HOURLY SIMULATION GUIDELINES

Version 2.2: August 2017

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.

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/DOE2.2 is currently the favored simulation package due to its widespread use in southeastern New England and fast run times. This program 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 that have been developed by the PAs and TA vendors providing most simulation services.
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.

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 2015 or ASHRAE 90.1-2013 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. The Massachusetts PAs and state regulators have agreed that baseline lighting power densities (LPDs) are to be defined solely by IECC 2015 C406.3. Thus, baseline LPDs for all studies are to be taken from IECC 2015 Table C405.4.2(2) and reduced by 10% regardless of compliance path.

D. For projects following IECC permitting, savings can be claimed for the use of C406 options other than the reduced lighting power density option (C406.3).

E. The Massachusetts stretch energy code (780 CMR Appendix 115 AA) does not impact baseline assumptions in studies for facilities located in Stretch Code communities.

F. 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.

G. ASHRAE 90.1 Appendix G is not an accepted baseline.

H. 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.

I. 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 2015 Table C402.1.4 and ASHRAE 90.1-2013 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. Infiltration modeling strategy, peak flow basis, and schedules (no savings for reduced infiltration)
11. Design ventilation rates at zone level[1]
12. Space temperature schedules (changes permitted to model unique control sequences)
13. DHW fuel type
14. 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

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

model account for every end use consuming electrical power to ensure accurate predictions of demand costs.

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 there is exposure to an exterior surface.

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. 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 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. The impact of occupancy sensor control shall be captured by applying a 10% reduction in LPD (applicable to baseline and proposed case models).

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 component improvements (e.g. efficient chillers)
6. HVAC control improvements (e.g. DCV)
7. 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.

Y. New Buildings with Combined Heat and Power (CHP) shall simulate individual measures in a sequence dictated by other Mass Save guidance specific to CHP projects.

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 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 is no tenant designs, adhere to the following for tenant spaces:

   1. 15 ft deep perimeter zones consisting of open office space separated from interior spaces by solid walls. The use of solid walls is considered to be more conservative from the standpoint of energy use relative to the use of air walls.

   2. Two core zones with 25% of tenant floor area devoted to conference rooms and the remainder to open office.

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 A provides sample diversity schedules for offices and schools. 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.

F. 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.

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. While post processing requires hourly reports, it allows the holiday schedule to be something other than the seven ISO-NE holidays.

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 2015 Table C402.1.4 and ASHRAE 90.1-2013 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 an update in 2016[2]. 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 reference 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. 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.

B. 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.

C. 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/ft^2) to arrive at the peak infiltration rate. This rate is then varied by an optional schedule (assumed

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

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 2015 C402.5 and ASHRAE 90.1-2013 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:

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

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/ft²	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, ft²	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:

((Parent("Z") - 0) + 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:

   Avg Ground Temp, °F = %P * Weather File Ground Temp + (100% - %P) * (Avg Space Temp – 2°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.

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

A. Baseline maximum allowable WWR is 40% for buildings pursuing code compliance via ASHRAE 90.1-2013. The baseline for buildings following IECC 2015 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.

