

# eQuest MODELING GUIDE FOR EXISTING BUILDING ELECTRIFICATION

Revised 7/6/2023

ASHRAE 90.1-2010 & 2020 NYCECC eQuest Templates

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# 1 Purpose

The purpose of this guide is to describe the specific modeling requirements for New York City School Construction Authority (SCA) projects where an existing School building is being retrofitted from older HVAC systems to new, fully electric designs. This guidance is designed to supplement the “eQuest How-to Guide for SCA Energy Models”, which describes the modeling guidelines for new construction buildings.

This guide should be used in conjunction with the “eQuest Input Summary for Energy Models” (referred to as the SCA Input Summary) and the “eQuest How-to Guide for SCA Energy Models” (referred to as the SCA How-to guide), which contain the guidance on inputs for new construction school projects. All values may be updated as the Energy Code and Local Laws change, and as new HVAC systems are considered by the SCA.

While this guide provides sample inputs for common existing building features such as envelope, internal loads and HVAC systems, these should not be considered as mandatory and may not be appropriate for every existing building scenario. Project documents, such as drawings, ASHRAE Level II or III audit reports or field observations should be used to inform the energy model inputs. Project specific documents should supersede any inputs from this guideline that may be deemed inappropriate for the project. The sample inputs provided in this document do not cover all possible existing building types, as the existing stock of SCA schools varies, has unique histories and has been built over a long span of time, following a wide array of design requirements and constraints.

The following hierarchy should be applied to the available data:

1. ASHRAE audit reports or site conditions assessment reports
2. As-built conditions drawings
3. Default assumptions from the modeling guidelines

As a general rule, since a drawing set is usually assembled before a building is constructed, and the project will aim to evaluate the building after it has been operated for a significant number of years, documented field conditions, when available, must take precedence over the rated performance described in design documents.

# 2 Definitions

*Proposed Design* - The model of the building based on the design documents

*Existing Building* - The model of the building before any retrofitting.

*ECM* – Energy conservation measure. A proposed design feature generally aiming to reduce the energy use in the final design. However, due to the nature of renovation projects, some aspects of the proposed design may aim to increase the building occupants comfort, or improve the air quality at the expense of increased energy usage. Therefore, an ECM may end up resulting in an increased energy use, contrary to its name.

*NYCECC 2020 Baseline* -- The baseline described by the Energy Cost Budget Method (Section 11) of ASHRAE 90.1-2016 with amendments per Appendix CA of the 2020 New York City Energy Conservation Code.

*GSG Baseline* -- the baseline described by the Performance Rating Method (Appendix G) of ASHRAE 90.1-2010.

*Ribbon* – Major dialog box that contains multiple sub-tabs. Divides the data input into major disciplines.

*Default Value* – A value assumed by the modeling software to operate. Does not require user input. Shows up as “green” in the dialog box in eQuest.

*SCA Input Summary* – Shorthand notation for the “eQuest Input Summary for Energy Models”, which is a report defining all major input values for a typical SCA building model.

*Work Around* – Non-standard modeling approach to approximate systems or equipment which cannot be directly modeled in the software package.

### 3 General Modeling Methodology

Prior to the start of energy modeling, the scope and funding of the renovation should be discussed with the design team. Different building components (walls, windows, lighting, air-side HVAC, boilers, etc.) may be replaced at different times, or may be funded by different agencies (SCA, DCAS). The energy model for the proposed design should separate the various building components into separate ECMs.

ECMs must be evaluated in the energy model report as follows:

1. Identify all areas where the proposed design differs from the existing building baseline.
2. Mark the differences that are modeled as ECMs with an ECM number in the energy model report.
3. Model each ECM in the simulation tool using the stacked approach as described in this section.
4. Report each ECM savings in the energy model report as a separate line item.

The energy impact of each difference between the existing building baseline and the proposed design must be captured only once to avoid double-counting savings.

#### 3.1 Energy modeling software

The intended choice of energy modeling software is the DOE 2.2 simulation engine. This is for the following reasons:

- Backward comparability of the energy modeling results with previously completed projects.
- Avoiding unnecessary time being spent debugging by the energy modeling team.

While the DOE 2.3 engine exists (available as a version of eQuest or stand-alone), it is not a finished product, containing numerous bugs and incomplete features. It is not backwards compatible with DOE 2.2, so downgrading to it requires rebuilding the entire energy model.

## 3.2 Weather file

The weather file used for a specific run should be closely reviewed. If the existing building baseline is required to match historic utility bills (per the procedure in section 10), a historical year weather file containing measured data should be used for that model. If the modeling team is instructed to utilize utility bill matching and calibrate the existing building energy model, the weather file from the same year of the utility bill shall be used for more accurate results.

Otherwise, the standard TMY3 files used in new SCA GSG projects should be used. These files contain weather data averaged over multiple years and are better suited to predict the building's future performance. Using a historical year weather file would be less accurate, as each year has unique seasonal characteristics that may not repeat in following years.

Historical year weather files can be purchased and downloaded from <http://weather.whiteboxtechnologies.com/>

## 3.3 Stacked Approach

With the stacked approach, ECM savings are modeled by starting with the existing baseline model, and gradually transforming it into the proposed design by adding the ECMs one-by-one in the following order:

1. Existing building baseline (historic weather file if bill matching is required, standard TMY3 otherwise)
  - 1.1. If a historic weather file has been used in step 1, a new run with the standard TMY3 weather file must be performed on the calibrated model. This will be the baseline for subsequent ECM comparisons.
2. Envelope measure(s) (standard TMY3 weather file)
3. Interior load measure(s) such as lighting, kitchen loads, plug loads, etc. (standard TMY3 weather file)
4. HVAC measure(s) (standard TMY3 weather file)
5. Non-interactive measures such as service water heating (standard TMY3 weather file)

If there are several ECMs of the same type, for example several HVAC ECMs, the order in which they are modeled relative to each other is not prescribed to allow flexibility in supporting the specific project circumstances. The order may be determined by the modeler based on communications with the design team and the SCA. For example, if a proposed design includes upgrading to air-source heat pumps for certain spaces and downsizing the central boiler to serve the remaining spaces, the air source heat pumps should be modeled first, as the new boiler will have a smaller size than the existing unit and will not be required or able to serve the same spaces.

With the stacked approach, the sum of ECM savings will differ from the total savings of the proposed design relative to the existing building baseline. This difference is attributed entirely to the impact of components that differ between the baseline and proposed models but are not included in any ECM.<sup>1</sup>

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<sup>1</sup> Adapted from the NYSERDA New Construction Program Simulation Guidelines v2.0 (6/27/2016) – Section 5.2

## 4 Building Shell

### 4.1 General Considerations

Existing walls and windows must be reflected in the energy model. These assemblies usually present a degree of uncertainty regarding their performance.

1. Challenges:
  - a. Even if an ASHRAE audit has been performed, sometimes the existing envelope assemblies are described with a range of performance values, or no value is provided. It is uncommon to have core samples from walls or roofs.
  - b. Sometimes existing schools have damaged envelope assemblies which are documented photographically but introduce energy use penalties that may not be directly quantifiable (such as increased air infiltration rates).
2. Proposed solution in absence of actual data:
  - a. For old materials such as masonry, concrete, gypsum board and wood, use the lowest R-value/inch in ASHRAE 90.1-2019 Standard or in the ASHRAE Handbook – Fundamentals.
  - b. For old fibrous insulation, degrade the R-value for compression and sagging – a 20% decrease is a value that may be used. If water damage is observed, the degradation could be higher. This should be balanced against the historic energy bills of the building.
  - c. For foam insulation, use the lowest R-value for long-term degradation from the ASHRAE 90.1 Handbook - Fundamentals.
  - d. Consult ASHRAE 90.1 Handbook - Fundamentals (current and previous editions) to obtain U-factors for materials that are no longer in use.
  - e. For windows, use the unlabeled ASHRAE 90.1-2019 values.

Assemblies for which the renovation or installation date is after the introduction of the 2011 NYC ECC (based on ASHRAE 90.1-2007) should be assumed to be compliant with the Energy Code in effect at the time of the renovation. Before that date, they should be assumed to comply with the version of ASHRAE 90.1 applicable that year, with the 1999 version being the oldest.

The applicable climate zone for all NYC school projects is 4A.

### 4.2 Opaque Envelope Construction Definitions

#### 4.2.1 Exterior Walls

Masonry wall constructions have been included in the template as it is the predominant assembly type found in existing SCA buildings. The default wall construction is a 20" thick brick assembly without insulation. If architectural drawings showing the wall thickness are available but no U-factor has been determined by any site assessment, the predominant wall thickness should be used along with the site-specific predominant type of construction materials. The information on conductivity and density should preferably come from the 2017 ASHRAE Handbook – Fundamentals, while ASHRAE 90.1 Appendix A should be used mainly for new assemblies.

Appendix A section A3.1.1 lists a new brick assembly 3-5/8" thick, with an overall R-0.74 (R-0.20/in). This converts to a conductivity of 2.45 Btu\*in/h\*ft<sup>2</sup>\*°F. Since the project is most likely a building older than 30 years, this type of material would be inappropriate.

The 2017 ASHRAE Handbook – Fundamentals, section 26, Table 1 (page 26.10) lists an interval of possible conductivity values for fired clay brick, ranging between 2.5 and 10.2 Btu\*in/h\*ft<sup>2</sup>\*°F, depending on density. While using a conductivity value in the middle of the interval, such as 5.44 Btu\*in/h\*ft<sup>2</sup>\*°F (R-0.18/in) might be a good starting point, it is advisable to model a conductivity of 9.05 Btu\*in/h\*ft<sup>2</sup>\*°F (R-0.11/in) from the beginning. Doing so will account for imperfections in the wall assembly and the degradation it has undergone over time, along with any potentially hidden thermal bridges that may exist (for example due to holes and cracks). This approach will shorten the iterations needed to match the utility bills in the last stage of modeling, especially for heating.

If an energy audit for the site conditions is available, and an estimated U-factor range is provided, the average value between the minimum and the maximum values could be used, along with the provided wall thickness. This is to properly account for the thermal mass of the assembly.

#### 4.2.2 Roofs

Roof assemblies may have been renovated more recently than walls. If the project documentation indicates a renovation time frame, the assembly should be modeled as compliant with the prescriptive NYC Energy Conservation Code applicable at that time, before applying the performance deration for the effect of the parapet. This deration should be applied, to better approximate the actual assembly U-factor. Prescriptive compliance with NYC ECC versions prior to the 2020 version did not require the effect of the parapet to be accounted for, so even if the roof R or U-factors are provided in existing design documents, these most likely do not include the parapet thermal bridge effect.

Derations can be performed if degradation of the assembly is observed.

