



HOURLY SIMULATION GUIDELINES

Version 2.3: July 2020

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1. Introduction

This document has been developed by the Massachusetts energy efficiency program administrators (PAs) to create a common set of expectations for technical assistance (TA) consultants providing hourly energy simulation services. This is intended to be a living resource that is regularly updated as energy codes, modeling methodologies, and analysis tools evolve. These guidelines pull together technical direction from a variety of sources to improve modeling accuracy. This is not intended to be a comprehensive manual for how to perform energy modeling and assumes a moderate degree of experience.

The main body of these guidelines is fairly brief and intended to define the general degree of rigor required for PA study submissions. These are requirements for hourly simulation studies.

Attachments to the guidelines include technical notes for the use of modelers and a technical review guide for the use of PA reviewers.

- The technical notes are recommended practices that are likely to improve the reliability and accuracy of simulation models. There may be cases where simulation requirements reference these technical notes. The technical notes are organized by general design discipline (e.g. architectural, HVAC, plumbing, electrical, process).
- The technical review guide is developed from the simulation requirements and provides step by step guidance.

These guidelines focus on simulation and are not specific to new construction, retrofit, stand-alone, or campus projects. Please see other Mass Save documents for current incentive program requirements such as baseline definitions for new construction projects.

2. Approved Modeling Software

The approved list of hourly simulation packages is based on current computational capabilities and current familiarity of the PA technical review staff and TA vendor community. There is a strong preference for open-source software capable of 8,760-hour analysis. Other software could potentially be used but this must receive pre-approval from the PA technical reviewer.

1. eQuest v3.65 operating with either DOE2.2 or DOE2.3 is currently the favored simulation package due to its widespread use in southeastern New England and fast run times. DOE2.2 has some clear disadvantages when simulating DOAS, displacement ventilation, chilled beams, natural convection, natural ventilation, and HVAC systems largely dependent upon radiant surfaces. Specific work-arounds are recommended in this guideline for DOE2.2 that have been developed by the PAs and TA vendors providing most simulation services. DOE2.3 may have effectively addressed some of these issues, though DOE2 continues to use rudimentary models for radiant heat transfer, natural convection, and infiltration.
2. EnergyPlus is capable of modeling the next generation of HVAC systems but it is hampered by a lack of a user-friendly open source interface and extended simulation run times. The PAs recognize the power of EnergyPlus but prefer to use eQuest. Discuss the use of EnergyPlus with the PAs during the proposal process.
3. Other software programs such as Trane TRACE and Carrier HAP models are not accepted at this time. Trane TRACE is in the process of incorporating EnergyPlus as the calculation engine but a fully workable simulation package has yet to be released.

3. Documentation Requirements

All simulation studies are required to provide the following documentation. Updated versions are required to be provided upon project completion. These guidelines introduce few changes to the work flow most TA vendors have used in the past and are likely to facilitate the documentation process.

- A. Study proposals shall follow the current proposal template available from the PAs and should provide a road map for how the study will be completed. Baseline assumptions, expected deviations from these guidelines, and anticipated work-arounds shall be described. The planned approach to developing model inputs and cost estimates shall be described for each measure.
- B. A modeling report conforming to documentation formats described in the current sample report available from the PAs.
 1. The report must state whether these guidelines have been followed in their entirety or describe what deviations have been required for the particular project.
 2. Graphical representations of energy use impacts by end use and month facilitate TA internal quality control and PA technical reviews. TAs may need to modify their post-processing spreadsheet templates to support automatic generation of these plots. Discussions of energy impacts for each measure should focus on these plots and explain the results.
 3. Use of work-arounds other than those described in the technical notes must be thoroughly and clearly explained.
- C. Modeling results for each considered ECM shall be provided to allow the relative impact of each upgrade to be assessed.
- D. Provide all simulation files necessary to open and run all models supporting the applications for incentives. For eQuest projects, this includes the .inp, .pd2, .prd, and weather files.
- E. Provide spreadsheet files used to generate unique model inputs supporting complex work-arounds.
- F. Should specific information from manufacturers or vendors be used to develop input assumptions, copies of supporting information should be attached in a report appendix.
- G. Cost estimation remains a program requirement for each ECM. The method of developing costs is at the discretion of the TA but the listed cost should be reasonably accurate.
- H. Screening tool input values (and results) shall be presented in a dedicated report appendix.
- I. The simulation report shall not include incentive offer amounts. These are to be provided in a separate letter from the PA to the customer.

4. Baselines

Energy savings are highly impacted by baseline assumptions, and the general approach toward baseline development for a specific project needs to be clearly defined in the study proposal submitted to the PAs.

- A. The current state energy code with associated amendments (780 CMR Chapter 13) serves as the general baseline reference. The PAs have developed a baseline document that summarizes code requirements, presents policy decisions, and covers non-regulated end use baseline assumptions. Several deviations between the PA

baseline and current code are clearly listed in the baseline document. All studies are to comply with the most recent baseline document.

- B. The energy code allows compliance with IECC or ASHRAE 90.1 but does not allow switching between the two. Design teams need to select a code basis for their projects and the PA study shall, generally, use whichever basis is selected by the design team. The compliance track needs to be clearly described in study proposals.
- C. Although federal buildings are not required to meet the Massachusetts state energy code, baselines for these buildings must meet the requirements of the most recent Mass Save baseline document.
- D. ASHRAE 90.1 Appendix G is not an accepted baseline.
- E. Pursuit of building design certification (e.g. LEED, Energy Star) does not impact choice of baseline assumptions used in incentive models. In cases where a design assistance model originally developed to support the certification process is used to support an incentive study, some attributes of the baseline may need to be changed to align with the requirements in these guidelines.
- F. The following design case attributes are to be the same in the baseline model:
 - 1. Weather file
 - 2. Building orientation
 - 3. Shading from adjacent objects
 - 4. Floor plan layouts and space use assignments
 - 5. Presence of plenums, voids, shafts, and other spaces that are not actively conditioned
 - 6. Distribution and width of windows (height is to be varied to change overall WWR if necessary)
 - 7. Category of envelope assemblies relative to IECC 2018 Table C402.1.4 and ASHRAE 90.1-2016 Table 5.5-5
 - 8. Load diversity schedules and HVAC system occupied period run time schedules
 - 9. Process loads (changes permitted to model unique control sequences)
 - 10. Design ventilation rates at zone level¹
 - 11. Space temperature schedules (changes permitted to model unique control sequences)
 - 12. DHW fuel type
 - 13. Average annual utility rates. For new construction projects, the rates are defined annually by PAs in the custom screening tool. For retrofit projects, the rates should be based on historical averages for the most recent year. Use of a customer's likely future electricity rate structure can be used provided that the energy model accounts for every end use consuming electrical power to ensure accurate predictions of demand costs.

Infiltration modeling strategy, peak flow basis, and schedules are to be the same in the base and proposed cases unless there are proven reductions in infiltration rates and the source of the infiltration loads are known through on-site testing. Translation of blower door test results to modeling inputs is a complex process that must be described to PAs in the study proposal and agreed upon by the PA.

¹ Savings cannot be claimed for implementing DCV in a system with ventilation rates exceeding code minimum requirements.

5. Required Modeling Methodology

These guidelines assume TAs are well-versed in standard modeling protocol necessary to generate a reasonably accurate prediction of future facility energy use. The following methodology descriptions define minimum acceptable standards for models developed for the Mass Save programs.

- A. Models shall use TMY3 data per direction included in Technical Note A.1
- B. Models are to be configured based upon designed or likely HVAC zoning layouts and shall adhere to Technical Note A.2.
- C. Include the effect of shading from adjacent objects that are likely to cast shadows on fenestration.
- D. Spaces located above ceilings (a.k.a plenums) are to be modeled as plenum zones if these spaces have exterior surfaces.
- E. Envelope assemblies are to be entered using layers and constructions rather than simplified methods.
- F. Envelope assemblies are to include the impact of bridging, see Technical Note B.1 for recommended options.
- G. Adequate mass is to be included in the building to more realistically dampen zone temperature swings.
- H. Zones with partial roofs, exposed floors, or subgrade walls are to include reasonably accurate representations of the actual surface areas.
- I. Spandrel assemblies shall be modeled as a separate wall or window type having thermal characteristics accounting for thermal bridging.
- J. For models that are to include daylighting controls in the baseline and/or proposed case, include adequate internal partitions to support accurate predictions of daylighting impact.
- K. Walls that do not have windows in the design shall not have windows in the model.
- L. Multiple windows on a single wall for a particular zone can be collapsed to one equivalent window having fixed width and variable height. The preferred approach is to model individual windows.
- M. Models shall account for the effects of infiltration but shall not claim savings for improved air barrier performance unless specifically accepted as an ECM by the PAs. The crack method shall be used for buildings taller than 4 stories since this approach accounts for stack effect. See Technical Note B.2 for recommended options.
- N. Models shall account for heat transfer to the ground, see Technical Note B.3 for recommended options.
- O. Separate occupancy, lighting, and equipment load schedules are to be defined for different use areas in the building. See Technical Note A.3.
- P. Schedules for a given space (e.g. occupancy, lighting, equipment) are to be consistent with one another. See Technical Note A.3.
- Q. Peak space load assumptions are to be consistent with the diversity schedules.
- R. Autosizing of HVAC systems is permitted in early and mid-design modeling and should generally not be used for final modeling unless required to capture the impact of load reductions or system type changes as part of a specific ECM. See Technical Note C.1.
- S. All end use equipment likely to consume energy on a regular basis is to be represented in the energy model regardless of whether its operation impacts systems considered by an ECM. This ensures that building-wide %

energy and cost impacts are accurately captured. See the technical notes pertaining to process equipment for further information and recommendations.

- T. Baseline and design case lighting power is to be modeled on a space-by-space basis. The whole-building approach shall not be used.
- U. Lighting diversity schedules assume the use of manually operated wall switches and code-required occupancy sensors. The impact of optional occupancy sensor control in the proposed case shall be captured by applying a 10% reduction in LPD.
- V. Savings shall not be claimed for items required by the baseline document.
- W. Individual energy conservation measures shall be evaluated incrementally in the following order:
 - 1. Envelope improvements
 - 2. Peak load factor reduction (e.g. efficient lighting design)
 - 3. Space load control improvements (e.g. additional lighting controls)
 - 4. HVAC system type (if a successful ECM, otherwise the baseline uses the designed HVAC type)
 - 5. HVAC zone control improvements (e.g. DCV)
 - 6. Combined Heat and Power (CHP)
 - 7. HVAC central plant component improvements (e.g. efficient chillers)
 - 8. ECMs with little interactivity with other measures (e.g. condensing DW heaters)
- X. Buildings receiving cooling and/or heating from a central plant shall comply with Technical Note C.2.

Technical Notes

The following technical notes are organized by design discipline per the following headings. Within each discipline, each note has been number incrementally as they have been added to the simulation guidelines document. This approach facilitates stable references over time.

- A. General
- B. Architectural
- C. HVAC
- D. Plumbing
- E. Electrical
- F. Process

A.1 General: Weather Files

This is a required item for all hourly simulation projects.

- A. Models shall use TMY3 data rather than TMY2 since weather data for the period 1991 to 2005 is more likely to reflect current and near future weather patterns. TMY2 data is based on 1960 to 1990 weather.
- B. TMY3 data files shall be selected based on the likely weather at the project site. The following observations shall be taken into account:
 - 1. Boston Logan airport is located in the middle of Boston Harbor and is generally colder than conditions not located immediately on the coast. Norwood Memorial is likely to be more accurate for inland locations such as Back Bay, Cambridge, etc.
 - 2. Worcester airport is located at an elevation of 1,009 ft whereas most of the city has an average elevation of 479 ft. Conditions at the airport are likely to be more representative of northwestern Worcester County. Locations within the city of Worcester and surrounding communities to the east and south (e.g. Northborough) should use Norwood Memorial Airport data.

A.2 General: Model Zoning

This is a required item for all hourly simulation projects.

- A. Models are to be configured based upon designed or likely HVAC zoning layouts to facilitate accurate entry of ventilation and air circulation rates, lighting and equipment power demand, and scheduling.
- B. Thermodynamically similar zones (similar exposure, space use, and schedules) can be combined.
- C. Core & shell projects shall model core spaces separately from tenant spaces. For tenant spaces, tenant designs are to be used, if available. If there are no tenant designs, adhere to the requirements described in Appendix E.
- D. Voids, shafts, and other areas without lighting, active conditioning, or exterior walls are to be modeled separately as unconditioned zones or omitted from the model. These spaces can be bundled together into a single equivalent zone on a per-floor basis.
- E. Tall spaces spanning more than 1 floor shall be modeled either as one space or as multiple spaces (1 per floor) separated by air walls.

A.3 General: Diversity Schedules

This is a required item for all hourly simulation projects.

- A. Each modeled zone is to be assigned schedules consistent with the activity in the space that will have the greatest impact on annual energy use. Generally, the space-by-space lighting definitions are helpful guidelines for assigning schedule types.
- B. Some HVAC zones may include more than one activity type and the modeler will need to use discretion when assigning schedules. For example, janitorial closets and small electric rooms could potentially be grouped into adjacent corridor spaces. Schedules appropriate for a corridor would be assigned to the zone even though they may over-estimate lighting use in the support spaces.
- C. Schedules for a particular space type are to be consistent with one another. Lighting and plug loads should track reasonably well with occupancy. Unoccupied period phantom equipment loads and night lighting should be reasonably represented.
- D. Schedules for school and university buildings are to include the impact of breaks and unique sessions such as summer school. Refer to the institutions' most recent annual scholastic calendar.
- E. Appendix B provides guidance on the use of activity codes and BDL functions in eQuest. While not required, the use of these BDL functions greatly facilitates model development and the consistency of schedules and load factors.
- F. Conservation of People - The peak number of occupants associated with each type of occupancy schedule should be determined and a calculation performed to ensure that the total facility occupancy counts for each hour make sense.
 - a. For example, occupants cannot be simultaneously in offices and in conference rooms. The occupancy diversity schedules can be adjusted to maintain a total population that is consistent with other assumptions (such as DHW use).
 - b. It is recommended that equipment and lighting schedules be developed in a manner that responds appropriately to the occupancy schedules.
- G. Appendix A provides sample diversity schedules for offices, schools, and laboratories. While these specific schedules do not need to be followed, they provide a starting point and guidance regarding the granularity of scheduling that is desired. ASHRAE 90.1 User's Guide default schedules do not provide adequate granularity.

A.4 General: Peak Period Reporting

This is a required item for all hourly simulation projects.

- A. The current peak reporting definitions are listed below. The seven ISO-NE holidays are New Years, Memorial Day, Independence Day, Labor Day, Veterans Day, Thanksgiving, and Christmas.
 - Energy Peak Summer: June through September, non-holiday weekdays, 7 AM to 11 PM
 - Energy Peak Winter: October through May, non-holiday weekdays, 7 AM to 11 PM
 - Demand Peak Summer: June through August, non-holiday weekdays, 1 PM to 5 PM
 - Demand Peak Winter: December & January, non-holiday weekdays, 5 PM to 7 PM
- B. Electricity use can be post-processed in a spreadsheet or the outputs can be calculated directly using flag schedules and utility rate blocks.

B.1 Architectural: Thermal Bridging

This is a required methodology for hourly building simulation projects.

- A. Historically, thermal bridging has not been properly accounted for in whole building simulation studies or in code reference materials. The U-Factor method limits appearing in IECC 2018 Table C402.1.4 and ASHRAE 90.1-2016 Table 5.5-5 account for likely bridging in the middle of walls based on 1-Dimension (1D) heat transfer. Similarly, the tables in ASHRAE 90.1 Appendix A also only cover center of wall bridging.
- B. ASHRAE Research Project 1365-RP investigated 3-Dimension (3D) heat transfer for a range of assembly types and found significant differences in overall heat flow that were not being captured by the 1D approach. Some assembly types could potentially be compromised by as much as 50% relative to 1D apparent conductance. This can potentially have a significant impact on facility energy use regardless of whether an ECM dealing with improved insulation is being considered.
- C. BC Hydro expanded the scope of the ASHRAE study and released their Building Envelope Thermal Bridging Guide (BETBG) in 2014 with ongoing updates². The guide can be found via an internet search. The BETBG does not need to be used but, if it is not, then the TA needs to cite what other method is employed to properly account for bridging.
- D. eQuest and other simulation tool interfaces assume 1D entry of assembly layers. The impact of bridging can be modeled by either reducing the thickness of insulation or by creating a unique material having the same density and specific heat as original but with reduced thermal resistance.
- E. Supporting documentation should show calculation details for how assembly U-values impacted by bridging have been developed. If the BETBG is used, it is recommended that the study report list which details from the guide have been incorporated into the analysis.
- F. If bridging factors are applied at floor edges, wall corners, and interfaces with fenestration, the same correction factors should be applied to the baseline U-value to ensure that the project is not unduly penalized. Capturing thermal bridging at these points and applying it to the overall wall construction is an emerging methodology and the PAs would appreciate input from the TAs. Future updates of this document may include more specific guidance.

B.2 Architectural: Infiltration

- A. Savings shall not be claimed for improved air sealing for new construction projects (regardless of IECC 2018 C406.9).
- B. Savings for reducing infiltration in existing buildings as part of a retrofit can potentially be claimed, but the TA vendor will need to provide pre- and post-retrofit blower door test results, historical trends of general building pressurization relative to ambient, and a clearly explained description for how these test results are used to develop appropriate energy modeling inputs.
 - a. The amount of infiltration air in a neutrally pressurized building cannot be greater than 50% of the total airflow quantified in a blower door test (half of the air is infiltrating while the other half is exfiltrating.)
 - b. It is unlikely that there are significant infiltration loads in a building or zone that is positively pressure relative to ambient.
 - c. Negatively pressurized buildings or zones can potentially claim infiltration reduction but only during those conditions and in those locations when negative pressurization exists.