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.

```
(#L("HEIGHT")+#L("WIDTH")) / -4 + (SQRT(%V) / (4 * %V)) *
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 if 1) design information is available and 2) there is not an ECM being considered that could potentially impact zone airflow sizing. Baseline zone circulation rates shall generally match design case.

D. If autosizing is to be used to quantify how an ECM impacts zone circulation flow rates, steps need to be taken to ensure the baseline sizing is developed on a similar basis as the proposed case. Study documentation shall include a description of what methodology is used.

E. 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.

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.

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 D provides background and a potential work-around methodology. Reporting can be streamlined by using this work-around and referencing it in the study report.

D. eQuest 3.65/DOE 2.2 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 E 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 90.1-2013 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 = $(7.84 \times 10^{-8} * EER * Cap_{CoolBtu} + 0.338 * EER) \div 3.412$ kBtu/kW
- Cooling COP = $(0.0076 * SEER^2 + 0.3796 * SEER) \div 3.412$ 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 other Mass Save direction regarding the sequencing of ECMs in new construction projects that include CHP. Standard heating 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 DOE2.2's inability to log thermal impact of ventilation air when the zone fan is not active. Work-arounds are 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 2.2'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:

      Peak DOAS Thermal Load, Btu/h = Zone Ventilation cfm * 1.08 * Max Temp Differential, °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.

<u>D.1 Plumbing: Service Water Temperatures</u>

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

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 2015 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.

B. 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 90.1-2013 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 when lighting takeoffs are being compiled. Hourly daylighting response is to be calculated by the simulation program.

D. Glare control direction indicators 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 ≤50% of code.

   6. Apply these task tuning control factors in addition to any control factors for occupancy sensors.

<u>F.1 Process: General Equipment Loads & Diversities</u>

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.

   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.

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.

<u>F.2 Process: Elevators</u>

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 by day and facility type are provided for offices and schools in Appendix A.

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 90.1-2013 Table 6.8.1-12 (Commercial Refrigerator and Freezers) and Table 6.8.1-13 (Commercial Refrigeration). Identical tables are included in IECC 2015 (Table C403.2.14(1) and C403.2.14(2). For systems with remote condensers that reject heat to ambient, the energy use of the system shall have 0% sensible and 0% latent loads.

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

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 M-F	Occupancy Sat	Occupancy Sun	Lighting M-F	Lighting Sat	Lighting Sun	Plug Loads M-F	Plug Loads Sat	Plug Loads 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 M-F	Occupancy Sat	Occupancy Sun	Lighting M-F	Lighting Sat	Lighting Sun	Plug Loads M-F	Plug Loads Sat	Plug Loads 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	Corridors			Stairs	Stairways w OS*			Restrooms			Support	
End	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 2015 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/ft²
100%	0%	0	167 ft²	10	Yes	0.25
100%	0%	0	125 ft²	10	Yes	0.33
50%	50%	1	167 ft²	10	Yes	0.40
50%	50%	1	125 ft²	10	Yes	0.50
0%	100%	1	167 ft²	10	Yes	0.60
0%	100%	1	125 ft²	10	Yes	0.80
0%	100%	2	125 ft²	10	Yes	1.00
0%	100%	2	85 ft²	8	Yes	1.50
0%	100%	2	85 ft²	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 baed 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	Occupancy		Lighting		Plug Loads	
End	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	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	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	Occupancy		Lighting		Plug Loads	
End	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	Occupancy		Lighting		Gas Cooking		Electric Cooking		Electric Servery		Refrigeration		Dishwash	