The proposed design for the opaque assemblies should be modeled per the design documents if they are included in the scope of the project. Otherwise they should be modeled identical to the existing building baseline.

*Table 1. Opaque Envelope Construction Properties*

<b>Description</b>	<b>Existing building Baseline</b>
<b>Exterior Wall</b>	Existing Mass Wall <ul style="list-style-type: none"> <li>• 20" Brick</li> <li>• U-0.327 BTU/Hr-ft<sup>2</sup>-°F</li> </ul>
<b>Roof</b>	Roof <ul style="list-style-type: none"> <li>• 2" Gravel</li> <li>• Polystyrene (R-15)</li> <li>• Hot rubberized asphalt</li> <li>• 8" MW Concrete</li> <li>• U-0.063 BTU/Hr-ft<sup>2</sup>-°F</li> </ul>
<b>Roof Parapet</b>	Roof parapet <ul style="list-style-type: none"> <li>• 12" Concrete curb</li> <li>• U-1.282 BTU/Hr-ft<sup>2</sup>-°F</li> </ul>
<b>Slab On Grade</b>	Unheated Floor <ul style="list-style-type: none"> <li>• 6" Concrete Slab</li> <li>• F-Factor: 0.730</li> </ul>
<b>Exposed Floor</b>	Mass Floor

Description	Existing building Baseline
	<ul style="list-style-type: none"> <li>• 6" Concrete Slab</li> <li>• U-0.322 BTU/Hr-ft<sup>2</sup>-°F</li> </ul>
<b>Below Grade Walls</b>	Wall <ul style="list-style-type: none"> <li>• 12" concrete wall</li> <li>• C-Factor: 1.140</li> </ul>
<b>Doors</b>	Swinging <50% glazing <ul style="list-style-type: none"> <li>• Solid Steel Door</li> <li>• U-0.70 BTU/Hr-ft<sup>2</sup>-°F</li> </ul> Non-swinging <ul style="list-style-type: none"> <li>• Roll Door</li> <li>• U-1.45 BTU/Hr-ft<sup>2</sup>-°F</li> </ul>

**4.3 Window Definitions**

Assemblies for which the installation date is after the introduction of the 2011 NYC ECC should be assumed to be compliant with the Energy Code in effect at the time of the installation, except for SHPO designated buildings that may have been single glazed due to the full height window size not being able to be dual glazed.

Assemblies installed between 1999 and 2011 date should be assumed to comply with the version of ASHRAE 90.1 applicable in the year of the installation.

Windows and skylights installed before 1999 should be modeled using the values in ASHRAE 90.1-2019 sections A8.1 – Unlabeled Skylights and A8.2 – Unlabeled Vertical Fenestration, per the applicable assembly type.

**5 Internal Loads**

**5.1 General Equipment Loads**

The plug loads in new schools adhere to a predictable format, dictated by the current SCA guidelines. In schools that have been in operation for many years the following situations have been observed:

- a. Staff bring personal appliances and electronics to use during work. These are small devices, in the range of a coffee maker, a printer, etc.
- b. Staff that is required to be stationary for most of the work day often bring personal electric heaters for use during the cold season. This happens especially in buildings with a poorly insulated envelope.
- c. There is a lot of aging equipment, with higher energy use than equivalent modern devices would have.

The standard GSG plug load values are, therefore, not applicable. The existing building should be modeled as having at least 10% additional plug loads. This can be increased as described in Section 9.2.3.

*Table 2. Occupancy & Equipment Loads by Space Type*



Space Type	Proposed Design Equipment Power Density (W/ft <sup>2</sup> )	Existing Baseline Equipment Power Density (W/ft <sup>2</sup> )	Equipment Schedule
Classroom (1 <sup>st</sup> -8 <sup>th</sup> grade)	1.52	1.67	CLASS-EQP-YR <sup>b</sup>
Classroom (9 <sup>th</sup> -12 grade+)	1.52	1.67	CLASS-EQP-YR <sup>b</sup>
Classroom (Pre-K & kindergarten) <sup>e</sup>	0.06	0.10	PREK-EQP-YR
Auditorium	0.1	0.11	AUD-EQP-YR
Corridor	0	0	ALWAYS-OFF-F-YR
Office	0.51 <sup>b,c</sup>	1.0	OFFICE-EQP-YR <sup>b</sup>
Lobby	0.1 <sup>b</sup>	0.11	LOBBY-EQP-YR <sup>b</sup>
All Locker Rooms	0	0	ALWAYS-OFF-F-YR
Storage	1.81 <sup>b</sup>	1.82	STORAGE-EQP-YR <sup>b</sup>
Library - Stacks	0.5	0.55	LIB-EQP-YR
Library – Reading Area	0.5	0.55	LIB-EQP-YR
Computer Classroom	2	2.2	TECH-EQP-YR
Music Classroom	0.29 <sup>b</sup>	0.32	MUSIC-EQP-YR <sup>b</sup>
Mechanical	0	0	N/A
Electrical	0	0	N/A
IDF/MDF	26.5 <sup>b</sup>	29.2	DATA-EQP-YR
Gymnasium (class period)	0	0	ALWAYS-OFF-F-YR
Conference Room	1.96 <sup>b</sup>	2.16	LOUNGE-EQP-YR <sup>b</sup>
Gymnasium (multiuse assembly)	0.25	0.28	GYM-EQP-YR
Cafetorium (multiuse assembly)	0.25	0.28	CAFE-EQP-YR
Cafeteria	0.25	0.28	CAFE-EQP-YR
Kitchen/ Servery	See 4.2		See 4.2
“Small” kitchen	See 4.2		See 4.2
Dance Studio/ Exercise	0	0	ALWAYS-OFF-F-YR
Stair	0	0	ALWAYS-OFF-F-YR
Community rooms	1.96 <sup>b</sup>	2.16	LOUNGE-EQP-YR <sup>b</sup>
Copy Rooms	See Table 2	See Table 3	See Table 10
Nurse’s Office	9.07 <sup>b</sup>	9.98	NURSE-EQP-YR <sup>b</sup>
Laboratory	2.48 <sup>b</sup> + 3.75 <sup>a</sup>	2.73 + 4.13	SCI-LAB-EQP-YR <sup>b</sup>
Media Centers/ TV Studios	1.25	1.38	LIB-EQP-YR
Playroom	0.26 <sup>b</sup>	0.29	MUSIC-EQP-YR <sup>b</sup>
Records Room	0	0	ALWAYS-OFF -YR
Workshop	7.42 <sup>b</sup>	8.16	SHOP-EQP-YR
Restrooms	0	0	ALWAYS-OFF-F-YR
Staff lunch/ lounge	1.96 <sup>b</sup>	2.16	LOUNGE-EQP-YR <sup>b</sup>
Resource Center/ Workroom	0.51 <sup>b</sup>	1.00	OFFICE-EQP-YR <sup>b</sup>

Space Type	Proposed Design Equipment Power Density (W/ft <sup>2</sup> )	Existing Baseline Equipment Power Density (W/ft <sup>2</sup> )	Equipment Schedule
Shaft	0	0	N/A
Plenum	0	0	N/A

<sup>a</sup> Add power density if space has fume hoods, assume sensible and latent contribution to space is 20% and rest is lost up hood.

<sup>b</sup> Derived from the SCA LL31 Feasibility Study for Q375 - Reports for Phases 1 and 2

<sup>c</sup> Additional loads required to account for large equipment such as printers, copiers and coffee makers. **See Table 2.**

*Table 3. Office Plug Loads – Proposed design (same as Table 10 from the SCA Input Summary)*

Description	Value	Value	Value
<b>Equipment Type</b>	Printer	Copier	Coffee Maker
<b>Equipment Schedule</b>	OFC-P-EQP-YR	OFC-CP-EQP-YR	OFC-CM-EQP-YR
<b>Equipment Type</b>	Electric	Electric	Electric
<b>Input Power (W/unit)</b>	700	700	780

*Table 4. Office Plug Loads – Existing Building Baseline*

Description	Value	Value	Value
<b>Equipment Type</b>	Printer	Copier	Coffee Maker
<b>Equipment Schedule</b>	OFC-P-EQP-YR	OFC-CP-EQP-YR	OFC-CM-EQP-YR
<b>Equipment Type</b>	Electric	Electric	Electric
<b>Input Power (W/unit)</b>	770	770	858

## 5.2 Kitchen Equipment Loads

While the current SCA Design Requirements call for all new kitchen equipment to be electric, existing schools are likely to have natural gas cooking appliances. This should be verified at the start of modeling, as it not only impacts the overall energy use of the building but also the types of utilities being used.

In schools that have old kitchen appliances (not purchased within the last 5 years), existing electric kitchen equipment should be modeled as having 10% higher energy use than the values given for new equipment in the SCA Input Summary. However, this is valid only if the equipment replacement is close to a 1:1 match. If the renovated kitchen will serve a different population density, or it will be changed in scope (from a small kitchen to a full kitchen, or vice versa), then the models should also reflect this difference by using inputs appropriate to the type and size valid for each case.

“Full” kitchen and “small” kitchen equipment loads and schedules will be determined based on the number of students served. If the kitchen is part of an addition, the total number of students served should be considered, not just those housed in the new addition space.

Sections 5.2.1 and 5.2.2 represent default inputs that are appropriate for the DD phase proposed design energy model. Once the proposed design moves to the 50% CD phase, the actual kitchen loads should be calculated based on the kitchen equipment schedules provided in the architectural drawing set. The calculations should be performed using the Appendix A spreadsheet calculator from the SCA How-to Guide.

Notes:

1. In this section, “SOURCE” refers to the related keywords in eQuest related to cooking appliances, and should not be confused with source energy used for LL31/16 or other site/source calculations.
2. A “full kitchen” is defined as a kitchen that includes cooking equipment such as a steamer, oven and cooking range. A “small” kitchen does not have these appliances, but will have one or more convection ovens and possibly a mobile steamer/holder unit.

### 5.2.1 Full Kitchen Equipment Loads

Full kitchens should have both equipment and source loads defined. These loads include all non-cooking equipment such as refrigerators, cash registers, deli slicers, etc. Source loads for cooking equipment, such as ranges and ovens, are detailed in Table 9 and Table 10.

Per the SCA kitchen design standards, full kitchens generally serve a population larger than 400 students. However, if a project is designed with a full kitchen serving a population smaller than 400 students (such as in a small stand-alone school with less than 400 students), the 401-500 interval should be used instead of the small kitchen default entries.

Kitchens using gas for cooking should follow Table 9, and kitchens with electric cooking appliances, should follow Table 10. Due to differences in gas and electric/electric induction cooking equipment, the input power for gas cooking and electric cooking equipment is different. Kitchen hoods and the outdoor components of walk-in coolers and freezers (refrigeration rack systems) should be modeled separately from the other non-cooking equipment as direct loads on the meters (See Table 23).

