Attachment E - Energy Modeling Guidelines

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Examples

Commercial Tenant Program Energy Modeling Guidelines
Revised August 2020

1 Purpose

The Commercial Tenant Program (Program) Simulation Guidelines (SG) outline the energy modeling methodology for projects that participate in the Program. This Program is specifically for tenant office spaces in existing buildings. It shall be used by Modeling Entities, and may be shared with developers, building owners and managers, future tenants, design teams, and other team members as required.
The Commercial Tenant Program focuses on tenant office fit-outs and renovations in existing buildings. It is assumed that the majority of these projects will incorporate some use of existing equipment (central plant, air handlers, etc.) while others may incorporate new equipment into their design (i.e. a large tenant incorporating a new chiller for their load, etc.). While these guidelines attempt to incorporate all potential tenant fit-out scenarios, project specific items and modeling parameters (i.e. baseline systems) that are not addressed here may need to be reviewed and approved by NYSERDA.
Updates to the SG will be released as needed, and will include clarifications and updates to the Program modeling policies, supporting calculations, and modeling methods based on references such as Commercial Buildings Energy Modeling Guidelines [3] and the ASHRAE 90.1-2016 User's Manual [2] (if a different version of ASHRAE 90.1 is used, refer to that version's User's Manual).

An important goal of the SG is to share peer-reviewed modeling approaches to help improve accuracy, consistency, and productivity of energy modeling, and to publish exceptional calculation methods that NYSERDA approves for use in the Program.

The intent of the Program is to provide a custom energy model resulting in a list of energy efficiency measures tailored to the unique needs and requirements of a tenant. This tenant-specific package (formerly known as "Custom Package") includes a financial analysis to allow the tenant to choose the options that work best for its business. The Program also provides a modified package applicable to the remainder of the tenant spaces in the building. This building-tenant package (formerly known as "Generic Package") is created for the building owner/manager to use in future lease negotiations and fit-out designs for tenants. The building-tenant package includes a list of energy saving opportunities applicable to tenant spaces within that specific building. This will allow for new tenants to use the building-tenant package and may eliminate the need for additional tenant-specific energy modeling. This Program will test the ability to standardize energy efficiency packages for tenant spaces within commercial buildings. These guidelines address the requirements of both of these energy modeling packages.

2 Scope and Applicability

The energy modeling approach is applicable to tenant fit-outs and major renovations of commercial tenant spaces that satisfy Program eligibility requirements as outlined in PON 4072 and summarized below. Refer to the PON for complete requirements.

- Commercial real estate space that is currently leased by a tenant or will be leased by a tenant.
- The tenant or the facility where the leased space is located must be a New York State electricity distribution customer of a participating utility company who pays into the System Benefit Charge.
- The program's recommended minimum area is 5,000 square feet per tenant (see Program Opportunity Notice for more information).
- If the tenant is renovating a space, the renovation must be significant enough to trigger code compliance and the recommended package(s) must include **measures that exceed the current code requirements** for at least two of the following five building systems: lighting, HVAC, service water heating, plug and process loads, and building envelope.

Projects must follow the Simulation Guidelines version that was in effect when the project was scoped. Modeling Entities may use a more recent version of the Simulation Guidelines retro-actively for older projects; however, the selected version of the Simulation Guidelines must be followed in its entirety.

3 General Approach

3.1 Deliverables Related to the Energy Model (per PON 4072)

Refer to PON 4072 Final Report Template for information related to required deliverables related to the energy models for tenant-specific and building-tenant packages. The following lists the models required:

- Baseline Energy Model
- Design Options Modeling (Tenant-Specific)
- Final Energy Model (Tenant-Specific)
- Building-Tenant Package Development

3.2 Simulation Methodology

a) Projects shall be simulated following one of the Compliance Paths prescribed in the version of ASHRAE/IESNA Standard 90.1, as per the requirements defined the New York State Energy Code adopted by the locality at the time the project is scoped. For example, the ICC 2020 Energy Conservation Construction Code of New York State is based on the requirements defined in ASHRAE Standard 90.1-2016 [1]. However, if the project is taking place in a locality that has its own energy code, the simulation should follow the requirements of the most recent version of that code. Simulations should follow Normative Appendix G Performance Rating Method (Appendix G, PRM) and as described in this document. The simulations developed must reflect the following:

The baseline case (the baseline):

- Shall be modeled as described in Appendix G.
- Shall not include end uses that do not exist in the proposed building, with the exception of space cooling that must be modeled where required per Table G3.1-10.d. See example 3-1.

The proposed design (including the Design Options Model and the Final Design Model):

- Shall be modeled as described in Appendix G.
- Must reflect the specified building components except where required otherwise in this document.
- Must comply with the mandatory provisions in Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4 of ASHRAE 90.1, including but not limited to demand control ventilation for high occupancy areas (section 6.4.3.8), automatic receptacle control (Section 8.4.2), electrical energy monitoring (Section 8.4.3), etc. Mandatory provisions adjusted by local authorities (i.e. plug load monitoring in 2014 NYCECC Appendix A Amendment) to prescriptive requirements

EXAMPLE 3-1 - No Cooling Specified

Q. A project involves an office that includes offices, common corridors, stairwells, tenant storage and mechanical/utility rooms. No cooling is specified for the building. Should cooling be modeled in either the baseline or the proposed design model?

A. Based on Table G3.1 Design Model, cooling must be modeled in all *conditioned* spaces in both the baseline and proposed models, except for in thermal blocks served by Baseline System types 9 and 10.

Based on the definition of *space* in ASHRAE 90.1 Section 3 and heating output of the equipment specified in the proposed design, the offices, corridors, and tenant storage are conditioned spaces. Tenant storage must be modeled with System 9/10 and no cooling based on G3.1.1 Exception 5. Offices and corridors have baseline System 1/2, and thus must be modeled with cooling in both the baseline and proposed design.