² <https://www.bchydro.com/powersmart/business/programs/new-construction.html#thermal>

- C. The amount of infiltration that flows into or out of perimeter thermal zones is difficult to accurately capture in any simulation program due to variations in construction quality, hour-to-hour wind force and direction, operation of doors, windows, and elevators, and the relative difference in temperature between indoors and outdoors. That having been said, there are some modeling methodologies that are likely to be more accurate than others.
- a. Energy Plus is likely to do a better job capturing infiltration effects due to its airflow network calculations. While infiltration can be a noticeable load on a building, the strength of Energy Plus in this area does not overcome the shortcoming of extended modeling run times.
 - b. eQuest offers six different infiltration calculation methodologies, and the wizard uses the air change method. The following two options are appropriate for commercial buildings:
 - The air change method combines arbitrary assumptions of air change per hour (ACH) and airflow per floor area (AC/ft²) to arrive at the peak infiltration rate. This rate is then varied by an optional schedule (assumed to be 1.0 if not entered) and the ACH component of the flow is varied by ambient wind speed. Modelers need to activate the infiltration load for those zones with above grade perimeter exposure.
 - The crack method uses infiltration coefficients applied to windows, doors, and exterior walls, roofs, and overhangs to calculate infiltration rates. The calculation takes into account stack effect, an optional user defined schedule, and wind speed. Modelers can activate infiltration for all zones since there would only be infiltration if there is an exterior type of surface.
- D. The crack method is the preferred approach, particularly in taller buildings since it is possible to derive infiltration coefficients from the air barrier requirements included in IECC 2018 C402.5 and ASHRAE 90.1-2016 5.4.3. Both standards have the same requirements for opaque surfaces and fenestration.

1. Infiltration Schedules

Infiltration schedules are to be used to model the impact of building pressurization on infiltration. Ideally, a building that is balanced to be slightly positive will have less infiltration when the ventilation system is operating. The associated infiltration schedule will therefore reduce infiltration during those hours of continuous ventilation system activity. The degree of reduction is dependent upon how well balanced the ventilation system actually is. Using a value 1.0 for hours when the ventilation system is off and a value of 0.5 when the system is on may be a good starting point. A value of 1.0 during all hours is likely to be more conservative and can be achieved by not assigning a schedule (the default is 1.0 during all hours).

2. Infiltration Coefficients: Opaque Surface

Peak infiltration rates for opaque surfaces (excluding spandrel) are calculated as follows:

$$\text{Opaque Surface Infiltration, cfm} = \text{INF-COEFF} * dP^{0.8} * \text{Area, ft}^2$$

Where dP is the pressure difference between outside and inside air ("w.g.). Using code's maximum allowable inflow rates for assemblies (0.04 cfm/ft²) and the rating condition (0.3" w.g.), the coefficient to use for opaque surfaces (walls and roofs) is:

$$\text{INF-COEFF}_{\text{opaque}} = 0.04 \div (0.3^{0.8}) = 0.1048$$

3. Infiltration Coefficients: Windows, Curtainwall, & Storefront

Fenestration infiltration coefficients can be modeled in a similar manner, though the DOE2.2 calculation is based on perimeter length rather than surface area:

$$\text{Fenestration Infiltration, cfm} = \text{INF-COEFF} * dP^{0.66} * \text{Length, ft}$$

Perimeter length is already in the model based on the window geometries (and is therefore an argument for modeling individual window assemblies). Code specifies infiltration for windows and curtainwall on an area basis, and converting these requirements to equivalent perimeter area requires knowledge of the National Fenestration Rating Council (NFRC) rating conditions. Figure B.2.1 presents recommended infiltration coefficients. Code specifies leakage rates for curtainwall and storefront systems at 75 Pa (0.30" w.g.) while window assemblies are rated at 300 Pa (1.20" w.g.).

4. Infiltration Coefficients: Doors

Loads at vestibules and other spaces with exterior doors are to be calculated using the infiltration coefficients in Figure B.2.2 (adapted from DOE2.2 Volume 2: Dictionary > Envelope Components > Door). Each exterior door in the building needs to be modeled in a manner that preserves the perimeter of the door opening. For glazed doors, separate window and door entries are required.

The energy modeler can use different infiltration coefficients provided that they are based on a specific study and developed in a manner consistent with DOE2.2's use of the infiltration coefficients.

Figure B.2.1
Window & Curtainwall Infiltration Coefficients

	Windows Fixed	Windows Operable	Curtainwall & Storefront
Max Infiltration, cfm/ft ²	0.20	0.20	0.06
Rating Diff Pressure, "w.g.	1.20	1.20	0.30
NFRC Perimeter, ft	13.8	17.7	26.3
NFRC Area, ft ²	9.8	19.3	43.3
INF-COEF	0.1261	0.1933	0.2186

Figure B.2.2
Door Infiltration Coefficients

	INF-COEF
Residential Normally Closed with Weather Stripping	0.24
Residential Average Use with Weather Stripping	9.8
Residential Average Use without Weather Stripping	12.0
Overhead Door, No Use	6.0
Overhead Door, Average Use	60.0
Commercial Door Closed	3.1
Commercial Door Open 10% of Time	9.3
Commercial Door Open 25% of Time	55.0
Commercial Door Open 50% of Time	153.0
Commercial Revolving Door, Average Use	12.0

5. Crack Neutral Zone Height

The Crack Method requires each space with infiltration to have an entry for the space's vertical deviation from the overall building neutral plane. This can most easily be entered by changing the default for the NEUTRAL-ZONE-HT to use the following expression:

$$((\text{Parent}("Z") - 0) + \text{Local}("HEIGHT")/2) * -1 + (A/2 + B)$$

Where A is the height in feet between the lowest grade elevation and the highest point in the building's air envelope. B is an adjustment that is required if the lowest FLOOR of the building has an elevation other than Z = 0. For example, if a model's first floor had Z = -14, the value of B would be -14.

B.3 Architectural: Ground Contact Modeling

- A. The importance of ground heat exchange is highly variable and depends on building geometry, space temperature setpoints, and activity in the spaces with ground contact. Few energy simulation programs are currently able to accurately model ground contact heat loss or accept an F-factor entry for slab-on-grade edge loss performance. The approach described below is likely to be warranted for projects that include optional insulation below slabs and projects that increase perimeter insulation above code minimum requirements. TAs can use other methodologies provided that they are explained in enough detail to support technical review and are agreed to be reasonable by the PA.

1. Average Floor Resistance & Ground Temperature Path

This method involves two steps: 1) the development of unique floor layers for each space based on the exposed perimeter and floor area and 2) the development of typical ground temperatures beneath the building. The eQuest Wizard does step 1 but does not appear to do step 2.

1. Create global parameters for slab insulation conduction (SLABU) and slab perimeter insulation conduction (SLABF).
2. Define SLABU based on the actual construction.
3. Define SLABF based on tables included in DOE2.2 Volume 3: Topics (July 2006) pages 166 to 168.
4. In a spreadsheet, determine the ratio of exposed perimeter length to floor area (R%) for each space.
5. For each space, define layers consisting of light soil, damp (0.5 ft thick), Polystyrene 4in, R-5/in, and Conc HW 140lb 4in (CC03). The thickness of the polystyrene layer should be defined as follows using a user defined expression:
6. $1/(R\% * \#PA("SLABF") + \#PA("SLABU"))/5/12$
7. Create constructions associated with each layer, apply to the appropriate spaces.

Soil located remotely from the edge of the building is more likely to be impacted by the constant far-field ground temperature than seasonal variations in ambient air temperature. The temperature of soil beneath these core areas is likely to be 2°F colder than the average monthly interior temperature. Given that each model can only have one ground temperature schedule and that each building has a unique aspect ratio, the following method is suggested for calculating monthly ground temperature values:

8. Create an hourly report of ground temperatures from the weather file, convert to °F, and determine average monthly values.
9. Use hourly reports to determine the average space temperatures of conditioned ground-contact zones and determine the average overall monthly value (weighted by floor area).

10. Determine a perimeter area that is 6 ft wide, divide this by the overall ground contact area of conditioned spaces (floor and any subgrade walls). The result is %P. For buildings with subgrade walls and basements, the 6 ft perimeter area could potentially include all or a portion of the vertical walls and no floor area. Consider two examples:
 - a. A 1st floor space has 3 ft of subgrade wall and 6 ft above grade. The perimeter area would include 3 ft of the below grade wall and 3 ft of the floor. The overall ground contact area would include all of the floor area and 3 ft of the perimeter wall.
 - b. A basement space has 9 ft high walls located entirely below grade. The perimeter area would be the top 6 ft of the wall and the total ground contact area would be the whole floor area plus the area of the subgrade walls.

11. Calculate monthly temperature using the following expression:

$$\text{Avg Ground Temp, } ^\circ\text{F} = \%P * \text{Weather File Ground Temp} + (100\% - \%P) * (\text{Avg Space Temp} - 2^\circ\text{F})$$

This approach is intended to support savings from improved perimeter and under-slab insulation as well as provide a realistic calculation of heat loss to the ground. It is admittedly not perfect but it is likely to be more accurate than 1) not accounting for heat loss to the ground or 2) assuming the temperature differential apparent from the model file would apply to the entire underside of a building.

2. Average Ground Temperature Path

Calculate monthly temperature using the following expression:

$$\text{Avg Ground Temp, } ^\circ\text{F} = (\text{Avg Space Temp} - 2^\circ\text{F})$$

This more simplified approach is appropriate for buildings with large core areas where perimeter losses are negligible.

B.4 Architectural: Window-to-Wall Ratio (WWR)

- A. Baseline maximum allowable WWR is 40% for buildings pursuing code compliance via ASHRAE 90.1-2016. The baseline for buildings following IECC 2018 is either 30% or 40% depending on the provisions of C402.4.1.1.
- B. When calculating WWR, the area of party walls is not to be included in the gross wall area. A party wall is a wall that is common to two adjoining buildings and is most common in building additions and urban spaces.
- C. If a building design has more than the maximum allowable WWR, window area is to be varied by changing the height of all windows uniformly around the building. Changing window height is less likely to impact daylighting calculations. When using eQuest, changing window height is most easily accomplished using a global parameter.
 - a. The reduction in window height in the baseline of a heavily glazed building will impact the fraction of lighting impacted by daylighting. The control fraction entries for daylit zones need to be changed when changing window heights.
 - b. Baseline windows in heavily glazed buildings shall be assumed to have lower sills located 2.5 ft above floor level.
- D. For eQuest projects, the actual WWR for the proposed and baseline cases needs to be calculated based on LV-D report details. This can be complex for buildings with sloped roofs since the roof surfaces can potentially be counted along with vertical exterior walls.

B.5 Architectural: Fenestration Performance

- A. Window and curtainwall performance is defined by code on the basis of assembly, not on the basis of center-of-glass ratings.
- B. The PAs prefer that fenestration performance be defined using glass library data rather than simplified U-value and SHGC (or SC) entries. This requires frame area and U-value to be separately defined. Assembly SHGC is based on the average of glazing and frame areas, where the frame SHGC is 0.0. Window inset fields can be used to capture hyperlocal shading impacts of frame projections.
- C. The simplified U-value approach is acceptable for non-transparent glazing since incidence angle does not impact solar heat gain.
- D. When using eQuest, window frame width can be defined based upon the vision fraction (%V) and the following expression entered as the default expression for FRAME-WIDTH. %V needs to be calculated for each general window type at the discretion of the energy modeler. Generally, %V is higher for curtainwall than it is for operable punched windows.

$$\frac{(\#L("HEIGHT")+ \#L("WIDTH"))}{-4 + (\text{SQRT}(\%V) / (4 * \%V)) * \text{SQRT}(\%V * (\#L("HEIGHT") * \#L("HEIGHT") - 2 * \#L("HEIGHT") * \#L("WIDTH") + \#L("WIDTH") * \#L("WIDTH"))) + 4 * \#L("HEIGHT") * \#L("WIDTH")}$$

- E. When using eQuest, it is recommended that frame U-value be entered as a user-defined default or via a global parameter to facilitate changing the assumptions. The actual window performance for the proposed and baseline cases needs to be calculated based on LV-H report details to ensure that the target performance values are entered into the program.

C.1 HVAC: Autosizing

This is a required item for all hourly simulation projects.

- A. Autosizing can be used in early to mid-design work when specific design information is unknown or likely to change.
- B. Autosizing shall not be used to assign zone-level ventilation rates if design information is available. Baseline zone ventilation rates shall match design case.
- C. Autosizing shall not be used to assign zone-level air circulation rates for centralized air systems (e.g. VAV) if design information is available. If there is no design information, the baseline autosized zone airflow rates shall be used in proposed case modeling runs.
- D. Autosizing can be used for zone circulation rates for FCUs and other systems utilizing cycling zone fans. The assumption is that run times are linearly related to space loads.
- E. Pump autosizing shall only be used in the absence of an analogous proposed case pump.
 - a. Baseline autosized water flow rates shall be hard coded in ECM modeling runs to prevent ghost savings from being calculated due to changing pump sizing.
 - b. Pump head resulting in Appendix G power demand can be calculated using the following user-defined expression:
$$\text{Pump Head, ft} = \text{Desired Pump W/gpm} * 1,000 \div (0.746 \text{ kW/hp} * 3960 * 77\% \text{ Pump Eff} * 93.0\% \text{ Motor Eff})$$
 - c. The number of baseline building circulation pumps shall be a reasonable estimate of what would be used in a typical installation (e.g. two pumps for lead/lag systems, 1 pump for lead/standby systems).

C.2 HVAC: Work-Arounds

This is a required item for all hourly simulation projects that use work-arounds.

- A. Not all simulation programs can directly model every type of HVAC system and it may be necessary to utilize 'work-arounds'. Generally, it is the TA's responsibility to 1) select a work-around they feel accurately models the HVAC system, and 2) defend their work-around during technical review. Extended review discussions can be avoided by including plots in the study report that illustrate important correlations. It is particularly important that work-arounds take into account all significant impacts on the primary system being modeled as well as on zones.
- B. eQuest 3.65/DOE 2.2 does not directly model energy recovery for dedicated outdoor air systems. Work-arounds need to accurately model 1) exhaust air temperature and humidity entering the wheel and 2) the thermal impact of ventilation air on zone loads. Appendix C describes the primary issues with eQuest/DOE and recommends a fairly complex work-around methodology. Reporting can be streamlined by using this work-around and referencing it in the study report. eQuest 3.65/DOE 2.3 may accurately model DOAS with energy recovery.
- C. eQuest 3.65/DOE 2.2 does not directly model variable flow chilled beams. Work-arounds need to accurately model 1) the impact of DCV on central airflow rates and 2) the impact of variable primary air on zone loads. Appendix C provides background and a potential work-around methodology. Reporting can be streamlined by using this work-around and referencing it in the study report. eQuest 3.65/DOE 2.3 may accurately model chilled beams.
- D. eQuest 3.65/DOE 2 does not directly model displacement ventilation or under-floor distribution. Work-arounds need to accurately model 1) the impact of stratification on loads governing thermostat operation and 2) the temperature of return air to the central AHU. Appendix C provides background and a potential work-around methodology. Reporting can be streamlined by using this work-around and referencing it in the study report.

C.3 HVAC: District Energy

- A. For projects focusing on individual buildings receiving heating and/or cooling from central plants, the preferred method of analysis is to include a central plant in the model based on ASHRAE 90.1-2016 Appendix G. District hot water systems shall assume a boiler efficiency of 75% while district steam systems shall use 70%. If the site can provide field tested system performance results, these values can be used instead.
- B. It is assumed that part-load effects experienced by the modeled building will be similar to the general loading on central chilled water plants.

C.4 HVAC: Disaggregation of Unitary Performance Ratings

- A. Most simulation software requires separate inputs for evaporator fan power (e.g. supply fans) and condensing section performance. EER, SEER, COP, and HSPF ratings for unitary and split systems include the power demand of evaporator fans, and this needs to be disaggregated. Several methods exist, but the following expressions are required to be used:
 - Cooling COP = $(7.84 \times 10^{-8} * EER * Cap_{CoolBtu} + 0.338 * EER) \div 3.412 \text{ kBtu/kW}$
 - Cooling COP = $(0.0076 * SEER^2 + 0.3796 * SEER) \div 3.412 \text{ kBtu/kW}$
 - Heating COP = $1.47 \times 10^{-7} * COP_{47} * Cap_{CoolBtu} + 1.062 * COP_{47}$
 - Heating COP = $0.0076 * HSPF_{47}^2 + 0.3796 * HSPF_{47}$
- B. The recently introduced IEER appears to be similar to SEER and the two are assumed to be interchangeable.

C.5 HVAC: Equipment Performance Curves

- A. Default performance curves are included with all hourly simulation packages. The defaults may be appropriate for use in some studies, but their ability to accurately capture the performance of baseline and proposed case equipment should be checked. TA vendors are encouraged to calculate IPLV and IEER values predicted by the default curves and make adjustments as needed to bring the curves into agreement with the target performance values.

C.6 HVAC: Energy Recovery Performance

- A. The effectiveness of energy recovery shall be calculated on the basis of how much load is avoided on the supply side. Performance needs to be explicitly calculated for design conditions and should take into account supply:exhaust flow imbalances. Simulation programs assume the entered recovery performance is on the supply side while manufacturers sometimes report exhaust side recovery.

C.7 HVAC: Combined Heat & Power

- A. Refer to Appendix D for direction regarding the sequencing of ECMs in new construction projects that include CHP. Standard heating or cooling (in the case of absorption) sources may not need to operate for as many hours per year with the installation of CHP and this can impact measure viability.
- B. New construction projects on campuses with a central CHP plant and single point of interconnection to the grid are to be considered as if they were stand-alone buildings.

C.8 HVAC: Nuances of eQuest Fan & Ventilation Control

- A. Fan schedules of type ON/OFF/FLAG are used to indicate when fan systems are to operate continuously or cycle as well as when ventilation is available and the range of optimized morning startup options. Values of 1.0 cause the fan to always be active throughout the entire hour, 0.0 causes the fan to be off unless required to cycle on, and -999 is the code for optimized morning startup. Optimized startup is required by code and is therefore required to be used. The occupied period carried in the fan schedule should correspond to the start of actual occupancy while the preceding 3 or 4 hours can be set to -999.
- B. Fan schedules are straight forward for standard HVAC systems such as VAV. Control of zone fans in DOAS designs is more nuanced due to DOE 2's inability to log thermal impact of ventilation air when the zone fan is not active. Work-arounds may be required, and the TA shall describe in their study proposal the methodology they plan to use. It is the TA's responsibility to demonstrate during the study technical review that whatever work-around is used is functioning properly and reasonably addresses DOE 2's shortcomings.