End	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 2015 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/ft^2 on 24/7 for corridors, stairs, and most support spaces
IDF/MDF rooms: 4.0 W/ft^2 on 24/7
Electrical closets: 0.5 W/ft^2 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	Occupancy		Lighting		Plug Loads	
End	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	Occupancy		Lighting		Plug Loads	
End	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	Occupancy			Lighting			Plug Loads		
End	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%

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

Source: TNZ

Table H.12

AUDITORIUM - Summer & Break Periods

Hour	Occupancy			Lighting			Plug Loads		
End	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%

Source: TNZ

Table H.13

COMMON SPACE LIGHTING

Hour	Corridors		Stairs	Stairways w OS*		Restrooms		Support Spaces	
End	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 facto

Source: TNZ

Table H.14

COMMON SPACE LIGHTING - Summer & Break Periods

Hour	Corridors		Stairs	Stairways w OS*		Restrooms		Support Spaces	
End	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 f

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%	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%	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 2015 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.

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/ft^2. Both the floor area and the number of people are from the loads side of the program and require the use of #LR.

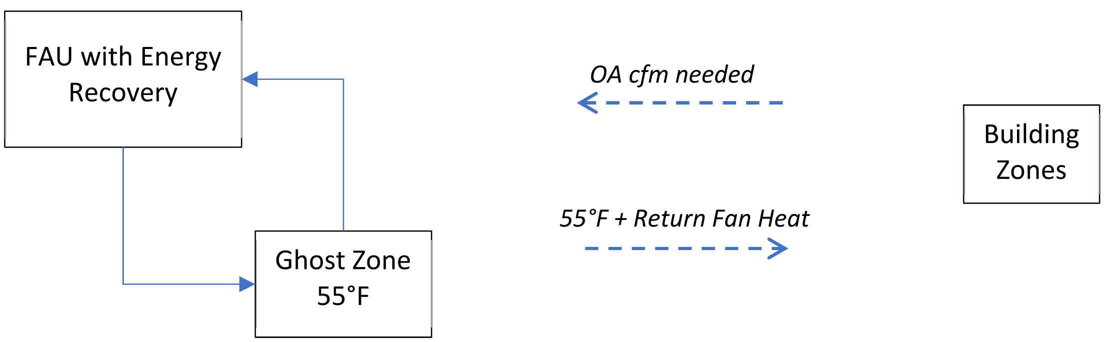
Appendix C: DOAS Modeling in eQuest

While eQuest has evolved to have few bugs, it is hampered to some extent by the DOE 2.2 calculation engine. One of these shortcomings impacts the program's ability to directly model dedicated outdoor air systems (DOAS) with energy recovery.

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:

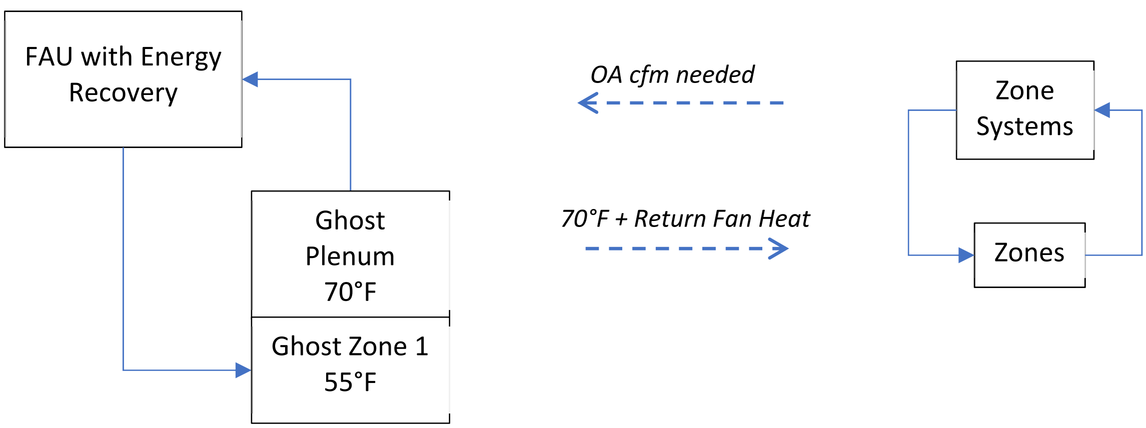
- The FAU is recommended to be a packaged VAV system (PVAVS) if the actual design has DX cooling or it can be a variable air volume (VAVS) unit if the FAU is served by a central chilled water plant. Code generally requires these 100% outdoor air units to have energy recovery, and the PVAVS and VAVS system 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
    a. 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.
    b. 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).
    c. 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.
    d. 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.
    e. 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.
    f. 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
    a. 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.
    b. If there are latent loads in the building other than occupancy, do the same to ensure the latent gain is taken into account.
    c. 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

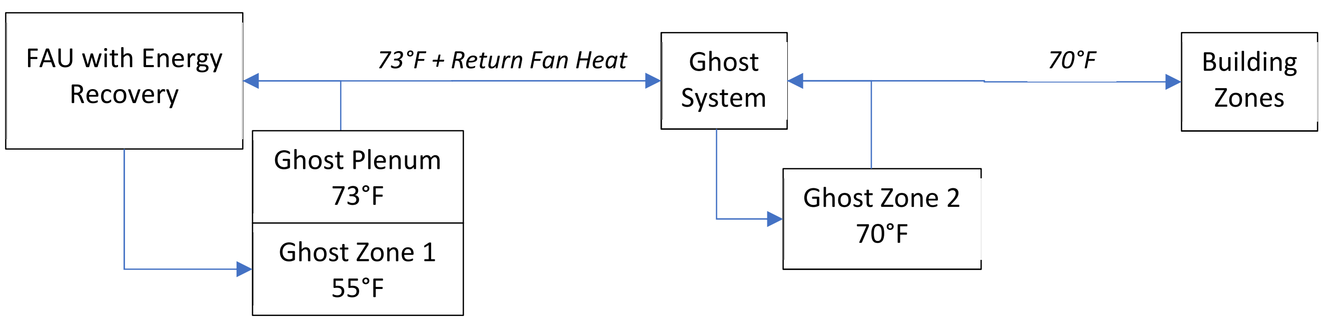
As shown in the two figures above, the air entering building zones from the DOAS is the return air temperature downstream of the exhaust fan. The air needs to be cooled back down to the desired DOAS supply temperature. This work around allows hot gas reheat, wrap-around heat pipes, and other passive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

Appendix D: 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 ≥6°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.

Appendix E: 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.

Technical Review Guide

This guide is intended to help PA technical reviewers assess the technical quality of models. The work flow is broken into three phases: Report Review, General Model Review, and Detailed Modeling Review. It is likely that PA technical reviewers will typically only perform the report and general model review steps. The detailed review may be warranted for complex projects. This guide is likely to be useful to TAs as a quality control check.

	Line	Parameter	Comments
Report Review	1.	Study report includes all important attributes of the current report template.	
	2.	The summary table at the start of the report clearly indicates utility use, cost, and EUI for baseline and proposed cases, the EUI for each, and the % savings for site energy use and energy cost.	This table is important for the customer as well as PAs
	3.	Facility EUI for base and proposed case models is reasonable. These values are required to be included in the study report.	Unexpectedly high or low EUIs suggest modeling issues or lack of a complete modeling effort.