Stairwells and mechanical/utility rooms fall into unconditioned or semi-heated categories based on 90.1 definitions, and are thus also modeled with no cooling.

do not need to be in the design,[1] but will be in the baseline (i.e. these items can be considered trade-offs).

b) Addenda to ASHRAE 90.1 may be used, but must be explicitly referenced in the submittals and followed in their entirety. One addendum or several addenda may be used without having to use all the addenda.

c) Simulation software must comply with the requirements outlined in Appendix G Section G2.2. Approval for use in LEED v4 for Building Design and Construction, LEED v4 for Interior Design and Construction or EPAct Tax Deduction for Commercial Buildings may serve as proxy for software admittance into the Program. Examples of allowed tools include eQUEST, DOE2.1, EnergyPlus, Carrier HAP, and Trane Trace 700.

d) If an approved simulation tool used for the project does not have the capability to calculate energy usage/savings for a design feature allowed by Appendix G protocol and the Program, supplemental calculations may be used. All such calculations must be documented in the report appendix following requirements of 90.1 Section G2.5.

e) Baseline and proposed design models shall include all the energy costs within and associated with the tenant space. This includes loads that are not regulated by ASHRAE 90.1, except where explicitly required otherwise. It is assumed that the models shall generate results and costing for the tenant space only.

f) If available and provided by the building owner, utility information may be used to inform the overall modeling procedure in an order of magnitude comparison. For example, if the existing building operates at 100 kBtu/ft^2 and \$3/ft^2, these metrics can be used to inform the model. Modifications can be made to bring the model in line with these values, but specific calibrations to existing utility consumption and costs is not expected. The baseline and design models shall be developed according to Appendix G.

3.3 District Systems & Central Plants

It is understood that most projects will use existing central plant equipment and larger base building air handlers outside of the scope of their projects. Some tenants may incorporate new terminal units and central plant equipment (fan coils, DX cooling, heat pumps, new chillers, etc.).

3.3.1 Existing Systems

When a building utilizes *an existing* district or central heating and/or cooling system/plant, the existing system must be held energy-neutral (equally efficient) in the baseline and proposed models. Only equipment included in the scope of the project may vary between the two models. One of the following analysis options may be used for such projects:

a) Follow modeling requirements of G3.1.1.3.

b) Complete modeling as described in option (a). Convert purchased energy/central plant usage/savings into the equivalent electric or fossil fuel savings in order to capture associated savings.

[1] Applicants wishing to apply for implementation incentives through the Commercial New Construction Program should be aware that they must comply with mandatory provisions adjusted by local code and ensure they meet eligibility requirements of both the Commercial Tenant Program and the Commercial New Construction Program. Engaging NYSERDA program staff early in the design process is highly recommended.

Conversion factors must be the same in the baseline and proposed models, and either based on the known efficiency and losses of the central plants, or the following defaults when the actual performance is unknown [7]. See Example 3-2.

EXAMPLE 3-2 - Converting Central Plant

Q. A project has a proposed cooling system that utilizes chilled water, and is connected to an existing central plant comprised of electric chillers with unknown efficiency. The project includes a lighting EEM that will cause a reduction in the cooling load for the building. An energy simulation is performed for the building. According to the simulation, the lighting EEM saved 65 MMBtu of chilled water, and reduced summer peak chilled water demand by 100 kBtu/hr. How can electrical savings from the reduction in the cooling load be determined?

A. The equivalent electricity savings are calculated as 65,000/(3.2*3.412)=5,953 kWh and 100/(3.2*3.412)=9.2 kW

i. District chilled water generated by electric chiller: COP 3.3 chiller efficiency, 2.5% distribution loss, with the overall system performance of COP 3.2.

ii. District chilled water generated by gas chiller: COP 0.95 chiller efficiency, 2.5% distribution loss, with the overall system performance of COP 0.93.

iii. District steam generated using conventional boiler technology: 80% boiler efficiency, 7.5% distribution loss, with the overall system performance of 74%.

iv. District steam generated using combined heat and power: 106.9% generation efficiency, 7.5% distribution loss, with the overall system performance of 98.9%.

v. District steam generated with unknown technology: 82.6% weighted average overall efficiency based on 41.35% CHP market share.

vi. District hot water: 80% boiler efficiency, 2.5% distribution loss, with the overall system performance of 78%.

c) Model a virtual plant representative of the existing district/central plant system. For example, a virtual chiller may be modeled to convert reduction in purchased chilled water to equivalent kWh/kW savings. Parameters of the virtual plant must be the same in the baseline and proposed models, and documented in the report. If the actual central plant efficiencies are unknown, the default efficiencies described under option (b) must be used.

3.3.2 New Systems

When a tenant project utilizes *a new* district/central heating and/or cooling plant, the new plant may be included in the scope of the project. In these cases, the baseline model would be determined by the requirements of ASHRAE 90.1 Appendix G.

If the new plant is intended to service existing and/or future loads not included in the scope of the application, the energy model and savings must be based only on the new load within the scope of the project.

3.4 Process and Plug Loads

The process and plug loads category includes systems and equipment that affect building energy consumption but are not regulated by ASHRAE 90.1. As a general rule, such loads must be modeled as energy-neutral (identical) in the baseline and proposed design, but some unregulated systems such as major ENERGY STAR labeled appliances and plug load management beyond code requirements may show energy savings.

The process and plug loads must be reasonably captured in the models to account for their impact on regulated systems due to the added internal heat gains.

3.4.1 Baseline Process and Plug Loads

The typical energy use intensity (EUI) of unregulated loads for different building types based on Pacific Northwest National Laboratory (PNNL) prototype models of commercial building stock compliant with 90.1-2013 is shown in SG Appendix A. Projects with a process and plug load EUI of 80% or less of the typical must justify the related modeling assumptions in the report. Automated receptacle controls required by the mandatory provisions Section 8.4.2 must be included in the baseline, except where these requirements are adjusted by local authorities (i.e. 2014 NYCECC Appendix A Amendment).

3.4.2 Proposed Process and Plug Loads

If the process and plug loads are not included in an Energy Efficiency Measure (EEM), they must be kept energy neutral, and must be modeled the same in the proposed design as in the baseline. If the process and plug loads are modeled as an EEM, the baseline must be established based on the applicable state, local, or national codes. Below are several examples of EEMs related to plug loads.

a) ENERGY STAR Appliances:
Savings from Energy Star appliances should be calculated using the latest version of the appliance calculator published by the EPA on the Energy Star website. Savings given by the appliance calculator should be converted into model inputs to show the interaction between plug loads and heating/cooling energy.

b) Additional Automated Receptacle Controls:
Savings for automated receptacle controls in addition to those required by 90.1 Section 8.4.2 may be modeled by adjusting proposed plug load schedule (Option 1) or plug load power density (Option 2) as follows:

Baseline Design:

- PL_B [W/SF] - Plug Load Power Density (PPD) based on values in Default Power Density column and Space-by-Space Classification for the appropriate space (lower portion of the table) of COMNET Appendix B.
- Plug Loads Schedule - based on the plug load schedule for appropriate building type from COMNET Appendix C.