1. Zone Units with Compressors

For zone units with compressors (e.g. WLHP, VRF), the fan schedule for the zone unit should be left at 1.0 for all hours, the fan power should be zeroed out by setting the static pressure to 0.0" w.g., and the fan energy should be included in the compressor EIR performance. This is appropriate since the fan only operates when the compressor is active. If a fan schedule value of 0.0 is used with night cycling set to 'cycle on any', ventilation air would only be supplied when the zone fans cycles on. This under-represents the thermal impact of ventilation air on zone conditioning.

2. Zone Units without Compressors

Correcting for the thermal impact of DOAS air on zone is much more difficult when zone units do not have compressors. Examples include hydronic FCUs and VRF zone units. The following approach treats DOAS air as a space load that is varied on an hourly basis throughout the year using post-processed hourly report data.

- a. The zone fan schedule can be set at 0.0 for all hours with night cycling commanded to ‘cycle on any’, and the fan kW/cfm is entered for the fan system.
- b. Ventilation rates at the zone level are not defined in order to prevent double counting the impact of ventilation air on zone loads when the zone fans cycle on.
- c. Create internal energy source loads of type ‘process’. Each zone receiving DOAS air is assigned a maximum thermal load factor developed from the following equation:

$$\text{Peak DOAS Thermal Load, Btu/h} = \text{Zone Ventilation cfm} * 1.08 * \text{Max Temp Differential, } ^\circ\text{F}$$

The product of the conversion factor, 1.08, and the maximum temperature differential can be entered as a global parameter for use with all impacted thermal zones. A user defined expression needs to be defined for each zone that is the product of the zone ventilation flow rate (e.g. 75 cfm) and the global parameter.

- d. Create hourly zone temperature reports for all zones receiving DOAS air. Create an hourly report for DOAS supply air temperature. Post-process this data to calculate:
 - i. The average zone temperature weighted by zone ventilation rate.
 - ii. The hourly difference between the average zone temperature and the DOAS supply air temperature; this is the temperature differential. The value should be negative when the DOAS temp is colder than the zone temp.
 - iii. Express the hourly temperature differential as a fraction of the maximum temperature differential.
 - iv. Generate an hourly schedule of type ‘multiplier’, which supports positive and negative values.
- e. Apply the hourly schedule to the internal energy source loads. Negative hourly values are cooling loads on the space.

This approach is likely to work fairly well provided that zone temperatures during DOAS operating hours are generally similar to one another. If there are significant differences among space temperatures, multiple hourly schedules would be required.

- C. Outdoor air schedules of the type FRAC/DESIGN are used to lock out ventilation during unoccupied periods. A value of 0 prevents outdoor air during unoccupied HVAC system cycling. A code value of -999 allows the ventilation flow rate to default to the design OA fraction. A value of 0.01 during morning startup periods allows airside economizer to activate when it is beneficial. For multizone systems (e.g. VAV) with DCV, a value of 0.01 should be used rather than -999 during occupied periods to allow the outdoor airflow rate to fall below the design flow rate.

D.1 Plumbing: Service Water Temperatures

This is a required item for all hourly simulation projects involving domestic water heating.

- A. Street water temperature data from the Massachusetts Water Resources Authority (MWRA) is presented in Figure D.1 below. This data is consistent with other studies of water main temperatures in central Connecticut.

Figure D.1

Municipal Water Supply Temperatures in Southern New England

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
46.2°F	43.6°F	45.0°F	49.9°F	56.6°F	63.6°F	68.9°F	71.6°F	70.7°F	66.5°F	59.7°F	52.0°F



D.2 Plumbing: DHW Loads

This is a required item for all hourly simulation projects involving domestic water heating.

- A. DHW flow rates entered into the energy model should be the flow rate of primary hot water (140°F), not the flow rate from the end use points. Assume 105°F average water temperatures for faucets (all types) and showers.
- B. Multifamily projects shall use the most recent version of the Energy Star MFHR Performance Path Calculator with the “medium” use type of occupancy and relevant appliances and fixture flow rates to determine peak loads.
- C. DHW diversity schedules in commercial projects shall track the dominant occupancy schedule. Residential DHW shall use the Energy Star MFHR diversity schedule presented in the Performance Path Calculator.

E.1 Electrical: Lighting Design

This is a required item for all hourly simulation projects.

- A. Lighting analyses shall be performed using the space-by-space method.
- B. Lighting takeoffs are to be performed on the basis of modeled spaces with the understanding that a particular HVAC zone could include multiple space use types defined in IECC 2018 Table C405.4.2(2). In these cases, an average power demand weighted by floor area should be used.

E.2 Electrical: Lighting Occupancy Sensor Controls

This is a required item for all hourly simulation projects.

- A. Lighting diversity factors provided by various sources are assumed to capture the impact of manually operated lighting controls as well as code-required occupancy controls.
- B. Non-code required occupancy-based lighting controls reduce lighting power density by 10% uniformly during all facility operating hours. Schedule modifications are not required to model occupant-controlled lighting in most spaces.
- C. Stairways and warehouses are required by ASHRAE 90.1-2016 9.4.1.1(g) to set back lighting by 50% during unoccupied periods. Lighting schedules shall be used to model 90% diversity during facility occupied periods and 50% during unoccupied periods.

E.3 Electrical: Daylighting Controls

- A. Daylighting shall be modeled with sensors located at 2/3 the depth into the daylit zone as defined by ASHRAE and IECC.
- B. Adequate interior surfaces are to be included in daylit spaces to support daylight modeling algorithms.
- C. Daylighting control factors (e.g. the fraction of installed lighting wattage impacted by automatic daylighting controls) shall be based on actual controlled wattage for each zone. These factors can be developed by determining the daylit portion of each zone from window data obtained from the LV-H report. Hourly daylighting response is to be calculated by the simulation program.
 - a. Different daylighting control factors need to be developed for baseline designs where fenestration area is limited to 40% of gross vertical wall area.
- D. Glare control direction indicators and glare factors shall be set in the model.

- E. Light level control values shall be 50 fc as measured 2.5 ft above the floor unless design requirements call for other specific values.

E.4 Electrical: Networked Lighting Controls

- A. Networked lighting controls provide code-required occupancy sensing, dual level, and daylighting controls and can also support these strategies in spaces where not required by code. The method of modeling savings for occupancy sensor and daylighting control are the same regardless of the use of networked lighting controls, stand-alone controls, or fixtures with integral controls.
- B. Networked lighting controls do support task tuning and this can potentially lead to reliable energy savings. However, there is no guarantee that savings will actually result unless the system is designed, installed, and commissioned to achieve task tuning. To claim credit, the following must be true:
 - 1. The lighting designer must provide the anticipated degree of turndown that is to be installed in each space with task tuning. This is the basis of savings to be claimed in the energy model. The modeling report needs to clearly list what tuning factors are applied to the space LPD. The tuning factor is to be considered in addition to control factors for occupancy sensors and lighting schedules.
 - 2. The project construction documents must clearly list the intended light level that the systems are to be tuned to (foot candles as measured below the light at a specific height above the floor).
 - 3. The project construction documents must clearly describe lighting controls commissioning requirements and methods for implementing task tuning.

For initial screening of potential savings arising from task tuning, the following methodology can be followed.

- 4. Determine the LPD reduction relative to the max allowed by code for each space.
- 5. Generate a task tuning control factor for each space that varies linearly between 10% for LPDs at 100% of code down to a value of 0% for LPDs at $\leq 50\%$ of code.
- 6. Apply these task tuning control factors in addition to any control factors for occupancy sensors.

F.1 Process: General Equipment Loads & Diversities

This is a required item for all hourly simulation projects.

- A. It is important that adequate process loads are included in a model in order to ensure the following:
 - 1. Support accurate estimates of percent impacts of design upgrades on overall energy use and
 - 2. Ensure that HVAC system loads are realistic.
 - 3. Ensure that HVAC autosizing, where used, is likely to be realistic.

Models with low equipment loads will have exaggerated % energy reductions, the impact of envelope characteristics will be skewed, and improvements to cooling system performance will be understated. Some loads, such as exterior lighting and water pressurization systems, may not impact HVAC but it does impact overall energy use.

- B. Separate equipment schedules and peak load factors are to be used for different space types. Appendix A provides suggested load factors and diversity schedules for common office and school space types. This default information is intended to serve as a starting point where specific information is not yet known for a project or where tenant activities are undefined. eQuest schedule library inputs can also be used provided that they are a realistic projection of future space use. All schedules should be correlated to occupancy and the peak occupancy for the facility verified to not be excessive for any particular hour.

- C. Modeling reports should include a description of the basis of loads used in the model.
- D. Baseline equipment loads and diversities are to be identical to the proposed case unless savings are being claimed for a specific measure.
- E. The ratio of sensible to latent loads should be taken into account and based on information such as ASHRAE Fundamentals Chapter 18, Nonresidential Cooling and Heating Load Calculations.
- F. HVAC autosizing generally assumes a diversity of 1.0 and the peak load factor for a particular space. It is not uncommon for spaces to be designed to support more equipment than would typically be operating during full occupancy on a typical day. Peak load factors should reflect the intent of the design team, and the diversity factors should be adjusted downward. For example, a tenant space in a spec office building may be designed to support 2.0 W/ft² of equipment (excluding lighting) but the likely load is probably around 1.2 W/ft² on a fully occupied hour. The maximum diversity factor should therefore be $1.2 \text{ W/ft}^2 \div 2.0 \text{ W/ft}^2 = 0.65$ (not 1.00) for a fully occupied hour.

F.2 Process: Elevators

- A. The number of elevators shall match the actual design.
- B. Peak power demand for each elevator is ideally based on the designed motor size with a peak loading factor of 70%. If motor size is not known, interpolation between 15 hp for 3 stories and 40-hp for 8 stories can be assumed. The % sensible fraction shall be 42% for hydraulic elevators and 36% for other technologies. Baseline elevator technology shall match design case unless the TA can provide a sound basis for claiming savings.
- C. Power demand shall be assigned to an elevator machine room if EMRs are included in the design. Otherwise, elevator power demand and schedules can be direct loads on electricity meters.
- D. Schedules are provided for different facility types in Appendix A. The diversity schedules account for the fact that elevator drive systems are typically only loaded for half of each trip and most systems generate electricity during non-drive travel.

F.3 Process: Food Service

- A. Kitchens, coffee shops, break room, and servery energy use is highly variable but can have a noticeable impact on energy use. The design case and baseline electricity and natural gas consumption should be the same unless savings are being claimed through an ECM. The energy modeling report should include a description of how peak load factors were developed and provide a narrative of the anticipated hours of operation for cooking and servery equipment.
- B. If a single schedule is used to model all food service electricity use, the base load is likely to be dominated by refrigeration. Peak hourly power demand values need to account for the brevity of some high-demand appliances such as dishwasher booster heaters or cappuccino makers that may not be in continuous service.
- C. Refrigeration annual energy use is to be developed from ASHRAE 90.1-2016 Table 6.8.1-12 (Commercial Refrigerator and Freezers) and Table 6.8.1-13 (Commercial Refrigeration). Similar tables are included in IECC 2018 C403.10. For systems with remote condensers that reject heat to ambient, the energy use of the system shall impart 0% sensible and 0% latent loads to the space.
- D. Equipment located under exhaust hoods can be assumed to exert space conditioning loads that are 25% sensible and 0% latent. Most of the heat is lost into the exhaust air stream while the loads in the space are due to radiant heat transfer from hot surfaces and the cooling of cooked food.
- E. Refrigeration in supermarkets requires specialized analyses and assumptions that are beyond the scope of these guidelines at this time.

- F. The Energy Star Commercial Kitchen Equipment Savings Calculator can be used to generate annual energy use of covered equipment. Care is required to ensure that the calculator assumptions match the anticipated operation of the kitchen being modeled.
- G. Servery equipment is not included in the Energy Star calculator and will need to be estimated by the modeler. One approach is to assume that heated and cooled basins will be active beginning 1 hour before food is served and extending through the serving period. Peak power demand can be estimated based on nameplate power and an average peak diversity factor of 25%. The sensible space load fraction can be assumed to be 80% and the latent 20%. Modelers are free to use different assumptions but the rationale needs to be documented.
- H. The purchase and installation of Energy Star rated commercial kitchen equipment shall be handled outside of the model via a prescriptive application or upstream. The modeled energy use shall assume the use of the proposed case equipment in the baseline model

F.4 Process: Servers & Telecom

- A. Server rooms can potentially dominate base load electricity consumption in a building. Projects can be described as follows:
 - 1. Customer plans to do a full or partial build-out of server capacity but IT load is not known. The design team will need to have some estimate of load to size HVAC equipment. The future IT power demand is likely to be approximately 75% of cooling capacity, converted from tons or Btu to kW. The value can be scaled down as needed if a partial server build-out is anticipated for the near to mid future.
 - 2. Customer knows what server equipment is to be installed. Review the nameplate wattage (or calculate from rated voltage and amperage) and assume the average operating peak demand is 50% of nameplate.
 - 3. An existing server room is in operation. Power metering is ideal if the IT load represents a large portion of the facility energy use. UPS units typically will provide a measure of output amperage or kW. Absent this information, a rough approximation of IT power demand can be developed from nameplate information or the room's installed cooling capacity and discussions with facility operators regarding how much excess cooling capacity they feel is installed. Convert the cooling load to input power demand.

Appendix A: Schedules and Load Factors

Assumptions about building and system use schedules, diversity factors, and load factors drive the energy use of an hourly simulation model yet the degree of certainty surrounding these inputs is generally moderate at best. Ideally these inputs are developed from details provided by the project owner and/or design team since it is likely that custom schedules will better predict future energy use. This is important since future evaluation efforts may choose to modify schedule and load factor assumptions based on what is found on site. If no other sources of information are available, the information contained in this appendix is intended to provide a starting point.

If information in this appendix is used to fill in gaps where project-specific information is not known, it is important that the default and custom schedules are consistent with one another. For example, if the schedule for office building HVAC assumes that there is no occupied Sunday operation. If other custom schedules indicate significant Sunday occupancy (e.g. to support an active call center), then the HVAC schedule needs to be updated as well.

Consistency among schedule assumptions is a common problem in energy models and is something that is focused on during PA technical reviews.

The current version of this guide includes schedules and load values for offices, elementary schools, high schools, and laboratories. Additional schedules and information is likely to be included in future revisions of this document. Feedback from TA vendors is encouraged.

The original spreadsheet for the Appendix A attachments is included in this PDF file.

Table L.1
LAB SPACES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	3%	3%	3%	20%	20%	20%
2	0%	0%	0%	3%	3%	3%	20%	20%	20%
3	0%	0%	0%	3%	3%	3%	20%	20%	20%
4	0%	0%	0%	3%	3%	3%	20%	20%	20%
5	0%	0%	0%	3%	3%	3%	20%	20%	20%
6	0%	0%	0%	3%	3%	3%	20%	20%	20%
7	5%	5%	0%	100%	100%	3%	23%	23%	20%
8	10%	10%	0%	100%	100%	3%	25%	25%	20%
9	20%	10%	0%	100%	100%	3%	30%	25%	20%
10	40%	30%	0%	100%	100%	3%	40%	35%	20%
11	40%	30%	0%	100%	100%	3%	40%	35%	20%
12	30%	30%	0%	100%	100%	3%	35%	35%	20%
13	40%	30%	0%	100%	100%	3%	40%	35%	20%
14	40%	10%	0%	100%	100%	3%	40%	25%	20%
15	40%	10%	0%	100%	100%	3%	40%	25%	20%
16	40%	10%	0%	100%	100%	3%	40%	25%	20%
17	40%	10%	0%	100%	100%	3%	40%	25%	20%
18	40%	10%	0%	100%	100%	3%	40%	25%	20%
19	30%	5%	0%	100%	100%	3%	35%	23%	20%
20	10%	5%	0%	100%	100%	3%	25%	23%	20%
21	10%	5%	0%	100%	100%	3%	25%	23%	20%
22	5%	5%	0%	100%	100%	3%	23%	23%	20%
23	0%	0%	0%	3%	3%	3%	20%	20%	20%
24	0%	0%	0%	3%	3%	3%	20%	20%	20%

Source: TNZ

Table L.2
OPEN OFFICES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	3%	3%	3%	20%	20%	20%
2	0%	0%	0%	3%	3%	3%	20%	20%	20%
3	0%	0%	0%	3%	3%	3%	20%	20%	20%
4	0%	0%	0%	3%	3%	3%	20%	20%	20%
5	0%	0%	0%	3%	3%	3%	20%	20%	20%
6	0%	0%	0%	3%	3%	3%	20%	20%	20%
7	5%	0%	0%	100%	3%	3%	24%	20%	20%
8	10%	5%	0%	100%	100%	3%	28%	24%	20%
9	30%	10%	0%	100%	100%	3%	44%	28%	20%
10	30%	10%	0%	100%	100%	3%	44%	28%	20%
11	30%	10%	0%	100%	100%	3%	44%	28%	20%
12	30%	10%	0%	100%	100%	3%	44%	28%	20%
13	20%	5%	0%	100%	100%	3%	36%	24%	20%
14	30%	5%	0%	100%	100%	3%	44%	24%	20%
15	30%	5%	0%	100%	100%	3%	44%	24%	20%
16	30%	5%	0%	100%	100%	3%	44%	24%	20%
17	30%	5%	0%	100%	100%	3%	44%	24%	20%
18	30%	5%	0%	100%	100%	3%	44%	24%	20%
19	10%	5%	0%	100%	100%	3%	28%	24%	20%
20	10%	0%	0%	100%	3%	3%	28%	20%	20%
21	10%	0%	0%	100%	3%	3%	28%	20%	20%
22	10%	0%	0%	100%	3%	3%	28%	20%	20%
23	5%	0%	0%	100%	3%	3%	24%	20%	20%
24	5%	0%	0%	100%	3%	3%	24%	20%	20%