*Table 5. Kitchen and Servery Equipment Loads, PS Full Kitchens, Proposed design (same as Table 6a from the SCA Input Summary)*

<b>Number of Students Served</b>	<b>401-500</b>	<b>501-700</b>	<b>701-900</b>	<b>901-1000</b>	<b>1000+</b>
<b>Equipment Schedule, General Non-Cooking Loads</b>	401-KIT-EQP-YR	501-KIT-EQP-YR	701-KIT-EQP-YR	901-KIT-EQP-YR	1K-KIT-EQP-YR
<b>EQUIPMENT-KW, General<sup>2</sup></b>	36.0	57.4	60.2	62.9	74.0

*Table 6. Kitchen and Servery Equipment Loads, PS Full Kitchens, Existing building baseline*

<b>Number of Students Served</b>	<b>401-500</b>	<b>501-700</b>	<b>701-900</b>	<b>901-1000</b>	<b>1000+</b>
<b>Equipment Schedule, General Non-Cooking Loads</b>	401-KIT-EQP-YR	501-KIT-EQP-YR	701-KIT-EQP-YR	901-KIT-EQP-YR	1K-KIT-EQP-YR
<b>EQUIPMENT-KW, General<sup>3</sup></b>	39.6	63.1	66.2	69.2	81.4

<sup>2</sup> TOTAL input power for kitchen and servery. If the kitchen and servery are modeled as separate zones, assign the kW to each zone based on the zone area. For example, if the kitchen area is 600 ft<sup>2</sup> and the servery area is 400 ft<sup>2</sup>, then 60% of the plug and source load will be assigned to the kitchen, and 40% will be assigned to the servery.

<sup>3</sup> TOTAL input power for kitchen and servery. If the kitchen and servery are modeled as separate zones, assign the kW to each zone based on the zone area. For example, if the kitchen area is 600 ft<sup>2</sup> and the servery area is 400 ft<sup>2</sup>, then 60% of the plug and source load will be assigned to the kitchen, and 40% will be assigned to the servery.

Table 7. Kitchen and Servery Equipment Loads, HS Full Kitchens, Proposed design (same as Table 6b from the SCA Input Summary)

Number of Students Served	401-500	501-700	701-900	901-1000	1000+
Equipment Schedule, General Non-Cooking Loads	401-KIT-EQP-YR	501-KIT-EQP-YR	701-KIT-EQP-YR	901-KIT-EQP-YR	1K-KIT-EQP-YR
EQUIPMENT-KW, General <sup>4</sup>	59.9	92.9	95.6	98.3	127.1

Table 8. Kitchen and Servery Equipment Loads, HS Full Kitchens, Existing building baseline

Number of Students Served	401-500	501-700	701-900	901-1000	1000+
Equipment Schedule, General Non-Cooking Loads	401-KIT-EQP-YR	501-KIT-EQP-YR	701-KIT-EQP-YR	901-KIT-EQP-YR	1K-KIT-EQP-YR
EQUIPMENT-KW, General <sup>5</sup>	65.9	102.2	105.2	108.1	139.8

Table 9. Kitchen and Servery Cooking Loads, Full Kitchens with GAS Cooking (same as Table 7 from the SCA Input Summary)

Number of Students Served	401-500	501-1000	1000+
Source Schedule	401-KIT-SRC-G-YR	501-KIT-SRC-G-YR	1K-KIT-SRC-G-YR
Source Type	GAS	GAS	GAS
Input Power (Btu/hr) <sup>6</sup>	310,000	408,000	506,000
Source Sensible HG (Ratio )	25%	25%	25%
Source Latent HG (Ratio )	25%	25%	25%

Table 10. Kitchen and Servery Cooking Loads, Full Kitchens with ELECTRIC Cooking (same as Table 8 from the SCA Input Summary)

Number of Students Served	401-500	501-1000	1000+
Source Schedule	401-KIT-SRC-E-YR	501-KIT-SRC-E-YR	1K-KIT-SRC-E-YR
Source Type	ELECTRIC	ELECTRIC	ELECTRIC
Input Power (Btu/hr)	174,429	230,627	286,791
Source Sensible HG (Ratio )	25%	25%	25%
Source Latent HG (Ratio )	25%	25%	25%

<sup>4</sup> TOTAL input power for kitchen and servery. If the kitchen and servery are modeled as separate zones, assign the kW to each zone based on the zone area. For example, if the kitchen area is 600 ft<sup>2</sup> and the servery area is 400 ft<sup>2</sup>, then 60% of the plug and source load will be assigned to the kitchen, and 40% will be assigned to the servery.

<sup>5</sup> TOTAL input power for kitchen and servery. If the kitchen and servery are modeled as separate zones, assign the kW to each zone based on the zone area. For example, if the kitchen area is 600 ft<sup>2</sup> and the servery area is 400 ft<sup>2</sup>, then 60% of the plug and source load will be assigned to the kitchen, and 40% will be assigned to the servery.

<sup>6</sup> TOTAL input power for kitchen and servery. If the kitchen and servery are modeled as separate zones, assign the kW to each zone based on the zone area. For example, if the kitchen area is 600 ft<sup>2</sup> and the servery area is 400 ft<sup>2</sup>, then 60% of the plug and source load will be assigned to the kitchen, and 40% will be assigned to the servery.

### 5.2.2 Small Kitchen Equipment Loads

Small kitchens are predominantly used to serve a student population of less than 400 students. The equipment loads are shown in Tables 11a thru 11c.

*Table 11. Kitchen and Servery Equipment Loads, Small Kitchens, Existing building baseline*

Number of Students Served	Under 300	301-400
Equipment Schedule	101-WKIT-EQP-YR	301-WKIT-EQP-YR
EQUIPMENT-KW	39.3	45.0

*Table 11b. Kitchen and Servery Equipment Loads, Small Kitchens, Proposed design*

Number of Students Served	Under 300	301-400
Equipment Schedule	101-WKIT-EQP-YR	301-WKIT-EQP-YR
EQUIPMENT-KW	31.0	33.7

*Table 11c. Kitchen and Servery Cooking Loads, Small Kitchens, Proposed design*

Number of Students Served	Under 300	301-400
Source Schedule	101-KIT-SRC-E-YR	301-KIT-SRC-E-YR
Source Type	ELECTRIC	ELECTRIC
Input Power (Btu/hr)	116,013	116,013
Source Sensible HG (Ratio )	25%	25%
Source Latent HG (Ratio )	25%	25%

### 5.2.3 Walk-in refrigerator/freezer loads

Existing walk-in refrigerators may be subject to renovation. Two possible improvements can be added – demand defrost to replace the timer-based control and additional enclosure insulation. The impact of these ECMs should be reflected solely in the yearly energy use of the outdoor compressor unit.

*Table 12. Walk-in refrigerator/freezer energy use – Existing building baseline*

Case	Meter	Load	Schedule	End Use	Annual Energy Use (kWh)
Existing baseline	KIT-MISC-METER	6.944	KIT-WALK-IN-YR	MISC-EQUIP	60,825
Demand defrost only		6.64			58,166
Additional enclosure insulation only		3.774			33,060
Demand defrost + enclosure insulation (same as new GSG unit)		3.47			30,397

### 5.3 Elevator Loads

Elevator loads should only be modeled if elevators are confirmed to be present in the project. While they are a standard design feature of new school buildings or additions, older buildings do not necessarily have them.

For projects that include existing elevators, standard (non-regenerative) drives should be assumed.

*Table 13. Existing building baseline - Standard Elevator Applications*

Elevator Type	Direct load <u>per</u> elevator (kW)	Schedule	Annual Energy Use (kWh)
Standard (3500 lb capacity)	18.6	ELEV-EQP-SCH	10,248
For reduced mobility population (6000 lb capacity)	30.8	ELEV-EQP-SCH	16,970

For projects in which the elevators will be upgraded to regenerative drives, the values from the standard new construction templates should be used.

*Table 14. Proposed design - Regenerative Elevator Applications (same as Table 11 from the SCA Input Summary)*

Elevator Type	Direct load <u>per</u> elevator (kW)	Schedule	Annual Energy Use (kWh)
Standard (3500 lb capacity)	11.93	ELEV-EQP-SCH	6,573
For reduced mobility population (6000 lb capacity)	19.71	ELEV-EQP-SCH	10,862

### 5.4 Lighting Loads

Existing school projects often have incompletely documented lighting systems. Given the constraints of project schedules and budgets, unless the lighting system is documented in an ASHRAE Level III audit before energy modeling begins, it is unlikely it will be evaluated to the extent it would be for a new design. Therefore, the existing building baseline must be modeled by combining known information with the default inputs and methods described below.

Schools with lighting installed after the adoption of the 2011 NYC ECC should be assumed to be compliant with the Energy Code in effect at the time of the renovation, for both lighting power density and lighting controls. The interior and exterior lighting power densities can be modeled as having the same power density as the values described in the corresponding version of ASHRAE 90.1 Tables 9.4.5 (exterior) and 9.6.1 (interior).

Schools with fluorescent lighting installed at an unknown date should be modeled using a multiplier of 2.5 applied to the 2019 SCA GSG values. This is the average energy use difference between T8 tubes and LED fixtures at a given light output. This can be increased as described in Section 9.2.3.

**Unless lighting controls are specifically mentioned to be present and functional, they should not be modeled in the existing building case.** As a starting point, the same lighting schedules should be modeled

between the existing conditions and the proposed renovation, assuming basic timer controls. This can be revised in the utility bill matching stage if it is found that the existing building model uses too little electricity for lighting.

If the project does not include lighting upgrades in the scope of work, the Proposed Design model should use the same values as the existing building baseline.

If the project includes lighting upgrades, the Proposed Design values shown in *Table 14* should only be used in the early stages of the energy model, when the information on the new lighting scheme may be missing. Once the proposed lighting information is available the energy model should use LPD values and controls matching the design documents.