Proposed Design (including the Design Options Model and the Final Design Model):
Option 1:

- In all thermal blocks where no automatic receptacle controls are specified, PPD and schedule must be the same as in the baseline
- In all thermal blocks where additional automatic receptacle controls are specified beyond mandatory requirements for some of the receptacles, plug loads must be separated into two components:

$PL_{P,AC}=PL_B*F$
$PL_{P,NC}=PLB*(1-F)$
Where:
$PL_{P,AC}$ [W/SF] – PPD affected by automatic controls
$PL_{P,NC}$ [W/SF] – PPD not affected by automatic controls
F- ratio of the total rating of the controlled receptacles to the total rating of all receptacles in the appropriate thermal blocks

- PPD not affected by automatic controls ($PL_{P,NC}$) must be modeled with the same schedule in the proposed design as in the baseline
- PPD affected by automatic controls ($PL_{P,AC}$) must be modeled with the following schedule:

- Zero schedule fraction during un-occupied hours (hours with 0 Occupancy Schedule fraction in COMNET Appendix C for the appropriate building type).
- Schedule fraction for all other hours must be reduced by 20%.

Exception: With prior NYSERDA approval, alternative schedules may be used to demonstrate greater than 20% savings during occupied hours. Acceptable sources include measurements performed on similar completed projects or peer-reviewed studies.
Option 2:

- In all thermal blocks where no automatic receptacle controls are specified, PPD and schedule must be the same as in the baseline
- In all thermal blocks where automatic controls are specified for some of the receptacles PPD must be modeled as follows:

$PL_P=PL_B*(1-F*0.2)$
PL_P [W/SF] – proposed PPD; must be modeled with the same schedule as in the baseline
F- ratio of the total rating of the controlled receptacles to the total rating of all receptacles in the appropriate spaces / thermal blocks
0.2 – allowed overall % PPD reduction

3.5 Modeling Existing and Future Components

Parameters related to *unmodified* existing conditions or future building components must be identical in the baseline and proposed design models, as described in Section G1.3.

- Future building components must be modeled as meeting applicable requirements of ASHRAE 90.1.
- Un-modified existing components must reflect the existing conditions where the existing conditions are known and documented in the report, or as meeting applicable requirements of ASHRAE 90.1.

The baseline design for systems and components that are altered as part of the project must be modeled as meeting appropriate requirements of Appendix G as applicable.

3.6 Energy Rates

Annual energy cost must be based either on the actual rates of purchased energy, state average energy prices (G2.4.2), or rates provided in COMNET Chapter 5 for the appropriate climate zone. The selected source must be used for all fuels in the project, except when a project elects to use actual utility tariffs, but actual tariffs are not available for one of the fuels in the project, average rates may be used for that fuel.

3.7 Simulated Schedules

Modeled lighting, occupancy, HVAC, and other schedules must be in line with Tables G-E to G-O of 90.1 User's Manual, and COMNET Commercial Buildings Energy Modeling Guidelines and Procedures Appendix C, as applicable, except as described in Sections 3.5.2 and 4.1.5 of this document.
Simulated schedules must support realistic demand reporting.
Alternative schedules may be modeled to reflect project-specific design requirements such as 24/7 operation in data centers and security areas.

4 Specific Requirements

4.1 Building Envelope

Refer to example 4-1.

4.1.1 Baseline Model

The *baseline* model must reflect surface type, solar and thermal properties as required in Appendix G Table G3.1-5.
Exception: Parameters relating to unaltered portions of existing building envelopes must be identical in the baseline and proposed design models, and shall be modeled to reflect the existing

conditions where the existing conditions are known and documented in the report per section 3.7 of this document (90.1 G1.3). Where the proposed design includes alterations listed as exceptions to 90.1 Section 5.1.3 Envelope Alterations, the baseline and proposed design shall be modeled identically to reflect these alterations.

4.1.2 Proposed Model

a) Thermal properties of steel-framed assemblies must be determined using ASHRAE 90.1 Appendix A to capture thermal bridging through steel members.

b) Fenestration must be modeled to reflect whole window assembly U-values (including frame) and not the center-of-glass U-value. Acceptable sources for overall fenestration U-value include:
- NFRC rating from the window manufacture for the entire fenestration unit. (This is usually available only for standard window sizes.)
- LBNL WINDOW software http://windows.lbl.gov/software/window/window.html
- Model the frame and glazing explicitly in the simulation tool used for the project based on the known thermal properties and dimensions of the frame and glazing
- ASHRAE 2009 Fundamentals [6], Chapter 15 Table 4.

EXAMPLE 4-1- Existing Envelope Components

Q. A project includes a major renovation of a 40,000 ft^2 office space located in ASHRAE Climate Zone 5a. As part of the renovation, the total window area in the existing space is increased from 1,000 ft^2 to 1,500 ft^2 and the existing windows (NFRC U-0.9/SHGC-0.68) are all replaced. Exterior walls in the renovated portion are left as is. The new windows installed in the renovated portion are metal-frame with a NFRC rating of U-0.50 /SHGC 0.4. Windows account for 25% of gross exterior wall area of the addition. How would the envelope be modeled in the baseline and proposed design?

A. Project inputs are shown in the table below.

	Renovated Portion	
	Baseline	Proposed
Window Area, ft^2	1,000 ft^2 (match pre-retrofit condition)	1,500 ft^2 (as specified)
Window U-value	U-0.5/SHGC-0.4/VT-0.44 (Table 5.5-5)	U-0.50 / SHGC-0.4 (as specified)
Wall Area	match pre-retrofit	As specified (500 ft^2 less

4.1.3 Reflective Roof

All roof surfaces in the baseline must be modeled with a reflectance of 0.30 and a thermal emittance of 0.90. In the proposed design, the exterior roof surface shall be modeled using the aged solar reflectance and thermal emittance determined in accordance with Section 5.5.3.1.1(a). Where aged test data are unavailable, the roof surface may be modeled with a reflectance of 0.30 and a thermal emittance of 0.90, as described in Table G3.1-5, Proposed Design column, Exception 3 to (a).