Source: TNZ

Table L.3
PRIVATE OFFICES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	20%	20%	20%
2	0%	0%	0%	0%	0%	0%	20%	20%	20%
3	0%	0%	0%	0%	0%	0%	20%	20%	20%
4	0%	0%	0%	0%	0%	0%	20%	20%	20%
5	0%	0%	0%	0%	0%	0%	20%	20%	20%
6	0%	0%	0%	0%	0%	0%	20%	20%	20%
7	5%	0%	0%	30%	0%	0%	24%	20%	20%
8	10%	0%	0%	35%	0%	0%	28%	20%	20%
9	30%	10%	0%	55%	35%	0%	44%	28%	20%
10	30%	10%	0%	55%	35%	0%	44%	28%	20%
11	30%	10%	0%	55%	35%	0%	44%	28%	20%
12	30%	10%	0%	55%	35%	0%	44%	28%	20%
13	20%	0%	0%	45%	0%	0%	36%	20%	20%
14	30%	0%	0%	55%	0%	0%	44%	20%	20%
15	30%	0%	0%	55%	0%	0%	44%	20%	20%
16	30%	0%	0%	55%	0%	0%	44%	20%	20%
17	30%	0%	0%	55%	0%	0%	44%	20%	20%
18	30%	0%	0%	55%	0%	0%	44%	20%	20%
19	10%	0%	0%	35%	0%	0%	28%	20%	20%
20	5%	0%	0%	30%	0%	0%	24%	20%	20%
21	0%	0%	0%	0%	0%	0%	20%	20%	20%
22	0%	0%	0%	0%	0%	0%	20%	20%	20%
23	0%	0%	0%	0%	0%	0%	20%	20%	20%
24	0%	0%	0%	0%	0%	0%	20%	20%	20%

Source: TNZ

Table L.4
CONFERENCE & MEETING ROOMS

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	50%	0%	0%	55%	0%	0%	50%	0%	0%
10	100%	0%	0%	100%	0%	0%	100%	0%	0%
11	50%	0%	0%	55%	0%	0%	50%	0%	0%
12	25%	0%	0%	30%	0%	0%	25%	0%	0%
13	25%	0%	0%	30%	0%	0%	25%	0%	0%
14	100%	0%	0%	100%	0%	0%	100%	0%	0%
15	50%	0%	0%	55%	0%	0%	50%	0%	0%
16	25%	0%	0%	30%	0%	0%	25%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: TNZ

Table L.5
KITCHENETTE / BREAK ROOM SPACES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	35%	35%	35%
2	0%	0%	0%	0%	0%	0%	35%	35%	35%
3	0%	0%	0%	0%	0%	0%	35%	35%	35%
4	0%	0%	0%	0%	0%	0%	35%	35%	35%
5	0%	0%	0%	0%	0%	0%	35%	35%	35%
6	0%	0%	0%	0%	0%	0%	35%	35%	35%
7	5%	0%	0%	100%	100%	0%	37%	35%	35%
8	25%	0%	0%	100%	100%	0%	45%	35%	35%
9	20%	5%	0%	100%	100%	0%	43%	37%	35%
10	15%	5%	0%	100%	100%	0%	41%	37%	35%
11	15%	5%	0%	100%	100%	0%	41%	37%	35%
12	50%	5%	0%	100%	100%	0%	55%	37%	35%
13	75%	5%	0%	100%	100%	0%	65%	37%	35%
14	50%	5%	0%	100%	100%	0%	55%	37%	35%
15	15%	5%	0%	100%	100%	0%	41%	37%	35%
16	25%	5%	0%	100%	100%	0%	45%	37%	35%
17	30%	5%	0%	100%	100%	0%	47%	37%	35%
18	5%	0%	0%	100%	100%	0%	37%	35%	35%
19	5%	0%	0%	100%	0%	0%	37%	35%	35%
20	5%	0%	0%	100%	0%	0%	37%	35%	35%
21	5%	0%	0%	100%	0%	0%	37%	35%	35%
22	5%	0%	0%	100%	0%	0%	37%	35%	35%
23	0%	0%	0%	0%	0%	0%	35%	35%	35%
24	0%	0%	0%	0%	0%	0%	35%	35%	35%

Source: TNZ

Table L.6
COMMON SPACE LIGHTING

Hour End	Corridors			Stairs	Stairways w OS*			Restrooms			Support	
	M-F	Sat	Sun	All	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Other
1	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
2	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
3	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
4	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
5	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
6	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
7	100%	100%	15%	100%	55%	55%	50%	30%	0%	0%	5%	0%
8	100%	100%	15%	100%	60%	60%	50%	35%	0%	0%	5%	0%
9	100%	100%	15%	100%	70%	60%	50%	55%	35%	0%	5%	0%
10	100%	100%	15%	100%	90%	80%	50%	55%	35%	0%	5%	0%
11	100%	100%	15%	100%	90%	80%	50%	55%	35%	0%	5%	0%
12	100%	100%	15%	100%	80%	80%	50%	55%	35%	0%	5%	0%
13	100%	100%	15%	100%	90%	80%	50%	45%	0%	0%	5%	0%
14	100%	100%	15%	100%	90%	60%	50%	55%	0%	0%	5%	0%
15	100%	100%	15%	100%	90%	60%	50%	55%	0%	0%	5%	0%
16	100%	100%	15%	100%	90%	60%	50%	55%	0%	0%	5%	0%
17	100%	100%	15%	100%	90%	60%	50%	55%	0%	0%	0%	0%
18	100%	100%	15%	100%	90%	60%	50%	55%	0%	0%	0%	0%
19	100%	15%	15%	100%	80%	55%	50%	35%	0%	0%	0%	0%
20	100%	15%	15%	100%	60%	55%	50%	30%	0%	0%	0%	0%
21	100%	15%	15%	100%	60%	55%	50%	0%	0%	0%	0%	0%
22	100%	15%	15%	100%	55%	55%	50%	0%	0%	0%	0%	0%
23	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
24	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%

*Assumes 50% Turndown, lighting power assumption should not account for any control factors.

Source: TNZ

Table L.7
OTHER COMMON SCHEDULES

Hour End	HVAC "Occupied"*			Elevator			DHW		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0	0	0	0%	0%	0%	5%	5%	5%
2	0	0	0	0%	0%	0%	5%	5%	5%
3	0	0	0	0%	0%	0%	5%	5%	5%
4	0	0	0	0%	0%	0%	5%	5%	5%
5	0	0	0	0%	0%	0%	5%	5%	5%
6	0	0	0	0%	0%	0%	5%	5%	5%
7	1	1	0	0%	0%	0%	7%	5%	5%
8	1	1	0	14%	0%	0%	19%	5%	5%
9	1	1	0	28%	6%	0%	35%	11%	5%
10	1	1	0	17%	8%	0%	38%	15%	5%
11	1	1	0	15%	7%	0%	39%	21%	5%
12	1	1	0	17%	10%	0%	47%	19%	5%
13	1	1	0	23%	8%	0%	57%	23%	5%
14	1	1	0	19%	5%	0%	54%	20%	5%
15	1	1	0	15%	3%	0%	34%	19%	5%
16	1	1	0	15%	2%	0%	33%	15%	5%
17	1	1	0	18%	2%	0%	44%	12%	5%
18	1	1	0	25%	2%	0%	26%	14%	5%
19	1	0	0	5%	0%	0%	21%	7%	5%
20	1	0	0	2%	0%	0%	15%	5%	5%
21	1	0	0	2%	0%	0%	17%	5%	5%
22	1	0	0	2%	0%	0%	8%	5%	5%
23	0	0	0	0%	0%	0%	5%	5%	5%
24	0	0	0	0%	0%	0%	5%	5%	5%

*Hours when ventilation for occupancy is active; morning startup begins ahead of these hours.

Source: TNZ

Table L.8
LAB BUILDING LOAD FACTORS

Occupancy

Ideally, the occupant counts are based on furniture counts in offices. Occupancy in offices is the same as labs if all office workers also work in labs. Otherwise, use the ASHRAE 62.1 default densities

Occupant Heat Loads

250 Btu/h/person sensible, 200 Btu/h/person latent

Lighting → Per design and IECC 2018 Table C405.4.2(2).

Office Equipment

Ideally, equipment loads are tied to occupant counts (rather than W/ft²) with peak power demand developed from ASHRAE Fundamentals 2013 Tables 18.8, 18.9, and 18.10.

If equipment is not known, reference ASHRAE Fundamentals 2013 Table 18.11:

% Laptop	% Desktop	No. Monitors	Workspace	Occs/Printer	Diversity?	W/ft ²
100%	0%	0	167 ft ²	10	Yes	0.25
100%	0%	0	125 ft ²	10	Yes	0.33
50%	50%	1	167 ft ²	10	Yes	0.40
50%	50%	1	125 ft ²	10	Yes	0.50
0%	100%	1	167 ft ²	10	Yes	0.60
0%	100%	1	125 ft ²	10	Yes	0.80
0%	100%	2	125 ft ²	10	Yes	1.00
0%	100%	2	85 ft ²	8	Yes	1.50
0%	100%	2	85 ft ²	8	No	2.00

Non-Office Equipment

Background miscellaneous loads: 0.2 W/ft² on 24/7 for corridors, stairs, and most support spaces

Labs: 4.5 W/ft²

IDF/MDF rooms: 4.0 W/ft² on 24/7

Electrical closets: 0.5 W/ft² on 24/7

Break Rooms:

Peak Watts Assumptions

Typical Refrigerator	191	constant operation
1,100 W Microwave Oven	80	1,100 W model, 1.0 hr/day, 251 days/yr
1,000 W Coffee Maker	110	1,000 W model, 1.5 hr/day, 251 days/yr
1,051 W Toaster Oven	19	1,051 W model, 0.25 hr/day, 251 days/yr

Peak Wattage is based on 3,431 EFLH for Table L.5 plug loads

Table O.1
OPEN OFFICES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	3%	3%	3%	20%	20%	20%
2	0%	0%	0%	3%	3%	3%	20%	20%	20%
3	0%	0%	0%	3%	3%	3%	20%	20%	20%
4	0%	0%	0%	3%	3%	3%	20%	20%	20%
5	0%	0%	0%	3%	3%	3%	20%	20%	20%
6	0%	0%	0%	3%	3%	3%	20%	20%	20%
7	10%	0%	0%	100%	3%	3%	28%	20%	20%
8	20%	0%	0%	100%	3%	3%	36%	20%	20%
9	85%	5%	0%	100%	100%	3%	88%	24%	20%
10	90%	5%	0%	100%	100%	3%	92%	24%	20%
11	95%	5%	0%	100%	100%	3%	96%	24%	20%
12	90%	5%	0%	100%	100%	3%	92%	24%	20%
13	75%	5%	0%	100%	100%	3%	80%	24%	20%
14	85%	5%	0%	100%	100%	3%	88%	24%	20%
15	90%	5%	0%	100%	100%	3%	92%	24%	20%
16	95%	5%	0%	100%	100%	3%	96%	24%	20%
17	85%	5%	0%	100%	100%	3%	88%	24%	20%
18	30%	0%	0%	100%	3%	3%	44%	20%	20%
19	10%	0%	0%	100%	3%	3%	28%	20%	20%
20	5%	0%	0%	100%	3%	3%	24%	20%	20%
21	5%	0%	0%	100%	3%	3%	24%	20%	20%
22	5%	0%	0%	100%	3%	3%	24%	20%	20%
23	0%	0%	0%	3%	3%	3%	20%	20%	20%
24	0%	0%	0%	3%	3%	3%	20%	20%	20%

Source: TNZ

Table O.2
PRIVATE OFFICES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	20%	20%	20%
2	0%	0%	0%	0%	0%	0%	20%	20%	20%
3	0%	0%	0%	0%	0%	0%	20%	20%	20%
4	0%	0%	0%	0%	0%	0%	20%	20%	20%
5	0%	0%	0%	0%	0%	0%	20%	20%	20%
6	0%	0%	0%	0%	0%	0%	20%	20%	20%
7	10%	0%	0%	15%	0%	0%	28%	20%	20%
8	20%	0%	0%	25%	0%	0%	36%	20%	20%
9	85%	10%	0%	90%	15%	0%	88%	28%	20%
10	90%	15%	0%	95%	20%	0%	92%	32%	20%
11	90%	15%	0%	95%	20%	0%	92%	32%	20%
12	90%	10%	0%	95%	15%	0%	92%	28%	20%
13	75%	5%	0%	80%	10%	0%	80%	24%	20%
14	85%	5%	0%	90%	10%	0%	88%	24%	20%
15	90%	5%	0%	95%	10%	0%	92%	24%	20%
16	90%	5%	0%	95%	10%	0%	92%	24%	20%
17	90%	5%	0%	95%	10%	0%	92%	24%	20%
18	40%	0%	0%	45%	0%	0%	52%	20%	20%
19	10%	0%	0%	15%	0%	0%	28%	20%	20%
20	10%	0%	0%	15%	0%	0%	28%	20%	20%
21	5%	0%	0%	10%	0%	0%	24%	20%	20%
22	5%	0%	0%	10%	0%	0%	24%	20%	20%
23	5%	0%	0%	10%	0%	0%	24%	20%	20%
24	5%	0%	0%	10%	0%	0%	24%	20%	20%

Source: TNZ

Table O.3
CONFERENCE & MEETING ROOMS

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	50%	0%	0%	55%	0%	0%	50%	0%	0%
10	100%	0%	0%	100%	0%	0%	100%	0%	0%
11	50%	0%	0%	55%	0%	0%	50%	0%	0%
12	25%	0%	0%	30%	0%	0%	25%	0%	0%
13	25%	0%	0%	30%	0%	0%	25%	0%	0%
14	100%	0%	0%	100%	0%	0%	100%	0%	0%
15	50%	0%	0%	55%	0%	0%	50%	0%	0%
16	25%	0%	0%	30%	0%	0%	25%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: TNZ

Table O.4
KITCHENETTE / BREAK ROOM SPACES

Hour End	Occupancy			Lighting			Plug Loads		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	0%	35%	35%	35%
2	0%	0%	0%	0%	0%	0%	35%	35%	35%
3	0%	0%	0%	0%	0%	0%	35%	35%	35%
4	0%	0%	0%	0%	0%	0%	35%	35%	35%
5	0%	0%	0%	0%	0%	0%	35%	35%	35%
6	0%	0%	0%	0%	0%	0%	35%	35%	35%
7	5%	0%	0%	100%	100%	0%	37%	35%	35%
8	25%	0%	0%	100%	100%	0%	45%	35%	35%
9	20%	5%	0%	100%	100%	0%	43%	37%	35%
10	15%	5%	0%	100%	100%	0%	41%	37%	35%
11	15%	5%	0%	100%	100%	0%	41%	37%	35%
12	50%	5%	0%	100%	100%	0%	55%	37%	35%
13	75%	5%	0%	100%	100%	0%	65%	37%	35%
14	50%	5%	0%	100%	100%	0%	55%	37%	35%
15	15%	5%	0%	100%	100%	0%	41%	37%	35%
16	25%	5%	0%	100%	100%	0%	45%	37%	35%
17	30%	5%	0%	100%	100%	0%	47%	37%	35%
18	5%	0%	0%	100%	100%	0%	37%	35%	35%
19	5%	0%	0%	100%	0%	0%	37%	35%	35%
20	5%	0%	0%	100%	0%	0%	37%	35%	35%
21	5%	0%	0%	100%	0%	0%	37%	35%	35%
22	5%	0%	0%	100%	0%	0%	37%	35%	35%
23	0%	0%	0%	0%	0%	0%	35%	35%	35%
24	0%	0%	0%	0%	0%	0%	35%	35%	35%

Source: TNZ

Table O.5
COMMON SPACE LIGHTING

Hour End	Corridors			Stairs	Stairways w OS*			Restrooms			Support	
	M-F	Sat	Sun	All	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Other
1	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
2	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
3	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
4	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
5	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
6	15%	15%	15%	100%	50%	50%	50%	0%	0%	0%	0%	0%
7	100%	100%	15%	100%	60%	50%	50%	35%	0%	0%	5%	0%
8	100%	100%	15%	100%	70%	50%	50%	45%	0%	0%	5%	0%
9	100%	100%	15%	100%	100%	55%	50%	100%	35%	0%	5%	0%
10	100%	100%	15%	100%	100%	55%	50%	100%	40%	0%	5%	0%
11	100%	100%	15%	100%	100%	55%	50%	100%	40%	0%	5%	0%
12	100%	100%	15%	100%	100%	55%	50%	100%	35%	0%	5%	0%
13	100%	100%	15%	100%	100%	55%	50%	100%	30%	0%	5%	0%
14	100%	100%	15%	100%	100%	55%	50%	100%	30%	0%	5%	0%
15	100%	100%	15%	100%	100%	55%	50%	100%	30%	0%	5%	0%
16	100%	100%	15%	100%	100%	55%	50%	100%	30%	0%	5%	0%
17	100%	100%	15%	100%	100%	55%	50%	100%	30%	0%	0%	0%
18	100%	100%	15%	100%	80%	50%	50%	65%	0%	0%	0%	0%
19	100%	15%	15%	100%	60%	50%	50%	35%	0%	0%	0%	0%
20	100%	15%	15%	100%	55%	50%	50%	35%	0%	0%	0%	0%
21	100%	15%	15%	100%	55%	50%	50%	30%	0%	0%	0%	0%
22	100%	15%	15%	100%	55%	50%	50%	30%	0%	0%	0%	0%
23	15%	15%	15%	100%	50%	50%	50%	30%	0%	0%	0%	0%
24	15%	15%	15%	100%	50%	50%	50%	30%	0%	0%	0%	0%

*Assumes 50% Turndown, lighting power assumption should not account for any control factors.