	4.	The % change in site energy use and cost seems reasonable for the types of measures under consideration.	This is a subjective check that can raise concern if values seem too high or low.
	5.	ECMs have been modeled separately per the study proposal or subsequent agreement.	Modeling of ECMs separately supports the tech review process.
	6.	ECMs have been staged incrementally per the study proposal or subsequent agreement.	
	7.	The ECM summary table lists utility savings, value of savings, incremental cost, and simple payback period. Check that values seem reasonable.	This is a subjective check that can raise concern if values seem too high or low.
	8.	Utility rates are within reason and consistent throughout the study.	
	9.	The facility description provides enough description to allow the reviewer to understand its size, use, patterns of operation, major envelope, HVAC, DHW, lighting, and process systems.	A poor facility description should raise suspicion of poor modeling.
	10.	Each ECM is explained in detail, including how the measure is expected to save and lose energy, the rationale for the base case, what model inputs are changed to simulate the proposed case, the basis of the cost estimate, output plots and tables that support technical review, and an explanation for what factors in the model lead to the apparent system response illustrated in the plots.	Plots showing the distribution of energy impacts by month and end use group are extremely helpful and should be required.
	11.	Energy penalties are to be expected with certain ECMs; ensure they are represented and reasonable.	Condensing boilers have a pump and burner electric penalty, lighting optimization can have heating penalties, etc.

	Line	Parameter	Comments
Report Review	12.	Screening input values match values listed in the main report and in post-processing spreadsheets.	Mistakes can understandably occur but need to be addressed before release to the customer.
	13.	The MRD contains enough detail to reasonably direct the installation/design team or owner to ensure adequate compliance and ensure energy savings are achieved.	Ensures the basic function of the MRD is met.
	14.	The MRD contains details that are relatively easy for post-installation inspectors to check.	Ensures the basic function of the MRD is met.
	15.	The basis of cost estimation is documented and values seem within reason.	The degree of rigor is at the discretion of the PA.
	16.	Input data for the model is provided in an appendix, including: • 3D images that allow all sides of the building to be seen. • 2D images of floor plates allowing zoning to be seen. • Envelope input development: assembly U-values • Fenestration input development: U-values, SHGC • Daily scheduling information, tabular or in plots • Peak load factors (occ, lights, plugs, infiltration) • Development of zone ventilation & circulation rates • Development of HVAC equipment inputs	This information can reduce the amount of writing in the text and can be print-outs of the TA's model input development spreadsheets. Clear organization of these spreadsheets can save a great deal of time when reporting. The PA tech reviewer should reference this information when reviewing model inputs for consistency.
	17.	Check opaque envelope U-value development for impact of thermal bridging.	
	18.	Supplemental information is provided describing work-around methodologies.	TAs can create narratives for common work-around methodologies to include in reports.
	19.	Post-processing spreadsheets for each modeling run indicate annual energy use for each end use group, facility EUI, and electricity peak period results.	This is the basis of savings.
	20.	Output spreadsheet savings calculations indicate the percent change in site energy consumption and cost for each end use group and for the facility overall.	These are the results.
	21.	Check that post-processing spreadsheet values match the annual energy use indicated in the model output reports (e.g. ES-D or PS-F reports in eQuest, excluding ghost meters).	Version confusion can occur but needs to be resolved before release to the customer.
General Modeling Review	22.	Hours out of range (eQuest BEPU/BEPS reports) <150 hrs for all modeling runs. High hours could potentially be acceptable provided that an explanation is provided by the modeler.	High hours out of range values suggests that space conditioning loads may not be adequately met in the model.
	23.	Model can be opened on your computer without any error messages. Have the TA determine whether any BDL load warnings are likely to impact model quality.	This ensures that the model does not have any significant flaws. Functioning models will be required by evaluation.