4.1.4 Exposure-Neutral Baseline

The baseline for projects involving renovations and additions must reflect the actual building orientation since these projects will be in existing buildings.

4.1.5 Infiltration

Infiltration rates must be modeled the same in the baseline and proposed design models, and must be calculated following G3.1.1.4.
Infiltration must be modeled at 100% (i.e. with schedule fraction of 1) during un-occupied hours when HVAC systems are off, and at 25% during occupied hours (i.e. with schedule fraction of 0.25) [9]. Infiltration can be ignored during occupied hours by modeling infiltration schedule fraction of 0 when fans are on if simulation tool restricts changes to infiltration schedule.

4.2 Heating, Ventilation, and Air Conditioning

4.2.1 Baseline HVAC System Efficiency and Extracting Fan Power from Efficiency Ratings

Fan power must be excluded from the efficiency ratings including EER, SEER, COP, and HSPF following equations provided in G3.1.2.1. Refer to example 4-2.

EXAMPLE 4-2 - Extracting Fan Power from Baseline SEER Rating

Q. If a baseline HVAC system for a project is determined to be System 3 – PSZ with a capacity range of <65,000 Btu/h, what are the inputs for the system efficiency?

A. Based on ASHRAE 90.1 Table 6.8.1A, the baseline system efficiency is 14.0 SEER for the selected capacity. Baseline efficiency excluding supply fan power based on G3.1.2.1 is:

$$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER = 3.8248$$

If eQUEST is used to perform simulation, system efficiency is modeled as follows:

$$EIR = 1 / COP_{nfcooling} = 0.2615$$

4.2.2 Ventilation Control for High Occupancy Areas

Mandatory Section 6.4.3.8 requires that demand control ventilation (DCV) is specified for spaces larger than 500 ft^2 and with a design occupancy greater than 25 people per 1,000 ft^2 of floor area and served by systems with one or more of the following:

- An air-side economizer

- Automatic modulating control of the outdoor air damper or
- A design outdoor airflow greater than 3000 CFM

Due to this requirement, spaces such as auditoriums, conference rooms, lecture halls, multipurpose rooms, etc., may have demand control ventilation in the baseline design unless baseline has energy recovery per section G3.1.2.11. This requirement is mandatory, thus in order to comply with ASHRAE 90.1, the proposed design must also have demand control ventilation unless exceptions to Section 6.4.3.8 apply.

If project's occupant density in spaces that are typically subject to the DCV requirement is less than the defaults listed in ASHRAE 62.1 Table 6-1 making DCV not required, the source of the project's data must be documented. Refer to example 4-3.

EXAMPLE 4-3 - DCV in the Baseline

Q. A proposed design for an office building in Albany (climate zone 5a) includes a 1,000 ft^2 conference room with a design occupant density of 160 people and a design ventilation rate of 2,400 CFM. In the proposed design, the space is served by a dedicated air handling unit with DCV. The simulation run for the baseline model showed that the cooling load in the lecture hall differs by more than 10 Btu/hr-ft^2 from the average for the building. How should the system be modeled in the baseline?

A. Because of the difference in load, the system should be modeled with a dedicated System 3 – PSZ (Section G3.1.1 Exception b) that has an economizer (Table G3.1.2.6A). Since the space occupant density is greater than the 25 people per 1,000 ft^2 limit (set in Section 6.4.3.8), AND the space area is greater than 500 ft^2, AND the system has an economizer, AND energy recovery is not required in the baseline (by section G3.1.2.1), AND none of the exceptions to 6.4.3.9 apply to the baseline system, the baseline system <u>must</u> be modeled with demand control ventilation.

4.2.3 Mechanical Ventilation Rate

Following G3.1.2.6 Exception #3, if the minimum outdoor air intake flow in the proposed design exceeds the amount required by applicable building code, such as in Mechanical Code of New York State Table 403.3, then the baseline building design shall be modeled to reflect the code requirements and will be less than the proposed design, resulting in a penalty for over-ventilation. An Exception to this requirement will be made in the Program for projects that do not include changes to existing air handling systems. These projects shall use the existing ventilation rates (if known) in the baseline & design. If unknown, ventilation code requirements will be used.

4.2.4 Dedicated Make-up Air Systems

Heating, cooling, and ventilation in the baseline model must be provided by the HVAC system selected as described in G3.1.1. Dedicated make-up air systems must not be modeled in the baseline even when they are specified for the proposed design. There is no additional fan power allowance in the baseline for projects with dedicated make-up air systems in the proposed design.

4.2.5 Baseline Heat Pump Efficiency

Baseline Systems 2 – PTHP and System 4 – PSZ-HP must be modeled with electric auxiliary heat controlled as required by G3.1.3.1 [8]. The electric auxiliary heat may not be used in the model at temperatures above 40ºF.

PTHP must be modeled to allow operation in conjunction with the auxiliary heat at temperatures of 25ºF and higher; below 25ºF, only the auxiliary heat should be modeled. PSZ-HP must be modeled to allow operation in conjunction with the auxiliary heat at temperatures of 10ºF and higher; below 10ºF, only the auxiliary heat should be modeled. For example, eQUEST users must set "Minimum HP Heat Temp" to 25ºF and "Maximum HP Supp Temp" to 40ºF when modeling PTHP.

4.2.6 Fan Power

4.2.7.1 Extracting Supply Fan Power from Efficiency Ratings

a. Modeled Baseline HVAC system efficiency must be calculated as described in section G3.1.2.1, which provides equations for extracting fan power at the rated conditions from the rated efficiencies.