*Table 15. Lighting Power Density by Space Type*

Space Type	Model Input Lighting Power Density Parameter	Proposed Design		Existing Building Baseline	
		Controls	LPD (W/sq ft )	Controls	LPD* (W/sq ft )
<b>Auditorium</b>	AUD-LPD <sup>7</sup>	Vacancy	0.63	Timer	1.58
<b>Cafeteria</b>	CAFETERIA-LPD	Partial Vacancy	0.53	Timer	1.33
<b>Cafetorium</b>	CFTRM-LPD	Timer	0.53	Timer	1.33
<b>Classroom (1<sup>st</sup>-8<sup>th</sup> grade)</b>	CLASS-LPD	Vacancy	0.5	Timer	1.25
<b>Classroom (9<sup>th</sup>-12 grade)</b>	CLASS-LPD	Vacancy	0.5	Timer	1.25
<b>Classroom (Pre-K &amp; Kindergarten)</b>	CLASS-LPD	Vacancy	0.5	Timer	1.25
<b>Community rooms</b>	COMMUN-LPD	Vacancy	0.7	Timer	1.75
<b>Computer Classroom</b>	COMP-CLASS-LPD	Vacancy	0.74	Timer	1.85
<b>Conference Room</b>	CONF-LPD	Vacancy	0.7	Timer	1.75
<b>Copy Rooms</b>	COPY-LPD	Vacancy	0.5	Timer	1.25
<b>Corridor</b>	CORR-LPD	Partial Vacancy	0.58	Timer	1.45
<b>Dance studio/ Exercise</b>	AUX-GYM-LPD	Vacancy	0.75	Timer	1.88
<b>Electrical</b>	ELEC-LPD	Timer	0.39	Timer	0.98
<b>Nurse's Office</b>	NURSE-LPD	Timer	0.8	Timer	2.00
<b>Gym Locker Room</b>	LOCKER-G-LPD	Partial Vacancy	0.45	Timer	1.13
<b>Gymnasium</b>	GYM-LPD	Vacancy	0.75	Timer	1.88
<b>Gymnasium</b>	GYMTRM-LPD	Vacancy	0.75	Timer	1.88
<b>Kitchen</b>	KITCHEN-LPD	Timer	0.8	Timer	2.00
<b>Small Kitchen</b>	KITCHEN-LPD	Timer	0.8	Timer	2.00
<b>Laboratory</b>	LAB-CLASS-LPD	Vacancy	1.0	Timer	2.50

<sup>7</sup> General lighting. Exempt stage lighting is project specific and should be entered as task lighting.



Space Type	Model Input Lighting Power Density Parameter	Proposed Design		Existing Building Baseline	
		Controls	LPD (W/sq ft )	Controls	LPD* (W/sq ft )
Library - General	LIB-GEN-LPD	Vacancy	0.8	Timer	2.00
Library - Reading	LIB-READ-LPD	Vacancy	0.77	Timer	1.93
Library - Stacks	LIB-STAC-LPD	Vacancy	0.8	Timer	2.00
Elevator Lobby	ELEV-LOB-LPD	Partial Vacancy	0.52	Timer	1.30
Lobby	LOBBY-LPD	Partial Vacancy	0.8	Timer	2.00
MDF/IDF	DATA-LPD	Occupancy	0.39	Timer	0.98
Mechanical	MECH-LPD	Timer	0.39	Timer	0.98
Media Centers/ TV Studios	MEDIA-LPD	Timer	0.74	Timer	1.85
Music Classroom	MUSIC-LPD	Vacancy	0.5	Timer	1.25
Office	OFFICE-LPD	Vacancy	0.6	Timer	1.50
Other Locker Room	LOCKER-O-LPD	Vacancy	0.45	Timer	1.13
Playroom	PLAY-LPD	Vacancy	0.75	Timer	1.88
Records Room	RECORDS-LPD	Vacancy	0.8	Timer	2.00
Resource Center/ Workroom	RESOURCE-LPD	Vacancy	0.8	Timer	2.00

### 5.5 Infiltration Loads

Existing buildings will have higher infiltration loads than what is shown in Table 15 of the SCA Input Summary. This is due to a combination of the following factors:

- Weather damage that has accumulated over the life of the building.
- Less stringent air leakage requirements in past construction standards.
- New buildings use more advanced materials and construction techniques.

*Table 16. Infiltration Defaults*

Description	Value
Infiltration Method	Air Change
Schedule	HVAC System Dependent, See SCA Input Summary Table 19
Air Changes/Hour	0.30, typical spaces with at least 1 major exterior wall that has more than 50% windows on that wall 0.225, cafeterias and other deep spaces with at least 1 major dimension on an exterior wall that has some fenestration, but less than 50%

Description	Value
	0.1, spaces with small windows on exterior walls, as may be the case with auditoriums or gyms 0.0, interior zones with no exterior walls 0.35, for vestibules with swinging doors
Infiltration Flow	Default (0.00)

The values in *Table 16* should be used as starting points. Please refer to Section 10.2.3 for further guidance on how they should be modified to match the historic utility bills.

## 6 HVAC Thermal Zones

Existing buildings typically have simple control systems, which may also be malfunctioning. Depending on the age of the building, central systems may not be present, or may be used only for ventilation purposes. Space types that are usually conditioned in a new building should not be assumed to be conditioned to the same level in the existing building. For example, assembly spaces of an existing school could be heated and ventilated only, without any mechanical cooling.

The existing building baseline model should reflect, as much as possible, the existing HVAC systems and controls, even if they significantly deviate from the current SCA design requirements. If energy audits or occupant testimony reports that the building does not provide occupant comfort levels up to the current standards (such as under-heating in winter), it is expected that the simulation may report more than 300 yearly unmet load hours when using the standard thermostat setpoints from the GSG templates.

The proposed design model should only follow the current SCA design requirements and modeling practices from the SCA GSG templates to the extent that these requirements are in the scope of the renovation. Systems that are outside of the scope should be modeled identically as in the existing building baseline. This means that a partial renovation project may still have more than 300 yearly unmet load hours.

### 6.1 Temperature Setpoints

Existing building spaces should be modeled using the temperature setpoints and schedules from the SCA Input Summary Tables 16 and 17 as a starting point. These should be adjusted at first to match the existing building conditions (for example, spaces that are not cooled should not have cooling setpoints and cooling schedules modeled), and then further adjusted as described in Section 10.2.3 of this document.

### 6.2 Ventilation Loads

Ventilation loads should be similar to those in Table 18 of the SCA Input Summary. In the case of existing window AC units, zero outside air flow should be assumed to be provided by the units.

## 7 Air-Side Systems

### 7.1 General Considerations

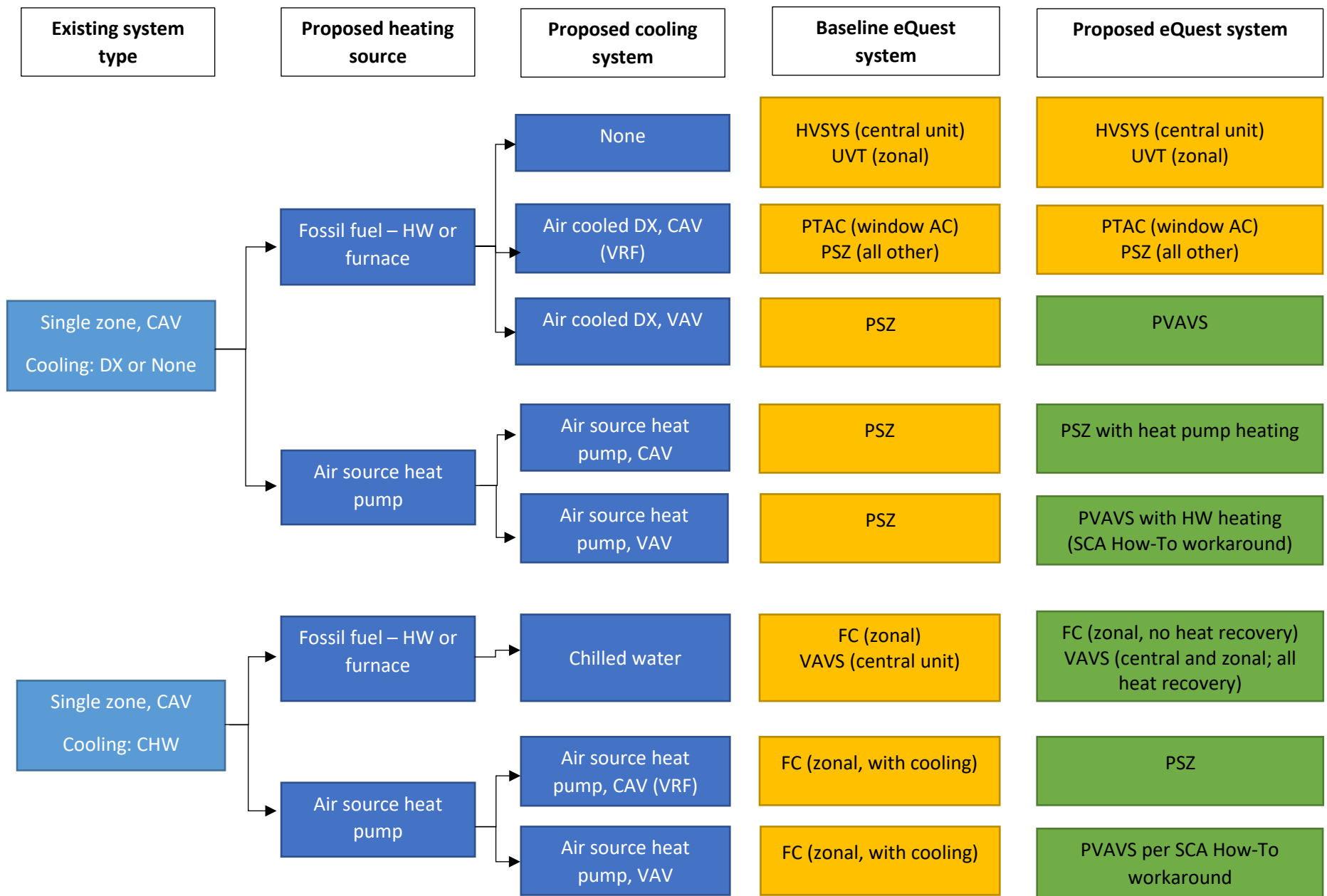
Some modern design features that are standard in new schools should not be assumed to be present in existing buildings. These features are to be modeled in the baseline only after positive confirmation that the equipment both exists and operates correctly.

