\ (\text{delta } T)$$

where:

qv = sensible heat exchange due to ventilation
V = CFM rate found in Step 3 - A
1.08 = a constant value derived from the multiplication of the density of air with the
delta T = the temperature difference between outdoosr and indoors

Combined CFM rate: 4420.004 CFM

delta T: 3 deg F

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(make sure you use the same delta T used to find the CFM and sensible cooling rates of the stack effect found in tab "Step 2")

Sensible Cooling Rate: 14320.81 *Btus/hr*

Building square footage: 1547.6 *SF*

Combined Cross and Stack Ventilation Cooling Capacity:	9.253562	*Btus/hr/SF*

Return to the tab "intro and Final Outputs" to compare this cooling capacity with the building's heat gain rate.

E. Night Ventilation of Thermal Mass Example

IPC and IDL Climate Tools Package

Night Ventilation/Thermal Mass Calculations

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Description:

Combining night flush ventilation with a thermal mass strategy can be one of the most effective forms of passive cooling. The basic concept of this strategy involves designing a building with high thermal mass and increasing the rate of ventilation during the night. The thermal mass will absorb the heat gained inside a building during the day, effectively acting as a heat sink, and this heat can be removed at night so that the cycle can continue. Additionally, admitting cool nighttime air can even "charge" the thermal mass with coolth, and provide an even higher sensible cooling rate to occupants through radiant-based surfaces. This strategy addresses the most important component of thermal comfort, seeing as most of our thermal perception as human beings is based off of surface and radiant temperatures. The optimization of this strategy is based off numerous parameters including the diurnal swing of the climate, the amount and type of thermal mass, and the ventilation rate, which can be mechanical or passive. Keep in mind that these calculations only account for the performance of the system during one day under one condition. More extensive analysis must be conducted by building simulation to understand performance over varying annual weather conditions to quantify

Instructions:

This page contains the final results of the calculations of the worksheet. Start with the tab labeled "Step 1" and follow the step-by-step process using the reference tab if needed. Finish going through all tabs before returning to this page to see if the night flush ventilation strategy's cooling capacity will cover all or part of the building's heat gain rate.

Cell Color Legend:

Certain cells are colored in a manner that dictates whether or not they are a user defined input, or if they automatically calculate based off of internal equation or climate specific parameters. A pink cell will require you to manually input a number, while the gold cells are self-calculating or contain predetermined values.

auto calculates	user defined

To begin this worksheet, proceed to the tab labeled "Step 1"

Final Outputs

use the worksheet named "Heat Gain Calculations" if you do not already have a heat gain rate. This number will always be compared against the cooling capacity of the system calculated throughout this worksheet to analyze the ability of the system to meet the cooling demand of the building.

Building or Zone Heat Gain Rate:	26.99	*Btus/hr-SF*
Night Flush Cooling Capacity:	4.21468	*Btus/hr-SF*
Airflow Rate Needed for Night Flush:	1548.674	CFM

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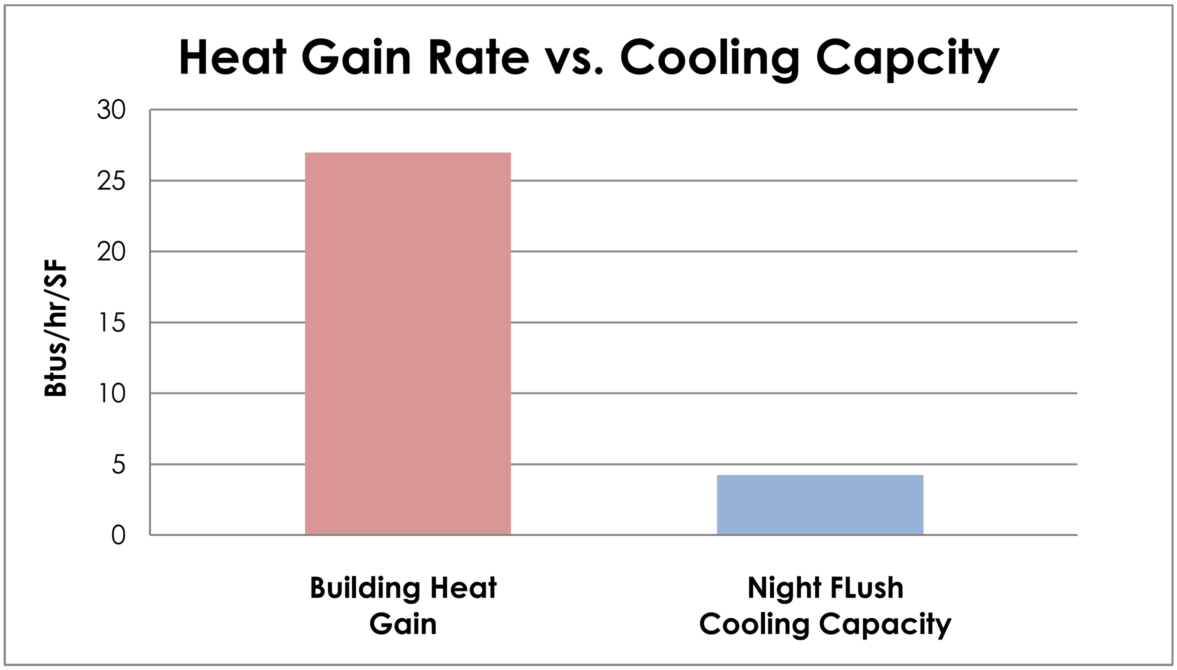
The chart below graphically represents the ability for night flush ventilation and thermal mass to satisfy the heat gain rate of the building.