When calculating $COP_{NFCOOLING}$, Q must be capped at the minimum capacity of the highest capacity bracket for the applicable equipment type in Tables 6.8.1-1 and 6.8.1-4. For example, if System 5 (Packaged VAV) is modeled in the baseline and the capacity of one of the baseline systems is 1,400,000 btu/h, $COP_{NFCOOLING}$ must be calculated assuming Q = 760,000 btu/h.
When calculate $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ for baseline System 1 & 2 (PTAC and PTHP), Q shall be capped at 15,000 btu/h and shall be no less than 7,000 btu/h.

b. Modeled Proposed HVAC system efficiency must be calculated as follows:

Packaged Air Conditioner and Heat Pump Cooling Equations:	
EER = Net Cooling [Btu/h] / Total Input Power [W]	(Equation 4.1.1)
Indoor Fan Power [W] = (Gross Cooling [Btu/h]-Net Cooling [Btu/h])/3.412[Btu/h x W]	(Equation 4.1.2)
$COP_{NFCOOLING}$ = Gross Cooling [Btu/h] / (Total Input Power [W] – Indoor Fan Power [W])x3.412[Btu/h x W]	(Equation 4.1.3)

Packaged Air Conditioner and Heat Pump Heating Equations:	
$COP_{HEATING}$=Net Heating [Btu/h]/ (Total Input Power [W] x 3.412 [Btu/h x W]	(Equation 4.2.1)
Indoor Fan Power [W]= (Net Heating [Btu/h]-Gross Heating [Btu/h])/3.412[Btu/h x W]	(Equation 4.2.2)
$COP_{NFCOOLING}$ =Gross Heating [Btu/h] / (Total Input Power [W] – Indoor Fan Power [W])x3.412[Btu/h x W]	(Equation 4.2.3)

All inputs in the equations for the proposed design must be based on manufacturer's data for the specified equipment at the AHRI rated conditions.

4.2.7.2 Baseline System Fan Power

a. The system baseline fan power must be calculated according to Appendix G section G3.1.2.9, and represents the total fan power allowance including supply, return, and exhaust fans, central and zonal.

b. Baseline fan power allowance should be allocated to supply, return and exhaust in the same proportion as in the proposed design, per G3.1.2.9.1.

c. The preferred method for modeling baseline fan power is by specifying Watt per CFM of air flow in the model, as this avoids the need to adjust fan power whenever flow rates change when evaluating EEMs. If a software tool does not allow inputting power per unit flow, the same purpose can be achieved by defining the total static pressure drop and overall fan efficiency fraction (including motor, drive, and mechanical efficiencies). Use equation 4.3 to convert from kW/cfm (power per unit flow) to in wg (TSP).

$$Power_{kW/CFM} = \frac{TSP_{in.wg}}{8520 \times \eta_{overall}} \qquad \text{(Equation 4.3)}$$

If overall fan efficiency fraction $\eta_{overall}$ is unknown, 0.55 can be used. The accuracy of this estimate does not affect the results of the simulation, since adjusting the efficiency fraction when using equation 4.3 will cause an offsetting adjustment in total static pressure.

For existing air handlers not included in the tenant design, existing fan power energy shall be used.

Refer to Example 4-4.

EXAMPLE 4-4 - Fan Power and Cooling Efficiency

Q. A 10,000 square foot office building has three thermal blocks, each served by a packaged rooftop unit with a gas furnace. The rooftop units have fully ducted return, MERV 13 filters, and sound attenuation sections. Each unit is identical and has a design supply flow of 4500 CFM, an ARI net cooling capacity 144,000 btu/h, and an EER of 11.5. Gross capacity at ARI conditions listed by the manufacturer is 151,000 btu/h. Supply and return fan BHP at design conditions for each unit are 2.8 and 1.1 respectively. Flow rate across the return fan is 90% of supply flow. Each thermal block also includes a restroom with a 200 CFM continuously running exhaust fan with a 75W motor (~1/10 hp). How should fan power and cooling efficiency be modeled for the baseline and proposed designs?

A. Baseline: According to Table G3.1.1A, the baseline is System 3, Packaged Single Zone with Fossil Fuel Furnace. Baseline thermal blocks are the same as in the proposed design. System auto-sizing , in the simulation tool gives cooling capacity of 165,000 Btu/h with design flow rate of 4850 CFM.

The baseline system efficiency from ASHRAE 90.1 2013 Table 6.8.1-1 is 11 EER. This rating includes supply fan power, which needs to be removed from the descriptor using equations from G3.1.2.1:

$COP_{nfcooling} = 7.84E\text{-}8 \times EER \times Q + 0.338 \times EER = 7.84E\text{-}8 \times 11 \times 165{,}000 + 0.338 \times 11 = 3.86$

In eQUEST the system will be modeled with $EIR = 1/COP_{nfcooling} = 1/3.86 = 0.259$

To calculate baseline fan power, first determine total baseline fan power allowance according to section G3.1.2.10:

A = (.5 + .15 + .9) * 4850 / 4131 = 1.82. [Table 6.5.3.1-2]

BHP = .00094*CFM + A = .00094 * 4850 + 1.8 = 6.4 [Table G3.1.2.10]

Pfan = bhp x 746 / Fan Motor Efficiency = 6.4 x 746 / 0.895=5335 W [G3.1.2.10, Table 10.8-2]]

The final step in determining baseline fan power is to apportion the total system Pfan to supply, return, and exhaust applications, directly proportional to the apportionment in the Proposed Design using the Application Ratios described above. For this example, total proposed fan bhp for each system is 2.8 + 1.1 + 75 / 746 = 4 bhp.. Application ratios and their usage in calculating power per unit flow for this example are listed in the table below.

	Proposed Application Ratio	Total Baseline Fan Power W	Baseline Fan Power kW	Baseline Flow CFM	Baseline kW/CFM
Supply Fan	2.8 / 4 = .7	5335	.7 * 5335= 3.73	4850	.000770
Return Fan	1.1 / 4 = .275		.275 * 5335= 1.47	4365	.000336
Bathroom Exhaust	(75 / 746) / 4 = .025		.025 * 5335= .133	200	.000667

This calculation need only be performed once, for the fully configured baseline design, and should not be redone for individual EEM runs. The result of this calculation, the Baseline kW/CFM column, should either be entered directly into the modeling tool, or first converted into TSP and efficiency fraction inputs using equation 4.3. Thermodynamically equivalent approaches that use modified versions of the concepts and equations outlined above are also acceptable.