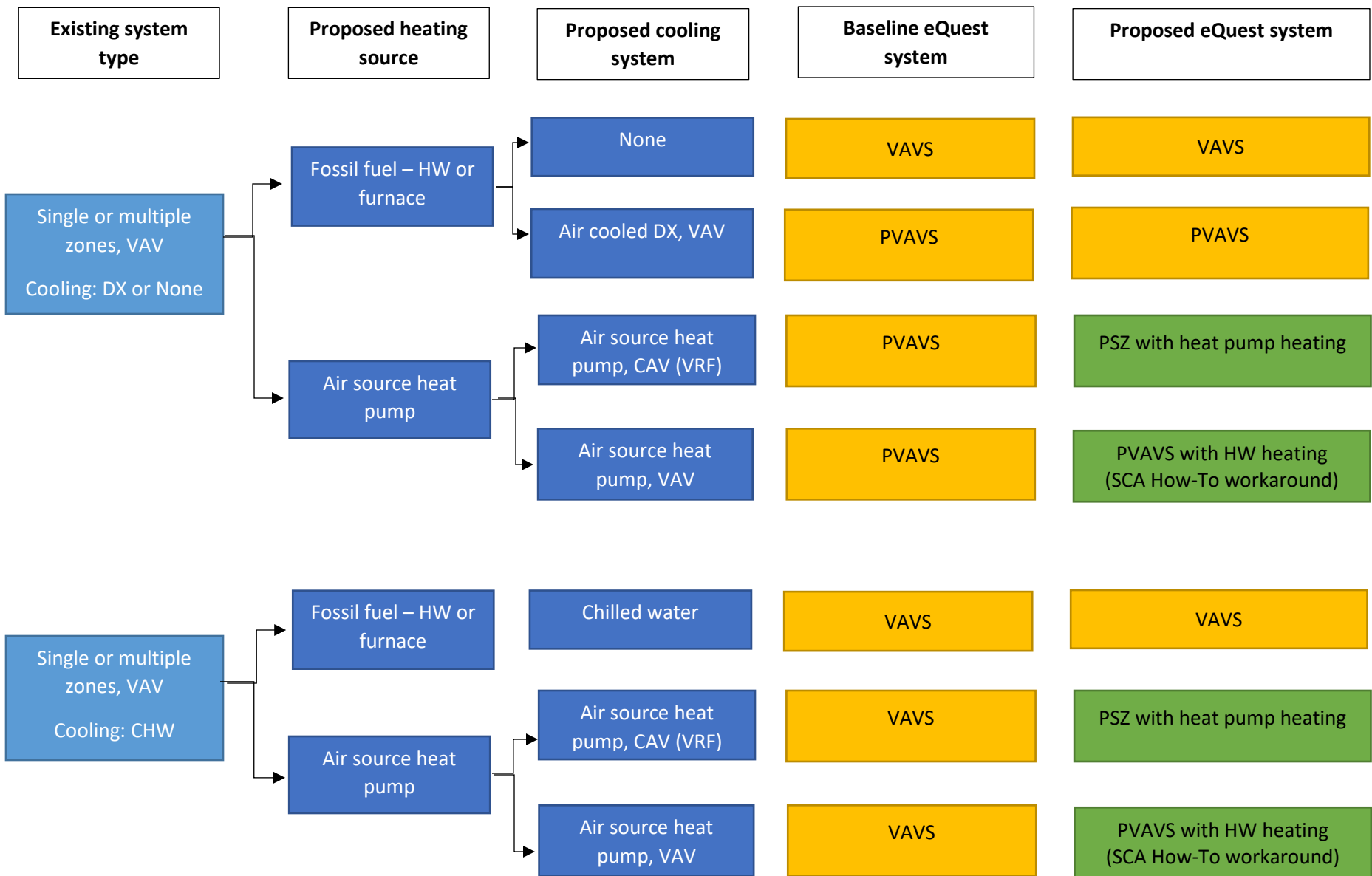
Equipment and controls that may fall under this category include, but are not limited to, the following:

- CO<sub>2</sub> sensors and other demand control ventilation strategies
- Heat recovery devices
- Airside economizer controls

Existing building HVAC systems that are not in the scope of the renovation must be modeled identically in the proposed design as in the baseline model.

HVAC units found in existing buildings can be modeled with a variety of eQuest system types. However, there are algorithm differences that may cause the energy use results to differ between system types even with equivalent inputs for capacity and efficiency. When the proposed design includes HVAC upgrades, it is advisable to use the same eQuest system type in both models to the extent that it is appropriate in the context of capabilities and controls. This will help alleviate unwarranted differences in energy use between the existing building baseline and the proposed design, resulting in a more direct comparison.





## 7.2 Natural Ventilation

Existing buildings sometimes rely on operable windows for ventilation and temperature control. In buildings that are overheated due to malfunctioning thermostats or due to lack of zone level controls, the windows will be opened at times during the winter to bring down space temperatures to acceptable levels. This will result in an increase in heating energy use. If the building is retrofitted with either central or zonal HVAC systems that provide ventilation, the proposed design should no longer be modeled with natural ventilation, and the corresponding inputs should be disabled.

Natural ventilation can be modeled at the system level. This will approximate the effect of operable windows being used at certain times of the day.

The eQuest user manual indicates that the applicable system types are only RESYS, RESYS2, PSZ, PVVT and EVAP-COOL. Of these, the most likely to be appropriate is PSZ. While other system types such as PVAVS might accept the keywords and the simulation will run without errors, the resulting outputs might produce incorrect results. For example, opening the windows during the winter might result in lower energy use, contrary to the desired effect.

*Table 17. Natural Ventilation*

<b>Outdoor Air Tab, Natural Ventilation</b>		
<b>Description</b>	<b>Value</b>	<b>Notes</b>
Ventilation Method	Sherman-Grimsrud	This method takes into account the data in the weather file for wind speed, outside and indoor conditions.
Vent. Use Schedule	CLASS-WIN-YR	This schedule approximates the times of the year during which the windows will be likely used. This takes into account the indoor and outdoor conditions, so the program will only model an opened window if certain conditions are met.  The windows are assumed to be operable during the weekdays in the 6 AM – 9 PM interval.
Ventilation temperature schedule	CLASS-T-SCH	The minimum temperature below which the windows are assumed to be closed.
Window Open Probability Schedule	CLASS-OPN-YR	The hourly probability (as a percentage) that the windows will be opened if the conditions set by CLASS-WIN-YR and CLASS-T-SCH are met.
Air Changes/Hour (max)	5 - 10	The maximum number of air changes per hour from the opened windows. This number should be adjusted so that the existing building baseline matches the historic utility bills.  The eQuest window incorrectly shows this input as being measured in kWh.
Total Vent Area Fraction	0.05 (default)	The keyword value is $0.6 * (\text{Open Window Area}) / (\text{Floor Area})$
Horizontal Vent Area Fraction	0 (default)	This variable is used to calculate the stack effect contribution to natural ventilation. This is only useful for skylights.

Image 18. Natural Ventilation Fan Control

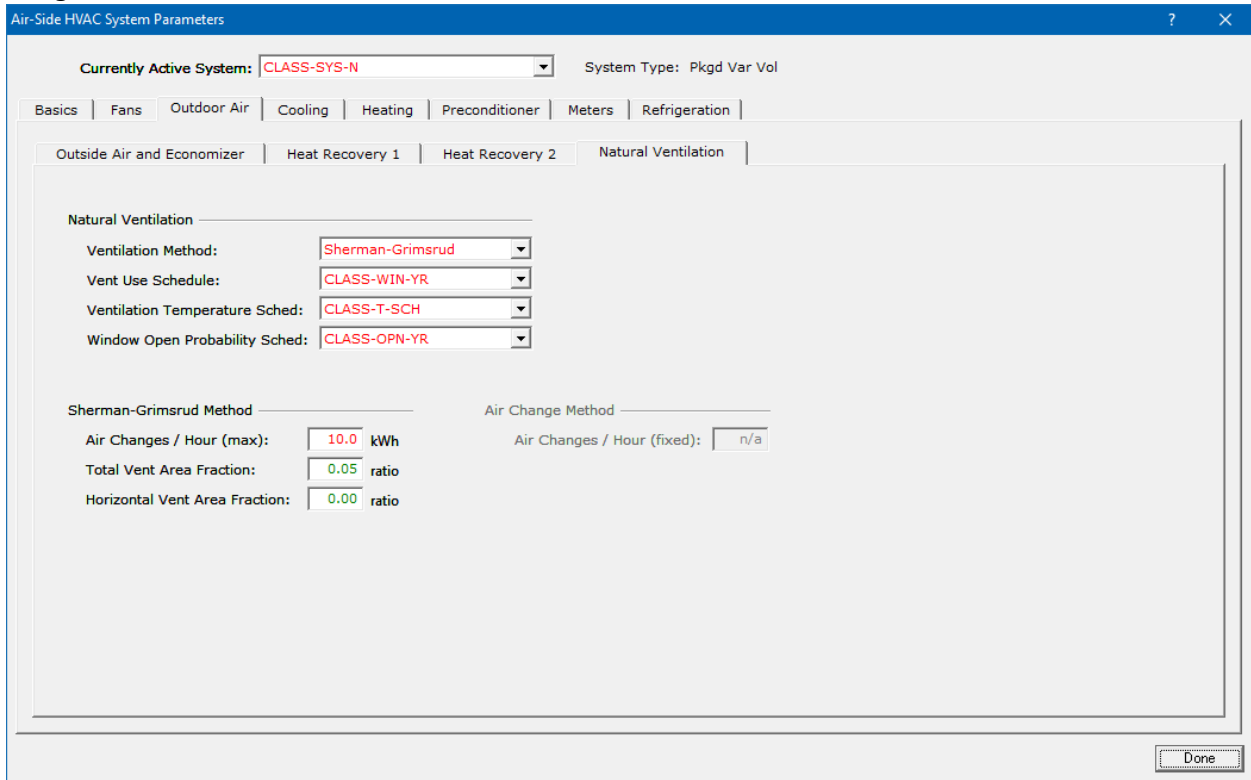


Table 19. Natural Ventilation Fan Control

Fans Tab, Night Cycle Control		
Description	Value	Notes
Night Vent Control	Not Available	No fans will be on when the main fans are off.
Ventilation temperature schedule	CLASS-T-SCH	The minimum temperature below which the windows are assumed to be closed.

Image 2. Natural Ventilation Night Cycle Control

Air-Side HVAC System Parameters

Currently Active System: **CLASS-SYS-N** System Type: Pkgd Var Vol

Basics **Fans** Outdoor Air Cooling Heating Preconditioner Meters Refrigeration

Fan Power and Control Flow Parameters **Night Cycle Control**

**Night Venting**

Night Vent Control: **Not Available**

Night Vent Schedule: n/a

Vent Temperature Sch: **CLASS-T-SCH**

Night Vent Delta T: n/a °F (delta)

**Night Cycle Fan Control**

Night Cycle Control: **Stay Off**

Night Cycle Fans: n/a

**Night Vent Ratios**

Supply CFM:	n/a	Return CFM:	n/a
Supply kW:	n/a	Return kW:	n/a
Supply dT:	n/a	Return dT:	n/a

Done



Table 20. Natural Ventilation Schedules

Schedule Name	Effective	12-1 am	1-2 am	2-3 am	3-4 am	4-5 am	5-6 am	6-7 am	7-8am	8-9 am	9-10 am	10-11 am	11-noon	noon-1 pm	1-2 pm	2-3 pm	3-4 pm	4-5 pm	5-6pm	6-7pm	7-8pm	8-9pm	9-10 pm	10-11 pm	11-12 mid
<b>CLASS-WIN-YR</b>	<b>Regular</b>	0	0	0	0	0	0	1	1	-1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	0	0	0
<b>CLASS-WIN-YR</b>	<b>Summer</b>	0	0	0	0	0	0	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0
<b>CLASS-T-SCH</b>	<b>All days</b>	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
<b>CLASS-OPN-YR</b>	<b>Heating season</b>	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0
<b>CLASS-OPN-YR</b>	<b>Shoulder season</b>	0	0	0	0	0	0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0	0	0
<b>CLASS-OPN-YR</b>	<b>Cooling season</b>	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0

### 7.3 Heating Only Systems

Spaces that are only heated by radiators (steam or hot water) should be modeled as having a Unit Heater system if there will be no outside air supply, or a Unit Ventilator if there will also be outside air flow. The static pressure should be set close to zero to model zero fan power since there is no fan.