	24.	Parametric tools are used to iteratively run each ECM. The number of separate models are minimized as much as possible.	This ensures as little disjunction as possible between separate modeling runs.

	Line	Parameter	Comments
General Modeling Review	25.	Run ExamDiff or a similar text analysis tool to review differences between successive model iterations. Identified differences should match the methodologies described in the modeling report. Value inputs should match values included in the input development spreadsheets provided in the report.	ExamDiff does not always catch every difference, and multiple comparison runs may be necessary.
	26.	The weather file used in the simulations is appropriate for the site and matches descriptions in the report.	
	27.	Review the zoning layout for the model to confirm 1) a realistic pattern typical for the building's use, or 2) if drawings are available that the layout matches the design.	Zoning can have a significant impact on model performance.
	28.	Check to see that unique equipment loads are reasonably represented in the model. Examples include elevators, food service, IT/server rooms, laundry, refrigeration, compressed air, process cooling, and manufacturing equipment.	These loads can significantly impact the reported % impact on future facility energy use and need to be included regardless of whether they directly interact with a studied ECM.
	29.	Review the method of assigning ventilation airflow rates to confirm that this entry is made at the zone level and that the values are reasonable. In eQuest, look at the Air-side HVAC tab, Summary view to see the OSA cfm/sf values.	Ventilation rates typically range between 0.08 cfm/ft^2 to 0.15 cfm/ft^2 for regularly occupied commercial spaces.
	30.	Review the design circulation flow rates for reasonableness. In eQuest, look at the Air-side HVAC tab, Summary view to determine if the Supply cfm/sf values are reasonable for the type of HVAC system.	Systems using air for all cooling generally range between 0.7 cfm/ft^2 and 0.8 cfm/ft^2 for typical new office space. Older buildings may be around 1.0 cfm/ft^2. Circulation and less densely loaded spaces may be as low as 0.3 cfm/ft^2.
	31.	Review the minimum flow turndown of zone circulation airflow. In eQuest, look at the Air-side HVAC tab, Summary view to determine if the Min Flow values are reasonable.	Reheat in VAV systems is heavily impacted by this value. Code requires it to be ≤30%.
	32.	Review the use of default equipment curves that relate performance to part load ratio (PLR). Defaults may be acceptable in some cases. The study report should describe whether defaults or modified curves are used.	Day-to-day performance of equipment is driven by operation at partial loading. Default curves may not accurately represent baseline minimum IEER or IPLV requirements or the part-load performance of the proposed equipment.
	33.	Review DHW loop loads and method of sizing water heater equipment. Loads should include all restroom, food service, and other uses.	Loads should follow a predictable pattern relative to end use equipment in the design. Water heater standby losses can be unrealistically high when systems are autosized.

	Line	Parameter	Comments
Detailed Modeling Review	34.	For projects that use complex work-arounds involving 8,760-hour schedules, ensure that the simulation year is 2018.	2018 is a non-leap year that starts on a Monday and is necessary to ensure the hourly schedules feed into the model as expected.
	35.	Review building orientation via the 3D view. It should be consistent with design drawings.	This primarily impacts solar loading.
	36.	Check the ground temperatures used in the model on the Project & Site tab, Site-Parameters item in the component tree. No entries indicate use of weather file defaults.	The impact of ground coupling varies greatly by project. Basement areas can drive air system cycling and impact DAT reset sequences.
	37.	Check that heat exchange with the ground has been modeled. In eQuest, select an underground wall from the component tree and click on spreadsheet view. Sort by 'Location' and review constructions.	Losses to the ground can impact the operation of central air systems.
	38.	Check that infiltration has been modeled. In eQuest, select a space from the component tree, click on spreadsheet view, and select Display Mode: Infiltration. Review the method used and associated inputs.	Infiltration is generally not a significant load for the building as a whole but can result in high energy use in heated vestibules (e.g. electric CUHs).