For the Proposed: To extract proposed fan power, use equations 4.1.1-3 For BHPsupply, take the difference between gross and net cooling capacities and convert to HP. For this example, equation 4.1 simplifies as follows:

Total Input Power [W]= Net Cooling [Btu/h] / EER = 144,000 / 11.5=12,522 [W]

Indoor Fan Power [W]= (Gross Cooling [Btu/h]-Net Cooling [Btu/h])/3.412[Btu/h x W]=(151,000-144,000)/3.412=2,052[W]

$COP_{nfcooling}$ =Gross Cooling [Btu/h] / (Total Input Power [W] – Indoor Fan Power [W]) /3.412= 151,000/(12,522-2,052)/3.412=4.23

Had the performance of specified unit s at ARI rating conditions been unavailable, we would have had to resort to equations in G3.1.2.1 for extracting fan power from efficiency ratings Proposed fan power should be modeled based on design documents, including all fan applications.

4.3 Service Water Heating

4.3.1 Baseline Hot Water Demand

Hot water demand in the Baseline Building Design shall be determined based on average daily hot water usage indicated in Table 4.3-1 below, based on Table 7 from Chapter 50: Service Water Heating of the 2015 ASHRAE Applications Handbook.

Table 4.3-1 - Hot-Water Demands and Use for Various Types of Buildings*

Type of Building	Average Daily Usage
Office Buildings	1.0 Gal/Person

For building types not included in Table 4.3-1, hot water demand may be established using other information given in Chapter 50: Service Water Heating of the 2015 ASHRAE Applications Handbook, such as Table 10 which provides hot water demand in gallons per hour per fixture for various types of buildings. Hourly demand must be coupled with the appropriate hourly schedules, such as those listed in [2] and [3].

4.3.2 Proposed Hot Water Demand

Technologies demonstrating a reduction in hot water usage can be modeled as reduced hot water demand in the Proposed Design based on Equation 4.4.

$$HWD_{PROP} = HWD_{BASE} * (1 - R) \qquad \text{(Equation 4.4)}$$

$$R = \sum R_A * F_A \qquad \text{(Equation 4.5)}$$

where

HWD_{BASE} baseline consumption [gal/day]

R - % reduction from baseline to proposed.

R_A - % reduction in hot water usage for a particular hot water application

F_A - hot water usage for the particular application as a fraction of total usage.

Table 4.3-2 shows R_A and F_A values for common building types and technologies. Values for other technologies must be documented and included in the modeling submittal. F_A values must reflect realistic run-time based on the number of fixtures specified for the project. See Example 4-8.

Table 4.3-2 - F_A and R_A values for calculating reductions in hot water usage

Application/ Technology	F_A	R_A	Notes
Low flow faucets (residential)	10%	1-FR/2.5	FR = average flow rate of installed faucets (GPM); 2.5 GPM = EPAct maximum
Low flow showerheads (residential)	54%	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = EPAct Maximum
Energy Star Appliances	$\frac{APPL_{BASE}}{HWD_{BASE}}$	WS	$APPL_{BASE}$ = Baseline water usage for the appliance from the Energy Star Calculator, in the same units as HWD_{BASE}; WS = % Water Savings from the Energy Star Calculator
Low flow faucets (commercial)	Estimate	1-FR/2.5	FR = average flow rate of installed faucets (GPM); 2.5 GPM = EPAct maximum
Low flow showerheads (commercial)	Estimate	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = EPAct Maximum

*sum of all F_A values must not exceed 100%

4.4 Lighting

4.4.1 Baseline Lighting Power Density Calculation Method

Baseline Lighting Power Density (LPD) must meet ASHRAE requirements in Table 9.5.1 or Table 9.6.1. The selected table must be used for all spaces in the project.

4.4.2 Lighting Exempt from Standard 90.1

Section 9.1.1 exception (2) excludes lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation from the scope of the Standard 90.1. The space-by-space method must be used to establish the baseline for both regulated and un-regulated lighting in such a project with exempt to lighting. The baseline for unregulated lighting must be established based on the illuminance levels and lighting power density of similar space types that are regulated by Standard 90.1. If the lighting design is required to provide higher illuminance levels compared to those used in IESNA 90.1 lighting models, as published at http://lpd.ies.org/cgi-bin/lpd/ShowSpaceTypes.pl, the baseline LPD may be increased in proportion to the increase in the illuminance.

4.4.3 Fixture Sampling

ASHRAE 90.1 Table G3.1 states that in the proposed design model "where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model." Following this requirement, use of representative spaces (sampling) for establishing lighting power density in the proposed design is not allowed.

4.4.4 Interior Lighting Controls

4.4.4.1 Occupancy sensors and timers

The following automatic occupancy lighting controls are required by ASHRAE 90.1:

a) Automatic Partial Off (bi-level lighting) occupancy sensors are required by Section 9.4.1.1 (g) for all space types that have REQ in Table 9.6.1 Column (g)
b) Automatic Full-Off occupancy sensors are required by Section 9.4.1.1 (h) for all space types that have "REQ" in Table 9.6.1 Columns (h)

Since these are mandatory provisions (except where changed to prescriptive requirements by local authorities), where such controls are required (if exceptions to these sections do not apply), they must be specified in the proposed design and included in both the baseline and proposed models. Table 4.4.4.1 below describes which spaces qualify for performance credit. Modeled proposed LPD in such spaces should be reduced by full or partial Control Factors (CF) based on Table 4.4.4.1.

Table 4.4.4.1

Automatic Full Off Required in Table 9.6.1 Columns (h)?	Automatic Partial Off Required in Table 9.6.1 Columns (g)?	Credit Allowed for Automatic Bi-Level Controls?	Credit Allowed for Full Off Controls?
Yes	NA	No	No
No	Yes	No	Yes, 50% of CF
No	No	Yes, 50% of CF	Yes, full CF

CF=10% for all qualified spaces except for shared sporadically used spaces
CF=40% for qualified sporadically used spaces such as stairs, restrooms or storage [4],[5].

In addition, credit may be claimed by reducing proposed lighting by Additional Interior Lighting Power Allowance calculated using Control Factors provided in 90.1 Table 9.6.3 for control strategies included in the table.