Source: TNZ

Table O.6
OTHER COMMON SCHEDULES

Hour End	HVAC "Occupied"*			Elevator			DHW		
	M-F	Sat	Sun	M-F	Sat	Sun	M-F	Sat	Sun
1	0	0	0	0%	0%	0%	5%	5%	5%
2	0	0	0	0%	0%	0%	5%	5%	5%
3	0	0	0	0%	0%	0%	5%	5%	5%
4	0	0	0	0%	0%	0%	5%	5%	5%
5	0	0	0	0%	0%	0%	5%	5%	5%
6	0	0	0	0%	0%	0%	5%	5%	5%
7	1	1	0	0%	0%	0%	7%	5%	5%
8	1	1	0	35%	0%	0%	19%	5%	5%
9	1	1	0	69%	14%	0%	35%	11%	5%
10	1	1	0	43%	21%	0%	38%	15%	5%
11	1	1	0	37%	18%	0%	39%	21%	5%
12	1	1	0	43%	25%	0%	47%	19%	5%
13	1	1	0	58%	21%	0%	57%	23%	5%
14	1	1	0	48%	13%	0%	54%	20%	5%
15	1	1	0	37%	8%	0%	34%	19%	5%
16	1	1	0	37%	4%	0%	33%	15%	5%
17	1	1	0	46%	5%	0%	44%	12%	5%
18	1	1	0	62%	6%	0%	26%	14%	5%
19	1	0	0	12%	0%	0%	21%	7%	5%
20	1	0	0	4%	0%	0%	15%	5%	5%
21	1	0	0	4%	0%	0%	17%	5%	5%
22	1	0	0	4%	0%	0%	8%	5%	5%
23	0	0	0	0%	0%	0%	5%	5%	5%
24	0	0	0	0%	0%	0%	5%	5%	5%

*Hours when ventilation for occupancy is active; morning startup begins ahead of these hours.

Source: TNZ

Table O.7
OFFICE BUILDING LOAD FACTORS

Occupancy

Ideally, the occupant counts are based on furniture counts
 Otherwise, use the ASHRAE 62.1 default densities

Occupant Heat Loads

250 Btu/h/person sensible, 200 Btu/h/person latent

Lighting → Per design and IECC 2018 Table C405.4.2(2).

Office Equipment

Ideally, equipment loads are tied to occupant counts (rather than W/ft²) with peak power demand developed from ASHRAE Fundamentals 2013 Tables 18.8, 18.9, and 18.10.
 If equipment is not known, reference ASHRAE Fundamentals 2013 Table 18.11:

% Laptop	% Desktop	No. Monitors	Workspace	Occs/Printer	Diversity?	W/ft ²
100%	0%	0	167 ft ²	10	Yes	0.25
100%	0%	0	125 ft ²	10	Yes	0.33
50%	50%	1	167 ft ²	10	Yes	0.40
50%	50%	1	125 ft ²	10	Yes	0.50
0%	100%	1	167 ft ²	10	Yes	0.60
0%	100%	1	125 ft ²	10	Yes	0.80
0%	100%	2	125 ft ²	10	Yes	1.00
0%	100%	2	85 ft ²	8	Yes	1.50
0%	100%	2	85 ft ²	8	No	2.00

Non-Office Equipment

Background miscellaneous loads: 0.2 W/ft² on 24/7 for corridors, stairs, and most support spaces

IDF/MDF rooms: 4.0 W/ft² on 24/7

Electrical closets: 0.5 W/ft² on 24/7

Break Rooms:

Peak Watts Assumptions

Typical Refrigerator	191	constant operation
1,100 W Microwave Oven	80	1,100 W model, 1.0 hr/day, 251 days/yr
1,000 W Coffee Maker	110	1,000 W model, 1.5 hr/day, 251 days/yr
1,051 W Toaster Oven	19	1,051 W model, 0.25 hr/day, 251 days/yr

Peak Wattage is based on 3,431 EFLH for Table O.4 plug loads

Table E.1
ADMINISTRATION OFFICES

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	10%	0%	100%	0%	28%	20%
8	50%	0%	100%	0%	60%	20%
9	100%	0%	100%	0%	100%	20%
10	100%	0%	100%	0%	100%	20%
11	100%	0%	100%	0%	100%	20%
12	90%	0%	100%	0%	92%	20%
13	100%	0%	100%	0%	100%	20%
14	100%	0%	100%	0%	100%	20%
15	50%	0%	100%	0%	60%	20%
16	50%	0%	100%	0%	60%	20%
17	0%	0%	0%	0%	20%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table E.2
ADMINISTRATION OFFICES - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	50%	0%	85%	0%	55%	10%
10	50%	0%	85%	0%	55%	10%
11	50%	0%	85%	0%	55%	10%
12	50%	0%	85%	0%	55%	10%
13	50%	0%	85%	0%	55%	10%
14	50%	0%	85%	0%	55%	10%
15	50%	0%	85%	0%	55%	10%
16	50%	0%	85%	0%	55%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table E.3
TYPICAL CLASSROOMS

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	5%	0%	100%	0%	24%	20%
9	45%	0%	100%	0%	56%	20%
10	90%	0%	100%	0%	92%	20%
11	90%	0%	100%	0%	92%	20%
12	25%	0%	100%	0%	40%	20%
13	90%	0%	100%	0%	92%	20%
14	90%	0%	100%	0%	92%	20%
15	35%	0%	100%	0%	48%	20%
16	5%	0%	100%	0%	24%	20%
17	0%	0%	0%	0%	20%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table E.4
TYPICAL CLASSROOMS - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	50%	0%	85%	0%	55%	10%
10	50%	0%	85%	0%	55%	10%
11	50%	0%	85%	0%	55%	10%
12	50%	0%	85%	0%	55%	10%
13	50%	0%	85%	0%	55%	10%
14	50%	0%	85%	0%	55%	10%
15	50%	0%	85%	0%	55%	10%
16	50%	0%	85%	0%	55%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table E.5
GYMNASIUM

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%
8	60%	0%	100%	0%	0%	0%
9	10%	0%	100%	0%	0%	0%
10	10%	0%	100%	0%	0%	0%
11	10%	0%	100%	0%	0%	0%
12	10%	0%	100%	0%	0%	0%
13	10%	0%	100%	0%	0%	0%
14	10%	0%	100%	0%	0%	0%
15	60%	0%	100%	0%	0%	0%
16	30%	0%	100%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%

Source: TNZ

Table E.6
GYMNASIUM - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%
11	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%
16	0%	0%	0%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%

Source: TNZ

Table E.7
LIBRARY / MEDIA CENTER

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	0%	0%	0%	0%	20%	20%
9	30%	0%	100%	0%	100%	20%
10	30%	0%	100%	0%	100%	20%
11	30%	0%	100%	0%	100%	20%
12	15%	0%	100%	0%	100%	20%
13	15%	0%	100%	0%	100%	20%
14	30%	0%	100%	0%	100%	20%
15	50%	0%	100%	0%	100%	20%
16	50%	0%	100%	0%	100%	20%
17	0%	0%	0%	0%	20%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table E.8
LIBRARY / MEDIA CENTER - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	5%	0%	100%	0%	100%	10%
9	15%	0%	100%	0%	100%	10%
10	15%	0%	100%	0%	100%	10%
11	15%	0%	100%	0%	100%	10%
12	15%	0%	100%	0%	100%	10%
13	5%	0%	100%	0%	100%	10%
14	0%	0%	0%	0%	10%	10%
15	0%	0%	0%	0%	10%	10%
16	0%	0%	0%	0%	10%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table E.9
CAFETERIA

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	20%	0%	100%	0%	20%	20%
9	5%	0%	100%	0%	20%	20%
10	5%	0%	100%	0%	20%	20%
11	5%	0%	100%	0%	20%	20%
12	100%	0%	100%	0%	100%	20%
13	100%	0%	100%	0%	100%	20%
14	5%	0%	100%	0%	20%	20%
15	5%	0%	100%	0%	20%	20%
16	5%	0%	100%	0%	20%	20%
17	0%	0%	0%	0%	20%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table E.10
CAFETERIA - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	0%	0%	0%	0%	10%	10%
10	0%	0%	0%	0%	10%	10%
11	0%	0%	0%	0%	10%	10%
12	0%	0%	0%	0%	10%	10%
13	0%	0%	0%	0%	10%	10%
14	0%	0%	0%	0%	10%	10%
15	0%	0%	0%	0%	10%	10%
16	0%	0%	0%	0%	10%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table E.11
KITCHEN & SERVERY

Hour End	Occupancy		Lighting		Gas Cooking		Electric Cooking		Electric Servery		Refrigeration		Dishwash	
	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
8	20%	0%	100%	0%	0%	0%	25%	0%	0%	0%	85%	75%	0%	0%
9	100%	0%	100%	0%	50%	0%	50%	0%	0%	0%	90%	75%	0%	0%
10	100%	0%	100%	0%	75%	0%	100%	0%	100%	0%	95%	75%	0%	0%
11	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100%	75%	25%	0%
12	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100%	75%	50%	0%
13	100%	0%	100%	0%	0%	0%	25%	0%	100%	0%	95%	75%	75%	0%
14	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	75%	100%	0%
15	75%	0%	100%	0%	0%	0%	0%	0%	0%	0%	85%	75%	50%	0%
16	5%	0%	100%	0%	0%	0%	0%	0%	0%	0%	85%	75%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%

Source: TNZ

Table E.12
KITCHEN & SERVERY - Summer & Break Periods

Hour End	Occupancy		Lighting		Gas Cooking		Electric Cooking		Electric Servery		Refrigeration		Dishwash	
	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
15	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
16	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	0%	0%

Source: TNZ

Table E.13
COMMON SPACE LIGHTING

Hour End	Corridors		Stairs	Stairways w OS*		Restrooms		Support Spaces	
	M-F	Other	All	M-F	Other	M-F	Other	M-F	Other
1	15%	15%	100%	50%	50%	0%	0%	0%	0%
2	15%	15%	100%	50%	50%	0%	0%	0%	0%
3	15%	15%	100%	50%	50%	0%	0%	0%	0%
4	15%	15%	100%	50%	50%	0%	0%	0%	0%
5	15%	15%	100%	50%	50%	0%	0%	0%	0%
6	15%	15%	100%	50%	50%	0%	0%	0%	0%
7	50%	15%	100%	60%	50%	50%	0%	25%	0%
8	100%	15%	100%	100%	50%	100%	0%	25%	0%
9	100%	15%	100%	100%	50%	100%	0%	25%	0%
10	100%	15%	100%	100%	50%	100%	0%	25%	0%
11	100%	15%	100%	100%	50%	100%	0%	25%	0%
12	100%	15%	100%	100%	50%	100%	0%	25%	0%
13	100%	15%	100%	100%	50%	100%	0%	25%	0%
14	100%	15%	100%	100%	50%	100%	0%	25%	0%
15	100%	15%	100%	100%	50%	100%	0%	25%	0%
16	100%	15%	100%	100%	50%	100%	0%	5%	0%
17	100%	15%	100%	50%	50%	100%	0%	5%	0%
18	15%	15%	100%	50%	50%	0%	0%	5%	0%
19	15%	15%	100%	50%	50%	0%	0%	0%	0%
20	15%	15%	100%	50%	50%	0%	0%	0%	0%
21	15%	15%	100%	50%	50%	0%	0%	0%	0%
22	15%	15%	100%	50%	50%	0%	0%	0%	0%
23	15%	15%	100%	50%	50%	0%	0%	0%	0%
24	15%	15%	100%	50%	50%	0%	0%	0%	0%

*Assumes 50% Turndown, lighting power assumption should not account for any control factors.

Source: TNZ

Table E.14
OTHER COMMON SCHEDULES

Hour End	HVAC "Occupied"*		Elevator		DHW		DHW - Vacations	
	M-F	Other	M-F	Other	M-F	Other	M-F	Other
1	0	0	0%	0%	5%	5%	5%	5%
2	0	0	0%	0%	5%	5%	5%	5%
3	0	0	0%	0%	5%	5%	5%	5%
4	0	0	0%	0%	5%	5%	5%	5%
5	0	0	0%	0%	5%	5%	5%	5%
6	0	0	0%	0%	5%	5%	5%	5%
7	1	0	0%	0%	5%	5%	5%	5%
8	1	0	5%	0%	34%	5%	10%	5%
9	1	0	5%	0%	60%	5%	10%	5%
10	1	0	5%	0%	63%	5%	10%	5%
11	1	0	5%	0%	72%	5%	10%	5%
12	1	0	5%	0%	79%	5%	10%	5%
13	1	0	5%	0%	83%	5%	10%	5%
14	1	0	5%	0%	61%	5%	10%	5%
15	1	0	5%	0%	65%	5%	10%	5%
16	1	0	5%	0%	10%	5%	5%	5%
17	0	0	0%	0%	10%	5%	5%	5%
18	0	0	0%	0%	5%	5%	5%	5%
19	0	0	0%	0%	5%	5%	5%	5%
20	0	0	0%	0%	5%	5%	5%	5%
21	0	0	0%	0%	5%	5%	5%	5%
22	0	0	0%	0%	5%	5%	5%	5%
23	0	0	0%	0%	5%	5%	5%	5%
24	0	0	0%	0%	5%	5%	5%	5%

*Hours when ventilation for occupancy is active; morning startup begins ahead of these hours.

Source: TNZ

Table E.15
ELEMENTARY SCHOOL LOAD FACTORS

Occupancy

Ideally, the occupant counts are based on furniture counts
 Otherwise, use the ASHRAE 62.1 default densities

Occupant Heat Loads

Teacher & Admin Spaces: 245 Btu/h/person sensible, 155 Btu/h/person latent
 Student Spaces: 231 Btu/h/person sensible, 158 Btu/h/person latent
 Gymnasium: 500 Btu/h/person sensible, 375 Btu/h/person latent

Lighting → Per design and IECC 2018 Table C405.4.2(2).

Office Equipment & Teach Break Rooms

See direction for office buildings

Classroom Equipment

Develop loads based on actual equipment planned for the space; the following are example average coincident peak values:

Computers	47.5 Watts	Display	19.5 Watts
Soundfield	98.8 Watts	Projector	63.3 Watts
		iPad Cart	183.0 Watts

Cooking & Servery Equipment

Develop peak demand using ASHRAE 2013 Fundamentals Tables 18.5A through 18.5E

Non-Office Equipment

Background miscellaneous loads: 0.2 W/ft² on 24/7 for corridors, stairs, and most support spaces
 IDF/MDF rooms: 4.0 W/ft² on 24/7
 Electrical closets: 0.5 W/ft² on 24/7

Table H.1

ADMINISTRATION OFFICES

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	50%	0%	100%	0%	60%	20%
8	100%	0%	100%	0%	100%	20%
9	100%	0%	100%	0%	100%	20%
10	100%	0%	100%	0%	100%	20%
11	100%	0%	100%	0%	100%	20%
12	90%	0%	100%	0%	92%	20%
13	100%	0%	100%	0%	100%	20%
14	100%	0%	100%	0%	100%	20%
15	75%	0%	100%	0%	80%	20%
16	50%	0%	100%	0%	60%	20%
17	50%	0%	100%	0%	60%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table H.2

ADMINISTRATION OFFICES - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	50%	0%	85%	0%	55%	10%
10	50%	0%	85%	0%	55%	10%
11	50%	0%	85%	0%	55%	10%
12	50%	0%	85%	0%	55%	10%
13	50%	0%	85%	0%	55%	10%
14	50%	0%	85%	0%	55%	10%
15	50%	0%	85%	0%	55%	10%
16	50%	0%	85%	0%	55%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table H.3
TYPICAL CLASSROOMS

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	50%	0%	100%	0%	60%	20%
9	90%	0%	100%	0%	92%	20%
10	90%	0%	100%	0%	92%	20%
11	90%	0%	100%	0%	92%	20%
12	25%	0%	100%	0%	40%	20%
13	90%	0%	100%	0%	92%	20%
14	90%	0%	100%	0%	92%	20%
15	35%	0%	100%	0%	48%	20%
16	5%	0%	100%	0%	24%	20%
17	5%	0%	100%	0%	24%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table H.4
TYPICAL CLASSROOMS - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	50%	0%	85%	0%	55%	10%
10	50%	0%	85%	0%	55%	10%
11	50%	0%	85%	0%	55%	10%
12	50%	0%	85%	0%	55%	10%
13	50%	0%	85%	0%	55%	10%
14	50%	0%	85%	0%	55%	10%
15	50%	0%	85%	0%	55%	10%
16	50%	0%	85%	0%	55%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table H.5
GYMNASIUM

Hour End	Occupancy			Lighting			Plug Loads		
	M-Th	Fr	Other	M-Th	Fr	Other	M-Th	Fr	Other
1	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	30%	0%	0%	100%	0%	0%	0%	0%	0%
8	30%	0%	0%	100%	0%	0%	0%	0%	0%
9	10%	0%	0%	100%	0%	0%	0%	0%	0%
10	10%	0%	0%	100%	0%	0%	0%	0%	0%
11	10%	0%	0%	100%	0%	0%	0%	0%	0%
12	10%	0%	0%	100%	0%	0%	0%	0%	0%
13	10%	0%	0%	100%	0%	0%	0%	0%	0%
14	10%	0%	0%	100%	0%	0%	0%	0%	0%
15	30%	0%	0%	100%	0%	0%	0%	0%	0%
16	30%	0%	0%	100%	0%	0%	0%	0%	0%
17	30%	0%	0%	100%	0%	0%	0%	0%	0%
18	5%	0%	0%	100%	0%	0%	0%	0%	0%
19	5%	50%	0%	100%	100%	0%	0%	100%	0%
20	30%	100%	0%	100%	100%	0%	0%	100%	0%
21	30%	100%	0%	100%	100%	0%	0%	100%	0%
22	5%	50%	0%	100%	100%	0%	0%	100%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%

Plug loads are assumed to be score board and game lights that are typically not used.