*Table 21. Existing Heating Only System Properties*

	<b>Existing Building Baseline</b>
<b>System Type</b>	Unit Heater
<b>Heating Efficiency*</b>	NA – heating from steam boiler
<b>Demand Controlled Ventilation?</b>	No
<b>Economizer Control?</b>	No
<b>Heat Recovery Efficiency</b>	NA
<b>Supply Static Pressure</b>	0.001
<b>Supply Efficiency</b>	0.999

eQuest system types capable of providing cooling to spaces (PSZ, PVAVS, PTAC, FC, VAVS) should be modeled as selecting the COOL-OFF-YR availability schedule. This will set the cooling as never being available. This can be used in both the existing building baseline and in the proposed design, as needed.

*Table 22. General heated-only systems*

	<b>Existing Building Baseline</b>
<b>System Type</b>	PSZ, PVAVS, PTAC, FC, VAVS
<b>Cooling availability schedule</b>	COOL-OFF-YR

At the zone level, not specifying a cooling schedule and allowing the indoor design cooling temperature to default to the value of 76°F will result in that zone not having any mechanical cooling capability.

*Table 22. General heated-only zones*

	<b>Existing Building Baseline</b>
<b>Thermostat schedule</b>	(undefined)
<b>Indoor design temperature</b>	76°F (default)

### 7.4 Existing Unitary Cooling Systems – Window AC units

Existing window AC units should be modeled using the PTAC system type. If no efficiency data is available, the starting point should be the ASHRAE 90.1 Table 6.8.1-1 for the 2013 and later versions, or Table 6.8.1A for the 2010 and earlier versions. The applicable category is “Air conditioners, air cooled, <65,000 Btu/h”.

Units for which the installation date is after the introduction of the 2011 NYC ECC (based on ASHRAE 90.1-2007) should be assumed to be compliant with the Energy Code in effect at the time of the renovation. Before that date, they should be assumed to comply with the version of ASHRAE 90.1 applicable that year, with the 1999 version being the oldest.

## 7.5 New VRF Heat Pumps Systems

### 7.5.1 General considerations

Variable Refrigerant Flow (VRF) systems are not natively supported in the standard version of eQuest 3.65 that runs on the DOE 2.2 simulation engine. A beta (unfinished) version using the DOE 2.3 engine (build 7173) has been available since 2018, which includes native VRF modeling capability. However, being unfinished, several features that work in the standard DOE 2.2 version such as the PTAC and HVSYS systems are reported as not functional.

### 7.5.2 eQuest system selection

For modeling VRF systems in eQuest 3.65 – DOE 2.2, the recommended modeling methodology has been adapted from the guidelines provided by two large VRF heat pump manufacturers, Daikin<sup>8</sup> and Mitsubishi. These guidelines are generally similar, both advising that the eQuest system type be a PSZ. The advantage of using this system type is the ability to also include energy recovery equipment.

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<sup>8</sup> <http://www.daikinac.com/content/resources/software-tools/>

### *Image 3. Mitsubishi modeling guidelines – eQuest system selection*

Several suggestions have been made to model VRF systems as PVVT systems, which will allow variable speed compressors to be used. It is not absolutely necessary to use a variable speed compressor to approximate VRF systems in eQUEST. Selecting a variable speed compressor will require that an additional low speed curve be used based on compressor RPM. This makes it more difficult to directly use the curves that can be provided by VRF manufacturers. The PLR curves, EIR curves, and capacity curves provided by the manufacturer should address the variable operation of VRF systems. It is because of this that PSZ is used for modeling described in this paper. When modeling VRF systems, it is generally best to break up each individual indoor unit as its' own mechanical system. This will help to better approximate the variable nature of VRF and better mimic the real world operation of a VRF system.

2013 Mitsubishi VRF modeling guidelines v1.1

#### 7.5.3 Part load curves

As a starting point, the Mitsubishi part load curves should be used. If a manufacturer other than Mitsubishi is selected, and specific performance curves are provided, the modeling team should use that data. If only the part load IEER value is provided, then the VRF HP IEER in the Appendix A spreadsheet should be used to create the appropriate part load curve for the compressor.

The following considerations should be taken into account:

1. The curves provided by Daikin appear to have been calculated specifically for Daikin units. The modeling manual provides the cooling and heating EIR values to be used with these curves for specific outdoor compressor models. These EIR inputs already exclude the fan power of the indoor units, which is provided separately for a variety of indoor terminal models. It does not appear that it is appropriate to modify these curves for use with non-Daikin equipment.
2. The curves provided by Mitsubishi show a behavior closer to that of the default eQuest PSZ curves. It appears they are more suitable for a general purpose modeling approach.
3. The Mitsubishi modeling manual provides specific inputs for certain outdoor unit models, similar to Daikin. Notably, the EIR values are calculated by using the cooling capacity and the cooling or heating power inputs. The EER and COP values are not used to derive the cooling and heating EIR. It can therefore be inferred that these EIR values do not include the indoor terminal fan powers, which would be part of the standard EER and COP values.
4. The difference between the VRF heating part load curves provided by manufacturers (Mitsubishi and Daikin) and the default eQuest curves are not as pronounced as for the cooling curves. This is because the heating inputs only reflect the COP, which is a descriptor of a unit's full load performance at the testing conditions. On the other hand, the cooling performance is expressed by EER, which reflects full load performance, and IEER, which reflects part load performance. There is no equivalent of the IEER for describing part load performance under heating mode.
5. Certain combinations of temperature settings, part load curves, heating capacities and weather files may cause the software to crash. If a crash occurs after changing any of these inputs on a previously working energy model, the heating part load curves should be reset to the default

eQuest inputs and the model should be re-run. If the crash no longer occurs, the heating part load curves should no longer be used for that particular air-side system. The resulting energy model results will be conservative.

The following part load curves, provided in the Mitsubishi modeling guidelines, should be used as a starting point:

```
"VRF COOLING CAPACITY" = CURVE-FIT
TYPE = BI-QUADRATIC-T
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (3.45972, -0.09322, 0.00086, 0.00948, -5e-005, -8e-005)
..
"VRF COOLING EIR F EWB / ODB" = CURVE-FIT
TYPE = BI-QUADRATIC-T
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (1.56571, -0.02679, 0.00021, -0.00566, 7e-005, 3e-005)
..
"VRF HEATING CAPACITY" = CURVE-FIT
TYPE = BI-QUADRATIC-T
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (-3.43603, 0.12032, -0.00088, 0.03598, -5e-005, -0.00038)
..
"VRF HEATING EIR F EWB / ODB" = CURVE-FIT
TYPE = BI-QUADRATIC-T
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (-3.62297, 0.12715, -0.00083, 0.05509, -0.00018, -0.00074)
..
"VRF COOLING PLR" = CURVE-FIT
TYPE = QUADRATIC
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (0.1181, 0.3937, 0.4731)
OUTPUT-MIN = 0.2
..
"VRF HEATING PLR" = CURVE-FIT
TYPE = QUADRATIC
INPUT-TYPE = COEFFICIENTS
COEFFICIENTS = (0.0575, 0.9193, 0.0183)
OUTPUT-MIN = 0.2
..
```

Performance Curve Properties

Currently Active Curve: **VRF COOLING PLR** Type: Quadratic

Basic Specifications | Data Points

Curve Name: **VRF COOLING PLR**

Curve Type: **Quadratic** Minimum Output: **0.20**

Input Type: **Curve Coefficients** Maximum Output: **1,000,000.00**

Curve Formula:  $Z = a + bX + cX^2$

Where: a = **0.11810000** b = **0.39370000** c = **0.47310001**

Done

Performance Curve Properties

Currently Active Curve: **VRF HEATING PLR** Type: Quadratic

Basic Specifications | Data Points

Curve Name: **VRF HEATING PLR**

Curve Type: **Quadratic** Minimum Output: **0.20**

Input Type: **Curve Coefficients** Maximum Output: **1,000,000.00**

Curve Formula:  $Z = a + bX + cX^2$

Where: a = **0.05750000** b = **0.91930002** c = **0.01830000**

Done

#### 7.5.4 VRF system inputs

It may not be practical to model a VRF system as one system per thermodynamic zone. Energy model zones can be grouped and assigned to a single system if the following conditions are observed:

- The indoor terminals serving the zones are assigned to the same outdoor compressor unit.
- The zones use similar schedules for occupancy, plug loads, heating and cooling setpoints and outside air delivery.
- The zones are subject to similar external loads, i.e. similar orientation and proportion of exterior walls, windows and roofs. For example, classrooms on the same building orientation placed one on top of each other can be safely modeled as served by a single eQuest system. Spaces with exterior walls and large windows should preferably not be modeled in the same system as spaces without any exterior surfaces.

*Table 23A. VRF system inputs - general*

<b>Basics Tab</b>		
<b>Description</b>	<b>Value</b>	<b>Notes</b>
System Name	*	The name of the component
System Type	Pkgd Single Zone	Do not use the Packaged Variable Volume system type. While it accepts a heat pump as the heating source, it will not utilize it, only the supplemental electric resistance. The heating load will appear to be met with very little (incorrect) energy use. This can be verified in the SS-P output reports.
Return Air Path	Default (Duct)	A "Direct" return air path is also acceptable as no duct losses are to be modeled. "Plenum" return shall not be used.
Control Zone	*	For systems with a single zone assigned, this is the name of that zone. For systems with multiple zones assigned, it should be the zone with the highest cooling demand. Some iterations may be required in order to identify the most suitable zone for this role.
System Reports	Default (Yes)	
System Sizing	Default (1.0)	Adjust as necessary for design to match design documents. No System oversizing in baseline. Oversizing shall take place at heating/cooling coils.
Duct Air Loss, Supply Duct UA, Duct Delta T	n/a	No duct losses shall be modeled for compliance.
Maximum Humidity	Default (100%)	Zone humidity indirectly controlled via minimum supply temperature
Minimum Humidity	Default (0.0%)	No humidifier, so left as default.