4.4.4.2 Daylighting

If a simulation tool does not have the capability to model daylighting, a specialized daylighting tool must be used. The savings projected by the external analysis must be incorporated into the simulation tool as an equivalent adjustment to the lighting schedule or lighting power density. The summary outputs from the daylighting software and explanation on how the findings were incorporated into the simulation tool must be included in the appendix to the report.

Visual light transmittance of specified windows will affect daylighting savings and must be captured in the tool used to calculate savings and included in the report.

Daylighting is a mandatory requirement of 90.1 for many space types and configurations, and thus must be modeled in the baseline where applicable (see 90.1 Section 9.4.1.1 and Table 9.6.1). For these applications daylighting must be specified in the proposed design but will not contribute to energy savings.

4.4.5 Decorative Lighting

Additional interior lighting power allowed by Section 9.6.2 (a) cannot be used to increase the baseline allowance for spaces where decorative lighting is not essential to space function, including but not limited to corridors of office buildings and hotels/motels. Examples of spaces where decorative lighting is permitted include but are not limited to theaters, galleries, and conference centers.

5 Measure Modeling

5.1 Background

In a typical project there are many areas where the proposed design differs from the baseline. Many of these differences involve improvements in the performance of like components. For example, the proposed design may have a higher thermal resistance of exterior walls compared to the baseline. Since the ASHRAE 90.1 modeling protocol allows performance trade-offs, some of the components in the proposed design may be less efficient than like components in the baseline. For example, the proposed design may exceed prescriptive lighting power density requirements of ASHRAE 90.1 in some or all spaces. The proposed design may also include equipment and systems that are not present in the baseline. For example, a project with an all-air baseline HVAC system may have pumps, boilers or chillers in the proposed design.

Following the ASHRAE modeling protocol, all the differences between the baseline and proposed design are captured by only two models – the proposed design model and the baseline design model. For reporting, additional models must be developed to reflect the impact of individual systems on the performance of the proposed design. These additional models help determine cost-effectiveness of systems to verify energy savings and support reporting requirements.

5.2 Measure Modeling Methodology

5.2.1 General

EEMs must be evaluated in the project as follows:

a) Identify all areas where the proposed design differs from the baseline.

b) Mark the differences that are modeled as EEMs with an EEM number.

c) Model each EEM using either the *stacked or top-down* approach as described in this section.

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

An example of applying the stacked and top-down approaches to a sample project is included in Appendix B.

5.2.2 Stacked Approach

With the stacked approach, EEM savings are modeled by starting with the proposed design model, and gradually transforming it into the baseline design by subtracting the EEMs one-by-one in the following order:

a) HVAC measure(s)

b) Base load measure(s) such as lighting, process loads, plug loads, etc.

c) Envelope measure(s)

d) Non-interactive measures such as service water heating

If there are several EEMs of the same type, for example several HVAC EEMs, the order in which they are modeled relative to each other is not prescribed to allow flexibility in supporting the specific project circumstances, and may be determined by the Modeling Entity based on communications with the customer. For example, if a design includes a high efficiency make-up air unit, and energy recovery is considered as a design alternative, the energy recovery EEM should be modeled (subtracted from the proposed design) first, to show the added energy savings for this option, with the unit efficiency EEM modeled (subtracted) second.

With the stacked approach, the difference between the sum of EEM savings and the total savings of the proposed design relative to the baseline is attributed entirely to the impact of components that differ between the baseline and proposed models but are not included in any EEM.

5.2.3 Top-Down Approach

With the top-down approach, savings of each EEM are modeled by starting with the proposed design model, reverting the components included in the EEM to their corresponding baseline, and comparing the resulting usage to the energy consumption of the proposed design model. *The difference between the sum of EEM savings and the total savings of the proposed design relative to the baseline is attributed to interactive effects (typically between 5% and 15%) and to the* impact of components that differ between the baseline and proposed models but are not included in any EEM.

For projects with different HVAC system types in the proposed design versus the baseline, the top-down approach may not directly support EEM granularity required without double-counting energy savings. In these instances, EEM savings must be isolated and reported as described in Example 5-1.

EXAMPLE 5-1 - Top-Down Approach ECM Modeling

Q. A project has a water-source heat pump (WSHP) with VSDs on cooling tower fans. The baseline HVAC includes packaged single-zone systems with DX cooling and a fossil fuel furnace (PSZ-AC). The VSDs are a design alternative and must be individually evaluated based on the TWO, in addition to WSHP ECM.

The stand-alone savings from the VSD and WSHP EEMs cannot be modeled directly with the top-down approach because it is impossible to model an EEM that changes the HVAC system type in the proposed design model to PSZ-AC, but still includes a VSD on the cooling tower fan. Therefore if the EEM modeling results are entered directly into the Incentive Calculator, the savings from the VSDs would be counted twice, first as part of the WSHP EEM, modeled by reverting the as-designed WSHP system to the baseline PSZ-AC (Model A), and then again as a VSD EEM, modeled by removing the VSD from the cooling tower fan (Model B).

How could the savings from the VSD EEM be calculated in this case?

A. The Savings from the VSD EEM are calculated as the difference between the usage of Model B and the proposed design model. Usage of Model B can be entered directly into the incentive calculator for the VSD EEM. However, these savings must be subtracted from the usage of Model A to obtain the value that must be entered into the incentive calculator for WSHP EEM without VSD.

5.2.4 Considerations in Selecting Measure-Modeling Approach

With the top-down approach, the outcome for most projects will be an overly conservative (lower) EEM savings compared to the stacked approach. In summarizing the results from several case studies, the sum of EEM savings modeled with the top-down approach was 5%-7% less than the savings of the proposed design relative to the baseline, compared to the savings obtained with the stacked approach. This penalty is not distributed evenly between the measures, hurting some EEMs more than others. For example, the kWh savings from envelope measures in the case studies were 28%+ higher with the stacked approach compared to the top-down approach.