Source: TNZ

Table H.6
GYMNASIUM - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%
11	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%
16	0%	0%	0%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%

Source: TNZ

Table H.7
LIBRARY / MEDIA CENTER

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	5%	0%	100%	0%	100%	20%
9	30%	0%	100%	0%	100%	20%
10	30%	0%	100%	0%	100%	20%
11	30%	0%	100%	0%	100%	20%
12	15%	0%	100%	0%	100%	20%
13	15%	0%	100%	0%	100%	20%
14	30%	0%	100%	0%	100%	20%
15	75%	0%	100%	0%	100%	20%
16	75%	0%	100%	0%	100%	20%
17	50%	0%	100%	0%	100%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table H.8
LIBRARY / MEDIA CENTER - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	5%	0%	100%	0%	100%	10%
9	15%	0%	100%	0%	100%	10%
10	15%	0%	100%	0%	100%	10%
11	15%	0%	100%	0%	100%	10%
12	15%	0%	100%	0%	100%	10%
13	5%	0%	100%	0%	100%	10%
14	0%	0%	0%	0%	10%	10%
15	0%	0%	0%	0%	10%	10%
16	0%	0%	0%	0%	10%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table H.9
CAFETERIA

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	20%	20%
2	0%	0%	0%	0%	20%	20%
3	0%	0%	0%	0%	20%	20%
4	0%	0%	0%	0%	20%	20%
5	0%	0%	0%	0%	20%	20%
6	0%	0%	0%	0%	20%	20%
7	0%	0%	0%	0%	20%	20%
8	20%	0%	100%	0%	20%	20%
9	5%	0%	100%	0%	20%	20%
10	5%	0%	100%	0%	20%	20%
11	5%	0%	100%	0%	20%	20%
12	100%	0%	100%	0%	100%	20%
13	100%	0%	100%	0%	100%	20%
14	5%	0%	100%	0%	20%	20%
15	10%	0%	100%	0%	20%	20%
16	5%	0%	100%	0%	20%	20%
17	0%	0%	0%	0%	20%	20%
18	0%	0%	0%	0%	20%	20%
19	0%	0%	0%	0%	20%	20%
20	0%	0%	0%	0%	20%	20%
21	0%	0%	0%	0%	20%	20%
22	0%	0%	0%	0%	20%	20%
23	0%	0%	0%	0%	20%	20%
24	0%	0%	0%	0%	20%	20%

Source: TNZ

Table H.10
CAFETERIA - Summer & Break Periods

Hour End	Occupancy		Lighting		Plug Loads	
	M-F	Other	M-F	Other	M-F	Other
1	0%	0%	0%	0%	10%	10%
2	0%	0%	0%	0%	10%	10%
3	0%	0%	0%	0%	10%	10%
4	0%	0%	0%	0%	10%	10%
5	0%	0%	0%	0%	10%	10%
6	0%	0%	0%	0%	10%	10%
7	0%	0%	0%	0%	10%	10%
8	0%	0%	0%	0%	10%	10%
9	0%	0%	0%	0%	10%	10%
10	0%	0%	0%	0%	10%	10%
11	0%	0%	0%	0%	10%	10%
12	0%	0%	0%	0%	10%	10%
13	0%	0%	0%	0%	10%	10%
14	0%	0%	0%	0%	10%	10%
15	0%	0%	0%	0%	10%	10%
16	0%	0%	0%	0%	10%	10%
17	0%	0%	0%	0%	10%	10%
18	0%	0%	0%	0%	10%	10%
19	0%	0%	0%	0%	10%	10%
20	0%	0%	0%	0%	10%	10%
21	0%	0%	0%	0%	10%	10%
22	0%	0%	0%	0%	10%	10%
23	0%	0%	0%	0%	10%	10%
24	0%	0%	0%	0%	10%	10%

Source: TNZ

Table H.11
AUDITORIUM

Hour End	Occupancy			Lighting			Plug Loads		
	M-Th	Fr	Other	M-Th	Fr	Other	M-Th	Fr	Other
1	0%	0%	0%	0%	0%	0%	5%	5%	5%
2	0%	0%	0%	0%	0%	0%	5%	5%	5%
3	0%	0%	0%	0%	0%	0%	5%	5%	5%
4	0%	0%	0%	0%	0%	0%	5%	5%	5%
5	0%	0%	0%	0%	0%	0%	5%	5%	5%
6	0%	0%	0%	0%	0%	0%	5%	5%	5%
7	0%	0%	0%	0%	0%	0%	5%	5%	5%
8	0%	0%	0%	0%	0%	0%	5%	5%	5%
9	0%	5%	0%	0%	100%	0%	5%	10%	5%
10	5%	100%	0%	100%	100%	0%	10%	100%	5%
11	5%	100%	0%	100%	100%	0%	10%	100%	5%
12	0%	5%	0%	0%	100%	0%	5%	10%	5%
13	5%	5%	0%	100%	100%	0%	10%	10%	5%
14	5%	5%	0%	100%	100%	0%	10%	10%	5%
15	5%	5%	0%	100%	100%	0%	10%	10%	5%
16	5%	5%	0%	100%	100%	0%	10%	10%	5%
17	0%	0%	0%	0%	0%	0%	5%	5%	5%
18	0%	0%	0%	0%	0%	0%	5%	5%	5%
19	0%	5%	0%	0%	100%	0%	5%	10%	5%
20	0%	100%	0%	0%	100%	0%	5%	100%	5%
21	0%	100%	0%	0%	100%	0%	5%	100%	5%
22	0%	5%	0%	0%	100%	0%	5%	10%	5%
23	0%	0%	0%	0%	0%	0%	5%	5%	5%
24	0%	0%	0%	0%	0%	0%	5%	5%	5%

Table H.12
AUDITORIUM - Summer & Break Periods

Hour End	Occupancy			Lighting			Plug Loads		
	M-Th	Fr	Other	M-Th	Fr	Other	M-Th	Fr	Other
1	0%	0%	0%	0%	0%	0%	5%	5%	5%
2	0%	0%	0%	0%	0%	0%	5%	5%	5%
3	0%	0%	0%	0%	0%	0%	5%	5%	5%
4	0%	0%	0%	0%	0%	0%	5%	5%	5%
5	0%	0%	0%	0%	0%	0%	5%	5%	5%
6	0%	0%	0%	0%	0%	0%	5%	5%	5%
7	0%	0%	0%	0%	0%	0%	5%	5%	5%
8	0%	0%	0%	0%	0%	0%	5%	5%	5%
9	0%	0%	0%	0%	0%	0%	5%	5%	5%
10	0%	0%	0%	0%	0%	0%	5%	5%	5%
11	0%	0%	0%	0%	0%	0%	5%	5%	5%
12	0%	0%	0%	0%	0%	0%	5%	5%	5%
13	0%	0%	0%	0%	0%	0%	5%	5%	5%
14	0%	0%	0%	0%	0%	0%	5%	5%	5%
15	0%	0%	0%	0%	0%	0%	5%	5%	5%
16	0%	0%	0%	0%	0%	0%	5%	5%	5%
17	0%	0%	0%	0%	0%	0%	5%	5%	5%
18	0%	0%	0%	0%	0%	0%	5%	5%	5%
19	0%	0%	0%	0%	0%	0%	5%	5%	5%
20	0%	0%	0%	0%	0%	0%	5%	5%	5%
21	0%	0%	0%	0%	0%	0%	5%	5%	5%
22	0%	0%	0%	0%	0%	0%	5%	5%	5%
23	0%	0%	0%	0%	0%	0%	5%	5%	5%
24	0%	0%	0%	0%	0%	0%	5%	5%	5%

*Plug loads are likely to be dominated by stage lighting (considered a process load by code).

Source: TNZ

Source: TNZ

Table H.13
COMMON SPACE LIGHTING

Hour End	Corridors		Stairs	Stairways w OS*		Restrooms		Support Spaces	
	M-F	Other	All	M-F	Other	M-F	Other	M-F	Other
1	15%	15%	100%	50%	50%	0%	0%	0%	0%
2	15%	15%	100%	50%	50%	0%	0%	0%	0%
3	15%	15%	100%	50%	50%	0%	0%	0%	0%
4	15%	15%	100%	50%	50%	0%	0%	0%	0%
5	15%	15%	100%	50%	50%	0%	0%	0%	0%
6	15%	15%	100%	50%	50%	0%	0%	0%	0%
7	50%	15%	100%	100%	50%	50%	0%	25%	0%
8	100%	15%	100%	100%	50%	100%	0%	25%	0%
9	100%	15%	100%	100%	50%	100%	0%	25%	0%
10	100%	15%	100%	100%	50%	100%	0%	25%	0%
11	100%	15%	100%	100%	50%	100%	0%	25%	0%
12	100%	15%	100%	100%	50%	100%	0%	25%	0%
13	100%	15%	100%	100%	50%	100%	0%	25%	0%
14	100%	15%	100%	100%	50%	100%	0%	25%	0%
15	100%	15%	100%	100%	50%	100%	0%	25%	0%
16	100%	15%	100%	100%	50%	100%	0%	5%	0%
17	100%	15%	100%	100%	50%	100%	0%	5%	0%
18	100%	15%	100%	50%	50%	100%	0%	5%	0%
19	100%	15%	100%	50%	50%	100%	0%	0%	0%
20	100%	15%	100%	50%	50%	100%	0%	0%	0%
21	100%	15%	100%	50%	50%	100%	0%	0%	0%
22	100%	15%	100%	50%	50%	100%	0%	0%	0%
23	15%	15%	100%	50%	50%	0%	0%	0%	0%
24	15%	15%	100%	50%	50%	0%	0%	0%	0%

*Assumes 50% Turndown, lighting power assumption should not account for any control fact

Source: TNZ

Table H.14
COMMON SPACE LIGHTING - Summer & Break Periods

Hour End	Corridors		Stairs	Stairways w OS*		Restrooms		Support Spaces	
	M-F	Other	All	M-F	Other	M-F	Other	M-F	Other
1	15%	15%	100%	50%	50%	0%	0%	0%	0%
2	15%	15%	100%	50%	50%	0%	0%	0%	0%
3	15%	15%	100%	50%	50%	0%	0%	0%	0%
4	15%	15%	100%	50%	50%	0%	0%	0%	0%
5	15%	15%	100%	50%	50%	0%	0%	0%	0%
6	15%	15%	100%	50%	50%	0%	0%	0%	0%
7	50%	15%	100%	55%	50%	50%	0%	25%	0%
8	50%	15%	100%	55%	50%	100%	0%	25%	0%
9	50%	15%	100%	55%	50%	100%	0%	25%	0%
10	50%	15%	100%	55%	50%	100%	0%	25%	0%
11	50%	15%	100%	55%	50%	100%	0%	25%	0%
12	50%	15%	100%	55%	50%	100%	0%	25%	0%
13	50%	15%	100%	55%	50%	100%	0%	25%	0%
14	50%	15%	100%	55%	50%	100%	0%	25%	0%
15	50%	15%	100%	55%	50%	100%	0%	25%	0%
16	15%	15%	100%	50%	50%	100%	0%	0%	0%
17	15%	15%	100%	50%	50%	100%	0%	0%	0%
18	15%	15%	100%	50%	50%	100%	0%	0%	0%
19	15%	15%	100%	50%	50%	100%	0%	0%	0%
20	15%	15%	100%	50%	50%	100%	0%	0%	0%
21	15%	15%	100%	50%	50%	100%	0%	0%	0%
22	15%	15%	100%	50%	50%	100%	0%	0%	0%
23	15%	15%	100%	50%	50%	0%	0%	0%	0%
24	15%	15%	100%	50%	50%	0%	0%	0%	0%

*Assumes 50% Turndown, lighting power assumption should not account for any control fact

Source: TNZ

Table H.15
OTHER COMMON SCHEDULES

Hour End	HVAC "Occupied"*		Gym HVAC		Auditorium HVAC			Elevator		DHW	
	M-F	Other	M-Fr	Other	M-Th	Fr	Other	M-F	Other	M-F	Other
	1	0	0	0	0	0	0	0	0%	0%	5%
2	0	0	0	0	0	0	0	0%	0%	5%	5%
3	0	0	0	0	0	0	0	0%	0%	5%	5%
4	0	0	0	0	0	0	0	0%	0%	5%	5%
5	0	0	0	0	0	0	0	0%	0%	5%	5%
6	0	0	0	0	0	0	0	0%	0%	5%	5%
7	1	0	1	0	1	1	0	0%	0%	5%	5%
8	1	0	1	0	1	1	0	10%	0%	34%	5%
9	1	0	1	0	1	1	0	10%	0%	60%	5%
10	1	0	1	0	1	1	0	10%	0%	63%	5%
11	1	0	1	0	1	1	0	10%	0%	72%	5%
12	1	0	1	0	1	1	0	10%	0%	79%	5%
13	1	0	1	0	1	1	0	10%	0%	83%	5%
14	1	0	1	0	1	1	0	10%	0%	61%	5%
15	1	0	1	0	1	1	0	10%	0%	65%	5%
16	1	0	1	0	1	1	0	10%	0%	10%	5%
17	0	0	1	0	1	1	0	0%	0%	10%	5%
18	0	0	1	0	0	1	0	0%	0%	5%	5%
19	0	0	1	0	0	1	0	0%	0%	5%	5%
20	0	0	1	0	0	1	0	0%	0%	5%	5%
21	0	0	1	0	0	1	0	0%	0%	5%	5%
22	0	0	1	0	0	1	0	0%	0%	5%	5%
23	0	0	0	0	0	0	0	0%	0%	5%	5%
24	0	0	0	0	0	0	0	0%	0%	5%	5%

*Hours when ventilation for occupancy is active; morning startup begins ahead of these hours.

Table H.16
OTHER COMMON SCHEDULES - Summer & Break Periods

Hour End	HVAC "Occupied"*		Aud & Gym HVAC		Elevator		DHW	
	M-F	Other	M-F	Other	M-F	Other	M-F	Other
	1	0	0	0	0	0%	0%	5%
2	0	0	0	0	0%	0%	5%	5%
3	0	0	0	0	0%	0%	5%	5%
4	0	0	0	0	0%	0%	5%	5%
5	0	0	0	0	0%	0%	5%	5%
6	0	0	0	0	0%	0%	5%	5%
7	1	0	0	0	0%	0%	5%	5%
8	1	0	0	0	5%	0%	34%	5%
9	1	0	0	0	5%	0%	60%	5%
10	1	0	0	0	5%	0%	63%	5%
11	1	0	0	0	5%	0%	72%	5%
12	1	0	0	0	5%	0%	79%	5%
13	1	0	0	0	5%	0%	83%	5%
14	1	0	0	0	5%	0%	61%	5%
15	1	0	0	0	5%	0%	65%	5%
16	1	0	0	0	5%	0%	10%	5%
17	0	0	0	0	0%	0%	10%	5%
18	0	0	0	0	0%	0%	19%	5%
19	0	0	0	0	0%	0%	25%	5%
20	0	0	0	0	0%	0%	22%	5%
21	0	0	0	0	0%	0%	22%	5%
22	0	0	0	0	0%	0%	12%	5%
23	0	0	0	0	0%	0%	5%	5%
24	0	0	0	0	0%	0%	5%	5%

*Hours when ventilation for occupancy is active; morning startup begins ahead of these hours.

Table H.17
HIGH SCHOOL LOAD FACTORS

Occupancy

Ideally, the occupant counts are based on furniture counts
 Otherwise, use the ASHRAE 62.1 default densities

Occupant Heat Loads

Teacher & Admin Spaces, Auditorium: 245 Btu/h/person sensible, 155 Btu/h/person latent
 Student Spaces: 245 Btu/h/person sensible, 200 Btu/h/person latent
 Gymnasium: 500 Btu/h/person sensible, 375 Btu/h/person latent

Lighting → Per design and IECC 2018 Table C405.4.2(2).

Office Equipment & Teach Break Rooms

See direction for office buildings

Classroom Equipment

Develop loads based on actual equipment planned for the space; the following are example average coincident peak values:

Computers	47.5 Watts	Display	19.5 Watts
Soundfield	98.8 Watts	Projector	63.3 Watts
		iPad Cart	183.0 Watts

Cooking & Servery Equipment

Develop peak demand using ASHRAE 2013 Fundamentals Tables 18.5A through 18.5E

Non-Office Equipment

Background miscellaneous loads: 0.2 W/ft² on 24/7 for corridors, stairs, and most support spaces
 IDF/MDF rooms: 4.0 W/ft² on 24/7
 Electrical closets: 0.5 W/ft² on 24/7

Gym and Auditorium Loads

Develop based on process type lighting such as stage lighting and infrequently used game lighting and displays.

Table 1
ELEVATORS

Hour End	Offices			Schools		Hotel/MF	Hospital			Outpatient		
	M-F	Sat	Sun	M-F	Other	All	M-F	Sat	Sun	M-F	Sat	Sun
1	0%	0%	0%	0%	0%	2%	8%	8%	8%	2%	2%	2%
2	0%	0%	0%	0%	0%	2%	8%	8%	8%	2%	2%	2%
3	0%	0%	0%	0%	0%	2%	8%	8%	8%	2%	2%	2%
4	0%	0%	0%	0%	0%	2%	8%	8%	8%	2%	2%	2%
5	0%	0%	0%	0%	0%	4%	8%	8%	8%	2%	2%	2%
6	0%	0%	0%	0%	0%	8%	8%	8%	8%	2%	2%	2%
7	0%	0%	0%	0%	0%	16%	8%	8%	8%	2%	2%	2%
8	14%	6%	0%	0%	0%	20%	20%	16%	8%	20%	16%	2%
9	28%	6%	0%	12%	0%	20%	30%	28%	16%	30%	18%	16%
10	17%	8%	0%	12%	0%	14%	40%	28%	16%	40%	28%	16%
11	15%	7%	0%	12%	0%	6%	40%	28%	16%	40%	28%	16%
12	17%	10%	0%	12%	0%	6%	40%	20%	16%	40%	20%	16%
13	23%	8%	0%	12%	0%	6%	40%	20%	16%	40%	20%	16%
14	19%	5%	0%	12%	0%	6%	40%	20%	16%	40%	20%	16%
15	15%	3%	0%	12%	0%	6%	40%	20%	16%	40%	20%	16%
16	15%	2%	0%	6%	0%	6%	40%	20%	16%	40%	20%	16%
17	18%	2%	0%	0%	0%	14%	40%	20%	8%	40%	20%	16%
18	25%	2%	0%	0%	0%	20%	40%	10%	8%	40%	10%	16%
19	5%	0%	0%	0%	0%	20%	21%	8%	8%	21%	2%	2%
20	2%	0%	0%	0%	0%	16%	21%	8%	8%	21%	2%	2%
21	2%	0%	0%	0%	0%	16%	21%	8%	8%	21%	2%	2%
22	0%	0%	0%	0%	0%	12%	11%	8%	8%	11%	2%	2%
23	0%	0%	0%	0%	0%	8%	8%	8%	8%	2%	2%	2%
24	0%	0%	0%	0%	0%	4%	8%	8%	8%	2%	2%	2%

Source: BC Hydro Modeling Guide

Appendix B: BDL Programming

BDL programming is a powerful tool that can help ensure consistency within a complex model. The most useful functions arise through use of the activity description field. This information is included in these guidelines since BDL programming is not very well described in DOE 2.2 reference manuals and since many energy models suffer from internal inconsistencies.