Table 23B. VRF system inputs - fans

<b>Fans Tab</b>		
<b>Description</b>	<b>Value</b>	<b>Notes</b>
Supply Static (in W.G.)	*	Weighted Average of all actual systems that this unit encapsulates.
Tot Eff. Frac	Default (0.63)	This input should be adjusted when scheduled values are available to make the modeled design fan power match the scheduled AHU fan power.
Mech Eff Frac	Default (0.72)	This input should be adjusted when scheduled values are available to make the modeled design fan power match the scheduled AHU fan power.
Alternative input: Design kW/CFM	*	As appropriate for the indoor unit(s) serving the zones(s)
Alternative input: Delta T °F	Default	
Alternative input: Supply Static (in W.G.)	None or 0	If the kW/CFM and Delta T inputs are used, the supply static should not be either blank or zero.
Fan Schedule	*	This defines the occupied and unoccupied schedule
Fan Control	Constant volume	This allows variable volume operation with a defined fan curve
Fan EIR = f(PLR)	n/a (Default)	
Fan Placement	Default (Draw Through)	Typical fan placement.
Motor Placement	Default (In Airflow)	Fans expected to be in the airflow.
Flow Parameters, Design CFM	*	Supply flow should be defined here, should be equal to the sum of the terminal unit airflows.
Flow Parameters, Min Flow (cfm/ft <sup>2</sup> )	n/a	Should only be used as a last resort to eliminate an excess amount of unmet load hours.
Flow Parameters, Min Flow Ratio	Default (1.00)	Will not be used. Not applicable to constant volume systems.
Min Fan Ratio	Default (0.30)	Will not be used. Not applicable to constant volume systems.
Max Fan Ratio	Default	
Night Venting	Default (Not Available)	This control is not typical in this climate zone.
Night Cycle Control	Proposed Design "Stay-off"	Heating setpoints will be met by baseboards



Table 23C. VRF system inputs – cooling and heating tabs

<b>Cooling Tab</b>		
<b>Description</b>	<b>Value</b>	<b>Notes</b>
Cool Source	Default (n/a)	
Total Cooling Capacity	*	Leave this value blank to let the software calculate based upon the supply air temperature and the supply air flow
Sensible Cooling Capacity	*	Leave this value blank to let the software calculate based upon the supply air temperature and the supply air flow
Cool Sizing Ratio	1.15	Oversizing ratio of cooling capacity, match the baseline requirement to minimize unmet load hours.
Coil Design Bypass Factor	Default (0.19)	Leave as default.
Min Supply Temp	56°F for GSG & NYCECC 2020 Design value when available	The lower bound of what is allowed off of the central cooling coil when supply air temperature needs to be reset.
Cool Control range	Default (4.0°F)	This default range is used to help the cooling components converge.
Availability Sch	*NAME*	Name of schedule that controls when cooling is available. Schedule is used to prevent the unintentional simultaneous heating and cooling with in a system.
Cool Control	Default (n/a)	
Reset Priority	Default (n/a)	
Maximum Cooling Reset Temp.	Default (n/a)	
Minimum Cooling Reset Temp.	Default (n/a)	
Cooling performance curves: COOL-EIR-FT	“VRF Cooling EIR F EWB / ODB”	Cooling EIR as a function of the entering WB temperature and outdoor DB temperature.  Mitsubishi VRF curve as a starting point, replace all curves as appropriate for the project.
Cooling performance curves: COOL-EIR-FPLR	“VRF Cooling PLR”	Cooling EIR as a function of the part load ratio. Adjust using the Appendix A spreadsheet – VRF HP IEER tab, according to the design EER and IEER at AHRI conditions.
Cooling performance curves: COOL-CAP-FT	“VRF Cooling Capacity”	Cooling capacity as a function of entering wetbulb and drybulb temperatures.  Mitsubishi VRF curve as a starting point, replace all curves as appropriate for the project.
Crankcase Heat	0	Included in the EIR value.
Min temp used in cooling curves	50°F	Valid for the Mitsubishi curves. For other manufacturer curves, please check corresponding documentation.

Heating Tab		
Heat Source	Heat Pump	
Zone Heat Source	Not Installed	If the energy model behaves in an unwanted manner (crashes or an excessive amount of unmet load hours) this input should be changed to "Heat Pump"
Heating performance curves: HEAT-EIR-FT	"VRF Heating EIR F EWB / ODB"	<p>Heating EIR as a function of the entering WB temperature and outdoor DB temperature.</p> <p>Mitsubishi VRF curve as a starting point, replace all curves as appropriate for the project.</p> <p>Please also refer to section 7.7.3 consideration 5.</p>

Image 4. VRF Cooling inputs – Unitary power

The screenshot displays the 'Air-Side HVAC System Parameters' window for system 'AC-1-6'. The 'Cooling' tab is selected, and the 'Unitary Power' sub-tab is active. Three red boxes highlight the following inputs:

- Cooling Power:** Cooling Electric Input Ratio is set to 0.2543 Btu/Btu.
- Performance Curves:**
  - Electric Input Ratio: VRF COOLING EIR F EWB / ODB
  - f(part load ratio): VRF COOLING PLR
- Crankcase Power:** Crankcase Heat is set to 0.000 kW.

Image 5. VRF Cooling inputs – Capacity curves

Image 6. VRF Heating inputs – Unitary power

### 7.5.5 DOAS with Demand Control Ventilation and Heat Recovery

Dedicated Outdoor Air Systems (DOAS) units are a HVAC retrofit option that will be unlikely to have a counterpart in the existing building. These systems typically consist of an Energy Recovery Ventilator (ERV) module that supplies tempered outside air to indoor terminal units by recovering heat from the exhaust air. In VRF installations that have space constraints the ERV unit may be ducted to provide the outside air directly to the spaces through separate diffusers. This design may allow the VRF indoor terminals to operate independently.

DOAS units are not natively supported in the standard version of eQuest 3.65 that runs on the DOE 2.2 simulation engine. **They are natively supported in the DOE 2.3 version.**

When DOAS units using DCV are ducted directly to spaces also served by VRF units, this combination should be modeled as two separate systems. The VRF will serve the majority of the zone level heating and cooling loads and the DOAS system will supply and precondition the outside air to a dummy buffer zone, as described below.

*Table 24. Independent DOAS System – Dummy Buffer Zone Properties*

<b>Description</b>	<b>Value</b>
Space Name	*NAME*
Parent Floor	*NAME*
Zone Type	Conditioned
Description	Not Required
Sunspace	No
Temperature	72°F
Space Multiplier	*
Floor Multiplier	*
Location	*
Shape	Use a Polygon
Polygon	*
X	Default
Y	Default
Z	Default
Azimuth	Default
Height	10
Width	Not used
Depth	Not used
Area	Roughly equal to the supplied air CFM
Volume	Default
Occupancy Schedule	Weighted average of the occupancy schedules of the spaces served by the DOAS
Area/Person	Not used

Description	Value
Number of People	Total occupancy of the spaces served by the DOAS
Total Heat Gain	Not Used
Sensible Heat Gain	Space type dependent values according to Table 3 of "SCA Input Summary"
Latent Heat Gain	Space type dependent values according to Table 3 of "SCA Input Summary"

*Table 25. Independent DOAS System Properties*

Description	Proposed Design
System Type	PSZ
False zone occupancy	Sum of occupancy of zones served by the DOAS system
Occupancy Schedule	Weighted average of zones served.
Sensible and Latent gains from Occupants	0
Heat Recovery Efficiency	NA
Heating and Cooling setpoints	Equal to dominant space condition of zones served
MIN-OA-METHOD	DCV-RETURN-SENSOR
Min-air schedule	CLASS-OA-SCH
OA-CONTROL	FIXED

When modeled this way, the VRF systems should include the OA-FROM-SYSTEM keyword, linking their outside air demands to the false zone.

## 8 Water-side HVAC

### 8.1 Existing Steam Boilers

#### 8.1.1 Steam Loop

eQuest is not able to model a steam loop, even though there is a steam boiler option. The only way that steam heating coils can be directly modeled is by using purchased steam. Otherwise, a hot water loop with minimal pumping power should be modeled.

*Table 23. Steam Circulation Loop*

Description	Value	Notes
Loop Name	*NAME*	
Loop Type	Hot Water	Each loop must be one of six available types

Description	Value	Notes
Loop Subtype	Primary	Secondary loops are served exclusively by primary loops
Primary Loop	Not used	Name of the primary loop that this secondary loop is attached to (and served by)
% Trans to Primary	Not used	Percentage of secondary loop flow that transfers to primary loop flow (at design conditions)
Sizing Option	Default	Size per "Secondary" if Boiler size unknown, and "Primary" if boiler size is known. Baseline will always be "Secondary".
Design Heat Temp	230°F	Design steam temperature from the plant. May be different than rated discharge steam temperature of boiler.
Loop Design DT	47°F	Design temperature change of the fluid in the loop
Fluid Volume	Default	Total volume of the fluid in the loop
Avg Circ Time	Default	Average time it takes for the fluid to circulate through the loop (at the design flow rate)
Loop Recirc Flow	Default	Recirculating flow rate of the fluid in the loop when the pump is running
Pipe Head	0.01	Should be minimal
Static Head	0	Closed Loop – No Static Head (no lift against atmosphere)
Loop Pump	*NAME*	Name of the dedicated Pump that pumps this loop
Loop Minimum Flow	Default	Minimum allowable flow rate in the loop, expressed as a fraction of the design flow rate
Loop Size Ratio	Default (1.0)	No safety factor applied to loop sizing. Required safety factor for baseline applied at the airside cooling and heating loads.

### 8.1.2 Steam Boiler

Table 24. Steam Boiler

Description	Value	Notes
Boiler Name	*NAME*	The name of the boiler component, should match mechanical drawing tag.
Boiler Type	STM-BOILER	
HW Loop assignment	*	Name of the primary Steam/HW Loop this boiler is assigned to
Electric Meter	Default (EM1)	Name of the Electric Meter that tallies the electric consumption
Fuel Meter	Default (FM1)	Name of the Fuel Meter that tallies the fuel consumption
Capacity	*	Nominal boiler capacity in MBTU/hr. Leave blank if boiler sizes are not yet known.
Capacity Ratio	0.50	Fraction of the design heating load used to size boiler when capacity is not known.