The origins of this trend are easy to understand by considering savings from a fenestration improvement in a project with a high efficiency HVAC system. With the top-down approach, the fenestration EEM is modeled by reverting the window properties in the proposed design model to the baseline U-value/SHGC. The resulting increase in the heating/cooling load is satisfied by an efficient proposed HVAC system, reducing the fenestration EEM savings. Similarly, the HVAC EEM is modeled by reverting the HVAC in the proposed design model to the Appendix G baseline. The more efficient envelope in the proposed design lowers the HVAC system load, reducing the savings projected for the HVAC EEM. With the stacked approach, the HVAC EEM is modeled first, by reverting the proposed system to the Appendix G baseline in the model with the efficient envelope. The fenestration EEM is modeled next, by changing the proposed windows to the baseline U-value/SHGC in the model that has the baseline HVAC (because the HVAC EEM is modeled before the envelope based on Section 5.2.2). Since the envelope loads in the model are met by a less efficient baseline HVAC, the resulting savings are higher. Thus, the top-down approach double-counts interactivity resulting in the lower total EEM savings. An example of applying the stacked and top-down approaches is included in Appendix B.

6 Modeling Submittals

The simulation reports with the following information for the baseline, proposed design, and each energy measure model must be included in the report appendix:

- Monthly Energy End-use Summary (such as PS-E)
- Overall annual building energy consumption including all fuels and meters (such as BEPS and BEPU)
- Energy cost summary (such as ES-D)
- Information on hours when space/system loads are not met (such as BEPS/BEPU)
- System design parameters report (SV-A)

Some simulation tools may produce reports that show the required data points for multiple runs in a compact format. For example, <*- Parms.csv> and <*-Parms-Mtr.csv> reports will satisfy the reporting requirements above for eQUEST models.

7 References

[1] ANSI/ASHRAE/IESNA Standard 90.1 -2016 Energy Standard for Buildings Except Low-Rise Residential Buildings

[2] ASHRAE 90.1-2016 User's Manual

[3] COMNET Commercial Buildings Energy Modeling Guidelines and Procedures (MGP). Green Building Ratings Based on Standard 90.1 – 2010 October 27 2014, http://www.comnet.org/mgp

[4] "Reducing Barriers to Use of High Efficiency Lighting System", Lighting Research Center, RPI. Final report: March 2002 to January 2003, sponsored by US Department Of Energy.

[5] An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems. Bill VonNeida, Dorene Maniccia, Allan Tweed; Lighting Research Center School of Architecture Rensselaer Polytechnic Institute and US Environmental Protection Agency Energy Star Buildings Program.

[6] 2009 ASHRAE Handbook Fundamentals IP, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

[7] ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf?ab4e-daed

[8] Interpretation 90.1-2007-09 – January 22, 2012 (Refers to the requirements presented in ANSI/ASHRAE/IESNA Standard 90.1-2007, Section G3.1.3.1, regarding heat pump operation.)

[9] Infiltration Modeling Guidelines for Commercial Building Energy Analysis, K Gowri, D Winiarski, R Jarnagin, September 2009 PNNL-18898

Appendix A: End Use Detail for Standard 90.1 2013 kBtu/SF/Yr

	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Process & Plug	Total
Large Office	6	1	1	9	9	4	1	42	74
Medium Office	6	2	1	8	4	1	0	14	36
Small Office	8	2	3	2	2	3	0	8	29

Based on PNNL 2013EndUseTables_2014jun20.xls derived from DOE building prototypes http://www.energycodes.gov/commercial-prototype-building-models and related analysis http://www.energycodes.gov/development/commercial/cost_effectiveness

Appendix B: Tenant-Space Package EEM Modeling Example

An office renovation project has additional insulation added to the existing façade and high efficiency lighting with code required lighting controls. Heating, ventilation, and air conditioning are provided by existing air handlers and central plant equipment. In addition, the renovation includes high efficiency supplemental cooling units. The scope of work requires that the following EEMs are evaluated:

EEM1 – Supplemental cooling

EEM2 – High efficiency lighting

EEM3 – Wall insulation

The modeler starts identifying all differences between the baseline and proposed design, and marking them as EEMs (1, 2, 3). The modeling steps for the project using the top-down and stacked approaches are described below.

<u>Stacked Approach</u>

Step 1: Develop the proposed design model.

Step 2: EEM1 is modeled by starting with the Step 1 model and replacing the specified supplemental AC units with units that meet efficiency requirements of ASHRAE Standard 90.1 for its class.

Step 3: EEM2 is modeled by changing the lighting power density in the Step 2 model to match the Appendix G baseline.

Step 4: EEM3 is modeled by changing the wall properties in the Step 3 model to reflect the baseline U-value and SHGC.

Savings for each EEM are calculated as the difference between the usage of the EEM run and the usage of the immediately preceding run that this EEM run is based on. For example, EEM2 savings are calculated as the difference between the Step 2 model (EEM1) and Step 3 model (EEM2).

<u>Top-Down Approach</u>

Step 1: Develop the proposed design model.

Step 2: EEM1 is modeled by starting with the proposed design and replacing the supplemental AC units with units that meet the efficiency requirements of ASHRAE Standard 90.1 for its class. EEM1 savings are calculated by subtracting the Step 1 model results from the results of this run.

Step 3: EEM2 is modeled by starting with the proposed design and changing the lighting power density to match the baseline. EEM2 savings are calculated by subtracting the Step 1 model results from the results of this run.

Step 4: EEM3 is modeled by starting with the proposed design model in Step 1 and changing the wall U-value to the baseline values. EEM3 savings are calculated by subtracting usage of the Step 1 model from the results of this run.

Appendix C: Building Tenant Package EEM Modeling

The Building-Tenant Package includes measures in addition to the tenant-specific package as described in the guidelines and the PON. The following is a list of potential EEMs for this package which include but are not limited to the following:

HVAC Measures:

- EEM1 – Supplemental AC (multiple efficiencies to be analyzed)
- EEM2 – New Terminal Devices (Induction Units, etc.)
- EEM3 – HVAC Controls (DCV, etc.)
- EEM4 – New Air Handling Equipment
- EEM5 – New Heating and Cooling Plants

Base Load (Electrical) Measures:

- EEM6 – High Efficiency Lighting (varying LPD levels)
- EEM7 – Lighting Controls Beyond Code Requirements
- EEM8 – Reduced Plug Loads
- EEM9 – Additional Plug Load Controls

Envelope Measures:

- EEM10 – Additional Envelope Insulation
- EEM11 – Window Film

Non-Interactive Measures:

- EEM12 – High Efficiency Service Water Heating
- EEM13 – Domestic Hot Water Load Reduction