Step 1 - Building Information

Description:

The first step in the process involves inputting information about the building or zone being analyzed. Additionally, key input parameters about the type and quantity of thermal mass are also considered in this step.

Step 1 - A - Building Information

Floor Area: 1582 SF

Building Volume: 24000 CF

Step 1 - B - Thermal Mass Information

Mass Surface Area: 1582 SF

The ideal mass to surface area - floor area ratio is 2:1. Typically, only exposed mass can be used for this calculation, as its ability to absorb heat is reliant directly upon its direct exposure to the space.

Mass Surface Area to Floor Area Ratio: 1

Mass Volume: 990 CF

Step 1 - B - Thermal Mass Information

Refer to **Figure 1** in "Reference tab A" or use the web resource Engineering Toolbox (specific links found below)

Density of Thermal Mass: 140 lb/CF

Refer to **Figure 1** or: http://www.engineeringtoolbox.com/material-properties-t_24.h (searching required)

Specific Heat: 0.21 Btu/lb-Deg F

Mass Heat Capacity: 29106 Btu/deg F

Refer to **Figure 1** or: http://www.engineeringtoolbox.com/specific-heat-solids-d_154.html

The mass heat capacity is found by multiplying the Density of the material by its specific heat. You may override this cell if you find a resource that lists your thermal mass type's Mass Heat

Mass Surface Conductance 1 Btu/hr/SF-Deg F

This value is typically assumed to be 1 unless found otherwise.

Starting Mass Temperature 80 deg F

This value is typically assumed to be 80 degrees F.

You may now proceed to the tab labelled "Step 2".

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Step 2 - Cooling Capacity Calculations

Description:

The next step involves defining a temperature profile for the design cooling day of the project's climate. This temperature will be the variable in determining the mass temperature and thus cooling capacity of the system. The 24 hour temperature profile should represent two conditions as closely as possible: the temperature should reach the selected design temperature of the climate, and the diurnal swing should be close to the average for that design day. For this temperature profile, the ASHRAE 1% cooling degree day for the climate was chosen to represent the cooling capacity of the system under hot summer conditions.

Step 2 - A Table Columns

Column A. Hour:
This column contains all 24 hours in a day that the cooling capacities will be calculated for.

Column B. Outside Air Temp
This column contains the climate specific average hourly temperature data

Column C. Storage Capacity
This value represents the amount of Btus the mass can absorb. This column is obtained by the following equation:

Cooling Capacity = (previous hour mass temperature [column D] - outdoor air temperature [columnB]) x (mass surface area [step 1 - B]) x (mass surface conductance [step 1 - B])

Column D. Mass Temperature
This column is obtained by the following equation:
Mass Temperature = (previous hour mass temperature [column d]) - (cooling capacity x mass heat capacity)

Column E. Building Mode
This value represents when the building should be in "open" or "closed" mode depending on whether the cooling capcity is negative or positive. Input "Open mode" for a postivie value, and "Closed Mode" for a negative value. A negative value would represent that the mass will be warmed by the ventilation versus being cooled and thus compromising the cooling effects of the system.

Please refer to the next page for the actual table of this informaiton.