The following guidelines are recommended when assigning activity descriptions:

- Activity codes need to be at least 4 letters long, and it is recommended that 4-letter codes be used. eQuest only references the first 4 letters in the activity type field.
- When BDL functions are used in user defined default fields, all spaces need to have an activity code.

There are two approaches that can be used: IF/THEN statements and switches. Switches can be more elegant than IF/THEN statements but may also be difficult to use in some fields. The following examples illustrate how BDL functions can be used to accelerate model manipulation:

1. Assign peak load factors based on activity descriptions

```
IF (#L("C-ACTIVITY-DESC") == "OFFC") THEN 0.98 ELSE
IF (#L("C-ACTIVITY-DESC") == "MEET" .OR.
    #L("C-ACTIVITY-DESC") == "CLAS") THEN 1.23 ELSE
no_def
ENDIF ENDIF
```

In this example, lighting power densities are being assigned to space W/ft² fields as a user defined default. Note the use of .OR. to reduce the number of IF statements. Each IF requires an ENDIF. Input fields in eQuest that are blank by default are able to be assigned no_def. Fields that are not blank by default require an input. The code word 'unused' could be used instead of no_def but this locks out the program from automatically populating the field with default values. Some fields require a numerical entry (e.g. window frame width).

An equivalent example of a switch is as follows:

```
switch (#L("C-ACTIVITY-DESC"))
case "OFFC": 0.98
case "MEET": 1.23
case "CLAS": 1.23
default: no_def
endswitch
```

In this methodology, the field defined by switch () is referenced to see what to do when the value of the field matches the listed cases. A default always needs to be defined.

2. Assign load schedules based on activity descriptions

```
IF (#L("C-ACTIVITY-DESC") == "OFFC") THEN
    #SI("LGHT OFFC YR", "SPACE", "LIGHTING-SCHEDUL" ) ELSE
IF (#L("C-ACTIVITY-DESC") == "MEET") THEN
    #SI("LGHT MEET YR", "SPACE", "LIGHTING-SCHEDUL" ) ELSE
IF (#L("C-ACTIVITY-DESC") == "CIRC" .OR.
    #L("C-ACTIVITY-DESC") == "REST") THEN
    #SI("CRS CIRC YR", "SPACE", "LIGHTING-SCHEDUL" ) ELSE
no_def
ENDIF ENDIF ENDIF
```

In this example, user defined schedule names (e.g. LGHT OFFC YR) are being applied to the lighting schedule field. #SI stands for 'symbol index' and is generally used for anything that references non-numeric inputs. The switch version of this is as follows:

```
switch (#L("C-ACTIVITY-DESC"))
  case "OFFC": #SI("LGHT OFFC YR", "SPACE", "LIGHTING-SCHEDUL" )
  case "MEET": #SI("LGHT MEET YR", "SPACE", "LIGHTING-SCHEDUL" )
  case "CIRC": #SI("CRS CIRC YR", "SPACE", "LIGHTING-SCHEDUL" )
  case "REST": #SI("CRS CIRC YR", "SPACE", "LIGHTING-SCHEDUL" )
  default: no_def
endswitch
```

3. Assign window frame characteristics based on glass type

```
IF(#L("GLASS-TYPE") == #SI("CURTAINWALL","WINDOW","GLASS-TYPE"))
THEN #PA("CFRAMEU") ELSE
IF(#L("GLASS-TYPE") == #SI("WINDOWS","WINDOW","GLASS-TYPE"))
THEN #PA("WFRAMEU") ELSE 1.00
ENDIF ENDIF
```

In this example, two different global parameter (designated by #PA) are being assigned to windows based on the glass type. This is a required entry, so no_def cannot be used. Instead, a value of 1.00 is assigned for windows that do not have glass type "curtainwall" or "windows". This same approach can be used to assign frame widths.

This field is an example where the switch approach may not work.

4. Assign zone temperature schedules based on activity description

```
IF (#LR("SPACE","C-ACTIVITY-DESC") == "OFFC" .OR.
  #LR("SPACE","C-ACTIVITY-DESC") == "COMM" .OR.
  #LR("SPACE","C-ACTIVITY-DESC") == "CIRC" .OR.
  #LR("SPACE","C-ACTIVITY-DESC") == "MEET" .OR.
  #LR("SPACE","C-ACTIVITY-DESC") == "STOR") THEN
  #SI("HEAT AHU YR","ZONE","HEAT-TEMP-SCH") ELSE
no_def
ENDIF
```

In this example, zone associated with five different types of space activities are being assigned the same temperature schedule. Referencing space attributes from the zone side of the program requires the use of #LR("SPACE","C-ACTIVITY-DESC"). The switch version is as follows:

```
switch (#L("C-ACTIVITY-DESC"))
  case "OFFC": #SI("HEAT AHU YR", "ZONE", "HEAT-TEMP-SCH")
  case "COMM": #SI("HEAT AHU YR", "ZONE", "HEAT-TEMP-SCH") )
  case "CIRC": #SI("HEAT AHU YR", "ZONE", "HEAT-TEMP-SCH")
  case "MEET": #SI("HEAT AHU YR", "ZONE", "HEAT-TEMP-SCH")
  case "STOR": #SI("HEAT AHU YR", "ZONE", "HEAT-TEMP-SCH")
  default: no_def
endswitch
```

5. Assign ASHRAE 62.1 ventilation rates based on space area and number of people

```
#LR("SPACE","AREA")*0.06 + #LR("SPACE","NUMBER-OF-PEOPLE")*5.0
```

In this example, zone ventilation rates (cfm) are being calculated based on space area and the maximum number of people using factors taken from ASHRAE 62.1. If the ventilation rates for zones are not known, this approach is recommended since eQuest only looks at the ventilation rate associated with the peak occupancy rather than both cfm/person and cfm/ft². Both the floor area and the number of people are from the loads side of the program and require the use of #LR.

6. Change chiller capacity control to reflect the use of a VFD on a centrifugal chiller:

```
switch #PA("CHILLER")  
case 1: #SIT("YES","CHILLER","VARIABLE-SPEED",#L("TYPE"))  
default: #SIT("NO","CHILLER","VARIABLE-SPEED",#L("TYPE"))  
endswitch
```

In this example, a global parameter called CHILLER is used as a switch to activate the use of a VFD on a particular chiller. Some entries, such as chillers and week schedules, require the use of an #SIT schedule rather than an #SI schedule. This generally is the case for DOE 2 entries where the available options are dependent upon the type of item being considered. In this case, there are different chiller models, some of which have VFD capacity control as an option. The expression #L("TYPE") pulls the local chiller type assignment into the expression so a more specific entry does not need to be entered.

7. Change day schedules used in a week schedule:

```
switch #PA("DHW")  
case 1: #SIT("HW RESET DAY - PROP","WEEK-SCHEDULE","DAY-SCHEDULES",#L("TYPE"))  
default: #SIT("HW RESET DAY - BASE","WEEK-SCHEDULE","DAY-SCHEDULES",#L("TYPE"))  
endswitch
```

In this example, a global parameter called DHW is used as a switch to activate the use of a different reset schedule. This is another #SIT example where the #L("TYPE") entry pulls in the type of schedule from the week schedule definition (RESET-TEMP).

8. Automatically set air-cooled unitary equipment EIR value:

```
(1/(switch #PA("RTUEER")  
case 1: 13.7  
default: 11.0  
endswitch)-0.012167)/((1/3.413)+0.012167)
```

In this example, a global parameter called RTUEER is used as a switch to activate the use of a different unitary EER value to be used in the unitary EER to condensing section EIR calculation. The switch could be replaced by just using an entered EER value for the global parameter. The approach as shown can be used if a single switch commanding the state of a lot of entries is desired (i.e. 0 for base case, 1 for proposed case).

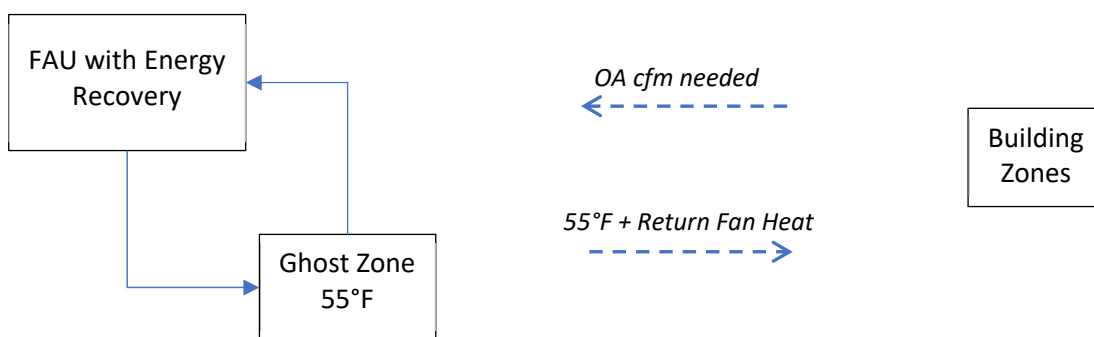
Appendix C: eQuest Workarounds for Unique Systems

While eQuest has evolved to have few bugs, it is hampered to some extent by the DOE 2.2 calculation engine. These shortcomings impact the program's ability to directly model dedicated outdoor air systems (DOAS) with energy recovery, chilled beams, and displacement ventilation. The release of DOE 2.3 and eQuest 3.65 Build 7175 may address some of these shortcomings.

DOAS Modeling Primary Issues

There are several methodologies that can be used to model DOAS within eQuest, and the most common is illustrated in the figure below and referred to as the "OA from System" method. The various zone systems are configured per the design and assigned to receive their outside air from a fresh air unit (FAU).

OA from System Method



The primary issue with this approach arises from the limited amount of information transferred from the zone systems to the FAU system. Only the air temperature downstream of the FAU return fan is conveyed to the zone systems and the only information transmitted upstream from the zones is the design outside air requirement. As a result, the exhaust air temperature handled by the FAU energy recovery section is whatever the ghost zone temperature is plus return fan heat. This essentially removes any ventilation cooling loads and significantly decreases the sensible heat recovery potential during winter operation.

A second issue is associated with the thermal impact ventilation air has on zone loads. Many DOAS provide air to zones with cycling fans, and eQuest only assumes fresh air thermal impacts when the zone fans are operating. There needs to be a method of accounting for what is generally a cooling effect of continuously supplied fresh air from the DOAS.

The basic "OA from System" method requires the following:

- The FAU is recommended to be a packaged VAV system (PVAVS) if the actual design has DX cooling or it can be a variable air volume (VAVS) unit if the FAU is served by a central chilled water plant. Code generally requires these 100% outdoor air units to have energy recovery, and the PVAVS and VAVS system types support this.
- The associated ghost space should have shape 'No Shape' with an area that is 10% of total outdoor air flow and a volume that matches the outdoor air design flow. This approach ensures stable air temperature maintenance that could be compromised if the ghost space is too small.
- The ghost space should not have any heat transfer surfaces or internal heat gain elements. Set internal mass to zero.
- Do not assign any space temperature schedules to the ghost zone.
- Control the DAT from the FAU by setting 'Cool Control' to 'Scheduled' and entering the desired schedule into the 'Min Supply Sch' field. This is the discharge air temperature from the unit downstream of the supply fan.
- Include a hot deck maximum leaving temperature if the FAU has a heating section.
- Set the system cool control range to a low number such as 0.5°R to optimize stability.

- Within the FAU heat recovery tabs, set the make-up air temperature control to 'mixed air reset'.

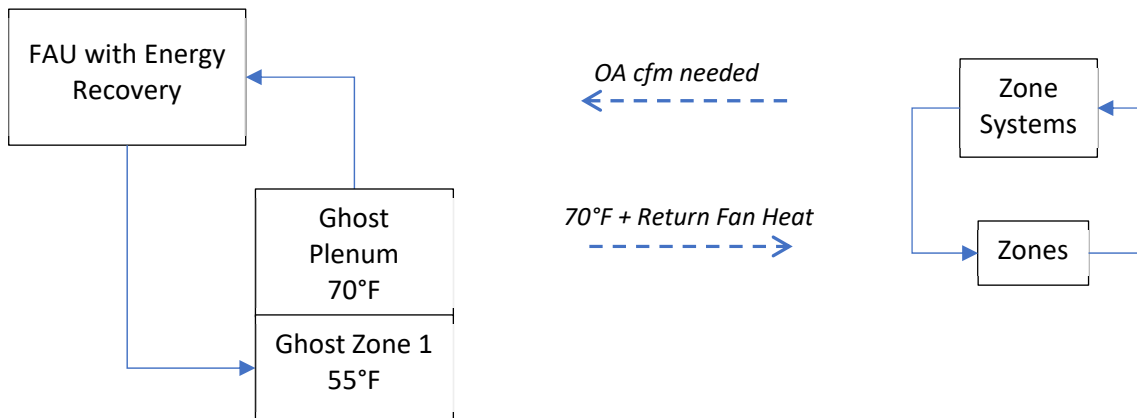
Correction for Exhaust Air Entering the Wheel

The following approach is intended to boost the sensible and latent heat of air entering the exhaust side of the energy recovery wheel.

1. Sensible Temperature Correction

- General hourly reports of space temperatures for a representative sample or all zones served by the DOAS. Process the data using ventilation flow rates to each zone to develop a weighted average space temperature value.
- Create a Temperature schedule to reflect the average zone temperature. This is ideally done via 365 day schedules with the simulation year set to 2018 (non-leap year, day 1 is a Monday).
- Create a ghost plenum space associated with the ghost space and a ghost plenum zone. Assign the return air temperature schedule as the heating schedule.
- Create a ghost electric utility meter if one is not already in the model. Assign the master meter for the ghost plenum zone to the ghost meter.
- Activate baseboard heating for the FAU, set the baseboard capacity to -0.001 for the ghost zone and -999,999,999 for the ghost plenum zone. This will ensure that the return air temperature downstream of the exhaust fan is representative of space conditions.
- If there are exhaust fans in the building that reduce the volume of air returning to the ERU, their impact can be modeled by adding exhaust fans to Ghost Zone 1.

OA from System Method with Ghost Plenum



2. Latent Heat Correction

- Determine the latent heat per person and the peak occupancy in the zones receiving DOAS air. Convert this to an equivalent kW load and assign it to the ghost plenum as a 0% sensible/100% latent equipment load. Apply the occupancy schedule to the load.
- If there are latent loads in the building other than occupancy, do the same to ensure the latent gain is taken into account.
- The latent loads will be placed on the ghost utility meter if the master meter for the ghost plenum zone is set accordingly.

Correction for DOAS Supply Air Temperature

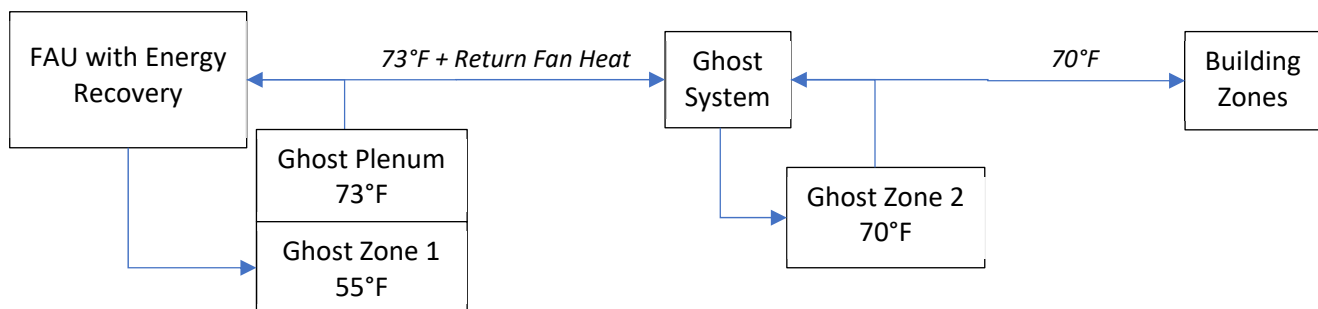
As shown in the two figures above, the air entering building zones from the DOAS is the return air temperature downstream of the exhaust fan. The air needs to be cooled back down to the desired DOAS supply temperature. This work around allows hot gas reheat, wrap-around heat pipes, and other passive reheating strategies to be modeled.

1. Create another ghost zone and a ghost packaged system, place both on the ghost meter
2. Assign the new ghost space the desired discharge air temperature schedule for the ERU. Use the same schedule for heating and cooling and set the zone throttle range and PSZ cool control range to 0.2°F/°R
3. Assign the building zone systems to receive fresh air from the ghost PSZ.

This approach will cool the DOAS air back down from the return air temperature to whatever is desired. Hot gas reheat can be modeled by using different schedules for the FAU cold deck schedule and the PSZ ghost zone temperature schedule.

Since the Ghost PSZ has no return fan, the temperature leaving to the building zones is whatever its ghost zone temperature is.