	39.	Check that interior walls are modeled as needed to support daylighting and that air walls are included where necessary. In eQuest, select an interior wall from the component tree, click spreadsheet view, and sort by construction type.	Air walls help dilute space loads and can have a significant impact on energy use as well as the number of hours out of range. Pay attention to tall spaces modeled with multiple zones.
	40.	Check exterior wall and window construction assignments in eQuest by going to the 3D view, right clicking, and changing the default 'by type' to 'by construction'. Orbit by holding CTRL and left-click drag. Note any inconsistent assignments or missing surfaces.	This is a quick and easy way to review exterior construction assignments.
	41.	Check local shading using the approach listed above.	Local shading should be included in the model.
	42.	Review the activity types assigned to each zone either through BDL activity codes or schedule/load descriptions.	The variety of activity/schedule types should be appropriate for the building.
	43.	Identify the most common activity types and review their occupancy, lighting, and plug load schedules for consistency.	Be sure the loads vary with one another by day and also by day of week.

	Line	Parameter	Comments
Detailed Modeling Review	44.	Review HVAC schedules to confirm that the HVAC systems reasonably track occupancy for the spaces that are served.	High hours out of range can occur when these schedules do not agree.
	45.	For educational facilities, ensure the impact of breaks and special sessions is taken into account.	Break periods can significantly reduce run hours in some facilities.
	46.	Review peak load assumptions for occupancy, lighting, and plug loads; verify consistency with the input development spreadsheets included in the report.	Peak values should be different for various space use types. Use of whole-building values is unacceptable.
	47.	Check how pump power demand is being calculated. Two options are 1) hard coded kW input or 2) let the model calculate kW based on head and efficiencies. Using neither approach enables full autosizing, which may not provide a realistic prediction of power demand. Over-constraining pump inputs can lead to warnings.	Pump energy use can be significant in some commercial buildings. The second approach is reasonable if hydronic loop sizing is based on the capacity of primary equipment rather than secondary loads.
	48.	Check that HW supply temperature reset schedules vary as expected and that non-condensing baselines reset between 180°F and 150°F.	Pump penalties need to be included when evaluating condensing boiler measures.
	49.	For chilled water plants, check that the minimum temperature listed on the chiller condenser tab is reasonable and compliant with the current baseline document.	This value can have a large impact on part-load chiller performance.
	50.	Review the use of sizing factors on airside systems.	If autosized equipment needs to have greater capacity to address hours out of range, the minimum airflow rate (cfm/ft²) should be changed at the zone level rather than scaling all system capacities upwards.
	51.	Check the thermostat throttle ranges at the zone level, default values are likely the most accurate.	Ensure that these values have not been unreasonably increased in an attempt to address hours out of bounds.
	52.	Check to see that baseboard heat has not been included as a way to address hours out of bounds.	In some cases this may be acceptable, but generally baseboard should not be included if it is not part of the baseline or proposed design.
	53.	Confirm that the type of economizer control and limits are appropriate for the project.	

	Line	Parameter	Comments
Detailed Modeling Review	54.	Check that baseline fan power is calculated using code maximum bhp limits and that the total fan fan power budget is reasonably distributed among supply, return, and exhaust fans.	This is most easily checked in the study supporting information where input assumptions are developed. All fan power can be carried on the supply fan if no other fans are modeled.
	55.	For DOAS systems, ensure that the impact of DCV is properly communicated to the ERU.	Plots in the study report can help reduce review discussion time.
	56.	For projects that use ghost meters as part of complex work-arounds, review system and zone meters as well as primary equipment meter assignments to ensure that energy use is being accounted for properly.	It is possible to accidentally not count energy that should be reported.
	57.	For projects that differentiate between landlord and tenant meters, ensure that end uses are properly assigned to the correct meters.	Post-processing spreadsheets should report the landlord and tenant energy use separately.