Column A. Hour	Column B. Outisde Air Temp	Column C. Storage Capacity	Column D. Mass Temp	Column E. Bldg Mode
8:00 PM	89.96	-15756.72	80.54	
9:00 PM	87.05	-10296.67	80.90	
10:00 PM	80.06	1321.16	80.85	
11:00 PM	75.02	9222.63	80.53	
12:00 PM	73.94	10429.91	80.17	
1:00 AM	69.08	17551.54	79.57	
2:00 AM	68	18306.12	78.94	
3:00 AM	64.94	22152.04	78.18	
4:00 AM	64.04	22371.81	77.41	
5:00 AM	62.96	22864.40	76.63	
6:00 AM	62.96	21621.65	75.88	
7:00 AM	66.92	14181.72	75.40	
8:00 AM	69.98	8569.98	75.10	
9:00 AM	75.02	130.90	75.10	
10:00 AM	78.98	-6140.94	75.31	
11:00 AM	82.94	-12071.88	75.72	
12:00 PM	87.08	-17965.21	76.34	
1:00 PM	91.04	-23253.47	77.14	
2:00 PM	98.02	-33031.93	78.28	
3:00 PM	95	-26458.91	79.18	
4:00 PM	96.08	-26729.34	80.10	
5:00 PM	96.08	-25276.52	80.97	
6:00 PM	96.08	-23902.67	81.79	
7:00 PM	95	-20894.92	82.51	
	deg F	*Btu*	*deg F*	

Step 2 - B Calculate Cooling Capacity

Total Mass Btu Storage Capacity (cooling): 160022.98 *Btus*

***note: you must drag the extents of this equation to add together all of the postive values in Column C of the table. The equation does not automattically do this, so the user must manually adjust the extents of the equation.**

Sensibe Cooling Rate: 6667.624285 *Btus/hr*

Night Flush Cooling Capacity: 4.214680332 *Btus/hr-SF*

note: this cooling capacity is only contingent upon the correct amount of ventilation. For ventilation requirements and calculations, proceed to tab "Step 3".

Step 3 - Ventilation Rate Calculation

Description:

Having the adequate thermal mass is only half of the equation when it comes to optimizing the night flush system. Given the thermal dynamics of the thermal mass calculated in tab "Step 2", a required ventilation rate to achieve the calculated cooling capacity can be extracted. This ventilation rate can be met either passively or mechanically.

Step 3 - A - Hour of Best Cooling

Refer to the table in tab "Step 2" and input the following data that corresponds to the LARGEST value in Column C. Btu Storage Capacity

Largest hourly Btu storage capacity:	22864	Btu
Outdoor Air Temperature during largest hourly Btu storage cap	62.96	deg F
Mass temperature during largest hourly Btu storage capacity:	76.63	deg F
Air Flow Rate:	92920.43	CFH
Air Changes per Hour:	3.871684	ACH

Night Flush Airflow Rate:	1548.674	CFM

This value must be met to achieve the cooling capacity derived in tab "Step 2"

The "Stack Ventilation Calculation" and "Cross Ventilation Calculation" worksheets can be used to size the ventilation system for night flushing. Use these worksheets to find the CFM flow rate based on nighttime wind direction, nighttime wind speed, and nighttime temperature difference (typically between 5-10 deg F).

F. Passive Design Tool Day Attendance List

2010 AIA/CES Course Attendance Template

Registered Providers are responsible for reporting to the AIA/CES the names of ALL AIA members.
Use this form to record the names of all attendees AIA members who have earned credit.
This document or another sign in sheet must be kept on file for six (6) years with the Provider Point of Contact.

Course Title: PASSIVE DESIGN TOOL DAY

Provider Number: ______ Course Number: IDL-06_24 Provider Name: ______

Name of Presenter: Ery Dunlaed

Date of Course: 6-24-11 City/State: Boise, ID

Participants at this course: **(Please print or type)**

AIA Member	AIA Membership # (required)	Name of Participant	Certificate* Request
1. ☐		Scott Mackay	☒
2. ☐		Rebecca Mirsky	☒
3. ☐		John Coldiron	☐
4. ☐		Greg Neruda	☒
5. ☒	3004612	Steve Simmons	☒
6. ☐		Mike Purcell	☐
7. ☒	30121536	Stan Cole	☒
8. ☐		Kristen Cunningham	☒
9. ☐		Matt Franklin	☒
10. ☐		David Davis	☒
11. ☐		Chris Tallow	☒
12. ☐	phone # 208 890 8669	Andrew Wheeler	☐
13. ☐		Elizabeth Young	☒
14. ☐			☐
15. ☐			☐

Submit these attendees within two weeks of course completion online to CES Discovery. Please do NOT mail, email, or fax this form this form to AIA/CES.

***It is the responsibility of the Provider to send out certificates of completion to all participants that request them.**