Description	Value	Notes
Min Ratio	0.25	Defines the minimum fraction that the boiler will operate down to.
Max Ratio	Default (1.00)	This is the maximum ratio. Should be set to 1 as there should be no oversizing.
Heat Input Ratio	1.3158	Ratio of heat input (in Btus) to full load heating capacity (in Btus), at rated conditions.  The starting point is 76% efficiency. This should be revised per the project documents.
Elec Input Ratio	Default (0.0033)	Ratio of electrical input (in Btus) to full load heating capacity (in Btus), at rated conditions. Used to approximate the contribution of controls and draft fan as a percentage of boiler capacity
Return Water Tmp.	190°F	For steam boilers this is the boiler's entering water temperature that the HIR and EIR are defined for. The design steam temperature should be defined in the HW loop.
Location	Zone	Location Zone is used to approximate the boiler's contribution to the zone's air temperature. Using "outdoor" is equally as acceptable.
Boiler Zone	*NAME*	Name of the zone boiler is located
Aquastat Setpoint T	n/a	Only significant if the boiler is set to maintain a temperature much higher than the loop temperature.

## 8.2 Hot Water Boilers

Refer to Section 5.2.3 and 5.2.4 of the SCA How-To Guide for modeling the Hot Water Loop and SCA Condensing Boiler in the design case. In the case of existing HW boilers, they can be modeled in the baseline similar to the GSG Baseline column in Table 29 of the SCA Input Summary. Inputs should be changed according to existing boiler information.

## 8.3 Chillers

Refer to Table 28 of the SCA Input Summary for modeling chillers. Existing chillers can be modeled similar to chillers in the GSG baseline. Inputs should be changed according to existing chiller information.

## 8.4 Domestic Hot Water Heaters

Refer to Section 7.4 of the SCA Input Summary for modeling DHW heaters. Existing equipment is likely to use natural gas or fuel oil, therefore the inputs in Appendix C should be used for the existing building baseline.

## 9 Utility and Economics

### 9.1 Electric Meters

The electric meters included in the template are detailed below. The site-to-source conversion rate for electricity is 2.55.

*Table 25. Electric Meters*

Meter Name	Description	Type	Loads
ME-MAIN-ELEC-METER	Main electric meter	Utility	All electric loads, including regulated and non-regulated loads
ELEV-METER	Meter for elevator use	Submeter to ME-MAIN-ELEC-METER	Elevators
KIT-MISC-METER	Meter for kitchen hood exhaust and return fans	Submeter to ME-MAIN-ELEC-METER	Kitchen hoods and kitchen return fans. All loads on this meter should be ZERO for schools that don't have kitchen hoods.
HP-FAN-METER (Heat pump heating with electric resistance baseboards only)	Meter for baseboard fan work-around in electric Case	Submeter to ME-MAIN-ELEC-METER	Heat pump fan power for morning warm-up baseboard work-around. (See SCA How-To Guide)

The following interior direct loads should be included.

*Table 26. Interior Direct Load*

Meter	Load	Schedule	End Use
ME-MAIN-ELEC-METER	Restroom exhaust per design documents	CLASS-FAN-EU-SCH	VENT-FANS * Do not include for GSG baseline unless exhaust is decoupled from main AHU's
ELEV-METER	Elevator load per Table 11	ELEV-EQP-SCH	MISC-EQUIP
KIT-MISC-METER	Ventilation hood load per kitchen equipment schedule	KIT-HOOD-YR	VENT-FANS
KIT-MISC-METER	Kitchen Return fan power per mechanical schedule	KIT-RETURN-YR	VENT-FANS
KIT-MISC-METER	3.47	KIT-WALK-IN-YR	MISC-EQUIP



The following exterior direct loads should be included.

*Table 30. Exterior Direct Loads*

Meter	Load	Schedule	End Use
ME-MAIN-ELEC-METER	Exterior lighting per design documents	EXT-LT-SCH	EXTERIOR-USAGE

## 9.2 Fuel Meters

### 9.2.1 Natural Gas

The site-to-source conversion rate for natural gas is 1.05.

*Table 31. Fuel Meter*

Meter Name	Description	Type	Loads	BTU/unit
MF-MAIN-FUEL-MET	FUEL-METER	NATURAL-GAS	Natural gas loads	eQuest Default

### 9.2.2 Fuel Oil

The site-to-source conversion rate for fuel oils is 1.01. The ENERGY/UNIT is in units of Btu/gal and depends on the category of fuel oil being used.

*Table 32. Fuel Meter*

Meter Name	Description	Type	Loads	Btu/unit (No. 2 oil)
FUEL-OIL-METER	FUEL-METER	FUEL-OIL	All fuel oil loads	140,000

## 9.3 Purchased Steam

If the steam is converted to hot water or low pressure steam through a heat exchanger, its efficiency should be assumed to be 90% for a new or well-maintained unit, and 85% for a unit in poor condition. This should be modeled as changing the MMBtu/unit conversion factor.

The site-to-source conversion rate for purchased steam is 1.2, per EnergyStar.

*Table 33. Fuel Meter*

Meter Name	Description	Type	Loads	BTU/Unit (bad condition)	BTU/unit (good condition)
STEAM-METER	STEAM-METER	Steam	All steam loads	869,565	909,091

## 9.4 Purchased Chilled Water

If the chilled water is passed through a heat exchanger, its efficiency should be assumed to be 95%.

The site-to-source conversion rate for purchased chilled water is 0.91.

*Table 34. Fuel Meter*

Meter Name	Description	Type	Loads	BTU/unit
CHW-METER	CHW-METER	Chilled Water	All CHW loads	952,381

## 10 Utility Bill Matching

### 10.1 Reviewing Existing Utility Bills

Existing buildings have a different workflow during the modeling process. Because the building is already in use, it has a record of past energy consumption in the form of utility bills. To accurately predict the impact of proposed design's electrification on a building's energy use and associated CO<sub>2</sub> emissions, the existing building model must first be calibrated to match the historic utility bills. These can also be used to identify the energy sources of the building (electricity, natural gas, fuel oil).

Utility bills spanning the 3 years prior to the project start date should be used. Due to the unusual circumstances in which the buildings were operated during the 2020 spring semester and the 2020 – 2021 school year, the corresponding data should be discarded. Depending on how the data is provided (by calendar year or by school year), either the 2020 and 2021 calendar years should not be used, or the 2019 – 2021 school years should not be used.

### 10.2 Matching Model to Utility Bills

#### 10.2.1 Initial Energy Model Setup

To match the existing building model, first build the existing building baseline according to the instructions above. Once this has been modeled, run the model using a historic weather file appropriate to the utility bill year (ex: if bills are available for 2019, use a recorded weather file from 2019 corresponding to a local weather station). Please note that the weather files used for the new construction GSG projects are averaged weather files. Once the model is adjusted to match the historical energy use data using the historical weather file, the TMY3 weather files used in typical GSG projects should be used going forward for both the baseline and the proposed design case in order to forecast the average future performance of the building.

#### 10.2.2 Adjusting the Model to Match Historic Utility Bills

Once the model has been run, input both the actual bills and the modeled results into the ASHRAE guideline 14-2014 Error Analysis spreadsheet. Generally, this will include Electricity use, Electricity demand, and Oil/Gas use. Bills that must be matched include all energy usage, typically including Electricity and Gas, but potentially also Steam or other fuel sources. Demand charges can be matched when provided but are not necessary to satisfy the SCA matching requirements. The error analysis spreadsheet will assess how much the modeled values vary from the actual recorded bills and provide a line graph of energy usage to illustrate where the billing and modeled use diverge.

The statistical analysis of each billed variable is broken down into two numbers; Coefficient of the Variation of the Root Mean Squared Error (CVRMSE), and the Normalized Mean Bias Error (NMBE). Per ASHRAE guideline 14-2014, for a building match to be considered acceptably accurate, **the CVRMSE must be below 15%, and the NMSE below 5%**. Much of the difficulty in matching a building model comes from getting within these boundaries, and it is likely that the preliminary model will fail to meet these requirements.

Energy models are idealized versions of the buildings that operate in real world conditions. Several things can be different in constructed buildings that will result in a mismatch between the model and the energy bill. Below are several strategies for aligning the modeled values to the actual bills, based on

common mismatches between modeled and actual buildings. Implementing these strategies is a balancing act to ensure that all bills are within the CVRMSE and NMSE cutoffs.

While all bills for monthly energy use should be matched according to the guidelines above, in some situations electric demand matching may be particularly difficult without unrealistic energy model inputs that would significantly deviate from common school usage patterns (such as 24/7 lighting). Therefore, demand matching is not necessary for compliance with these guidelines. It is encouraged that the general pattern of the provided demand data be followed as close as realistically possible so as to avoid situations in which the energy usage is created by abnormal demand spikes in the energy model.

### 10.2.3 Matching Strategies

**Electric demand too low:** Increase lighting power density (LPD) and space equipment power density (EPD) above the values listed in sections 5.1 and 5.4. If it is not possible to match the recorded demand values using reasonable inputs (e.g. not by having plug load or lighting power densities that exceed by more than 3 times the modeling guideline default values), the energy model demand curve should be as parallel as possible to the recorded values.

**Electric demand too high:** Ensure that cooling is actually provided for all spaces in the existing building. Some older schools may lack cooling in some/all spaces. If it is not possible to match the recorded demand values using reasonable inputs (e.g. not by having no HVAC system operate during the summer, or having an LPD below that of a new school project), the energy model demand curve should be as parallel as possible to the recorded values.

**Electric use is too low year-round:** Increasing LPD and EPD may improve this, particularly if this is a problem across the entire year. Operational schedules may also require adjustment.

**Electric use is too low in the summer:** Reduce the efficiency of DX cooling to reflect the degraded efficiency of older units.

**Electric use is too high in summer:** Ensure that the school is occupied during the summer, and that cooling setpoints are accurate. Some schools may not have cooling or may be inadequately cooled during the summer months. It is reasonable to incur some under-cooled hours by under-sizing the cooling system in the existing building model.

**Electric use is too low in winter:** The building may have a different schedule during the winter or may use electric heat. Site visits can be useful for identifying problems like this. Additionally, the base load of the building may be higher than modeled and increasing LPD may raise the floor of the electric usage.

**Gas/Oil use is too low:** Reduce the efficiencies of furnaces, water heaters, and boilers to reflect degradation over time. Also, if the school has a gas kitchen ensure it is not undersized.

**Gas/Oil use is too low in summer:** Increase idling energy use of boilers, hot-water heaters and kitchen equipment. Check to see if cooling systems utilize gas powered compressors.

**Gas/Oil use is too low in winter:** Adjust scheduling of baseboards and heaters. Consider adjusting control zones and causing spaces to be overheated, especially if this was mentioned during site visits. Again, some over-heated/under-cooled hours are expected to occur here. In actual operation, classrooms may overheat leading to open windows during winter months, or schools may continue to rely on natural ventilation during cold months.

**Gas/Oil use is too low in the winter, and electricity is too low in the summer:** Reduce the R-value of the walls, windows, and roofs. This can reflect the degradation of the insulation in walls or built conditions that are worse than illustrated in drawings. Increasing infiltration can also help this issue, although it may cause a stronger effect on the heating energy use than the cooling energy use.