OA from System Method with Ghost Plenum and Ghost PSZ



The 70°F ghost zone 2 thermostat setpoint may be appropriate for FCU and VRF systems where neutral air is generally provided. For chilled beam systems, the primary air DAT is probably closer to 55°F to reflect dehumidification operation. Smart controls that modulate FAU DAT in response to aggregate building load may require 8,760-hour zone temperature schedules.

Overall, the most rigorous aspect of this workaround is the development of the return air schedules and the FAU coil discharge schedules. These schedules need to be updated as the model develops to ensure accuracy. When considering multiple measures, it is reasonable to use the integrated design modeling run hourly results (all design improvements modeled) to develop the return air schedule.

Chilled Beam Modeling in eQuest

Chilled beams can be classified as active or passive, while active chilled beams can be further broken down as constant or variable volume. Each requires a different strategy to model accurately in eQuest. All three flavors of chilled beams can potentially save energy with passive systems consuming the least and constant-flow active systems using the most. The key variables impacting energy use are associated with central air handling units.

Passive Chilled Beams

Passive chilled beams do not require airflow directly from a central AHU and can be reasonably modeled using the DOAS methodology described in Appendix C and fan coil units with 0 kW/cfm (or 0" w.g.) fan power. Alternatively, FCU fan energy can be logged against a ghost utility meter.

This same approach can potentially be used for chilled ceilings.

Passive chilled beam systems typically require radiant heat, which can be modeled via the FCUs as well. From the standpoint of the DOE2 simulation engine, the most important system characteristic is the transfer of space loads to the heating and cooling systems. Use of FCUs as a stand-in system will probably result in faster response to abrupt changes in loads, such as coming out of unoccupied setback. This seems unlikely to impact overall energy performance of the building model.

Active Chilled Beams

In an active chilled beam system, the amount of cooling or heating that is conveyed to the space is dependent upon how much air from a primary system is being provided. Ventilation rates are likely to exceed the airflow rate required to meet space loads under many circumstances, but not all. Energy savings arise from reducing the volume of air that is passed through the primary air system and reheat is generally eliminated. However, there can be penalties at the primary AHU fan associated with increased pressurization requirements. The system is similar to DOAS/4-pipe FCU and DOAS/VRF systems in many respects. Active chilled beams offer reduced O&M since there are typically no filter changes but they run the risk of condensation problems since there is no provision for drip pans and drains.

Active Chilled Beams: Constant Volume

eQuest is able to model constant volume chilled beam systems using the induction unit (IU) system type. The system is able to model DOAS with energy recovery and appears to be able to account for induction ratio. The downfall of the IU system is that the primary air flow rates to the zones cannot be modulated. If the IU system type is used with a variable flow system, the thermal impact of primary air on zone loads will be over-estimated and will also model return air mixing with outside air at the main AHU.

The DOE2 programming was developed to support simulation of induction systems that were installed in the 1960s and 1970s where there were separate core and perimeter HVAC systems. There are few applications where the IU system would actually match a new design.

Active Chilled Beams: Variable Volume

There are various work-arounds for modeling active chilled beams that vary primary airflow in response to time of day or occupancy. This would be required in laboratories where ventilation is able to be reduced during unoccupied periods and also classrooms, conference rooms, and other spaces that are required by code to have demand controlled ventilation. The approach that follows has been developed to ensure consistency between ventilation airflow rates, the thermal impact of ventilation air, and variations in total static pressure experienced at the central fan systems.

1. Create a DOAS per the methodology described in Appendix C but ensure that the temperature of supply air provided by the system to the building is reasonable (e.g. 55°F all year rather than, say, 70°F).
2. Create an initial VAV system to support the configuration of default values for the following. Using defaults minimizes the amount of data that needs to be entered for multiple similar systems.
 - a. RETURN-AIR-PATH: Direct
 - b. SUPPLY-STATIC: 0.00
 - c. FAN-SCHEDULE: User defined ON/OFF/FLAG schedule with morning startup (-999) for 3 hours prior to actual occupancy.
 - d. NIGHT-CYCLE-CTRL: Always off or Cycle on Any depending on actual project
 - e. OA-FROM-SYSTEM: User defined DOAS system
 - f. OA-CONTROL: Fixed fraction
 - g. CHW-VALVE-TYPE & HW-VALVE-TYPE: Two Way
 - h. CHW-LOOP & HW-LOOP: User defined CHW loop and HW loop names
 - i. COOL-SIZING-RATI: 1.15 (ASHRAE 90.1 Appendix G default) or 1.00 if design values are known

- j. MIN-SUPPLY-T: 62.0°F (or per design; this value needs to be $\geq 6^\circ\text{F}$ warmer than the medium-temperature CHW loop)
 - k. COOL-CONTROL: Warmest
 - l. RESET-PRIORITY: Temperature First
 - m. HEAT-SIZING-RATI: 1.25 (ASHRAE 90.1 Appendix G default) or 1.00 if design values are known
 - n. REHEAT-DELTA-T: 55.0°F (or whatever is intended in the design)
3. Create one VAVS system per zone (most easily done within the INP file).
 4. Create a global parameter called "IR" for the typical chilled beam induction ratio. If a design value is not known, use a default of 3.0.
 5. At the zone level, create the following default for ASSIGNED-FLOW: #L("OUTSIDE-AIR-FLOW") * #PA("IR").
 6. Develop separate MIN-FLOW-SCH for various space types. The schedules should account for any schedule-based ventilation reset or any demand-controlled ventilation strategies (e.g. CO2 sensors, occupancy sensors linked to primary air delivered to zones). This is applied at the zone level and assumes a linear relationship between ventilation rates and zone circulation rates.
 7. The chilled water system needs to be configured with a primary and secondary loop. Configure the design CHW temperature values to match the design. If unknown, use 44°F primary and 55°F secondary. Set the primary system loop design DT to a relatively high value such as 15°F given the difference between secondary return temperature and primary supply temperature. It is likely that the DOAS AHU will be the only load placed directly on the primary loop while all of the chilled beams will be on the secondary loop.

The most arduous aspect of this work-around is the development of individual systems for each chilled beam control zone and the development of the zone minimum flow schedules.

Displacement Ventilation Modeling in eQuest

Most HVAC systems attempt to maintain mixed conditions in the control zones. Displacement ventilation strategies rely upon stratification to deliver cool air at floor level and remove hot air from the top of spaces. If ventilation rates are generally high, the ventilation flow can provide most cooling required to maintain comfort within the occupied portions of a given space. The approach works best where occupants are sedentary for relatively extended periods (e.g. classrooms), there are few internal partitions (e.g. cubicles) and ceiling heights are ≥ 10 ft. Stratification is enhanced and occupant discomfort minimized by introducing air at low velocities and moderately cool temperatures (62°F to 70°F). Fresh air delivery is improved by 20%, which allows ventilation rates to be reduced by 16.7% per ASHRAE 62.1-2010.

Energy savings can result from reduced ventilation rates and warmer AHU cooling coil discharge air temperatures (DATs). The warmer DATs can result in extended hours of economizer operation and may allow central chilled water plants to operate at warmer temperatures. For systems that are able to maintain high outdoor air fractions in the system supply, a great deal of return heat is directly vented from the building.

Energy penalties can arise from the increase in air volumes necessary to provide cooling with warmer DATs. For example, a 65°F DAT would require twice as much airflow as a 55°F DAT to achieve the same cooling effect. The impact can be reduced through oversizing of ductwork.

In New England's climate, supplemental baseboard heating or radiant panels are likely to be required. Zone mixing is a drawback during cooling operation but is beneficial during heating operation. A significant loss of space heat from lighting, occupants, and equipment can lead to increased zone heating during some periods. Use of DAT reset and energy recovery at the main AHUs is important to minimize negative impacts.

Modeling Direction

eQuest assumes that each conditioned zone is perfectly mixed. The challenge is to model the effects of stratification on the zone thermostats while modeling reasonable return air temperatures. The following approach is recommended:

1. Configure the model with spaces and associated plenums.
2. Assign the same occupancy, lighting, and equipment load factors and schedules to both the occupied spaces and the plenums.
3. Multiply the occupied space sensible and latent load factors (Btu/h-person) by 29.5%. Multiply the load factors in the plenum spaces by $100\% - 29.5\% = 70.5\%$. These scaling values are taken from ASHRAE RP-949. The factors are applied to the sensible and latent load fractions to allow DCV calcs to operate correctly.
4. Use equipment power demand scaling factors of 29.5% in occupied spaces and 70.5% in the associated plenum spaces.
5. Use lighting power demand scaling factors of 13.2% in occupied spaces and 86.8% in the associated plenum spaces.
6. Configure HVAC controls to reflect the intended sequences.

The methodology does not call for the exterior walls and fenestration to be divided between occupied and plenum spaces since code minimum opaque envelope requirements diminish the impact of conductive heat transfer and since most solar heat gain is transmitted by radiation that falls on objects in the occupied zone.

The thermal impact of ventilation air on zone load should be imparted entirely to the occupied space.

Appendix D: Guidelines for New Construction Projects with CHP

When CHP is incorporated in the design of a new building, extra care should be taken to develop savings calculations methodology when using modeling tools like eQuest as there are interactions between several energy efficiency (EE) measures. If EE measures are not analyzed in the proper order in a whole building, interactive analysis, the resulting whole building savings may be accurate, but measure-level savings may not be. The inaccuracies in the measure level savings may significantly distort the value of the measures, misleading the customer about the value/payback of the design improvement. This can be problematic for evaluation as well as the customer.

Example: A building with the following measures is proposed for a whole building analysis. The sequence of operations states that CHP will satisfy the thermal needs of domestic hot water (DHW), heating hot water (HHW), and the hot water absorption chiller before the boilers and electric chillers are dispatched. The EE measures are analyzed as follows:

- ECM 1: Improved Building Envelope
- ECM 2: High Efficiency Lighting
- ECM 3: Ventilation Load Reduction (improved heat recovery and DCV)
- ECM 4: High Efficiency Chillers
- ECM 5: HW Pump VFDs
- ECM 6: Condensing Boilers
- ECM 7: Condensing DW Heaters
- ECM 8: CHP with Absorption Chiller

If the analysis is structured incrementally, savings for some measures may be misrepresented due to the effect of CHP for the following reasons:

- The CHP will displace some or all of the heating, cooling, and DW heating loads at different parts of the year since CHP is the first stage of heating and cooling. There is unlikely to be much value in optimizing the secondary sources of heating and cooling due to limited annual loads. The customer should save their money and invest in higher efficiency CHP systems rather than spend it on better chillers, boilers, and water heaters.
- The CHP system output is required to follow the thermal load, and the potentially net negative effect of central plant optimization on electricity production will not be taken into account when evaluating these design upgrades.

The following general guidelines shall be used when determining the order of energy efficiency measures:

1. Determine that solar-source inputs to the building are used preferentially before any other thermal or electricity source.
2. Determine the minimum power import imposed by interconnection agreements with the local electric utility.
3. Determine that the CHP installation is the first stage of heating (or cooling if an absorption chiller is proposed).
4. Optimize envelope performance
5. Optimize internal gains (e.g. lighting)
6. Optimize HVAC loads (e.g. energy recovery, DCV)
7. Optimize HVAC performance via VFDs
8. Account for solar thermal or solar photovoltaic impacts if PV is proposed
9. Perform savings analysis for the CHP system assuming thermally following control and hourly electricity production limits.
10. Assess savings for optimizing DHW equipment using the remaining DHW load.

11. Assess savings for optimizing HHW equipment using the remaining HHW load.
12. Assess savings associated with optimizing chillers based on the remaining CHW load.

Provide hourly trend data for the analysis year (8,760 hrs) in Excel format for total building power demand (kW), CHP output (kW, Btu/h), PV output (kW), solar thermal output (Btu/h), CHP fuel use, absorption cooling tons produced, and parasitic loads. Calculate the hourly and total annual average electrical, thermal, and total system efficiencies.

If a photovoltaic (PV) system is part of the initial buildout of the proposed building, modeling of the PV output should be performed in eQuest or as an on-site generation source using an 8,760-hr schedule with input values developed from a different PV modeling source. If CHP production is constrained by electrical power demand and export from the site is not possible, PV output will impact the output from the CHP system.

Appendix E: Guidelines for Core & Shell Buildings

Incentivizing core & shell building is difficult since tenant activities and design choices can significantly impact loads on core building systems. Core & shell labs are a particularly difficult situation. This guideline is developed to provide consistency across projects and to define a methodology that will bracket the likely range of savings that can be expected.

There are five primary sources of uncertainty in core & shell studies:

- Tenant buildout schedules
- Tenant plug and lighting load intensities
- Tenant process ventilation requirements, primarily applies to labs
- Tenant space type distribution and zoning
- Tenant zone system selections

Taking each factor in turn:

1. Tenant buildout schedules may or may not be known. The core & shell model shall assume full tenant occupancy with the target tenant type mix estimated by the owner at the time of final design.
 - a. The modeling report shall include a clearly labeled description of the tenant buildout schedule and tenant type mix as it is understood at the time of the release of the final modeling report.
2. Tenant plug and lighting load intensities drive interior heat gain and overall facility energy use more than any other two end use categories.
 - a. Plug load and lighting intensities used for sizing tenant space conditioning equipment shall be based on the same W/ft² basis used by the HVAC design engineer.
 - b. Lighting power densities used by the design engineer should reflect the maximum allowable LPDs under the code that will govern tenant fitouts. Lighting schedules should assume a value of 1.0 corresponds to the HVAC designer's peak power lighting power density (W/ft²) and all fixtures being active. If the LPDs are based on code, then this approach prevents double-claiming of energy savings should the tenant optimize their lighting design and apply for incentives through a separate application.
 - c. Plug load schedules should assume the design power densities (W/ft²) correspond to a diversity of 1.0. Actual hourly diversity values should be scaled down by the the ratio of actual likely future plug load density to sizing plug load density. This is intended to more accurately capture the tendency for core & shell projects to oversize cooling capacities.
 - i. As an example, a common power density allowance in core & shell office construction is 2.0 W/ft² while a typical office is likely to have full-occupancy power densities closer to 1.5 W/ft². The scaling factor in this case would be $1.5 \div 2.0 = 75\%$. This scaling factor would be applied to all of the hourly load diversities appearing in Appendix A Table O.1.
 - ii. Actual peak power density assumptions can be set at the discretion of the energy modeler but should be substantiated in the report text by stating the assumed maximum occupant density (ft²/occ) and a power demand budget per person (e.g. ASHRAE's estimate of 115 W/occ having a desktop computer and two monitors).
3. Process ventilation loads installed to support tenant activities are generally limited to lab spaces but could also be required for large printing operations in offices. Lab exhaust rates are dominated by background occupied and unoccupied air change requirements, though it is possible for zones with high concentrations of fume hoods

and/or bio safety cabinets to elevate the overall process ventilation rate. The simulation shall assume the following:

- a. For spaces that are to be classified as 'lab' tenants, the tenant space shall be broken into the following space types and distribution.

Space Type	Perimeter	Core
Non-Lab Circulation	0%	15%
Conference Rooms	5%	5%
Laboratories	Distribute 45% of tenant area in contiguous core and perimeter spaces.	
Offices	Distribute 25% of tenant area in contiguous core and perimeter spaces.	
Storage & Support	0%	5%

- b. The spaces with process ventilation shall be limited to the laboratory areas. Other areas shall be considered to have standard commercial HVAC characteristics.
- c. Laboratory ventilation rates shall be assumed to have space ventilation air change rate setback during scheduled unoccupied periods per the schedules in Appendix A for laboratories.
 - i. If no other information is available regarding the characteristics of tenant ventilation requirements, assume 6 ACH during occupied periods and 4 ACH during unoccupied periods.
 - ii. The model shall assume that hood operation does not drive ventilation rates. This will result in lower overall ventilation rates and less aggressive savings for optimization of the core building systems.
- 4. Tenant space type distribution concerns the mix of potential tenant areas in a typical floor. It is unreasonable to assume 100% office-type occupancy given the need for conference, break, storage, and support spaces. This will impact the lighting and plug loads as well as ventilation rates given the requirement for DCV in conference rooms.
 - a. Core spaces for stairs, restrooms, voids, and support rooms included in the core & shell design scope shall be modeled as designed. Multiple similar spaces can be bundled together as an equivalent zone representing the total floor area for that particular space type.
 - b. Tenant spaces shall assume 15 ft deep perimeter zones with separate zones located at corners and along each perimeter.
 - c. Walls in perimeter zones are to be modeled to support daylighting calculations (floor, ceiling, exterior and interior vertical walls).
 - d. Perimeter zones are to be modeled as being separated from interior zones with wall assemblies consisting of 5/8" gypsum drywall, thermally bridged batt insulation, and 5/8" gypsum drywall. The overall assembly U-value shall be U-0.115 Btu/h-ft²·°F (R-8.7)¹

¹ Based on ASHRAE 90.1-2013 Table A3.3.3.1 for 16" o.c. steel stud walls with R-11 infill batt (U-0.132 Btu/h-ft²·°F) and R-0.56 for each layer of drywall



- e. For spaces that are to be classified as ‘office’ tenants, the tenant space shall be broken into the following space types and distribution. Office spaces shall be modeled as ‘open office’.

Space Type	Perimeter	Core
Break Room	0%	3%
Circulation	0%	10%
Conference Rooms	10%	10%
Offices	Distribute 60% of tenant area between core and perimeter spaces.	
Storage & Support	0%	7%

For lab tenants, see the previous table for tenant space use distribution.

- 5. Tenant zone system type can be defined either by the core & shell design or left to the tenants. If the core building design does not include installation of floor-by-floor AHUs, the core & shell energy model shall assume the type of HVAC system that the core building systems are design to support.
 - a. As an example, a core design that provides fresh air, hot water, and chilled water could potentially be used to support 4-pipe FCUs, chilled beams with reheat, or tenant-installed VAV systems. The modeling report shall include a description of the design intent and any limitations that constrain tenant HVAC system options.
 - b. Savings for the core & shell project shall not be claimed for changing tenant level system type.